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Tracking technologies and urban analysis: Adding the emotional dimension☆

Noam Shoval[a,*], Yonatan Schvimer[a], Maya Tamir[b]

[a] Department of Geography, The Hebrew University of Jerusalem, Israel
[b] Department of Psychology, The Hebrew University of Jerusalem, Israel

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ABSTRACT

Recent technological advancements—most notably the proliferation of tracking technologies (GPS), real-time surveying techniques, and ambulatory sensing—have allowed researchers to advance the empirical investigation of the interaction between space and emotion. Over the past few years, two approaches to the assessment of spatial-emotional interactions have emerged: the assessment of emotion using subjective self-reported measures and the exploration of objective physiological measures of emotional arousal using ambulatory sensing techniques. To date, most empirical research exploring spatial-emotional interactions has focused on the individual level. The present study is the first to systematically map the emotional characteristics of a large-scale urban environment using aggregative measures of emotion (subjective and objective). By mapping the *subjective* emotional experience of 144 individuals through real-time surveys administered through Experience Sampling Methods (ESM) as well as mapping an *objective* physiological measurement of emotional arousal (Skin Conductance Level) of 68 tourists, we were able to create 'emotional maps' of the city of Jerusalem. The maps identify emotionally arousing areas of the city, point to emotional 'clusters' and 'boundaries', and identify discontinuities (and continuities) in emotional space throughout the city. The theoretical and practical implications of this new method for planning and policy are discussed.

Approximately a decade ago, a study published in *Cities* pioneered a path in urban spatial analytics. It did so by demonstrating the potential of using aggregative GPS data to obtain a better understanding of individuals' impact on cities (Shoval, 2008). A year later, Nold (2009) presented his innovative concept, 'emotional cartographies', which—although not using the scientific approach—explored the feasibility of pairing GPS data with emotion-related physiological measurements in an urban context for the first time.

The past decade has seen immense progress in the implementation of tracking technologies for research (Birenboim & Shoval, 2016; Ngai-Ming, Forrest, & Xian, 2016; Shoval & Ahas, 2016; Shoval, Kwan, Reinau, & Harder, 2014) as well as the integration of novel sensing technologies (embedded in smartphones or easily connected to them). Ultimately, these advances enabled the collection of various types of data regarding the environment and individuals (Shoval, Schvimer, & Tamir, 2017). Below, we introduce new opportunities for urban research that stem from these technological advances, primarily focusing on 'adding the emotional dimension' to urban analysis by incorporating subjective and objective emotional data with high-resolution locational data collected in real time and space. This is the central contribution of this article to the literature in urban studies.

1. Introduction

The emotional relationship humans have with the urban environment has been of fundamental interest to urban scholars for decades. The forefathers of urban studies, including Park, Burgess, and McKenzie (1925), Simmel (1903), and Lynch (1960), all postulated that the individual's emotional experience in an urban environment is framed by a city's cultural, social, and physical dimensions. Recent technological advances—most notably the proliferation of tracking technologies (GPS), real-time surveying techniques (Panek & Benediktsson, 2017), and ambulatory physiological sensing—have allowed scholars to embark on empirical investigations of the complex interactions that exist between space and emotion (Shoval et al., 2017).

Over the past few years, two leading approaches to the assessment of spatial-emotional interactions have emerged. One is the assessment of *subjective* measures of emotion (Birenboim, 2016; Birenboim, Reinau, Shoval, & Harder, 2015; Greenberg-Raanan & Shoval, 2014; Kwan & Ding, 2008; MacKerron & Mourato, 2013; Snizek,

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* Corresponding author.
E-mail address: noamshoval@huji.ac.il (N. Shoval).

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Nielsen, & Skov-Petersen, 2013; Solymosi, Bowers, & Fujiyama, 2015). More recently, the assessment of emotions using *objective* physiological measurements collected using ambulatory sensors has become prevalent (Resch, Summa, Sagl, Zeile, & Exner, 2015; Sagl, Resch, & Blaschke, 2015; Zeile et al., 2015). One recent study attempted to integrate these two types of measures to achieve a more comprehensive assessment of emotions as they occur in urban contexts, primarily from the individual perspective (Shoval et al., 2017).

The present study is the first to systematically map the emotional characteristics of a large-scale urban environment, using aggregative measures of emotion in a large sample of individuals in the city of Jerusalem. In the study, one objective physiological measure of emotional arousal (Skin Conductance Level, or SCL) was mapped for 68 tourists. The subjective emotional responses of 144 individuals in real time (collected using Experience Sampling Methods, or ESM) were recorded as well. In this way, we were able to create objective and subjective emotional maps of the city of Jerusalem, to identify emotionally stimulating areas, to identify emotional boundaries, and to identify discontinuities (and continuities) in emotional space.

1.1. Measuring emotions objectively and subjectively

Prior to addressing the literature on spatial-emotional interactions, we must first present a working definition of emotions. In so doing, we must consider how emotions are manifested and assess to what extent subjective and objective measures can be used as indicators of individuals' emotional states. The answers to these questions are far from obvious and unresolved disagreements between psychologists over these fundamental issues abound (Barrett, 2006). According to Scherer (2005), emotions are comprised of five interrelated components: the cognitive, neurophysiological, motivational, expressive, and subjective.

The use of physiology to infer emotional states has been widely explored (Ekman, Levenson, & Friesen, 1983; Kreibig, 2010; Larsen, Berntson, Poehlmann, Ito, & Cacioppo, 2008; Levenson, 1992). Although there is considerable disagreement regarding whether discrete emotions (happiness, sadness, fear, etc.) can be inferred from specific physiological patterns, there is evidence to suggest that physiological patterns may reflect emotional arousal (Kreibig, 2010; Larsen et al., 2008; Levenson, 1992; Wilhelm & Grossman, 2010). Emotional arousal involves the activation of the sympathetic nervous system, which prepares the body to respond to urgent situations. Emotional arousal is manifested through a number of physiological responses including electrodermal activity, cardiovascular activity (heart rate, blood pressure, and other measures), and cortisol levels (Dawson, Schell, & Filion, 2007).

In the past few years, ambulatory sensing—i.e., using external mobile sensors to measure physiological responses as they occur in their natural environment—has often been used in psychological research. However, inferring emotional states from physiological responses in ecological settings is complex. Unlike controlled laboratory environments, the assessment of emotions in ecological settings cannot control for intervening variables. Wac and Tsiourti (2014) meta-analyzed 173 studies that employed methods of ambulatory assessment. Of these, 35 used ambulatory assessment techniques in the ecological assessment of emotion. Measures of skin conductance, heart rate, and blood volume were all found to be valid and widely used measures of emotional arousal in ecological ambulatory assessment studies. That said, there are as yet no gold standards for research in this emerging field (Dawson et al., 2007). Thus, it appears that there is a theoretical and empirical basis to the hypothesis that physiological measures can be used as indicators of emotional states in general, though inferring exactly which discrete emotions the individual is experiencing solely from physiology is not possible (Wilhelm & Grossman, 2010).

The exploration of subjective self-reported emotion has progressed immensely since the 1970s, with the introduction of the Experience Sampling Method (ESM) and Ecological Momentary Assessment (EMA). These techniques aim to capture momentary experiences of individuals as they occur in real time in their natural environment (Csikszentmihalyi & Larson, 1987; Csikszentmihalyi, Larson, & Prescott, 1977). By asking individuals to report behaviours and feelings as they occur in their natural environment and in real time, a more ecologically valid assessment of experience can be achieved, recall bias can be minimized, and reporting is less likely to coincide with social norms (Scollon, Kim-Prieto, & Diener, 2003). In the past decade, the proliferation of smartphones has allowed ESM techniques to be employed using a wide range of dedicated smartphone apps (Birenboim, 2016; Birenboim et al., 2015; Tussyadiah & Zach, 2012).

1.2. Assessing emotions in an urban context

Urban scholars and geographers tend to address issues of emotion in a more lenient manner than do psychologists, often unintentionally blurring the distinction between emotion and related concepts. This has led to diverse approaches regarding how to measure emotional aspects of human activity in urban analysis.

Only a few studies have explored emotions and spatial interactions using the definition and measures of emotion we have operationally defined above. These studies can largely be divided into two: (1) the assessment of the subjective component of emotion as assessed by self-reports of emotion and, more recently, (2) the assessment of physiological manifestations of emotional arousal (Shoval et al., 2017).

Whether assessing spatial-emotional interactions from an objective or subjective perspective, the most fundamental necessity for integrating emotional experiences in spatial analysis is the ability to couple 'emotional data' with precise locational and temporal data—i.e., the ability to georeference emotional data. This has now become possible. Recent technological innovations have allowed for the widespread use of digital tracking technologies, most notably GPS sensors, in smartphones and in some ambulatory sensing devices.

1.3. Incorporating subjective measures of emotion into spatial analysis

From a geographic perspective, the integration of ESM with smartphone technologies carries tremendous potential; it allows for subjective reporting to be collected and accurately georeferenced in real time (Birenboim & Shoval, 2016). Nevertheless, only a handful of studies have integrated ESM with spatial analysis, and of those only a scarce few have assessed emotion. MacKerron and Mourato (2013) used an iPhone application to gather repeated reports of momentary happiness at random times, finding that participants tended to be happier in green or natural environments than in urban environments Ettema and Smajic (2015) utilized smartphones to record in-situ, self-reported experiences of students during a random walk. The study found that happiness and activation were highest in places in which many activities were going on and many people were around. In terms of volunteered geographic information (VGI) and citizen sensing, Solymosi et al. (2015) assessed 'fear of crime' for six individuals over a one-month period, prompting surveys on participants' smartphones four times a day. The small sample size and low variance in responses did not fully allow for the mapping of spatial patterns of fear of crime, though significant spatiotemporal variation in individuals' fear of crime levels was observed. Birenboim (2016) assessed individuals' 'sense of security' while attending a leisure event (concert). Using time-triggered surveys, single 'sense-of-security' ratings were reported at predefined time intervals. The ratings were then spatially interpolated to map the feeling over space, which allowed the researchers to identify general areas of high and low 'sense of security'.

In addition to ESM techniques, post-hoc reporting has also been used to identify subjective emotionally-arousing localities. Snizek et al. (2013) asked cyclists to map the route of their commute and mark positive and negative emotional experiences along the way. They found that the type of road (traffic volume), the on-route cycling facilities, and