Are we there yet?
Exploring distance perception in urban environments with mobile Electroencephalography

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Summary

This paper explores the use of mobile Electroencephalography (EEG) in the study of environmental perception and the ways the perception of physical measurements of a space may affect individual walking behaviour. The hypothesis of this study is that obtrusive and complex street environments stretch the perception of walking time and distance. So far, the factor of an individual's affective state has not been taken into account in perceiving space. We propose the use of mobile EEG, a technology that permits such insights, to augment the traditional arsenal of questionnaires and self-reported measures of experience and mental representations of space.

KEYWORDS: mobile EEG; distance perception;Emotiv; urban mobility, walkability.

1. Introduction

This paper explores the use of mobile Electroencephalography (EEG) in the study of environmental perception and the ways the perception of physical measurements of a space may affect individual walking behaviour. The hypothesis of this study is that obtrusive and complex street environments stretch the perception of walking time and distance. So far, the factor of an individual's affective state has not been taken into account in perceiving space. We propose the use of mobile EEG, a technology that permits such insights, to augment the traditional arsenal of questionnaires and self-reported measures of experience and mental representations of space, in order to further our understanding of how distance perception is modulated by the static and dynamic characteristics of the environment.

2. Background

The study of urban mobility behaviour is of great importance in the context of a rapidly urbanising population worldwide, together with the increasing efforts from authorities to encourage active transport, such as walking and cycling, along with the use of public transport (British Department for Transport, 2013), with benefits for urban planning, population health and wellbeing. Individual perceptions of the environment affect the way we travel in the city, and also our trip-planning choices (Cadwallader, 1976). In this context, studying travel behaviour, route-choice and understanding which factors influence transport mode choice, is an important step towards better cities. As most daily trips are purposive (to work, home, school, shopping etc), one of the primary factors influencing behaviour is the distance between origin and destination. As the geographer Dan Montello notes, "[distance] is used to evaluate costs of traveling from one place to another, and it helps us utilize resources efficiently (time, money, food)" (Montello, 1997). Distance between our present location and our destination, or even the distance between forthcoming destinations in a trip chaining case (e.g. Garling, 1999) is subject to multiple cognitive biases that influence spatial decisions, including individual differences between people (Wolbers and Hegarty, 2010). In the context of urban mobility, perception of distance is an important factor influencing the spatial decision making techniques employed by pedestrians, as it affects the decision whether to walk towards a destination or seek an alternative means of transport. Architects and planners should take into account different factors that affect perceptions of the environment to produce better spaces.

Existing research on distance perception and walking behaviour has been focused on walkability, route and space complexity and cost functions, based on walking time, ease of navigation and route pleasantness (Saelens et al., 2003; Dewulf et al., 2012; British DtF, 2012). Modal choice procedures are influenced by the evaluation of time, comfort and wait-time annoyance. A less explored factor of distance perception and walking behaviours is the role of the affective state of mind of the pedestrian. Electroencephalography is a method of brain imaging that can provide us with such an insight. For this purpose, this study uses an electroencephalography (EEG) device, measuring brain activity, and a software that interprets this brain activity into emotional states of an individual when walking in different types of urban environments.

This choice of method looks into the subject of distance perception in urban mobility from a new perspective. The role of brain activity and emotions - as measured in real time with an EEG device - has been used before in urban setting experiments. In a study by Aspinall et al. (2013) the Emotiv EPOC headset was used to explore the differences between walking in urban versus natural environments (park). The study presented here, however, uses this technology to explore the effects of an individual's affective state on the perception of walking distance and time. Correlating the findings with the environmental attributes the participants come across aims to give a new insight on our knowledge of the topic.

3. Methods

In order to estimate a distance between two locations, we rely either on external resources (e.g. a map) or our (internal) mental representation of space, also referred as 'cognitive maps' (for a discussion see Kitchin and Blades, 2002). In Spatial Cognition research, the acquisition of environmental knowledge from maps, virtual reality and real environments has been extensively studied. Learning modality, individual differences in spatial abilities or cognitive strategies used influence the detail and accuracy of resulting mental representations of space. Distance estimates between locations are a standard procedure to test the quality of mental representations of space, and several researchers have explored how fast and accurately such representations are established (Ishikawa and Montello, 2006) or how different forms of spatial experience (map, virtual reality or real experience) affect them (Richardson et al., 1999; Waller and Greenauer, 2007).

However, it is less clear how the emotional state of the individual affects their perception of travelled distance. To address this questions, a field experiment was conducted in the area of Fitzrovia, in central London. For this exploratory study, a total of eight participants were asked to walk a designated route that was divided into four segments. Each of the four route segments had different environmental characteristics (main, busy road, backstreet, shopping street, wide pavement, presence of trees). During the experiment, participants were instructed to walk normally, wearing an Emotiv EEG headset and carrying a GPS recording device. After completing the route, participants were asked to evaluate various aspects of the route through a combination of interview and self-reported questionnaires.

The hypothesis of this research is that EEG can capture the effects of static as well as dynamic aspects of the environment on the individual. However, the brain activity of the individual is influenced by incidental events or situations that occur during the experiment, that are not directly relevant to the urban environment. The experimenter, in this case, has to annotate the route with observations of a number of events that occur during the experiment, like the confrontation of an obstacle (another pedestrian for example), or verbal communication.

In order to explore the effects of subjective experience and individual incidents, we used a Neuroscience approach named "Event-Related Potential" (ERP) which studies brain activity in response to particular visual, auditory or other stimuli (Picton et al., 2000). In Neuroscience, the ERP method compares the neural signal during two different conditions (e.g. baseline vs stimulus) to determine whether and how a certain brain area is engaged in a particular task. In our research context, we were interested in the effects of a variety of incidental events, such as verbal communication, the confrontation of an obstacle, a busy (or uncontrolled) crossing. By geo-annotating and time-locking these "events" to the EEG data, we can explore how these correspond to different neural activity or emotion state. Two important differences with classic ERP studies and this research is that in a naturalistic experimental paradigm (urban walk) there is a variety of stimuli and, secondly, we have so far compared the emotional state levels (interpreted EEG) and not the raw signal.

In order to geo-annotate and timestamp with precision such events, a custom Android application was developed that enables the experimenter to make these annotations. The app, given the name "Logger", is collecting data about the phone's (the experimenters/subject's) location, speed, GPS recording accuracy, the altitude, the current time in unix epoch time and in human readable format, at a sampling rate of 1Hz. The user can collect behavioural data out of eight "event" options: "Instructions/Talk", "Pause", "Obstacle", "Looks Around", "Start Walking", "Hesitates", "Controlled Crossing", "Uncontrolled Crossing". The app is open-source, available online[1] and is currently being used in more studies, contributing to the toolkit for conducting neuro-behavioural research in natural environments.

4. Results

Early analysis of participants' neural, behavioural and self-reported data from the routes illustrate the potential of our approach. Raw EEG data were analysed with the software *Emotiv Affectiv suite*, translates the raw EEG signal to four different mood readings: "Excitement", "Frustration", "Meditation" and "Engagement/Boredom". Based on these, the route segments were ranked from most to least "Frustrating", "Exciting" and "Boring". Route segments were also ranked by participants according to 7 characteristics: *stressfulness, pleasantness, length, fatigue, scale, light* and *noise*.

[1]https://github.com/mandarini/Logger

Comparing self-reported with direct measures of affect, the routes that were reported to be the shortest were the ones with the highest “excitement” levels, meaning the ones where positive feelings were dominant. “Frustration” levels were affected significantly by obstacles on the pathway, and influenced the perception of a route as long, tiring and unpleasant. The complexity of the route also played a significant role in characterising a route tiring, but had little impact on “frustration” levels.

Using an analytical method similar to the Event-Related Potential, a representation of the changes in the affective state of mind of the subject, as invoked by the events that occur at that specific moment was attempted. The frustration of the subjects peaks during an encounter with an obstacle and declines considerably after 30 seconds, close to the initial state before the obstacle. Some peaks of frustration appear also at crossing points, and at points where the environmental situation changes, like in the transitions from a busy street to a quiet street.

5. Analysis

Distance perception was the main focus of this study. As expected by the literature, participants could report well when asked to rank the segments from shortest to longest. Interestingly, participants were less accurate between the two of the segments that were of different environmental nature. Each one of them had a characteristic that caused participants to consider them unpleasant and frustrating, the one being busy and noisy, and the other having a complex route with turns.

Initial analyses suggests that the segment that was characterised as tiring, stressful and evoked the least positive feelings (“excitement”) was also perceived as being the longest. There was also a trend between a route being characterised as tiring and long and other environmental attributes such as the lack of light and shops.We tested the Interaction between factors and some interesting results have been observed, indicating a relationship between certain environmental parameters and the presence of negative perceptions and feelings. To conclude, in our paper we will further present a detailed analysis of behavioural, affective and neural data, highlighting the role of the environment in walking behaviour, and also the potential of mobile EEG to address questions of environmental perception and behaviour.

6. Discussion and Future Work

The results of such studies contribute in our better understanding of the role of urban planning. Handy et al., 2002, insist on evidence that “a combination of urban design, land use patterns, and transportation systems that promotes walking and bicycling will help create active, healthier, and more livable communities”. Furthermore, as the American Planning Association eloquently notes, urban planning “improves the welfare of people and their communities by creating more convenient, equitable, healthful, efficient, and attractive places for present and future generations”, also acting as an enabler for the creation of strong communities. On the other hand, we continue to live in cities that urban planning has not met its stated purpose. The reasons are always complex, and design alone will not be enough, without the corresponding education, culture and customs. However, if this one arbitrary parameter of “feeling” and “”perception” is attempted to be measured, a valuable insight can be offered to us, planners, of how people respond to the labeled “attractive” and “convenient” planning. This study produces some valuable results, however it can also serve as a case study of a wider subject, possibly pointing to new methods of evaluating the efficiency of urban design.

An innovative use of mobile EEG was used to investigate walking behaviour, the impact of environmental attributes on individuals' state of mind and people spatial perceptions. Future research could explore how this technology might support innovative architecture and urban planning strategies.

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8. Biography

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