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Stress and emotional arousal in urban environments: A biosocial study with persons having experienced a first-episode of psychosis and persons at risk

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ABSTRACT

This article examines the entanglement between feelings of stress and discomfort, physiological arousal and urban experiences of persons living with early psychosis. It adopts a biosocial approach, using mixed methods combining ambulatory skin conductance monitoring, mobile interviews and contextual data, collected through GPS and video recordings. The study draws on and strives to cross-fertilize two recent strands of research. The first relates to the use of digital phenotyping in mental health research. The second explores stress and emotional arousal in cities using ambulatory physiological measures. Empirically, the paper is based on fieldwork in Basel, Switzerland, with nine participants recruited within the Basel Early Treatment Service (BEATS), and four controls. We focus on three salient elements in our results: visual perception of moving bodies, spatial transitions and openness and enclosure of the built environment. The analysis shows how these elements elicit physiological responses of arousal and expressed feelings of discomfort. In the concluding section we discuss the methodological implications of these results and suggest the notion of *regime of attention* as a focus for future biosocial research on urban mental health.

1. Introduction

Prevalence of psychosis varies considerably according to geographical location: in the last two decades, a substantial number of studies conducted in Europe and North America show a strong correlation between urban living and the development of psychosis (Allardyce et al., 2001; Kelly et al., 2010; Kirkbride et al., 2007; Mortensen and Pedersen, 2001; Sundquist et al., 2004; Van Os, 2004; Vassos et al., 2012). Today, urban living is widely considered as a risk factor for psychosis (Vassos et al., 2012, p. 1118). Although urban living also affects other mental disorders — such as mood and anxiety disorders — it does so at a much lower rate (Peen et al., 2010). Therefore, the link between urban living and psychiatric disorders is very specific to psychosis.

Despite the identification of various factors associated with 'urbanicity'[1] that may potentially contribute to the development of psychosis, the nature of the link involved in this association – *why* and *how* the social and built environment of cities affect the risk for psychosis – remains unclear (Fett et al., 2019; Heinz et al., 2013; Helbich, 2018; Kelly et al., 2010; Manning, 2019; Peen et al., 2010). One prominent hypothesis is the role of stress (Krabbendam et al., 2021). Hence identifying which urban situations are the most stress-inductive as well as why they are so is of crucial importance (Abbott, 2012, p. 164), also because it may eventually lead to interventions oriented towards mental health-supportive urban design and planning.

Most studies in psychiatry interested in the urban-rural differences in prevalence rates approach the urban phenomenon through the fixed categories of urban birth, urban upbringing or urban residence. Studies that focus on cities – interested in prevalence rates across neighborhoods – work on areal level factors, such as social deprivation or levels of criminality (Kirkbride et al., 2014), social deprivation (Bhavsar et al.,

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[1] Urbanicity is the term used in research within psychiatry to refer to the effect of urban environments, generally defined through population density, on mental health. Within this literature, it commonly refers to urban birth, urban upbringing or urban residence. However, these categories are challenged by an experiential approach, because being born, raised or living in an urban area doesn't offer any information about how one "spends time in the city, or tends to avoid it, or deploys very selective forms of urban practice" (Söderströ;m et al., 2016, p. 109).

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2014), social adversity (Heinz et al., 2013), or density (Vassos et al., 2012). The static and substantialist conceptualization of space and urban environment that underpins such approaches, has been identified as a limitation in our understanding of urban stress (Söderström et al., 2016). Consequently, there have been recent calls in the social sciences and in psychiatry in favor of *in situ* studies, conducted on an individual level (Bromley et al., 2012; Freeman et al., 2015). One of the first studies in that direction is known as the 'Camberwell walk', where researchers looked at symptoms before and after a walk in a busy street for persons with persecutory delusions (Ellett et al., 2008; see also Freeman et al., 2015). In the same line of research, Ecological Momentary Assessment (EMA) using smartphones has been deployed (see van Os et al., 2014 & 2017; Myin-Germeys et al., 2009). In EMA-based studies, participants are asked to answer questions about their feelings and emotional state several times over the course of a longer period of time (days or week), as well as giving simultaneously contextual information (e.g about their location, activity and entourage). Hence, studies within psychiatry developing these approaches are much more attuned to the relational aspects of the social and material environment and their effects upon wellbeing than traditional epidemiological approaches – a domain where the social sciences have a long tradition. Recently, geographers and psychiatrists, in a common effort, have pushed further these investigations, using video elicitation and video analysis to explore how persons having had a first experience of psychosis handle stress in cities. The results show that urban stress for these participants relates to (i) urban density, (ii) high levels of sensory stimulation, (iii) unchosen social interaction and (iv) obstacles to fluid mobility (Söderström et al., 2016 & 2017). In another study, more focused on the physical environment, crowding, noise, light, air quality as well as housing type and quality have also been identified as urban stressors (Evans, 2003). However, as we have argued elsewhere (Winz and Söderström, 2021), we see two limitations in most of these *in situ* studies. The first is to rely solely on the patient's narratives, and therefore on perceived stress that is verbalized. The second, closely related to the first one, is the lack of research into biosocial pathways.

We respond to these limitations by analyzing how urban environments get to the skin through urban experience of distress and arousal. More specifically, we are interested in how aspects relating to sensory perception, spatial sequences and the built environment are experienced and embodied (see Winz and Söderström, 2021), for a detailed discussion of each of these research axes). Adopting a biosocial approach, the research uses mixed-methods, combining ambulatory skin conductance (hereafter SC), qualitative interviews and geographical and contextual data. SC – also called electrodermal activity (EDA) or galvanic skin response (GSR) – describes variations in the resistance of the skin to a small electrical current, measured through the activity of the eccrine sweat glands, which are under control of the autonomic nervous system (ANS) (Dawson et al., 2007). The involuntary changes in skin conductance are widely used as an index in different domains for cognitive and emotional processes arousal or attention, as well as stress (Boucsein 2012; Dawson et al., 2007). SC has been used in laboratory studies as a psycho-physiological indicator of arousal, emotions and stress in participants with psychosis (Lincoln et al., 2015; Peterman et al., 2015, Dawson et al., 2007) and *in situ* to detect signature of illness severity (Cella et al., 2018). Here, we propose to take it out of the lab, to monitor *in situ* physiological arousal and stress in persons with early psychosis, which has not been done yet. We conducted our fieldwork in Basel, Switzerland, with five participants who have experienced a First Episode of Psychosis (FEP), four who have been identified as 'At Risk Mental State' (ARMS) [2] and four controls.

[2] Also known as 'ultra-high risk' or 'clinical high risk', 'at risk mental state' refers to persons who are considered, according to clinically established criteria, to present an increased risk of developing a psychotic disorder in a foreseeable future.

The article is structured as follows. We start by discussing the use of mobile health devices and biosensing, first within research on mental health, and second within research on urban environments. Then, we expose our methodology: the study design, the way we processed and analysed our data and their limitations. We focus the presentation of our results on three aspects - the visual perception of bodies in motion, transitions between urban contexts and openness/closure of these contexts - in a third section. We discuss these results and suggest future research perspectives in a final section.

1.1. Mobile health and biosensing research

Over the past decade, mobile health (mHealth) and sensor-based technologies have been increasingly used both in research on mental health, and in the study of embodied experiences of urban environments. In this section, we briefly shed light on both of these research strands.[3] We point to the fact that they contribute to advances in their respective fields, but that research combining the two is scarce. Merging the two, we argue, should allow honing our understanding of the hyphen between them: the entanglement between cities and psychosis. Thereby, we also aim to respond to the call for the development of innovative methodologies, situated at the intersection of biology and ethnography (see Fitzgerald et al., 2016; Manning, 2019).

1.2. Mobile health in mental health research

Within research on mental health, the use of mobile technologies to collect data in everyday life is often referred to as 'digital phenotyping', and divided into 'passive' and 'active' data collection modalities(Raugh et al., 2021). The former refers to the monitoring of either physiological or behavioral variables – such as heart rate and skin conductance, or gestures and localizations (Raugh et al., 2021). In the latter, participants are asked to accomplish specific tasks, such as survey completion or share their state of mind, at various moments.

Historically, the 'passive' mode of research has been used in psychiatric research within laboratories, to detect biomarkers of illness and/or of various illness features, such as functioning difficulties in the context of schizophrenia (Cella et al., 2018; Torous and Keshavan, 2018). The advent of mobile and wearable devices offers new opportunities, allowing to take these devices out of the lab, to examine the role and relevance of these biomarkers for various disorders in real-life settings (Adams et al., 2017). With regard to psychosis, SC has been used *in situ*, to study the association symptoms and functioning level and autonomic activity (Cella et al., 2018). Behavioral sensing (i.e., physical activity, geospatial activity, speech frequency, and duration) has been used to identify indicators of relapse (Ben-Zeev et al., 2017). Here, the spatial dimension has been explored: using passively collected smartphone behavioral data to identify changes in mobility patterns and social behavior, it has been found "that the rate of behavioral anomalies detected in the 2 weeks prior to relapse was 71% higher than the rate of anomalies during other time periods" (Barnett al. 2018, p. 436).

'Active' data collection methods have been implemented increasingly in research on psychosis. Smartphones based Ecological Momentary Assessment (EMA) has been used to study subjective emotional states and/or symptoms dynamically, over the course of various time frames (Myin-Germeys et al., 2003; Myin-Germeys et al., 2009; Gard et al. 2014; Moran et al., 2017; Oorschot et al., 2013, Oorschot et al., 2012; Kluge et al., 2018). Such EMA-based research has highlighted patterns of both positive and negative symptoms, in showing for example "individual moment-to-moment and daily variation in paranoia intensity, positive affect (PA), and negative affect (NA)" (Orschoot et al., 2012, p. 406) in persons diagnosed with schizophrenia.

[3] For a systematic review on each of these fields, refer to Adams et al., 2017, respectively Dritsa and Biloria 2021.

'Active' and 'passive' modes have been combined in various ways in research on psychosis. Together, EMA and autonomic cardiac regulation, have been used to study stress (Kimhy et al., 2010) and auditory hallucinations (Kimhy et al., 2017) in persons diagnosed with schizophrenia. Combined with passive GPS tracking technologies, EMA allows the exploration of the spatialities of such experiences, highlighting the fact that, in individuals living with a diagnosis of schizophrenia, greenspace is associated with lower symptoms of anxiety, depression and psychosis (Henson et al., 2020, p. 1). This combined approach also revealed that reduced mobility is associated with negative symptoms, particularly diminished motivation, but not with positive symptoms, depression or cognitive outcomes in patients with schizophrenia (Depp et al., 2019). In sum, mobile methods provide the possibility to explore and test laboratory findings in real-life or close to real-life situations. Moreover, such approach allows for an ecological – temporal and spatial – account of the lived experiences of people living with mental health problems.

1.3. Biosensing in research on urban emotions and stress

In recent years, urban environments have been the site of a growing number of studies using real-time physiological data collection. Referred to as 'biosensing', these techniques are frequently used in combination with more traditional data collection techniques. While research using SC in this field was originally focused on emotions, there has been a shift towards stress-related research (Dritsa and Biloria, 2021; Pykett et al., 2020a,b). This still emerging strand of research has produced an abundant literature in recent years. Researchers have explored physiological arousal using SC in a broad range of population categories, working with tourists (Kim and Fesenmaier, 2015; Shoval et al., 2018), police officers (Furberg et al., 2017), visually impaired adults (Massot, 2011), young men (Song et al., 2015) and older adults (Pratiwi et al., 2020; Neale et al., 2017; Tilley et al., 2017). These studies focus on various activities, such as walking (Hogertz, 2010; Hijazi et al., 2016; Li et al., 2016; Clark et al., 2018; Engelniederhammer et al., 2019; Xiang et al., 2021), cycling (Zeile 2016; Werner et al., 2019), commuting (Pykett et al., 2020a) and driving (Healey and Picard, 2005).

This body of literature is not turned towards questions of wellbeing and/or (mental) health (for an exception, see Pykett et al., 2020a,b), and to our knowledge, there are no studies involving persons living with a diagnosis of psychiatric disorder. However, in studies working on urban walking, several aspects of the social and built (physical) urban environments relating to physiological arousal are particularly interesting, since they resonate with research axes identified in urban mental health research (see Winz and Söderström, 2021). These relevant features concern crowding density (Engelniederhammer 2019), visual fields (Hijazi et al., 2016; Li et al., 2016; Xiang et al., 2021) and urban sequences (Li et al., 2016; Xiang et al., 2021).

Personal space intrusion in high density areas has been found to elicit both aversive and positive emotional responses (Engelniederhammer et al., 2019). Discussing these contrasted results, the authors understand that the urban context may play a significant role in explaining these differences, but they could not "uncover the specific aspects of the different street paths of the test route, to make personal space crossing eliciting aversive or appetitive responses" (2019, p. 643). Contrasted results have also been found in relation to isovists, understood as "the area which is visible from a given point in space" (Dritsa and Biloria, 2021, p. 2021). Isovists allow to work on the built environment – more precisely on the spaces between buildings – through various quantifiable parameters. In Zurich, Switzerland, greater visibility and higher compactness "seem to be advantageous in causing positive emotions, indicating that people may prefer spaces with good vista within a suitable distance and clearer boundaries. However, this does not mean that people prefer an unlimited field of view" ((Li et al., 2016, p. 15). Similar results have been found in Hong Kong (Xiang et al., 2021). Conclusions diverge for what concerns occlusivity, which refers to the degree of enclosure of space (Xiang et al., 2021), with contrasting impact on autonomic arousal. Higher occlusivity can elicit both a sense of security (Li et al., 2016) and stress (Xiang et al., 2021). In relation to the way the urban environment is experienced, urban sequences, rather than specific urban places have been hypothesized as being crucial in eliciting physiological arousal (Li et al., 2016; Xiang et al., 2021). Resulting from the fact that urban dwellers walk, and therefore move through the city, it has been suggested that "urban spaces may influence people's emotional responses through both spatial sequence arrangements and shifting scenario sequences" (Li et al., 2016 p. 1).

In sum, this review of recent studies in two research fields shows first that research involving digital phenotyping – for assessing emotional arousal and stress in real-world settings among other aims – is increasingly implemented in research on mental health, and second that urban emotional arousal and stress research using ambulatory skin conductance is burgeoning and leads to a series of converging results. However, there is as yet, no attempt to cross-fertilize these two strands of research. This is what the study reported in this article does, by examining the entanglement between feelings of stress and discomfort, physiological arousal and urban experiences of persons living with early psychosis. We suggest that, through this combination, we can offer important insights into the embodied experience of urban environments of people living with early psychosis, and by doing so, pursue investigations of one of the suggested biosocial pathways between urbanicity and psychosis: urban stress.

2. Methodology

2.1. Design and protocol

It is widely accepted that stress is a multifactorial phenomenon related to biological, psychological, social and environmental processes (Adli, 2017), and that it "comprises both physiological and psychological components in a short- and long-term perspective" (Hedblom et al., 2019, p. 2). In our approach, we focus on short-term, conscious and embodied expressions of stress. Therefore, our study design is based on a biosocial mixed-method approach, combining: (i) ambulatory biosensing – skin conductance – to examine physiological arousal and stress; (ii) narrative data collected through qualitative mobile interviews, to provide participants' interpretations of situations of arousal; and (iii) environmental data, collected through GPS and video recordings, to provide a rich sense of the urban context. Data was collected during urban walks in the city center of Basel,[4] Switzerland, with participants wearing an Empatica E4 bracelet to monitor skin conductance (SC). The Empatica E4 is a wrist-worn wearable device designed for continuous, real-time data acquisition in daily life. We selected the E4 because it offers a medical-grade device designed for research that is commercially available, and that is increasingly used in ambulatory biosensing in urban contexts (e.g. Chrisinger and King, 2018; Pykett et al., 2020a; Shoval et al., 2018). With sensors placed on the inside of the wrists, the E4 collects simultaneously skin conductance, heart rate measures, blood pressure, and skin temperature. Skin conductance is collected at a sampling rate of 4 Hz, and the frequency of data collection is not configurable. The data collected from the E4 is synched to an online platform, where the raw data is accessible. Participants were accompanied by the first author of this article, who conducted mobile interviews. Here, our approach draws on the "commented city walks" (Thibaud, 2013). This method consists in carrying out walks with informants, asking people to comment on their experience, feelings and relationship to space, both while walking and afterwards. The walks

[4] Basel is the third largest city in Switzerland, with an agglomeration of 550′000 permanent residents in 2019, spreading over three different countries. It is a medium-sized city, with densities varying considerably across neighborhoods, ranging from 4000 to over 20′000 inhabitants per square kilometer.

lasted between 45 and 60 min, followed by a semi-structured interview of 20–30 min. The path followed in the walks was partly imposed, for the sake of comparison,[5] partly left up to the decision of the participants. It was monitored with a GPS tracker (Garmin eTrex 20). In addition, the urban environment was filmed by the researcher, with a chest-worn action camera.

2.2. Participants and recruitment

The participants we worked with in this study were recruited within the Basel Early Treatment Service (BEATS), a specialized mental health unit at the University Psychiatric Clinics Basel, committed to the early detection and treatment of psychotic and other serious mental illnesses in young people. We recruited participants between 18 and 35, having received a first diagnosis of psychosis less than 2 years prior to study participation, and with presence of psychotic symptoms in any form for less than five years (FEP, n = 5), and at risk mental state individuals (ARMS, n = 4), identified as such within the BEATS program according to established criteria (Andreou et al., 2019). Given that recruitment of participants living with early psychosis can be complicated (Patterson et al., 2014), our sample size was dictated by the number of participants willing to take part in the study. Pre-selection of eligible participants through the BEATS team proved to be very helpful here. All the patients meeting the inclusion criteria in the BEATS program have been contacted in a first step. A total of 23 participants expressed their initial interest in participating. Out of the 23 participants, 5 could not be reached for further recruitment process and 8 declined participation for various personal reasons. We invited the 10 remaining participants for a meeting, after which one declined to sign the informed consent document. Hence 5 FEP and 4 ARMS persons participated in the study. We also included a control group with similar size (n = 4). We worked with these three groups to identify potential differences in the way city environments may represent a source of physiological arousal and psychological stress.

All participants provided written informed consent to a research protocol that was approved by the local Swiss Ethics Committee.

Working at the confluence of health geography and psychiatry, the study protocol has been elaborated in collaboration with members of the BEATS team. Therefore, it partially follows existing standards within psychiatry. Participants were asked to take the Current CAPE-15 survey (Capra et al., 2017), which allows to evaluate psychotic like experiences (PLEs) and associated distress in the last three months. The survey was completed after the walk, during the debriefing interview. It comprises 15 items with 3 subscales (persecutory ideations, bizarre experiences and perceptual abnormalities). For each item, participants are asked to report on the frequency at which a specific symptom is experienced, and the psychological distress associated with it, using a 4-point Likert scale from 0 (never/not distressed) to 3 (nearly always/very distressed). Following Capra et al. (2017), we calculated the Frequency x Distress score (ranging from 0 to 135) for each participant. Mean scores are the following: FEP = 4.8 (ranging from 0 to 23), ARMS = 3 (ranging from 1 to 6) and control group = 1 (ranging from 0 to 2). This indicates that, although there are identifiable differences in symptom distress between the three groups, the participants in our study did not experience a lot of the symptoms assessed by the CAPE-15 in the three months preceding the study participation, and/or that the symptoms they do experience are not experienced as distressing. This can be explained by the ethical stance taken within our research, where exclusion criteria included severe hostility, suspiciousness or formal thought disorder as determined by the BEATS team and participants whose active participation in the study was considered at risk of decompensation by the BEATS team.

[5] This section of the path was designed to include various urban settings and configurations, such as busy and calmer roads, pedestrian areas, parks, squares, etc.

2.3. Skin conductance data processing

SC data is reputed to potentially contain a lot of artefacts, especially in ambulatory settings. Hence, we first identified these artefacts and rejected invalid portions of the signal. Authors three and four implemented following rule-based approach to do so: first, raw SC was inspected for values below 0.01 μS, which indicates a loss of contact between the skin and the electrode. Second, we applied a moving-median filter (width 4, since SC is sampled at 4 Hz), which is a common way to reject outliers (Posada-Quintero et al. 2019). Third, following Kocielnik et al. (2013) and Kikhia et al. (2016), we identified artefacts as portions of the signal showing more than a 20% increase or 10% decrease within 1 s. These segments were removed and end-points were connected using a cubic spline. After pre-processing the data, the final step concerned the extraction of relevant SC features. Skin conductance includes two main components, resulting from the sympathetic neuronal activity: (i) background tonic activity: skin conductance level (hereafter *SCL*), and (ii) rapid phasic components: skin conductance response (*SCRs*) (Braithwaite et al., 2013: 4). Following the publication recommendations for electrodermal measurements (Society for Psychophysiological Research Ad Hoc Committee on Electrodermal Measures, 2012), we retained the SCL component for our study in an ambulatory context. SCL has been widely used as an index of physiological arousal of emotions (Dawson et al., 2007), as well as an indicator of stress, both in lab (Hedblom et al., 2019) and ambulatory contexts (Kocielnik et al., 2013).

We used LEDALAB (Benedek and Kaernbach, 2010) and the continuous decomposition analysis approach, to decompose the SC signal into tonic and phasic components.

A typical practice when working with SCL, based on experiments carried out in labs, includes wearing the sensor prior to the experiment, while the participants are asked to relax. In an ideal case, the SCL signal drops to become low and smooth, and the lowest values are averaged to obtain a baseline measurement, which is then compared to the data collected during the experiment. Such 'resting baseline' anchored in lab-based practices are not necessarily appropriate in an ambulatory setting. This is why when working on walking tasks, Cho et al. (2021) use a walking baseline, measured during a flat level indoor walking period of 2 min before the outdoor experimental walking course. We choose to extract the baseline value from the data that was collected during the urban walks, for a baseline that holds more ecological validity, as recommended by the manufacturer.[6] To do so, we averaged the SCL data on a 12 s non-overlapping window for the whole walking period. SCL variations fluctuate over longer periods of time (typically, from 10s of seconds to minutes). We chose a window of 12 s because it is the smallest common denominator between sampling frequencies of SC (4 Hz) and our GPS data (3 Hz). We identified the window with the lowest average, which provides the baseline skin conductance level during walking. We then followed standard practices and expressed the SCL for every 12 s window as the variation in percentage when compared to this 'activity-based' baseline using the following equation (with SCLw = SCL during walking and SCLb = SCL walking based baseline):

$$\Delta SCL = 100\frac{SCL_w - SCL_b}{SCL_b}$$

Calculating the percent variation within the walking period reduces the confounding influence of sweating caused by the physical activity, as well as the inter-individual differences in SCL amplitudes. In a further step, SCL data was then associated with geolocations based on the timestamps of the Empatica E4 and the GPS tracker by the fith author, to produce SCL percent variation maps for each participant and aggregated maps for each group of particpant (see Fig. 1).

[6] https://support.empatica.com/hc/en-us/articles/203621955-What-should-I-know-to-use-EDA-data-in-my-experiment-.

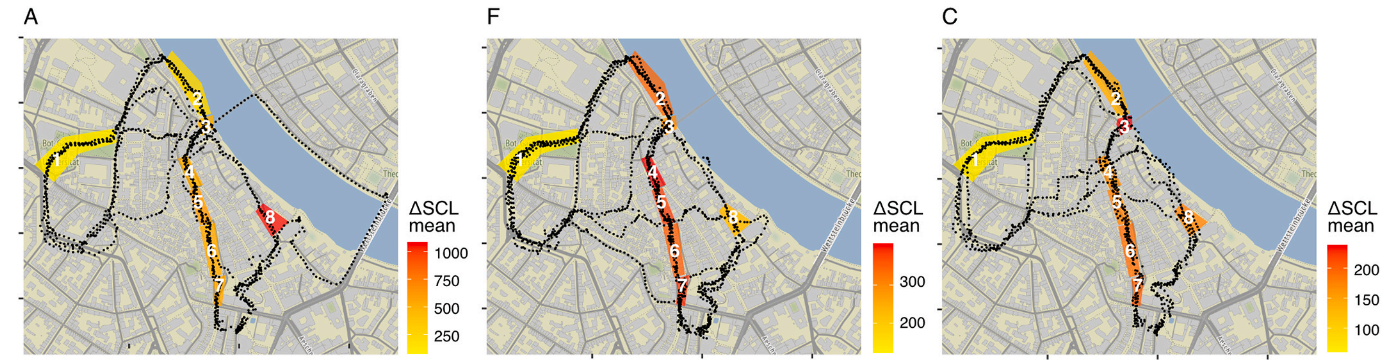

Fig. 1. Aggregated ΔSCL maps for each group of participants.

2.4. Analysis

Our analysis aims to identify relevant urban situations implicated in the advent of feelings of stress and physiological arousal in people living with early psychosis. Adopting an *in situ* approach, we are also particularly attentive to the way the urban environment – in its interactional and geographical dimensions – is experienced by participants. We do so by combining physiological, narrative data and environmental data, in relation to the proximate urban environment encountered during the walks on two levels. In a preliminary step, we aggregated the ΔSCL data per group, to detect general patterns between FEP, ARMS and Controls. To analyze the data, we segmented the imposed part of the path in 8 contrasting and subsequent zones (parks, riverside, intersection, squares, heavy traffic road, pedestrian area, public transport hub). For each zone, we calculated the mean and median ΔSCL for the three groups of participants (see Fig. 1).

In a second step, since our main objective is to explore the personal experiences of urban situations and to unpack the "[…] temporalities, spatialities, and psychophysiologies of the 'moments of stress' (Kyriakou et al., 2019) for each individual participant" (p. 7), we produced SCL percent variation maps for each participant. Analysis of SC data is based on visual analysis of these maps (see Fig. 2). Such approach is common is studies working on the association of SC and environmental contexts in real-life settings (see Hogertz, 2010; Bergner et al., 2013; Chen et al., 2018; Fathullah and Willis, 2018; Osborne and Jones, 2017; Shoval et al., 2018). Transcription of the interviews was segmented into the geographical zones mentioned above. Coding of the interviews was theoretically guided, according to our research axes, and relevant verbatims were reported on a map of the city, for each participant using the video footage. In a following step, the three different datasets (video, narratives and physiological data by means of the ΔSCL maps) have been examined and compared for each individual participant, to explore the way "how the various aspects of stress map together" (Pykett et al., 2020a, p. 7). Here, our approach is inspired by Osborne and Jones (2017), who work with similar data, recommend to analyze data by means of triangulation, entering the analysis each time with a different set of empirical data (SC, qualitative interviews and video). However, they also note that the "reinforcing effect does not occur in every case, as things that seem interesting to the researchers in, say, the video footage, may have been of little significance to the participant, thus not appearing in the interview or biosensing data" (Osborne and Jones, 2017, p. 168). We chose to combine the three datasets in a specific manner for each of our research axes. To study the sensory dimension, we started with the narratives, and then enriched and densified analysis with the video recordings and the skin conductance maps. To investigate the importance of urban sequences, we started with the SC maps, and confronted these to the narratives and enriched it with video. To explore aspects of the built environment, we started with video recordings, and confronted them to SC and interviews. The rationale for each analytical process is detailed in the following sections. Subjective or perceived stress does not necessarily overlap with physiological stress, or as Bettiga et al. put it, mind and body do not always agree, since "[u]nconscious arousal and conscious arousal are distinct emotional responses" (Bettiga et al., 2017, p.108). Thus, both the co-evolutions and discrepancies between skin conductance and expressed feelings are important. They are complementary, in that they participate in revealing different aspects of the relation between the participants and the urban environment.

3. Results

3.1. Aggregated-level

Using Pairwise Wilcox Rank sum Test, differences in mean ΔSCL were statistically significant ($p < 0{,}05$) between all three groups of participants for zones n°1, 5, 6 and 7. For zone n° 2, 4, 8, differences in mean ΔSCL were significant between ARMS and Controls, as well as between ARMS and FEP participants. In zone 2, the differences in ΔSCL were significant between Controls and FEP. We produced aggregated mean ΔSCL maps for each group, to allow comparison of arousal in the considered areas between groups.

The spatially distributed mean ΔSCL percent variations for each group of participants allow several general observations. First, they indicate lower values of ΔSCL in urban walking as well as a steadier level of SCL along the path for Controls compared to ARMS and FEP participants. Similarly, the maps highlight a higher level of ΔSCL during urban walking for ARMS than for FEP. Based on this observation, urban walking is the most arousing for ARMS followed by FEP and Controls, in that order. As a result, in terms of physiological arousal, ARMS participants stand out. Second, for FEP and ARMS, some locations seem to exert stronger wear-and-tear on the physiologies of the participants, while situations allow for physiological recovery. Third, locations with low ΔSCL values show more consistency across all three groups. In contrast, places eliciting physiological arousal are more heterogeneously distributed throughout the city and across participants. The qualitative analysis of the interviews reveals contrasts between ARMS and FEP participants on the one side, and Controls on the other, with higher attention and sensitivity towards the urban environment, as expressed by the FEP and ARMS participants.

3.2. Individual level

We dig further into the entanglement of physiological arousal, expressed feeling of discomfort and the situational characteristics of the various locations in the following, using our three research axes: sensory perception, spatial sequences and aspects of the built environment as an entry point. Exploring individual subjective experience allows us to investigate the way how expressed feelings and physiological indices of stress relate to one another, by means of the localisation. The high resolution of ΔSCL cartography allows us to locate shifts in SCL data with

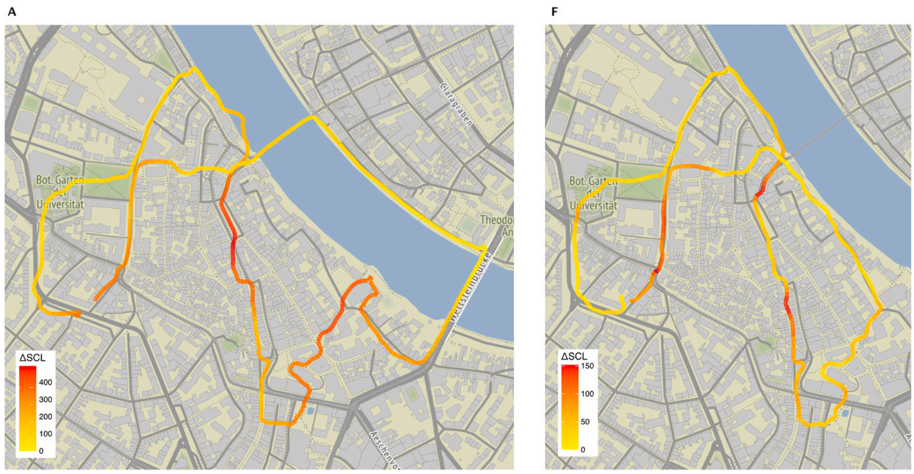

Fig. 2. Examples of ΔSCL maps for two participants.

precision, and relate them to subjective feelings expressed either during the walk in that same location and/or during the debriefing interviews when commenting the walk. This association through space is of primary interest in our study. In localising ΔSCL and narrative data in the city, for each individual participant, we are able to highlight spatial associations of physiological and narrative data. However, it is hard to assert causality between the two.

3.2.1. *Sensory perception*

To explore the way sensory perception is experienced, narrative data is of primary interest to start analysis with, since we retained the tonic component of SC (SCL), which indicates general level of autonomic arousal, and does not react to sensory stimuli per se.[7] Therefore, and because sensory perception has been commented on during the interviews, we chose to start our analysis with the narratives of our participants. In a following step, video recordings were analysed accordingly, to detect related situations, and the narratives were compared with the skin conductance maps, to pinpoint accompanying variations in ΔSCL.

As mentioned above, interviews revealed high contrasts between controls on the one hand and FEP and ARMS on the other. Sensory stimulations, and their impact upon wellbeing, are more present in FEP and ARMS narratives, compared to controls. While noise has been reported as a potential source of stress in our study and in others (Söderström et al., 2016), confronting our interview data to the video footage, we found that the parts of the city that were described as 'calm' or 'hectic', were so primarily from the point of view of what is going on around the participants. Moving elements (pedestrians, cars, streetcars, bikes, scooters and so forth) and especially situations where several of these elements travel at various speeds and take place at the same time and in the same location, were reported as difficult to manage and potential sources of stress:

> "Interviewee: Here I have to … So there, I am often briefly a little … I look first, and only then I walk. Because it's a little bit of a switch after all. And since if we are already with this whole energy thing, here, much more is going on, I would like to pay attention somehow to everything, or should, because streetcars, bus, bicycle pedestrians ….
>
> Interviewer: Then back there, the attention, was a bit less … ehm active or …
>
> Interviewee: I think it's a little bit more on the houses, and a little bit more focused on this [built] environment. And here it's so much more on everything that's moving, so I am a little bit like 'okay, there's someone running there, the bus, the streetcar, there's a bike trying to get through'. So I pay a little bit of attention to everything that's moving".

These visual situations are generally described as 'hectic' and can be paired with a sense of being a 'bit overwhelmed'. They are described as requiring 'more attention', where one 'has to be concentrated on what's going on' and on 'everything that's moving'. In these situations, ARMS and FEP participants felt that their attention had to be focused on the environment, in order to analyze what is going on, take a decision and act accordingly. These places can be experienced as stressful, also because of a sense of fear of acting wrongfully or 'coming in the way of other users':

> "I feel called upon to be more attentive, so to speak, so that nothing bad happens, so that I cannot be blamed for something".

In contrast to noise, which, in our study, is reported to be a potential source of stress depending on the state of mind of the participants, these hectic situations – where moving elements have to be visually 'scanned' and taken into consideration – were described as being more constantly a source of discomfort, depending less on these states of mind. Some participants shared that they filter sensory stimuli in a sequential and/or hierarchical manner in such situations: visual perception and hearing come to the foreground, while other sensory channels are muted.

We took a closer look at one specific location – 'Barfüsserplatz' – to investigate the way these expressed feelings relate to physiological arousal. 'Barfüsserplatz' is located in the center of the city of Basel (see Fig. 3), and with eight streetcar lines crossing it, the square is one of the city's most frequented hubs. For two FEP participants, entering and crossing 'Barfüsserplatz' is shows with a noticeable increase in ΔSCL data. Without reaching peak intensities, the ΔSCL rise occurs precisely at the entrance to the square itself, continues throughout the crossing, and starts to decrease only afterwards. In both cases, the increase in ΔSCL values is accompanied by a negative judgement, as expressed by the participants during or after the walk. For the other three FEP participants, the ΔSCL data does not show an upward trend for this section of the walk; the data either remains stable compared to the previous sections, or they show only very small variations, even with a slight downward trend for one of them. 'Barfüsserplatz' is commented less systematically by these participants, but characterized as 'lively' and

[7] for this, the phasic component of SC – *SCRs* – would be more appropriate. However, in ambulatory setting it is not recommended to work with this component, since it is impossible to isolate relevant sensory stimulations and associate them with a specific skin conductance response.

Fig. 3. Examples of maps showing the variations of skin conductance levels (SCL) for two participants.

'animated' and 'full of people', without expressing any real judgment (positive or negative). Similarly, the ΔSCL data of none of the ARMS participants shows a clear and strong upward or downward break at the entrance and during the crossing of 'Barfüsserplatz'. Here, appreciation of the square is nevertheless generally negative; participants reported the need to be attentive, that they felt some kind of ambient stress, emanating from the people around them who rush from one side to the other or that the square is 'not very attractive'. In sum, confrontation of video footage and narratives reveals that situations described as calm show generally low activity in terms of moving elements, and/or situations where the different travel modes are clearly separated. In contrast, hectic areas refer to places where several different kinds of moving elements join in one place. While narratives identify such situations – described as hectic – as potentially problematic, ΔSCL patterns in these hectic situations are variegated, showing no clear spatial association with physiological arousal of the participants. In contrast, ΔSCL levels are more systematically low a place described as calm by the participant. While calm environments allow for reflection and introspection, as reported by the participants, this is difficult or impossible in highly animated environments, where all attention is laid on the surroundings.

3.3. Spatial sequences and transitions

We chose to conduct the analysis of urban sequences and transitions through the lead of SC data, by means of our ΔSCL maps, because SC has been reported to be sensitive to spatial transitions rather than to the atmosphere of specific places (Xiang et al., 2021). Therefore, rather than looking at arousal hotspots, we looked at variations in ΔSCL data along the path (where does it start to increase/decrease?), through visual inspection of the ΔSCL maps. In a following step, we confronted these locations to the narratives, in order to explore association with reported experiences and feelings, and to the video recordings to enrich our analysis.

Interested in points of fluctuations, we identified significant contrasts in ΔSCL levels between two sections of the route: (i) the 'Drei Könige Weglein', a pedestrian path on the Rhine shore, shows very low ΔSCL values for almost all participants (especially in the FEP and ARMS groups). And (ii) the following section of the path, 'Schifflände' and 'Eisengasse', which are busier roads and street crossings, where ΔSCL values rise significantly for almost all ARMS participants, but not for the FEP participants. When confronted to the narratives, we find nevertheless similar explanations on how this transition is experienced, across the two groups.

Independently of the ΔSCL patterns, the transition between the riverside and 'Schifflände' is repeatedly commented in terms of attention, pointing out the fact that the section on the Rhine shore allows for introspective thoughts, rumination or relaxation, while one has to concentrate on the 'outside world' when arriving at 'Schifflände'. This overlaps with noticeable rises in ΔSCL on the maps for 3 ARMS participants, while nothing in the ΔSCL data of the fourth ARMS participant indicates autonomic arousal. However, when turning to the interview data, it is precisely this fourth participant who expresses the most this change in terms of attention. He says that he 'strongly feels' the transition between the calm section at the banks of the river and the 'Schifflände' area, and what he notices is a change in his regime of attention: he describes the section at the Rhine as relaxed and that his 'attention was turned inwards' and that then it 'is suddenly turned outwards again'.

In contrast, only one participant's ΔSCL level in the FEP group rose significantly in the considered location, while the other did not show any particular increase or decrease in SCL. It is striking to notice here that FEP participants, in general, comment the transition from the 'Drei Könige Weglein' to 'Schifflände' in terms of unconscious adaptation to a novel situation, a novel environment. They point to a change in the regime of attention, which suddenly has to be more vivid, and directed outwards. But they feel they do not do it consciously: it is, they say, 'something that happens rather in the affect', that the 'body or head adjusts attention automatically' and that they do 'not really feel the change consciously'.

To conclude this section, it is interesting to note that 'Schifflände' is not arousing per se. When approached from a different angle, this location did elicit different, or even opposite autonomic reactions in three participants (1 FEP, 1 ARMS, 1 Control) with whom we passed twice. For these three participants, ΔSCL showed autonomic activation on the first passage, when coming up from the riverside, but not on the second. This supports the hypothesis that the chronology and sequences through which these spaces are encountered play a role in autonomic activation and that a specific situation is not inherently arousing. The change in terms of attention might be at stake here although as we highlighted here, it is embodied differently by the participants. While, in our case, ARMS participants generally expressed that they feel this change very consciously, FEP participants point to an automatic adjustment of the body or the mind.

3.4. Built environment

The built environment is the elephant in the room in the study of the relation between the urban environments and psychosis. Omnipresent, but difficult to operationalize, it is often left aside in empirical research on the topic.[8] We chose to investigate the built environment through its characteristics of enclosure and openness. In contrast to the abovementioned studies approaching these aspects through isovists, we chose not to compute isovists properties, because they rely on a static and two-dimensional projection of urban space. Instead, we documented the urban environment of every walk with a first-person perspective video. Enclosure and openness, the way they unravel during a walk, can be observed in detail. Therefore, we enter the analysis here with the video footage. We identified significant portions of the path in terms of changes relating to enclosure and openness of the built environment, and confronted these sections of the walk to the interview and the biosensing data.

Through the video footage, we narrowed down the focus on locations where we entered or left a square, coming from or engaging into a much narrower street: 'Marktplatz' or 'Münsterplatz', two of the main pedestrian squares in Basel. 'Marktplatz' is circled by motorized traffic and welcomes the daily market (we crossed it during the afternoon, when the market had already finished), and 'Münsterplatz' is located in the old town and bordered by ancient buildings. Entering and crossing 'Marktplatz' as well as 'Münsterplatz' triggers either downward trends in ΔSCL data for all participants except two, indicating physiological deactivation, or causes no distinguishable impact upon ΔSCL levels. These ΔSCL patterns are accompanied by positive appreciation of the squares in the interview data. On entering these squares, participants often describe them as more 'open'. Hence, the built environment is commented in such situation from the point of view of its enclosure and openness. Generally, this is immediately put into relation with how the space is occupied: the fact that people are scattered is appreciated. Combined to the fact that these squares are pedestrian areas where no other kind of transports is allowed, these situations become 'overseeable', as several participants observed. This refers to their ability, to grasp and understand the situation in its entirety, which conveys a sense of manageability, controllability and risk reduction. Having an overview allows also to gauge the situation, to evaluate 'the amount' and 'kind of people' present, and adapt one's attitude or itinerary accordingly. While openness is generally appreciated, it has its downside as well, since it entails exposure. The fact that there are not too many people on a square is paired in one FEP participant with a 'slight feeling of being observed, at least of being exposed to the view of everyone'. She explains that she feels it, but that it doesn't really bother her. In this case, no arousal was associated with it.

Significant rises in ΔSCL data on these portions of the route are identifiable in two participants only. ΔSCL values increased in one FEP on 'Marktplatz' and one ARMS on 'Münsterplatz'. We hypothesise here that arousal can be associated with elements relating to the interaction between researcher and participants. First, the ARMS participant associates the area with very positive memories, since she went to school there. Second, the interaction between the participant and the researcher also gives crucial insights into potential reasons explaining physiological arousal. Arriving on 'Münsterplatz', we asked participants, as they were informed previously, to take the lead and decide which way to go, in order to eventually return to the starting point. This particular participant explained that this is something she has trouble achieving. Similar interactional dynamics may explain the rise in ΔSCL data in the FEP participants. When crossing the square, the participant explained in detail and very vividly what she went through and how she perceived her environment during a manic episode.

In sum, entering and crossing the two squares elicits generally downward ΔSCL trends or no arousal. This physiological reaction overlaps with positive appreciation of the openness of these squares, which is associated with an overseeable environment. The exceptions to this statement described above highlight the importance of the interaction between researcher and participant.

4. Discussion and conclusion

We discuss our results on two levels; first, we summarize main results and suggest future research perspectives through the notion of *regime of attention*, which we see as a connecting point of our three research axes. Second, we discuss the limitations of our study. Finally, we put our approach in perspective with recent developments in urban studies on the one hand, and mental health research on the other.

Walking in urban environments elicits higher physiological arousal in ARMS participants that in FEP and controls. While acoustic stimulations have been found to be a source of stress for young patients living with psychosis, we found that visual perception of elements in motion were experienced as problematic. However, we found no direct and consistent association with physiological arousal, meaning that expressed stress relative to this aspect does not necessarily correspond to physiological stress as measured by skin conductance. The visual environment, which has been less documented in research as yet, proved also to be important with regards to the built environment. This was revealed

[8] Golembiewski (2016, 2017) discusses the relevance of the built environment to the city-psychosis entanglement as well as he discusses possible ways for the built environment to become 'psychotoxic'.

by narratives and physiological data, since a wide field of view allows for FEP and ARMS participants to observe and analyze the situation they are confronted with, and adapt their attitude or route accordingly. This could be explained by impairments in basic visual function – e.g perception of contrast, speed and orientation – that have been found in individuals with psychosis and clinical high risk groups, in laboratory settings (Türközer and Ross, 2021). Saccadic eye movement and deficits in smooth pursuit eye movement, which allow to track objects in motion, have thus been established as a biomarker for psychosis (Brakemeier et al., 2020). Much less is known about the relevance and implications of such impairments for patients in daily life activities, such as walking (Kogata and Iidaka, 2018). Eye-tracking technology, increasingly used to work on biomarkers of schizophrenia (Morita et al., 2020), could be used *in situ* to further investigate our findings. Finally, our analysis of spatial sequences showed that the urban environment does not permanently exert wear-and-tear on the physiologies of the participants: certain situations, such as the riverside, decrease physiological arousal. However, transitions between these situations act like triggers of attention.

Common to these results is the importance of *regimes of attention*.[9] While walking in an urban environment, participants' attention shifts from an inward examination of thoughts, ideas and feelings, to a careful scrutiny of their surroundings. Situations that are experienced and described as calm allow for introspection. In our study, these are generally associated with low physiological arousal. On the opposite, hectic environments, and the perceptual stimulations that come with them, engage attention towards the outside world. In such situations, sight and hearing predominate. Transitions between calm and hectic environments thus act like triggers moments that prompt a switch in the *regime of attention*. In future work, we will investigate further the relations between urban transitions and regimes of attention.

There are limitations to our research. The first is the sample size, which is rather small. This is primarily due to the difficulty in recruiting participants within the BEATS and other early psychosis programs and to our time-intensive methodology. The sample size is nevertheless comparable to other studies working with ambulatory SC in urban contexts with similar approach based on visual analysis (Bergner et al., 2013: n = 7; Zeile et al., 2016, n = 12; Chen et al., 2018,n = 4; Fathullah and Willis, 2018, n = 9). Second, for ethical reasons and following the publication recommendation of SC measurements on that matter (Society for Psychophysiological Research, 2012), medication intake was not interrupted for the purpose of the study. Results of studies on effects of medication on autonomic arousal are contrasted and mainly carried out in lab. Nevertheless, it has been found that "skin conductance level can serve as a stable and useful index of autonomic arousal in clinical trials, even in patients using beta-blocking medications" (Jacobs et al., 1994, p. 1170). Third, our approach allows to identify spatial associations between expressed feelings of stress, arousal or wellbeing and ΔSCL patterns. However, due to the real-life and *in situ* approach, we cannot determine definite causality between physiological arousal, narratives and location. Fourth, our research is committed to the study of the impact of the proximate environment, and to the study of event- and context-based distress. Thus, our study design did not allow us to extend the analysis neither to broader socio-contextual factor that come into play[10], nor to the cumulative and long-term effects of distress. Future research should work towards integrating these dimensions. Finally, the presence of a researcher, the fact that the participants had to wear the Empatica E4, that the discussion was recorded and the environment was filmed all participate in creating a situation that is still an experimental set-up, rather than truly representative of ordinary daily life. However, the methodology we developed and implemented in this pilot study, is informed by and contributes to current epistemological debates and methodological developments, both in urban geography and mental health research. In addition, our observations provide a starting point for future research.

Ambulatory monitoring of physiological variables is still dawning. In geography, ambulatory physiological measurements are increasingly used to study how persons are affected by their (urban) environments, "offering cultural geographers and others a significant new technique for examining questions around embodiment" (Osborne and Jones, 2017). However, in this research strand, questions of health and wellbeing remain marginal (for an exception, see Pykett et al., 2020a,b; Chrisinger and King, 2018), and issues of mental health even more. This is the terrain we have sought to explore. Working with persons having experienced a first episode of psychosis and persons 'at risk mental state', we extend in this paper research on urban emotional arousal to bear on important questions of mental health. Mobilizing physiological measures, contextual data and narratives, we have developed a mode of analysis inspired by Osborne and Jones (2017): a hypothesis-driven data triangulation that allowed us to grasp aspects of the « affective complexity of moment-to-moment bodily engagements with the environment » (Amin and Richaud, 2020, p. 863) of persons living with early psychosis and those identified 'at risk mental state'. Such endeavor overlaps with recent calls from sociologists working on urban mental health to embrace a biosocial approach to the city-psychosis nexus, in order to work towards a "thicker ontology of urban mental health" (Fitzergald et al., 2016, p. 154). However, "it is not immediately clear how to put this strategy into practice" (Manning, 2019, p. 2). The methodological procedure we experimented in this paper, based on the possibilities offered by ambulatory biosensing and digital phenotyping, is one of the ways to "develop a finer-grained, ethnographically informed analysis of the accumulation of urban situations that constitute stress and their spatial, temporal and sensorial characteristics" (Rose, 2020, p. 46).

In times of rapid urbanization, where cities emerge both as crystalizing multiple (mental) health risks[11] and as an important resource able to tackle these questions, it is crucial to pursue efforts towards a better understanding of how specific elements of the urban environment affect embodied experiences, how they impact perceived and physiological stress, and more generally our wellbeing and quality of life. In recent years, health has been put on the agendas of city governments, through programs such as the *WHO Healthy Cities movement* or initiatives such as *Thrive in the City*. Biosensing and digital phenotyping have been suggested as holding great potential for informing healthier urban design and planning strategies (Ellard, 2015; Millard et al. 2021). Our approach highlights that, while holding great potential, physiological measures alone are far from sufficient. Moreover, prioritizing biological (stress) responses to environment while sidestepping conscious and lived experiences, entails the risk of creating "a less human(e) account of urban stress" (Pykett et al., 2020a, p. 9).

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[9] Attention has been defined as a "cognitive function that allows humans and other animals to continually and dynamically select particularly relevant stimuli from all the available information present in the external or internal environment" (Talsma et al., 2010, p. 402, p. 402).

[10] See Pykett et al. (2020a,b) for a critical discussion on the importance of such macro determinants in biosocial research.

[11] It is worth reminding here that urban areas are not inherently harmful, that they are also associated with positive health outcomes (Galea et al., 2005), in particular through greater (mental) health services availability (Sørgaard et al., 2003).

Declaration of interest

We have no conflict of interest to declare.

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