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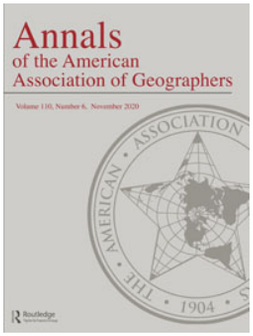

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From Urban Stress to Neurourbanism: How Should We Research City Well-Being?

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Urbanicity has long been associated with stress, anxiety, and mental disorders. A new field of neurourbanism addresses these issues, applying neuroscience laboratory methods to tackle global urban problems and promote happier and healthier cities. Exploratory studies have trialed psychophysiological measurement beyond laboratories, capitalizing on the availability of biosensing technologies to capture geo-located physiological markers of emotional responses to urban environments. This article reviews the emerging conceptual and methodological debates for urban stress research. City authorities increasingly favor new data-driven and technology-enabled approaches to governing smart cities, with the aim that governments will be enabled to pursue evidence-based urban well-being policies. Yet there are few signs that our cities are undergoing the transformative, structural changes necessary to promote well-being. To face this urgent challenge and to interrogate the technological promises of our future cities, this article advances the conceptual framework of critical neurogeography and illustrates its application to a comparative international study of urban workers. It is argued that biosensing data can be used to elicit socially and politically relevant narrative data that centers on body–mind–environment relations but exceeds the individualistic and often behaviorist confines that have come to be associated with the quantifying technologies of the emerging field of neurourbanism. *Key Words: Biosensing, embodied geographies, neurourbanism, urban emotions, well-being.*

城市化长期以来伴随着压力、焦虑和精神障碍。新兴的神经城市主义解决了这些问题，它将神经科学实验室方法应用于解决全球城市问题并促进城市变得更幸福、更健康。探索性的研究已通过在实验室外使用心理生理测量得到了尝试，这是利用现有的生物传感技术，以捕获对于城市环境的情绪反应的地理位置生理标记。此文章回顾了有关城市压力研究中的新兴概念和方法论辩论。城市当局越来越倾向于采用新的数据驱动和技术驱动的方法来管治智慧城市，其目的是使政府能够奉行循证的城市福祉政策。然而，几乎没有迹象表明我们的城市正在为促进福祉而进行变革性、结构性的变化。为了应对这项急迫的挑战并盘诘我们未来城市的技术前景，本文提出了关键神经地理学的概念架框，并说明了其在城市工人的国际比较性研究中的应用。有人认为，生物传感数据可用于得出与社会和政治相关的叙事数据，而这些数据以身体、思想与环境的关联为中心，但它超出了个人主义和行为主义的范围；这些范围已与新兴的神经城市主义的量化技术相关联。 *关键词：生物传感、体现地域，神经城市主义，城市情感，福祉* 。

La urbanicidad ha sido un término asociado durante años con el estrés, la ansiedad y los desórdenes mentales. Corrientemente, estas cuestiones son enfrentadas por el campo nuevo del neurourbanismo—aplicar métodos de laboratorio de la neurociencia para abordar problemas urbanos globales y promover ciudades más felices y saludables. En estudios exploratorios se ha ensayado la medición psicofisiológica más allá de los laboratorios, capitalizando la disponibilidad de tecnologías bioperceptoras para captar marcadores fisiológicos geolocalizados de respuestas emotivas a los entornos ambientales urbanos. Este artículo hace una revisión de los nuevos debates conceptuales y metodológicos sobre la investigación del estrés urbano. Cada vez más las autoridades urbanas privilegian los enfoques basados en datos y apoyados en tecnología para gobernar las "ciudades inteligentes", con la intención de que el gobierno adquiera la capacidad de propender por políticas de bienestar urbano basadas en evidencia. No obstante, hay pocas señales de que nuestras ciudades estén experimentando los cambios transformativos y estructurales necesarios para promover bienestar. Para enfrentar este urgente desafío y para interrogar las promesas tecnológicas de nuestras futuras ciudades, este artículo presenta esquemas conceptuales de la neuro-geografía crítica e ilustra su aplicación en un estudio

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comparativo internacional de los trabajadores urbanos. Se argumenta que los datos bioperceptivos pueden usarse para establecer centros de datos de una narrativa social y políticamente relevante de las relaciones corpóreo–mental–ambiental, así exceda los confines individualistas y a menudo conductistas que han llegado a verse asociados con las tecnologías cuantificadoras del campo emergente del neurourbanismo. *Palabras clave: bienestar, biopercepción, emociones urbanas, geografías personificadas, neurourbanismo.*

Interviewer: To what extent do you feel your feelings are shaped by the place where you live? An urban environment in particular?

Respondent: Definitely yes. Because I was living in half a year in New York.

Interviewer: Oh right.

Respondent: And it's quite the opposite of my village.

Interviewer: Yes, yes, and how did that affect you?

Respondent: I was stressed all the time.

Interviewer: Right.

Respondent: Definitely, yeah, I couldn't sleep.

Interviewer: Oh?

Respondent: Never. It was always too hot or too warm in my room.

Interviewer: Right.

Respondent: And so many people always running, running, running, running.

—Salzburg Participant 6 (male, age 20–30)

The complex relationship between the urban condition and the human condition has long been a major preoccupation, and this concern will be intensified as the population of the world's cities rapidly expands. Arguably, attention has been focused most on the damaging effects of cities, and renewed interest in the concept of urban stress over the last two decades from neuroscientists and epidemiologists exemplifies this trend. This renewed interest, however, often occurs in isolation from a much earlier history of urban stress within urban sociology (Simmel [1903] 2004; Wirth 1938; Faris and Dunham 1939). Acknowledging this, contemporary social scientists have begun to engage with neuroscientific research on the urban brain. They outline significant potential for urban and social theory to challenge the potential reductionism, determinism, and medicalization associated with this field (Callard 2003; Fitzgerald, Rose, and Singh 2016). Recent contributions have thus centered on the value of interdisciplinarity between the life sciences and more sociological and anthropological perspectives on embodied and lived experience (Fitzgerald, Rose, and Singh 2016; Söderström 2019). Yet despite many studies now demonstrating correlations between urban living and mental disorder, "it has been difficult to identify exactly how urban life 'gets under the skin'" (Manning 2019, 2).

In current explorations of these potential mechanisms, stress has found a renewed importance as the potential conduit by which the urban condition is embodied in human experience. Lederbogen and colleagues (2011), for instance, described the correlations between mood, anxiety, and psychotic diagnoses; urban upbringing; and current city living. Their work is significant in beginning to explain some of the neural mechanisms that could mediate these relationships. Yet as this article sets out, there is still much disagreement over the definition, conceptualization, mechanisms, and measurement of stress. The booming interest from neuroscientific, medical, and psychological perspectives could therefore benefit from deeper engagement with social and urban theory to advance understandings of the body–mind–environment relationship, recontextualize specific kinds of stress in relation to specific practices in specific places, and shape polices for improving city well-being. Current interdisciplinary efforts are hampered by either individualistic or sociological reductionism and a lack of a shared vocabulary and understanding of "what counts as knowledge, argument, indeed good science in biology and sociology" (Manning 2019, 2). We need new ways to explain the embodied experiences, spatialities, and temporalities of urban spaces. What drives the sense of pace, crowding, stress, bodily discomfort, early life experiences, and city encounters outlined in the opening quote, which can have lasting effects on the experiences of city living?

The fields of neuroarchitecture, neurourbanism, and related psychophysiological research on urban stress and well-being have emerged to investigate the relationship between the human brain, urban density, city landscapes, and architectural forms.

Brain-based landscape design addresses the relationship between psychological and neuroscientific mechanisms and the architecture of the built environment (Zeisel [1981] 2006; Eberhard 2009), paying particular attention to how the physical environment shapes neural processes of memory, orientation, learning, sensation, perception, emotions and affects, movement, and decision making. Neurourbanist planning considers the longer term impacts of urban living as a risk factor in mental health (Adli et al. 2017). These new fields carry with them specific accounts of spatiality and temporality, and, as such, this article highlights the opportunities and limitations of these fields from a geographical perspective. We build on previous geographical work on the space-times of decision making (McCormack and Schwanen 2011; Whitehead, Jones, and Pykett 2011), as well as political economic perspectives on subjective embodied experiences, which connect biological knowledge with capitalist relations (Callard 1998; Choudhury and Slaby 2012).

The article advances a novel conceptual framework of critical neurogeography to provide a bridge between the vastly different scales of analysis that characterize the molecular worlds of neuroscientists and the political economic worlds of geographers and urban theorists (Pykett 2018). This sets out a research rationale for the novel integration of (biological) biosensing and (anthropological) narrative methods to critically evaluate the promise of neuroarchitecture and neurourbanist planning that can inform city well-being and urban health policies. Drawing on an international comparative study of urban workers in two cities—Birmingham, UK, and Salzburg, Austria—we detail an urban condition that is increasingly dominated by scientific narratives of stress, medical accounts of urban mental distress, and technologically driven promises of future well-being. We argue that these scientific narratives do not pay sufficient attention to either the ways in which fixed, clinical diagnostic categories of mental health are increasingly being challenged (Johnstone and Boyle 2018) or the ways in which urban stress as a phenomenon must necessarily be understood as the embodied manifestation of capitalist relations. To address this, we offer reflections on a biosocial methodology intended to treat urban stress as a set of situated emotional encounters with the city as a relational space, pointing to ways in which researchers can productively navigate the inevitable tensions between the imperative toward psychophysiological measurement and emotional experience (Cromby 2007; Davies 2015).

Novel Neuroscience of the Stressed Urban Brain

In terms of mental health, it is widely argued in the psychiatric literature that city upbringing and within-city neighborhood social variations can interact with genetic risk factors to cause psychotic illnesses categorized through the diagnostic construct of schizophrenia (Krabbendam and van Os 2005). Crucially, however, the stability of the term *schizophrenia* itself has been increasingly challenged, and consistent biological markers of this collection of symptoms are not well evidenced (Boyle 2002; van Os 2016; Tew 2017). So, too, the specific urban mechanisms that can convincingly explain a diversity of experience and confounding factors remain unknown (Fett, Lemmers-Jansen, and Krabbendam 2019). Similarly there are studies that have shown differences in the prevalence of mood, anxiety, and depression diagnoses between urban and rural settings (Peen et al. 2010). The urban environment has also been linked to a diminished neural ability to process stress (Lederbogen et al. 2011). Bringing neuroscience conceptually and methodologically out of the lab has thus become a central factor shaping research on urban emotions, but applied research on the combined biological and sociological mechanisms of urban mental life is still relatively rare (Manning 2019).

There are several factors inherent in cities and the built environment that have been reported as key stressors and, in contrast, as sources of well-being, restoration, and stress reduction. Social factors include living in an inner-city area or socially deprived neighborhood, which has been associated in the psychological literature with higher prevalence of discrimination (Prelow et al. 2004), powerlessness (Geis and Ross 1998), aggression (Kuo and Sullivan 2001), and impulsivity (Frankenhuis, Panchanathan, and Nettle 2016). Several stress pathways relevant to urban stress have been identified, including increased social threat (Dickerson, Gruenewald, and Kemeny 2009), a harsh and unpredictable environment (Frankenhuis, Panchanathan, and Nettle 2016), perceptions of neighborhood problems (Steptoe and Feldman 2001), social isolation (Steptoe et al. 2004), conditions of

chaos (Evans et al. 2005), and commuting stress (Koslowsky, Kluger, and Reich 1995). These findings are, however, limited by the predominant use of psychological scales to enumerate contested constructs such as threat or powerlessness, which some regard as methodological artifacts of model building (Harré 2002). To get closer to closing the gap between identifying correlations between measured psychological traits, states, and environments and outlining causal mechanisms at an expanded level of explanation, we arguably need better ways to investigate urban experience and encounter.

Psychologists have sometimes tended to approach this gap quite literally; for instance, by examining the effects of the physical landscape of the built environment on mental well-being. The urbanicity effect was tested by Corcoran et al. (2017), who found that even just briefly looking at photos of desirable or undesirable landscapes (urban or rural) had some effect on participants' anticipations of threat, which is linked with increased depression, anxiety, and paranoia. Others have presented evidence that the geometric and statistical properties of repetitive patterns found in urban landscapes in contrast to those exhibited in natural scenes produce feelings of visual and cognitive discomfort (Le et al. 2017). Several stressors in the built environment have been identified, including noise, crowding, housing type and quality, light, and air quality (Evans 2003). The methodologies pursued here, however, have tended to treat the research subject as a passive monad whose personal background must often be normalized to enable population-level analysis of data. The active subjectivity of human agents is often denied or reduced to psychometric scores that obscure personal and collective meaning, nuance, or internal contradiction. Indeed, internal consistency is the desired endpoint of the validation of survey instruments. Furthermore, the mediation of human action by social, cultural, economic, and political mechanisms is often unaccounted for. Instead, humans are addressed as habitual creatures of their immediate environment. In this regard, there is sometimes a risk of reducing human behavior to a model of stimulus–response, with biological processes as the primary mediating factors requiring analysis. Geographical research on urban emotions and mental life has the potential to shape the discursive agendas, methodological practices, and policy applications of these emerging fields.

A new field of neuroarchitecture established in 2003 (Zeisel [1981] 2006; Eberhard 2009) aims to identify the effects of the built environment on brain activity. Architects have become interested in assessing the impact of light, noise, geometry, and materials on embodied and affective emotional states, looking at the height of buildings, practices of wayfinding, sensory stimuli, and building complexity in a variety of settings such as schools, workplaces, and hospitals (Edelstein 2008; Eberhard 2009). There is a key drive to measure stress responses, cognitive reactions, and emotional reactions through eye movement, brain activity, and heart rate variability, for instance, among research participants immersed in virtual reality environments (Zhang et al. 2010; Shemesh et al. 2017). The unit of analysis here is the physiology of the individual research subject, and the spatiotemporal dimension is the behavior elicited by the immediate and proximate environment (Zeisel [1981] 2006). More recently, researchers have called for a new discipline of neurourbanism to widen the focus "on the interdependencies between urbanisation and mental wellbeing" (Adli et al. 2017, 183). Such research has been informed by lab-based neuroscience techniques such as functional magnetic resonance imaging scanning (Lederbogen et al. 2011) and epidemiological studies (Fett, Lemmers-Jansen, and Krabbendam 2019). The latter draw on a much more expansive conception of the urban as a specific kind of space and a longer temporality that focuses on the formative experiences of an urban upbringing. In this article, we argue that more attention needs to be paid to the complexity of the spatial and temporal imaginaries deployed within these emerging research agendas, offering an impetus to engage in more interdisciplinary biosocial research to inform contemporary urban well-being policies.

Ambulatory Assessment and Psychophysiological Approaches to Urban Stress and Well-Being

Taken together, the findings from neurourbanism and neuroarchitecture suggest that several social and physical aspects of city living have a lasting impact on mental health and stress. Recent studies in environmental psychology and GIScience have similarly advanced the mobile, in situ investigation of the

relational pathways between urban living and stress. Various methods of ambulatory assessment or biosensing have been used, including e-diaries, salivary cortisol measures, wrist-worn biosensors, and chest-worn heart rate monitors. Biosensing describes the use of technology to collect physiological or biometric data, often coupled with psychometric data and analyzed through psychophysiological models. It has much in common with methods of ambulatory assessment that have a longer tradition in psychology (Wilhelm and Grossman 2010). These methods are commonplace in health care and emergent in the neurosciences (Reichert et al. 2018). They largely take a components approach to modeling the effects of urban stressors and environmental characteristics on psychological measures or neurobiological correlates and offer researchers fine-grained, time-specific accounts of psychological response. Seldom, though, do they attempt to position these responses in the broader historical and geographical context in which people emotionally engage with specific cities.

Some psychological research on emotions is now advocating an explicit escape from the controlled experimental laboratory context. Concerns about reproducibility, confounding variables such as physical activity, person-specific health (e.g., diet and smoking), the difficulties of isolating emotional triggers, and unresolved debates on the physiological correlates of discrete emotions have arguably slowed this scientific project (Kreibig 2010; Stephens, Christie, and Friedman 2010; Wilhelm and Grossman 2010), and commercial and policy applications of novel psychological knowledge about mobile city life abound. Researchers are keen to respond to international political enthusiasm for addressing urban stress and improving urban well-being, in terms of making cities "healthier and happier for all" (World Health Organization 2018). Biosensing technology is central, for instance, to the potential use of predictive analytics and empathic artificial intelligence, which aim to draw on human emotional data and emotional processes to build intelligent technologies and algorithms able to measure and potentially improve subjective well-being in smart cities (Bin Bishr 2018) and commercial desires to automate human understanding (e.g., Sensum 2018). Rapid commercial and technological developments are driving research agendas, yet knowledge about what is theoretically, methodologically, and analytically plausible in this field is arguably lagging behind.

These practices of digital and mobile monitoring of our own dynamic biometric data transform our relationships to our bodies, by treating the body as a source of valuable data and as a resource to be optimized. The discursive frame of *biocapitalism* is thus useful for advancing understanding of the contemporary uses of biometric data in urban analytics and the workplace. Biocapitalism is a term used by political economists to describe the shift of the source of economic value from the abstract laborer to the subjective, relational experience of the worker, whose workplace performances are increasingly immaterial, emotional, creative, and cognitive (Morini and Fumagalli 2010). Significantly, it is through the immediate promise of workplace emotion monitoring technologies to help "people to better 'connect' with their body" (BioRICS 2018) that the historical specificity of the scientific concept of stress has been obscured and our ability to engage with workplaces stress (and by extension, urban stress) at a political level arguably becomes diminished. The emerging practices and applications of biofeedback and self-tracking around urban stressors and workplace well-being thus call for forms of urban analytics that empower diverse citizens to engage with scientific data gathering, production, and analysis in the context of wider understandings of the intersections of bioscience, capitalism, and society (Choudhury and Slaby 2012).

The added value of identifying the causal pathways between the situated environment, the body, brain, mind, and behavior are proposed as the cornerstones of ambulatory psychophysiological research methods. Researchers have started to integrate GIScience, subjective reports of emotions, and physiological data to investigate urban stress. Findings have been generated on correlations between residents' positive or negative ratings of built environment features and their electrodermal activity (Chrisinger and King 2018) in the San Francisco Bay Area, California; stress hotspots identified by urban cyclists in Boston, Massachusetts (Zeile et al. 2016); patterns of physiological arousal at religious sites and sites of security risk in Jerusalem, Israel (Shoval, Schvimer, and Tamir 2018); and statistically significant correlations between heart rate and skin conductance and video-coded and self-reported stress points of drivers in Boston (Healey and Picard 2005). Others have adopted salivary cortisol measures of stress combined with area-based, rather than

GIScience, measures leading to results that show positive relationships between green space and lower stress (Ward Thompson et al. 2012; Olafsdottir, Cloke, and Vögele 2017).

Urbanists and advocates of urban well-being have themselves also begun to explore the potential of and experiment with biometric sensors, although they express some reservations about the validity and reliability of the results produced outside of the laboratory (Happy City 2016; Happier by Design 2017). This same caution, in addition to the quest to move beyond correlation to explanation, has led geographers and designers with an interest in embodiment to advocate mixed-methods approaches, including narrative interview data and phenomenological interpretation (Olafsdottir, Cloke, and Vögele 2017), postphenomenological accounts (Spinney 2015; Osborne and Jones 2017), and the collective and performative dimensions of biomapping visualizations (Nold 2009, 2018). This article develops these approaches by advancing a conceptual framework of critical neurogeography that moves beyond mixed methods to advocate an embodied geography of stress, using the stress experiences of urban workers to generate novel questions about neuroarchitectural and neurourbanist imaginaries of space and time.

Biosocial Methodology

Acknowledgment of the complexity of human–environment interaction and environmental stressors or stimuli has led to calls within several social science disciplines to reconnect the self, the social, and the spatial. It has been argued that a new biosocial framework is required to advance understanding of both the historical representation of the stressful city and the "measurable differences in brain function—differences which might well be traced to that subject's inhabitation of, or experience in, the tumultuous urban scene" (Fitzgerald, Rose, and Singh 2016, 222). One of the most intractable challenges of the biosocial research agenda is to find methodologies that can straddle the inevitable tension between the biological and the social, to elucidate mechanisms of interaction, and to provide explanations that acknowledge the nonlinear relationship between scientific evidence and social experience. We conducted our study in Birmingham, UK, and Salzburg, Austria, between November 2017 and January 2018, as part of a larger project that compares urban well-being in different national contexts.[1] The sole eligibility criterion for participants was that they were adults who were currently working in the case study city. Thirty participants were recruited through two higher education institution workplaces via posters and flyers distributed at a workplace well-being event and a union mailing list. Our target sample included both men and women, a range of ages between eighteen and sixty-five to reflect the working-age population,[2] and a variety of job roles. Ethical approval was granted by the University of Birmingham institutional ethics board.

To combine our focus on embodied experience, psychophysiological methods, and geography, the outcome measures we used included biosensing, an ecological momentary assessment (EMA) diary, stress and well-being surveys, and qualitative interviews. We used a wrist-worn medical grade biosensing device (Empatica E4) to collect time-stamped biometric data continuously throughout the participants' journeys to work, their working day, and their journeys home. The use of a wearable biosensor was intended to encourage research participants to reflect on their embodied experiences of stress at particular times and spaces. Biometric data collected included changes in electrodermal activity (EDA), blood volume pulse (BVP), wrist movement (tri-axial accelerometry, showing the three-dimensional movement of participants), heart rate (HR), and skin temperature. Simultaneous increases in EDA and HR were used to infer autonomic arousal or stress response, but we were mindful that there is still considerable debate within biological psychology concerning the differences between emotions such as anxiety, fear, and, stress, whether stress is indeed an emotion, and significant, what emotions even are (Harré and Parrott 1996; Fox 2008; Kreibig 2010; Boucsein 2012; Norman, Necka, and Berntson 2016). The EMA diary was completed at hourly intervals, responding to the following questions: (1) What are you doing right now? (2) What is the main feeling you are currently experiencing? (3) What is the intensity of this feeling? (4) How stressed are you feeling right now? and (5) How do you rate your ability to cope with this situation? The purpose of this was to be able to combine the "objective" biometric data with "subjective" momentary self-report of participants' own stress and well-being.

We recorded general demographic data including gender, age, education level, marital status, perceived

health status, employment role and duration, job satisfaction, and mode and length of commute to work to be able to investigate correlating variables for the larger project. Participants completed the twenty-six-item World Health Organization Quality of Life Survey, which covers aspects of physical health, psychological well-being, social relationships, and environment. They also completed the Perceived Stress Scale–10, which asks participants about their own perceptions of stress and is made up of ten items (e.g., feeling upset, nervous, and stressed; coping with difficulties; and feeling in control). The purpose of these surveys was to be able to compare people's own appraisals of their perceived stress with the indicators derived from the biosensing data and the narratives from the qualitative interviews.

The qualitative interviews were transcribed verbatim and imported into the qualitative data analysis software NVivo 12 (Version 12, QSR, Melbourne, Australia). The textual data were coded thematically by the lead author according to (1) participant descriptions of the journey to and from work and the working day; (2) key features and appraisal of the journey; (3) experiences of workplace stress; (4) descriptions of embodied and emotional stress indicators; (5) perspectives on Birmingham or Salzburg as a city, urban–rural upbringing, and political and societal trends as potential drivers of stress; and (6) reflections on participating in data collection and measures used. The aim of the study was to develop a new method of bioelicitation, combining GIScience, biosensing, and narrative approaches to enable research participants to develop their own thick descriptions of stress experiences and feelings, transcending divisions between biological, psychological, and sociological approaches. In this article, we draw mainly on the qualitative interviews to illustrate the theoretical, epistemological, methodological, and political questions raised by biosocial research.

Critical Neurogeography

Critical neurogeography has been proposed as one such integrative, biosocial framework that focuses on the object of "brain culture" as a social formation that takes spatial forms. This describes how the discipline, technologies, ontologies, and epistemologies of neuroscience have shaped society and how specific neuroscientific insights have been manifest in policy and diverse fields of social practice in particular spaces (Pykett 2015, 2018). A key problematic for critical neurogeography is to assess the relative extent to which the brain, mind, and world are narrated as the locus of behavior and the source of sociological and scientific explanation. Theoretically, this framework is informed by philosophies of critical realism and critical neuroscience, and it draws on the anthropological methodologies of science and technology studies. It builds on previous work that has called into question the depoliticization of human emotions and the rush for technical fixes for mental ill health (Cromby 2007; Choudhury and Slaby 2012; Rose 2013; Fitzgerald and Callard 2015). It engages with research in human geography that has been influenced by neuroscientific and behavioral insights (Thrift 2004; McCormack 2007; Whitehead et al. 2012) while seeking more skeptical ways of working with the supposed ontological primacy of embodiment, materiality, and affective resonances (Korf 2008).

By advancing a geographical focus on the brain in its social milieu, the framework of critical neurogeography foregrounds a relational account of space. It challenges us to consider the partiality of approaches that overlocalize complex and diverse social experiences of stress within neural mechanisms. The spatial imaginaries of neurourbanism, neuroarchitecture, and ambulatory assessment are characterized by localization and correlationism. This tends to reduce the spatial properties of urbanism to immediate environmental forms and stressors or forms that—as in epidemiological accounts—regard space as a container for population-level data and tend to ignore the significance of social practices. As Manning (2019) argued, these paradigms are strong on identifying associations but limited in identification of convincing causal mechanisms of the relationship between city living and mental ill health and inadequately address what constitutes the "social" within the social variables considered. By contrast, in Massey's (1993) conceptualization of relational space, places are internally heterogeneous, constituted through social relations, and shaped by external structures and factors. Relational space is therefore dynamic, shaped by networks and flows, and connected to processes operating across multiple scales. From a relational perspective, it is not possible to isolate the place-specific components of urban stress without appreciating the wider social,

economic, cultural, and environmental context in which space is produced.

A relational conception of the city thereby proposes urban space as more than a physical backdrop of human activity. When approaching the city instead as a spatial manifestation of capital flows and societal relations, it becomes necessary to scale up both our methodologies and analytical frameworks to expand what it is possible to regard as a causal pathway for urban stress and to emphasize stress as a reflective socially situated emotion as opposed to a conduit of mental ill health. Our cultural perceptions of urban well-being and our bodies are both shaped by the dispositional, generative, and vital spatial rationalities of the city that have historically pursued an ideal of the hygienic biosocial city in assuring the optimum circulation of goods and people (Huxley 2006). The city understood as a historical landscape and a spatial product of work (Harvey 1989) impels us to investigate the stress experiences of the urban workforce. Work and commuting, after all, are for many people a source of stress and unhappiness to the extent that people find almost any other activity preferable (Bryson and MacKerron 2017), and public commentary on work-related stress and burnout continues to provoke concern (Sarner 2018). Narrative, imagery, and political rhetoric have long shaped experiences of city life, and such factors play an important role in mediating experiences of urban stress. As Amin (2013) articulated in his geographical account of the urban condition, the city is more than the sum of its parts: "Always pushing against even the most cemented, planned, and regulated of cities is the city of unsteady states and emergent combinations" (206).

These contextual and emergent factors do not have to be rendered scientific for them to count as causal mechanisms, and limiting our methods to wearable biosensing alone would have excluded these wider social determinants of stress from the analysis. Indeed, several of our research participants, particularly in the United Kingdom, described how contextual factors were shaping their experiences of stress, including aspects that did not directly refer to their own spatial contexts but were related to events occurring elsewhere or things primarily affecting other people. Critical realism provides a useful framework for appreciating these links. Sayer (2000) distinguished between three aspects of the world's reality: the *empirical*, or that which is experienced; the *actual*, referring to things that occur but are not necessarily directly experienced; and the *real*, or the deep structures and mechanisms that generate phenomena. In this account, the causal mechanisms underpinning human action and lived reality cannot be observed directly, and reality cannot be reduced to a supposed empirical word understood as our direct experience or to empirical evidence that is generalizable and replicable. In the following responses, we can see that actual determinants of participants' stress might be real although not empirical in Sayer's terms:

> *Interviewer*: How do you think people in society's stress levels have changed over the last ten years? Or have they not changed?
>
> *Respondent*: That again is quite a different concept—I think they may have become—in some ways, either neutral or slightly better. It's been a tough old ten years really, hasn't it, because people have gone from having a lot of, you know, a lot of sort of income, a lot of support, to you know, we've gone through austerity, people have lost jobs, etc., etc. So I think there's probably been a real dip. But I think that maybe, it's starting to lift. But then you know, maybe that's just the way I'm feeling, that I'm projecting onto society as a whole. (Birmingham Participant 14, male, age 30–40)
>
> *Interviewer*: We were talking briefly about Brexit and how that's made things quite stressful for you.
>
> *Respondent*: My husband and I sit at breakfast going "Oh dear!" That's cast a pool over the end of my life. I think the financial uncertainty means that I don't particularly want to give up my job, although my father was a university lecturer 'til he was 85, so we don't mind keeping on working in our family. So, yes, I remember the year that the Soviet Union invaded Afghanistan over Christmas and that really ruined my Christmas! So things like that do. (Birmingham Participant 5, female, age 60–70)

These narratives exemplify experiences of emotional stress that can be identified by participants when they are invited to consider wider spatiotemporalities of stress beyond urban, environmental, or architectural stressors. They might not have personal experience of job loss or economic insecurity, and the emotional atmosphere of Brexit or distant warfare might not have replicable and generalizable impact on any psychometric measure of their stress. As a

narrative emotional experience, however, these phenomena could play a part in shaping someone's physiological stress response to urban living.

This challenges the behaviorist notion of stress as a psychophysiological response to any given environmental situation. Instead, the mechanisms of urban stress can be articulated through *retroductive* inferences. Retroduction provides researchers with the best possible explanation for a particular phenomenon or mechanism, which emerges from the researcher's engagements in the spaces between the empirical data and theoretical framework. It is in the spaces between theory and data that new questions and new knowledge about the world are thus generated, because the researcher is required to identify the conditions of possibility of phenomena, experiences, and concepts. Data that do not fit with a preconceived hypothesis are also allowed to emerge in the process of theory construction (Meyer and Lunnay 2012).

Hence, a multilayered analysis of the empirical, actual, and real (rather than the empiricist account of space provided by neuroarchitecture, environmental stressors, and biosensing) helps us to demonstrate how the distinct biographies and social relationships of our participants shape their experiences of urban stress through a spatiotemporal imaginary that is relational and contextual. This can mean that people's personal relationships in the space of the home shape their experiences of stress in the daily workplace; their embodied experience of a particular space-time exceeds that specific situation:

> I think obviously outside of work then just trying to balance a full-time and quite responsible job, as with my partner and obviously we've got a toddler, which I've made a conscious decision to work and whatever, but there is a real, there is a constant stress because of the ability to be an adequate mother to my daughter and the time—so in the week there's very limited time. (Birmingham Participant 16, female, age 30–40)

It can also mean that their experiences of the qualities of the urban environment itself could be shaped by multiple complex factors such as upbringing, ideas of what aspects of city and rural living should be valued, whether one identifies as a "city person," and the unequal embodied and gendered experience of urban space:

> I mean, but it's really crowded, I don't like it that much because, for example, I came from the countryside and I'm not used to being around many people. I mean I just … and we don't have bus lanes at all so. (Salzburg Participant 7, male, age 20–30)

> I have wondered about whether I'd like to move out into a more sort of rural environment. But then when I try it, even for a short period, like I'm actually—no I'm a city person. So I think deep down, I'm a city person. (Birmingham Participant 14, female, age 50–60)

> Oh yeah, I'm not like a country bumpkin. I don't do nature. (Birmingham Participant 13, female, age 30–40)

> I wish it was safer for women to walk at night. I drive around at night in my car and I see millions of men walking. I hardly ever see a woman. And I feel men don't appreciate the privilege they've got. They don't appreciate that it's safer for them. They feel—I walk to the car park at night, and if I work late I will have my keys in my hand, as useless as they are. (Birmingham Participant 11, female, age 40–50)

These responses articulate the relevance of the actual to emotional encounters with and in the city. These can be gendered, informed by cultural representations and processes of self-identification that are not necessarily well captured by physiological instrumentation or psychometric surveys. Yet a further depth of interpretation is needed if we are to get closer to understanding what Sayer (2000) termed the ontologically "real," or the "structures or powers of objects" (12). These might be directly unobservable but have real effects or can refer to possible outcomes that can emerge when such powers are exercised. The ontologically real but nonempirical is rarely acknowledged in neuroarchitecture and neurourbanism. Next we explain what is therefore missing from their causal explanations and analyses of the qualities of urban spaces.

Narrative Approaches: Urban Workers in the Context of Biocapitalism

The identity and biographical experience of research participants in the kinds of neuroscientific, biosensing, and ambulatory studies outlined earlier are seldom the primary focus of enquiry; often we only know that participants were residents, walkers, cyclists, or drivers. There are several reasons to bring biographical and narrative interpretation into a psychophysiological analysis of urban stress. First, if we

are to engage with research participants not as research subjects but as active citizens, ambulatory assessment will be enhanced by an understanding of why these people are moving through space. Because cities and dense forms of inhabitation exist primarily as sites of economic exchange, most urban dwellers are engaged in some kind of work, are on their way to or from work, or are contributing in some way to activities of production, consumption, exchange, and distribution.

When biosensing data are analyzed alongside narrative interview data at an individual participant level or perhaps used to elicit interviewee explanations of their biometric readings, there is potential for this combination of methods to generate novel understandings of urban work stress through fine-grained analysis of the experiences of each research participant (see Figure 1). With the detailed and accurately timed information provided in the interview relating to their train times and meeting times, it is possible to see visible increases in EDA and HR measures at points at which they said they felt emotional arousal. For this participant, this was specifically when she was having her six-monthly personal work appraisal meeting (at time point 13:00). She described this in the following terms, already reflecting on her own embodied experiences of stress:

> It was a meeting where I probably was a bit surprised that I felt my manager wasn't necessarily being terribly supportive but basically saying, "You need to do it yourself," so I was kind of, like, "Right, okay, then, I will." So I suspect my heart rate will be quite high there. (Birmingham Participant 12, female, age 40–50)

At time point 15:15, this participant recounted (without seeing the visualized data) her feelings of anger and "kick-ass mood" following this meeting, suggesting how feelings of surprise, anger, and stress can converge into motivation:

> After that I went back to my desk, started moving some stuff over to the [other building] like moving trolleys and boxes, I think because I was a bit angry that I didn't feel I was being terribly supported, so I thought right, I started moving some stuff and then e-mailed the director to arrange a meeting the following morning, which I had and was actually surprisingly positive, but I think I was in a bit of a kick-ass mood, which you don't normally do.

In terms of the journey to and from work, there were at least two visible rises at time points 8:40 and 16:30, and these coincide with the precise timings provided by the participant for arrival at Birmingham's busy interchange central station, New Street. Investigating the interview data further relating to these points allows us to begin to engage in the kind of retroductive reasoning that can generate new theories of urban stress. As the participant recounted:

> New Street is hell. And, to be honest, I nearly changed jobs when New Street was being developed because it was just horrendous, people were funneled—no actually they were cattled, is the best way to describe it—they were cattled into this tiny corridor and it was just horrendous. And I kept thinking right, no, I'll give it another year because the train station's going to be better. And actually the train station isn't much better. It's better for shoppers.

This feeling of being "cattled" is confirmed by other participants traveling since this redevelopment, who variously described being "squeezed," "rammed in," "crushed," nearly vomited on by drunk people, verbally abused by fellow passengers, and having very little expectation that they would ever get a seat or a train running on time. Taken together, a picture builds up of the difficulties people experience just getting to work, which is before we have even begun to analyze our research participants' stressors at work and home, in their lives, in their physical and mental health, in their relationships, and in their expressed ability to cope with changing circumstances. As researchers we could be satisfied to infer that urban transit is therefore the cause of stress for city workers, tracing the psychophysical pathways by which this affects them, and recommending urban design changes to ease the circulation of people getting to work. Yet as the participant recalled, Birmingham's central station has been recently redeveloped. This redevelopment cost over £600 million (Bell and Jones 2015), and the developers themselves believe the new station to be "a stunning, cathedral-like atrium that floods passengers with daylight" (Mace 2018). This is a feeling clearly not shared by the participants in this study.

To take our analysis beyond understanding the psychophysiological facts meant to inform improvements in urban design and governance, we must bring them together with explanations of the underlying social, political, and economic mechanisms by which people experience being herded as if like farm animals through city transport infrastructures. Critical realist data analysis allows interpretive

Food					Cheese roll, 3 mini sausage rolls, banana			Peanuts & raisins		
Drink			Cup of tea		Peppermint Tea		Water			
Activity		Arrive at work Interview a student	Meeting	Meeting	Lunch. Desk Work.	PDR Review	PDR Review	Moving boxes. Emails	Leave Work. Catch packed out train.	Arrive home
Emotion	(Tired)	Relaxed	Relaxed & calm	Alert	Alert, excited, happy & relaxed	Alert & tense	Alert, upset & tense	Alert		
Intensity	Quite	Quite	Quite	Very	Very	Quite	Quite	Quite		
Stress Level	Neutral	Not at all	Not at all	Quite		Quite	Neutral	Quite		
Coping Ability	Good	Good		Good		Neutral	Good			
Interview Data	Arrived at central station 8:44; arrived at work 9:00		Had a "really productive meeting"			Had a "huge", "difficult" meeting		Felt ä bit angry"	Left work 16:15, arrived central station 16:37	

Figure 1. Annotated visualized biosensing data from Empatica Connect dashboard combined with ecological momentary assessment diary entries and interview data (Birmingham Participant 12, female, age 40–50). *Note:* EDA = electrodermal activity; HR = heart rate; BVP = blood volume pulse.

comments to generate new meaning ("It's better for shoppers"), and we can begin to consider how our experiences of inhabiting and moving through cities are intimately bound with the economic structures by which capital flows, economic developments, urban design priorities, our embodied labor, sacrifices in comfort, and behavioral motivations are shaped, and the stresses of commuters are traded off with the needs of shoppers.

A third benefit of bringing a narrative approach to bear on urban stress, then, is that it allows us to see how the social, political, and economic contexts of digital technology development itself are changing the nature of our embodied experiences as workers. It is now evident that the very same biosensing technologies and ambulatory assessment methods described earlier are being used to increase worker productivity, manage stress, and improve health; we therefore need to account for how technology becomes narrated as both the source and solution to the problem of urban workplace stress. There are ethical, privacy, legal, regulatory, and political concerns around biosensing at work. These need to be addressed if we are to fully understand the drivers of workplace stress and the relationship between digital technology production and urban capitalism itself (Moore and Piwek 2017).

This analysis goes some way to explaining why—despite a growing body of evidence on urban stress and designing for well-being—transformation of our cities, mental health infrastructures, communities, transportation systems and elimination of social threat, isolation, poverty, and inequality have been notably slow. Biometric data on urban well-being are being used to monitor and manage, rather than eliminate, urban stress and have done little to address some of the exploitative, precarious, and insecure conditions that characterize contemporary working life. Given the pace of technological development and emerging use of biosensing technologies by nonspecialists, we urgently need to reflect on how to engage citizens with biological and psychological forms of knowledge and to establish the principles for multilevel approaches that can advance community-driven action (Hinckson et al. 2017). By treating research participants as experts in their own lives, we can begin to see significant value in working across multiple scales of analysis and explanation and beyond biological stress pathways and stimulus–response articulations of human–environment interaction.

Conclusion

Neuroscientific, epidemiological, and psychophysiological approaches to researching urban stress and well-being point toward a developing bioscientific discourse on urban inhabitation. A neo-metabolic picture of city life is emerging, reminiscent of earlier eras in which the city dweller is conceived of as an organism in a distinct ecology itself made up of metabolic flows of materials, populations, resources, stimuli, stressors, or stress-reducing factors and disease (Gandy 2004). Because the links between mental health, city life, and urban landscapes are becoming increasingly scientifically researched, there is optimism that results will inform new biological approaches to the active promotion of urban health and well-being. Indeed, the UK industry–government–university partnership, Future Cities Catapult, funded the *Neuroscience for Cities Playbook* projects that "twenty years from now we may look back and wonder how we ever planned cities without the use of cognitive and biological data" (Camargo, Artus, and Spears 2018, 9). The transformational potential of emotion tracking apps, embedded sensors, and biometric technologies is thus lauded as enabling new neuroscientific engagements with architecture and urban design. Ellard (2014), for example, asserted that "these technologies are actually redefining everything from public space to the meaning of a wall, and for better or worse, revolutionizing the ways in which our surroundings can affect us" (14). A spatially constrictive definition of environment, however, is operationalized in much of this work; there is a significant difference between analyzing public space and the meaning of a wall. Novel biosensing methods might garner significant findings in terms of the impacts of light, materials, sound, and geometrical form on stress responses, but they are less interested in what research subjects are actually doing in cities, who they are, where they are going, and why. Such methods therefore could be usefully complemented by analyses of the experiences, coping strategies, and wider determinants of stress, including political circumstances, economic structures, and sociocultural relations.

In explicitly addressing the necessary partiality of bioscientific explanation of psychosocial phenomena, it becomes important to extend some of the key spatial and temporal imaginaries within the definitions of urbanicity, well-being, and stress used within disciplinary approaches that are influencing current thinking on urban well-being and stress. Although in some emerging neuroscience of city dwelling, urbanicity

refers to urban density, in other manifestations (neuroarchitecture and neurourbanism) it often refers to form and design. There is thus some inconsistency to be dealt with. Second, the neuroscience of urbanicity does not have the means to operationalize well-established social science and more lay understandings of urban space as a public realm, a site of social enaction, and a locus of political conflict, negotiation, struggle, and resolution. The urban has long been considered a "way of life" or a "state of mind." The founders of urban sociology, including Wirth (1938), set out a definition of the urban as "the initiating and controlling center of economic, political and cultural life" (2) and inseparable from the rural. We can therefore surmise that attempts to ascertain the unidirectional impacts of urban living on neuropsychological response unhelpfully leave out a substantial set of causal interdependencies. For many scholars, the idea of quantifying well-being through psychometric measures or biomarkers is a form of reductionism that illegitimately overrides centuries of philosophical and public debate about the purpose of life and historically specific ethical judgments about the good life (Scott 2015). When we experiment with new biosocial methodologies, we need to be cognizant of these debates and maintain a healthy skepticism toward well-being research that proposes to be able to engineer the ideal urban conditions for happiness.

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Notes

1. The cities of Salzburg and Birmingham were selected for comparison for ease of data collection, but being diverse cities in terms of population density, composition, and history has the additional benefit of problematizing the notion of the urban deployed in urban emotion research. The interviews were conducted by Jessica Pykett and Tess Osborne.
2. One interviewee was seventy years old and still in paid employment.

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