Geo-EEG:
Towards the use of EEG in the study of urban behaviour

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1. Introduction

The scope of this paper is to outline the intellectual framework, and the are of recent and forthcoming research of a doctoral project on the relation of human emotions with urban behaviour. The study of the role of emotions in the city, targets how the environment evokes emotions and behaviour, but also how human emotions influence urban phenomena in return. The elaboration of a method for the fusion of affective computing with urban research now allows the assessment of subjective and collective affective experience and aims to contribute to existing simulation models of urban behaviour.

2. Urban behaviour in context

The French philosopher Michel de Certeau argued that walking is a spatial practice, having its own "rhetoric" of actualising the urban space as one walks through it: "[i]f it is true that a spatial order organizes an ensemble of possibilities and interdictions, then the walker actualizes these possibilities. In that sense, he makes them exist as much as emerge. But he also moves them about and he invents others, since the crossing, drifting away, or improvisation of walking privilege, transform or abandon spatial elements" (de Certeau, 1997, p.98). Resonant of his ideas, the cornucopia of data produced by the contemporary city are now explored in various ways, revealing a palimpsest of human trails and traces that can be related with phenomena as diverse as from urban mobility to waste management. The ubiquitous presence of gps and tracking technologies in objects of everyday life enable the study of the city and urban phenomena as they emerge from local spatial practices of city-dwellers.

Indeed, the proliferation of smartphone usage, spurred a trend of "apps" to track the spatial dimension of one's own activities (walking, running or exercise records), but also informing scientific methodologies in geography, planning, transport and other disciplines engaged in the

study of urban phenomena. While the new science of big-data draws the picture of the city as it emerges from the traces of human interaction to describe large human systems, new modalities can enable us to study human behaviour unsolicitedly; the direct measurement of emotional and cognitive experience in real-time is now possible, while people are situated in real, rather than virtual, architectural and urban spaces.

In this context, affective computing – a term and domain of research coined by Picard (1998) to describe a set of technologies that would "give computers the ability to recognize, express or sometimes 'have' emotions" – and of Brain Computer Interfaces (BCI), enable unprecedented insights in the neurological basis of thought, action and behaviour. Even though BCI was, initially, intended for medical purposes and for people with neuromuscular disabilities, BCI is increasingly used in other domains, such as experimental art, market research or computer-games. Recent studies have validate the use of affordable EEG devices and of-the-shelf software to register complex cognitive processes such as insight (Cernea, 2011), suggesting a new territory of scientific exploration. Of particular relevance in our context is the development of emotion recognition algorithms based on the spatial patterns of brain activity using EEG technology.

3. Are emotions relevant?

While the role of the affect and emotion has been pertinent to the architectural discourse in many ways, especially in relation the quest for meaning and sense of place, the role of emotions in human behaviour was, until recently, undermined. As Picard (1998) noted emotions are often considered synonymous with sentimentality and irrational action. However, Neuroscience and Neuropsychology provided evidence about the impact of emotions in cognitive functions such as reasoning, memory and decision-making. The neuropsychologist Antonio Damasio, in his influential book "Descartes' Error", argued for the 'somatic marker' hypothesis (1994 / 2006), suggesting that emotions enable us to "turn" towards potential choices based on previous experience. But how does emotion relate with the city and with urban processes such as navigation and wayfinding, orientation and route-choice, land-use, population density or the quality of the built environment? How could the study of emotional and cognitive processes of the individual be part of established research methods of urban or environmental study?

Previous research have explored the study of emotions and urban space. The artist Christian Nold (2009) mapped arousal patterns in the city using electrodermal measures, while more ambitious projects, such as the Road Frustration Index developed by MIT SENSEable City Laboratory and Audi predicted traffic by analysing Twitter activity. The Mappiness LSE research and homonymous iPhone app, combines psychological studies with geographical analysis, in order to explore the socio-economic patterns related with emotion and well-being (MacKerron, 2010).

4. Research

Motivated to explore the affordances of new mobile and commercial EEG technology, we elaborated a research methodology to study subjective emotional experience in an urban context. In this study we used Emotiv EPOC, a multisensor electroencephalography (EEG) device, that reads brain activity directly from the user's scalp. EEG is a non-invasive brain imaging technique, usually used in medical and clinical context to study brain functions while, more recently, it is used extensively in BCI systems which enable to communicate with the brain with "messages or commands that an individual sends to the external world do not pass through the brain's normal output pathways of peripheral nerves and muscles" (Wolpaw et al, 2002). Significantly, Emotiv EPOC comes equipped with multimodal software packages that perform emotion detection algorithms to translate brain waves into emotional states in real-time. Recent studies have used EPOC in various context from creating a "neurophone" (Campbell, 2010) to detecting insight in information retrieval (Cernea, 2011).

The first challenge was to conceive and design a research framework that would employ a BCI system developed for the computer games industry, to use it in urban studies. We developed a software to geo-annotate and record readings from Emotiv's 'Affectiv Suite', in order to analyse later not only the trail of the users but also their emotional state at each point of their location in space (Mavros *et al.*, 2012).

This experimental modality was then tested in a real urban setting, to measure its operation and performance and test it against research hypotheses on the impact of urban space on the affective states of people. A 30 minute route through Edinburgh was carefully designed to travel through varying degrees of urbanity, from quiet, pedestrian streets to busy intersections and from dense urban locations to Edinburgh's major park, the Meadows. Twelve participants were monitored walking this route wearing the EPOC neuroheadset and carrying a high-performance laptop to register the geo-annotated data (Mavros *et al.*, 2012). The findings of this first study are consistent with restorative theory and environmental psychology, showing that attentional loads and excitement levels drop while a person moves from an urban setting to a natural (though man-made) environment (Aspinall et al, 2012). Perhaps even more important is simply the fact that this study successfully employed EEG in an outdoor setting, obtaining useful and meaningful results, when EEG was, until recently, notoriously sensitive to various forms of electronic noise, while being bulky and inconvenient to use.

5. Outlook

The study of subjective aspects of urban behaviour, such as the emotional and affective experience aims to inform our understanding of urban behaviour and, in particular, to contribute in the field of modelling of urban phenomena related with transport, navigation and pedestrian

behaviour in cities. Previous research in Neuroscience has studied the neural basis of navigation mechanisms, the effects of the environmental and orientation information on brain structures. For example, Hartley et al (2003) illustrated that wayfinding is a neurally different process than route-following, activating more the hippocampal areas and caudate nucleus respectively, a finding manifested in the varying degrees of success in navigational tasks. But how does knowledge like this feed in routing models or simulations of pedestrian behaviour in spaces?

5.1 Social simulation - ABM

Simulation and modelling are all the more used in social sciences constituting, according to Axelrod (1997), a "third research methodology" and "a new way of conducting scientific research". Agent-based models (ABM) are used to simulate social processes or human behaviour, such as pedestrian movement, traffic or crime, where software "agents" follow simple behavioural rules and provided a sufficient number of interactions, complex behavioural patterns emerge. Recent research has used such simulations to study and ameliorate urban infrastructure for mass gatherings or prepare for epidemiologic events (Johansson *et al*., 2012). ABM is often based on principles of rational choice or rational abstractions of human processes.

However, in line with Damasio's insights about the role of emotions in human behaviour, Urban and Schmidt argue that "the view of human beings as rational decision-makers who are perfectly informed and maximise an exogenously given utility function turns out to be too restrictive" (Urban and Schmidt, 2001). To tackle this issue, they proposed the "PECS" reference model (for *Physis, Emotion, Cognition* and *Social Status*) which aims at the representation of the external and the internal states of the agent, similar to the intersecting domains of human behaviour (Urban and Schmidt, 2001). The PECS model was used to simulate employed the PECS model to simulate burglaries in Newcastle (Malleson 2012).

Of the four components of PECS, emotions are the more difficult to obtain quantitative data to study, especially in terms of urban phenomena, although a lot of research is situated in virtual reality environments. This is where our research framework using EEG in urban context is situated aimed to provide a method to study and understand how human emotion interacts with urban mobility, navigation, route-choice and other aspects of urban behaviour.

6 Conclusion

Concluding, this research aspires to contribute to the understanding of cities as complex systems (Batty, 2011) that emerge from bottom-up, local interactions among individual agents. New technologies such as portable EEG, enable the study of emotional and affective responses of individuals in urban contexts, and thereby permit the exploration of new hypotheses about the nature of urban behaviour.

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Biography

Panagiotis Mavros is a doctoral researcher at the Center for Advanced Spatial Analysis (CASA), The Bartlett, UCL. After his studies in Architecture Engineering at the National Technical University of Athens, and he completed an MSc by Research in Digital Media and Culture from the University of Edinburgh.