Journal of Travel Research
2018, Vol. 57(1) 3–16

DOI: 10.1177/0047287517691155
journals.sagepub.com/home/jtr
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Real-Time Measurement of Tourists' Objective and Subjective Emotions in Time and Space

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Abstract

The examination of tourists' experiences is an essential subject in tourism scholarship. This study presents novel methods by which spatio-temporal data can be combined with physiological measures of emotion and semantic contextual information in order to obtain a comprehensive and integrative understanding of tourists' experience in time and space. Four data collection techniques were combined and applied to a sample of 68 tourists in Jerusalem: high-resolution locational data, real-time surveying techniques using the experience sampling method, physiological measures of emotion (electrodermal activity), and traditional surveying techniques. We present methods for using these techniques in exploring data on the individual level, comparing pairs of individuals, and examining a sample, providing insight both on the individual's personal experience and, more broadly, on the emotional characteristics of locations and tourist attractions in a city. Theoretical and methodological implications as well as the limitations of these techniques are discussed.

Keywords

smartphone, tracking technologies, real-time surveys, mobile sensing, physiological sensors, objective, subjective

Introduction

Until ten years ago, time-budget techniques, such as activity diaries, were the most common techniques for collecting information about human activity and trajectories, in general (see, e.g., Sorokin and Berger 1939; Szalai 1972; Chapin 1974; Bhat 1997; Kwan 2000), and about tourist activity more specifically (see, e.g., Murphy and Rosenblood 1974; Debbage 1991; Thornton, Williams, and Shaw 1997; McKercher and Lau 2008). The past decade has seen a rapid increase in the exploitation of tracking technologies such as GPS, and lately smartphones as well, for similar purposes (Shoval and Ahas 2016), replacing, to some extent, many of the functions of activity diaries (Shoval and Isaacson 2010). However, until recently, data sets generated by tracking technologies were limited solely to spatial and temporal aspects of activity. When researchers wish to characterize the activity and behavior of individuals beyond parameters of location and time (e.g., expenditure patterns, subjective experiences, and descriptions of decision-making processes), additional tools are necessary.

This article explores novel methodologies, which can be employed in the investigation of tourism experience in time and space. We examine the ability to integrate high-resolution location data with real-time momentary experience data in the form of objective physiological measures of emotion as well as subjective measures of emotion (collected through experience sampling methods [ESMs], location-triggered and time-triggered surveys) on the individual level, comparing pairs of individuals and aggregating multiple sets of individual-level data. These methods are demonstrated for the first time on a large sample of individuals traveling within a large-scale urban setting—the city of Jerusalem. By combining multiple sets of data, we address ways in which these methodologies may be used to provide a richer, more comprehensive, and integrative understanding of the individuals' tourist experience.

Measuring Subjective Experiences in Tourism and Leisure Activities

While researchers have been familiar with the importance of immediate conscious experiences in leisure and tourism for some time (Mannell and Iso-Ahola 1987), the evaluation of experiences in these fields is largely limited to general, one-time measurements of experiences through traditional questionnaires. In the case of recreational sites, these measurements

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take the form of post-visitation surveys that may focus on specific amenities that the sites have to offer (see, e.g., Pizam, Neumann, and Reichel 1978).

Data collection techniques that measure people's moment-by-moment experiences have been available in the disciplines of psychiatry and psychology for some time now. These methods were developed during the 1970s and have become known as the experience sampling method, or the ecological momentary assessment (EMA). In ESM studies, participants are asked to report about their behaviors, experiences, and moods as they occur in their natural environment and in real time (Csikszentmihalyi, Larson, and Prescott 1977; Csikszentmihalyi and Larson 1987).

Only a few studies have examined real-time or near-real-time experiences during leisure or tourism activity in practice (Cutler, Doherty, and Carmichael 2016). Lee, Dattilo, and Howard (1994) used a combination of near-real-time, self-initiated, tape-recordings of their respondents' experiences and in-depth interviews to understand the multidimensional and transitory aspects of tourist experiences. Stewart and Hull (1992) compared the immediate satisfaction of day-trip travelers using reports that were logged during a hike with the travelers' retrospective or post hoc evaluation, ultimately discovering that the two differed greatly. A similar data collection method was employed in the Grampians National Park in western Victoria, Australia (Chhetri, Arrowsmith, and Jackson 2004), where visitors reported on 15 dimensions of their experiences at a series of points along the track. Pettersson and Getz (2009) conducted a participant observation study in which 25 trained observers manually logged their positive and negative experiences during the 2007 Alpine World Ski Championship; the research suggested that a more accurate geographical recording of the observations would be useful.

In recent years, ESM data collection techniques have been utilized in combination with digital tracking technologies in order to study people's subjective experiences and their spatial interactions. Loiterton and Bishop (2008) used GPS and Personal Digital Assistant devices in the Royal Botanic Garden in Melbourne in order to track visitors. Using the PDAs, they generated location-sensitive questionnaires in specific places within gardens that included questions about subjective feelings such as boredom, fatigue, and hunger. Entering these data in their agent-based model, they were able to use it to predict the movement of visitors in the garden. Pettersson and Zillinger (2011) utilized tracking technologies in order to study the immediate experiences of visitors at a sporting event. They supplied participants with GPS devices during the Biathlon World Championships of 2008 that took place in Östersund, Sweden. Half of their participants were instructed to geotag their location whenever they experienced positive feelings, and the second half were instructed to record their location when experiencing negative feelings. A more detailed textual report on the factors that led to the negative and positive experiences was obtained using additional questionnaires that were delivered to the respondents. Birenboim et al. (2015) employed a combination of SMS messages and GPS devices to understand visitors' emotions during their visit to the Aalborg Zoo in Denmark. Using GPS data and reports collected using a dedicated smartphone application, Birenboim (2016) mapped the "sense of security" and "positive/negative experiences" at an outdoor music event.

To our knowledge, the works of Loiterton and Bishop (2008), Pettersson and Zillinger (2011), Birenboim et al. (2015), and Birenboim (2016) are the only studies in the field of tourism and leisure activity in which experiences and/or emotions were accurately geotagged using digital tracking technologies. One should note that these studies all took place in confined and relatively small environments and for a limited time frame of several hours, and dealt with visitors' subjective feelings.

Physiological "Objective" Measures of Emotion

It should come as no surprise that a plethora of psychological research has been dedicated to the exploration of physiological aspects of emotions (Ekman, Levenson, and Friesen 1983; Levenson 1992; Cacioppo Berntson, Larsen, Poehlmann, and Ito 2000; Larsen Berntson, Poehlmann, Ito, and Cacioppo 2008; Kreibig 2010). The question of inferring emotional states from physiological measures is part of a larger discussion that has occupied psychology research for many years: whether emotions are discrete psychological states (and thus should show distinct physiological responses) or constructed from more basic dimensions (with each dimension characterized by distinct physiological responses; see Russell 1980; Ekman 1992; Barrett 2006). Within this discussion, a great deal of literature has been dedicated to the question of whether specific emotions evoke discrete physiological responses. Both Levenson's (1992) and Kreibig's (2010) meta-analysis conclude that there are indeed unique physiological responses that can be attributed to specific emotions. Other studies have failed to find consistent empirical evidence in support of distinct physiological responses that characterize discrete emotions (Cacioppo et al. 2000; Larsen et al. 2008). Mauss and Robinson's (2009) review of measures of emotion supports this claim and concludes that across physiological response systems, the bulk of the evidence favors the idea that measures of emotional response may reflect underlying dimensions rather than discrete states.

Wac and Tsiourti (2014) were among the first to comprehensively assess the ability to measure emotions through ambulatory assessment using external mobile sensors to measure physiological responses as they occurred in their natural environment. They meta-analyzed 173 studies that employed methods of ambulatory assessment, of which 35 used ambulatory assessment techniques in the ecological evaluation of emotions. Measures of skin conductance, heart rate, and blood volume pulse were all found to be valid and widely used measures of emotion in ecological ambulatory assessment studies. This said, the research emphasizes that gold standards for research are as yet nonexistent in this emerging field. Other scholars were more cautious regarding the measurement of specific emotions outside a controlled laboratory environment. After a thorough review of the benefits and shortcomings of employing ambulatory methods in the investigation of emotion, Wilhelm and Grossman (2010) concluded that inferring the kind of (specific) emotion a person experiences solely from immediate physiological patterning is typically impossible and requires additional contextual information.

In the past few years, some research has begun to combine tracking technologies and spatial analysis techniques with ambulatory physiological sensing to assess momentary experience in a more "objective" manner. When these indicators include geographical references, they allow researchers to map and study people's emotional reactions to various environments and places.

Sagl, Resch, and Blaschke (2015) and Zeile et al. (2015) establish an important theoretical and methodological basis for integrating ambulatory sensing with urban spatial analysis, presenting a conceptual model of how one can exploit these novel technologies in investigating a wide range of questions related to urban studies as they occur in their natural settings and not only in research laboratories.

It should be noted that although technically plausible, only a few studies have applied ambulatory sensing in the investigation of spatial behavior. Most studies that have done so have assessed data at the individual level by pairing individual locational GPS data with physiological measurements, most notably looking at the change in skin conductance over time and space (Nold 2009; Hogertz 2010; Kim and Fesenmaier 2015).

Kim and Fesenmaier (2015, 2016) are the first researchers, to our knowledge, to demonstrate the feasibility of investigating "objective" emotions of visitors during their visit to a destination by tracking changes in electrodermal activity (EDA) over time and space. However, their groundbreaking work did not fully combine GPS and SCL data, but rather showed SCL over time and the participants' routes. The majority of these studies present case study exemplars, and can be seen as a proof of concept.

A fundamental question standing at the base of these studies that is yet to be addressed is what one can conclude from the change of an individual's physiology over time and space. Many of these studies show a shift in physiology; however, they fall short when trying to translate these changes into a concrete understanding of the individual's experience and the implications this has on spatial and temporal behavior. Is the change in skin conductance indicative of stress? Excitement? Fear? Without a thorough grasp of the contextual setting and the integration of this information with other forms of data, our abilities to interpret this type of data are limited.

This article presents novel methods by which objective physiological measures of emotion can be combined with semantic contextual information such as ESM methods (location-triggered and time-triggered surveys) in order to build a more comprehensive emotional profile. Combining the emotional profile with the individuals' spatial and temporal activity (measured by GPS location data) can be used to attain a richer understanding of the individuals' tourist experience.

Data and Methods

A combination of four data collection techniques were employed in order to conduct a comprehensive and integrative examination of tourism experience in time and space: high-resolution locational data derived from GPS and cellular network locations; real-time surveying techniques employed through ESM, including location-triggered surveys and time-triggered surveys; physiological measures of emotion; and traditional surveying techniques, such as questionnaires.

Data

The sample used for this study included 68 tourists visiting Jerusalem and residing at a centrally located youth hostel. Individuals were considered for participation if it was their first or second day visiting the city and they planned to visit the city for at least one full day. Participants were rewarded the equivalent of US$10 in return for their participation.

Table 1 summarizes descriptive statistics of sociodemographic as well as tourism-related variables including age, religion, religious observance, income, sex, education, trip duration, and companionship during the trip. In general, the sample can be characterized as "WEIRD"—Western, educated, industrialized, rich, and democratic (Henrich, Heine, and Norenzayan 2010). Our sample was predominately young, with 53% of participants below age 25 years and 88% under 35. Regarding religious affiliation, 43% of the sample was of Christian faith, 12% was Jewish, and 41% identified as having "no affiliation" or "atheist." Of the participants, 66% stated that the primary purpose of the trip was sightseeing, 12% cited visiting relatives or friends, and only 4% offered religious pilgrimage as the visit's primary purpose. Of the sample, 29% were solo travelers and 71% traveled with companions. The median number of nights planned in Jerusalem was four; the median number of nights planned in Israel was 10.

Measures and Methods

On the evening before their first or second day of travel in the city, potential participants received an explanation about the study. After showing interest, participants provided written informed consent through an online form approved by

Table 1. Sample Description.

	Total: (n=68)
Average nights planned in Jerusalem (SD)	6.03 (10.47) Median = 4
Average nights planned in Israel (SD)	19.87 (22.97) Median = 10
Age group, years	
18–24	52.94% (36)
25–34	35.29% (24)
35–44	7.35% (5)
45+	4.41% (3)
Religion	
Christian	42.65 (29)
Jewish	11.76% (8)
Muslim	–
Other	4.41% (3)
No affiliation/atheist	41.18% (28)
Level of religious observance	
Non-observant	52.94% (36)
Somewhat observant	35.29% (24)
Very observant	11.76% (8)
Strictly observant	–
Estimated income	
Considerably below median	7.35% (5)
Below median	17.65% (12)
Median	36.76% (25)
Above median	35.29% (24)
Considerably above median	2.94% (2)
Purpose of trip	
Sightseeing	66.18% (45)
Religious	4.41% (3)
Visiting friends/relatives	11.76% (8)
Other	17.65% (12)
Sex	
Female	42.65% (29)
Male	57.35% (39)
Education	
High school	19.12% (13)
BA	55.88% (38)
MA or higher	25% (17)
Companions	
Solo traveler	29.41% (20)
Traveling with companion(s)	70.59% (48)

the ethics committee of the Faculty of Social Sciences at the Hebrew University of Jerusalem. They were then enrolled in the study. Participants underwent the following procedures:

Classic surveying techniques. First, participants answered an extensive survey. The survey encompassed a wide range of questions, including sociodemographic information and questions related to expected and desired tourism experience and emotional experience throughout their trip and their day visiting the city. On the evening following their participation, participants filled out another survey addressing aspects of their tourist experience during their visit to the city and questions regarding emotional aspects of their day. They also participated in a semistructured interview in which they were presented with a map of their tour of the city and asked to recall specific events related to emotion and tourist experience at the different locations they visited.

Locational data. As participants toured the city, high-resolution spatiotemporal and locational data were collected through a dedicated smartphone application (Birenboim 2016). The application utilized the smartphone's GPS and cellular network location to record the participants' whereabouts throughout their tours of the city.

Real-time surveying of subjective emotional experience. A central feature of the "Sensometer" application is the ability to employ real-time surveying techniques through the ESM. ESM surveying techniques allow for the assessment of momentary experiences of tourists, providing insight into the characteristics of their immediate physical and social environments. Using two general types of surveys, location-triggered surveys and time-triggered surveys, the subjective emotional experience of tourists was assessed. In location-triggered surveys, participants rated three affective states—arousal, pleasure, and unpleasantness—on a seven-point Likert-style scale from 1 (low) to 7 (high). In predefined time-triggered surveys, participants rated a set of six discrete emotions (happiness, sadness, fear, excitement, calmness, and anger) on a seven-point Likert-style scale from 1 (low) to 7 (high). We asked participants to rate their emotional state both in terms of the key affective dimensions of pleasure and arousal and in terms of discrete emotions in order to capture the dimensional and categorical aspects of the individuals' emotional experience.

"Objective" Physiological Measures of Emotion

Given the current state of research and the technology of ambulatory assessment devices, physiological measurements can and should be used to assess emotion in ecological studies using ambulatory sensors. This said, inferring exactly which discrete emotions the individual is feeling solely from physiological data may be misleading. Instead, such data allow for the inference of arousal levels as a component of emotional experience (Mauss and Robinson 2009; Wilhelm and Grossman 2010).

Different emotional states are characterized by different levels of arousal. For instance, fear and excitement are both characterized by high arousal, although they differ significantly with regard to their valence. Similarly, sadness and calmness are both characterized by low arousal, although they too differ in valence. Arousal levels reflect the activation of the sympathetic nervous system, which prepares the body to respond to urgent situations.

A wide range of physiological measures have been used to assess emotion and emotional arousal. Physiological reactions of the sympathetic nervous system—most notably changes in heart rate, EDA, blood pressure, and cortisol levels—are widely used (Dawson, Schell, and Filion 2007; Resch et al. 2014). Since changes in heart rate and blood pressure are affected by physical effort, the predominant measure of "arousal" is EDA, which is also known as galvanic skin response (GSR) or, more commonly, "skin conductance." The physiological mechanism underlying this response is subtle changes in sweat secretion from eccrine sweat glands throughout the body. As sweat secretion intensifies, the surface of the skin becomes moister and allows for better conduction of an electric current.

The two most common measures of skin conductance are skin conductance level (SCL) and skin conductance response (SCR). SCL is a continuous measure of the (tonic) level of electrical conductivity of the skin. It is typically measured in kilo-ohms of microsiemens, with nominal measures ranging from 2 to 20 microsiemens. SCRs are the number of "spikes" in skin conductance (typically changes greater than 0.5 microsiemens) that occur over a defined time interval (known as a "latency window," usually no longer than 1–3 seconds). Ecological studies tend to use SCL rather than SCR as a measure of EDA because the stimuli are not controlled for, making it complicated to differentiate between specific (stimuli-related) and nonspecific responses. In addition, SCL can more easily be recorded over long periods of time.

In the past five years, portable sport and health devices have become widely available, usually paired with a smartphone to track daily health and physical activity. Many of these devices include a wide range of sensors including heart rate and blood pressure monitors and accelerometers (for a detailed review of sensors embedded in smartphones, see Birenboim and Shoval 2016). Unfortunately, these devices still suffer from weaknesses that do not allow for their implementation in academic research: First, the data recorded on these devices are typically not available in their "raw" form. Most devices are supplied with a dedicated application for viewing the data recorded, though raw data are typically not accessible to the end-user. Some devices, such as the popular "Fitbit" or "Microsoft Band," do allow compatible applications to be developed through dedicated application program interfaces (APIs), some of which allow for the recording of "raw" data. However, these apps suffer from other weaknesses, such as where the data are stored, compatibility, timestamping, recording, and synchronizing multiple sensor measurements. A second weakness relates to these devices' accuracy. Although the manufacturing costs of sensors have dropped dramatically in recent years, the accuracy of consumer devices is inferior to that of devices designed primarily for clinical purposes. With regard to skin conductance, EDA sensors in most commercial devices are not intended to accurately measure skin conductance, but rather are used in the device as a means to detect whether the device is worn or not (in order to shut the device down automatically when contact with the skin is lost). A third weakness is in the temporal resolution of the measurements. Often, the data recorded by consumer devices are recorded at larger intervals, compounding accuracy problems.

Because of the weaknesses of commercially available devices, we chose to conduct all physiological measurements using clinical devices. The device chosen for this study was the Empatica E4. It allows for simultaneous recording of skin conductance, heart rate measures, blood pressure, and skin temperature. Measurements from the E4 are synched to an online cloud platform, where the data can be visualized and accessed in its raw form. The device constitutes a next generation of the Affectiva Q-Sensor device, which has been used in multiple studies. The device has been clinically tested and shown high validity and accuracy (Garbarino et al. 2014; Empatica 2014).

"Mapping" Emotion at the Individual and Group Levels

As Dawson, Schell, and Filion (2007) state, gold standards do not yet exist for analyzing skin conductance in ambulatory assessment research. This is even truer in studies that integrate ambulatory sensing (both general sensing and skin conductance sensing) with spatial analysis, reflecting human mobility in ecological settings.

GPS data consist of several fields. One important feature is the time when GPS location data was recorded by the device. This "timestamp" can be used to pair location records with physiological data. One key feature of clinical ambulatory sensing devices is their ability to accurately record the starting time of physiological measurements. Once a "start" timestamp is recorded by the device, consecutive timestamps can be calculated for all measurements by continually adding the sampling frequency. On the individual level, pairing locational data with physiological data (SCL measurements) is quite simple; using GIS software, each GPS reading is given the value of the SCL recorded at the time reported for the GPS location.

Once researchers begin comparing or aggregating the SCL data of multiple individuals, they can no longer relate to the measure of skin conductance in its "raw" units (kiloohms or microseimens). Each individual tends to exhibit a unique pattern and range of SCL; 10 microseimens may be an extremely high SCL for one individual but only an average SCL for another. Thus, SCL measurements must be normalized in a manner that allows for their comparison. After researching multiple data-analysis techniques, we found that the most effective way to aggregate or compare the SCL of multiple individuals was to calculate z-scores for each measurement. SCL tended to be distributed normally at the individual level; thus, for each measurement, a Z-SCL score could be calculated. The Z-SCL score represents how each SCL measurement compares to that individual's mean SCL score. Thus,

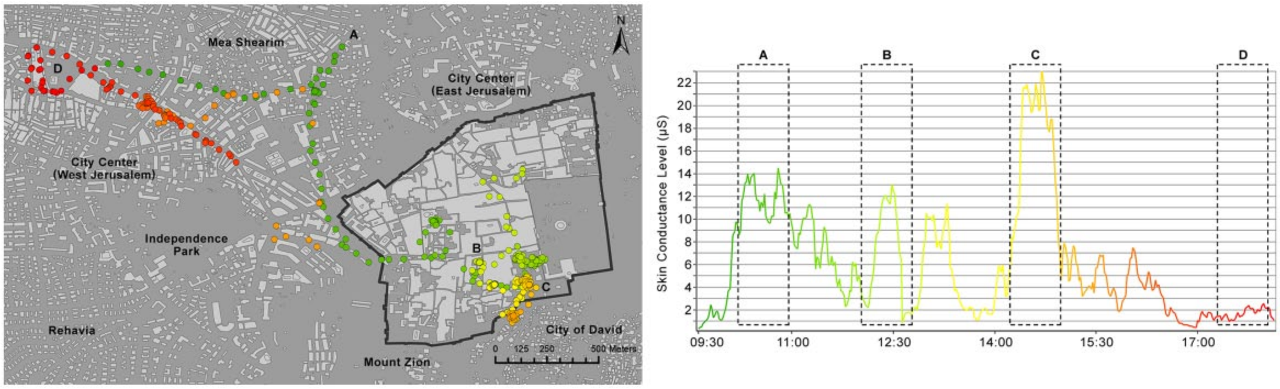

Figure 1. Route of a participant (above) and his SCL graph over time (below).

SCL is transformed from a "raw" (and largely meaningless) value to a value that represents how high or low the SCL is relative to the individual's other SCL measurements.

Most important, this representation also makes it possible to compare different individuals' SCLs. After a z-score was calculated for each SCL measurement, locational GPS data was paired with the SCL data. Since location data (GPS) were recorded at 1-minute intervals, SCL (which was recorded at a higher resolution of 16 Hertz) needed to be reduced and averaged over 1-minute intervals. Thus, each GPS location record was given the average Z-SCL scores recorded throughout a 1-minute window before and after the location was recorded.

Measuring Real-Time Subjective and Objective Tourist Experiences in Time and Space

Five cases that demonstrate the potential of real-time measurements of tourists' objective and subjective emotional experiences in time and space are presented below. They serve to demonstrate this new methodological approach, which integrates the interactions between spatial behavior and emotional experience.

Individual-Level Data

Exploring individual patterns of spatial behavior gives us insight into the personal experiences of each participant. In addition, we can explore how the individual's objective and subjective layers of emotional experience relate to one another.

Figure 1 maps the route of a single participant in our study. This approach to representing spatiotemporal and physiological data resembles that of previous studies, such as that of Kim and Fesenmaier (2015). The map presents GPS location readings at 1-minute intervals throughout the day, symbolized with a color ramp presenting the time the location was recorded. A graph of the participant's SCL over time uses the same colors. Four time intervals (A–D) and corresponding locations are indicated. At times/locations A, B, and C, high levels of SCL were observed, whereas at time/location D a low SCL was observed.

Although this representation provides insight into the general trends of SCL over time, it falls short in addressing two important concepts: First, it is hard to define precisely in which location shifts in SCL occurred, since the spatial resolution is quite low. Second, it is hard to assign meaning to the shifts in SCL over time and space without broader contextual information—for instance, the individual's subjective emotional experiences.

Figure 2 maps the route of another individual who participated in the study, as well as his or her SCL (objective emotional experience) and subjective reporting along the route. The individual began the day walking down Jaffa Street, entered the Old City through Damascus Gate, continued through the Muslim Quarter and the Jewish Quarter, walked on the southern periphery of the Old City and up through the churches of the Mount of Olives, and finished the day at the Mount of Olives lookout overlooking the Old City. Figure 2A maps the route traveled by the participant and his or her objective emotional experience (SCL) along the route. The height dimension (z-axis) of the route and color represent the objective measure of emotion, SCL measurements, along the route at the specific location/time of day. With the visit presented visually, it is easy to identify areas of heightened levels of SCL (the lower part of Jaffa Street, the upper part of the Mount of Olives) as well as areas with reduced SCL (the upper part of Jaffa Street, the southern periphery of the Old City, and the Mount of Olives lookout).

Figure 2B represents the participant's subjective emotional experience by mapping the answers to survey questions regarding emotional state (along the route). A column indicates the location where a survey was completed. By

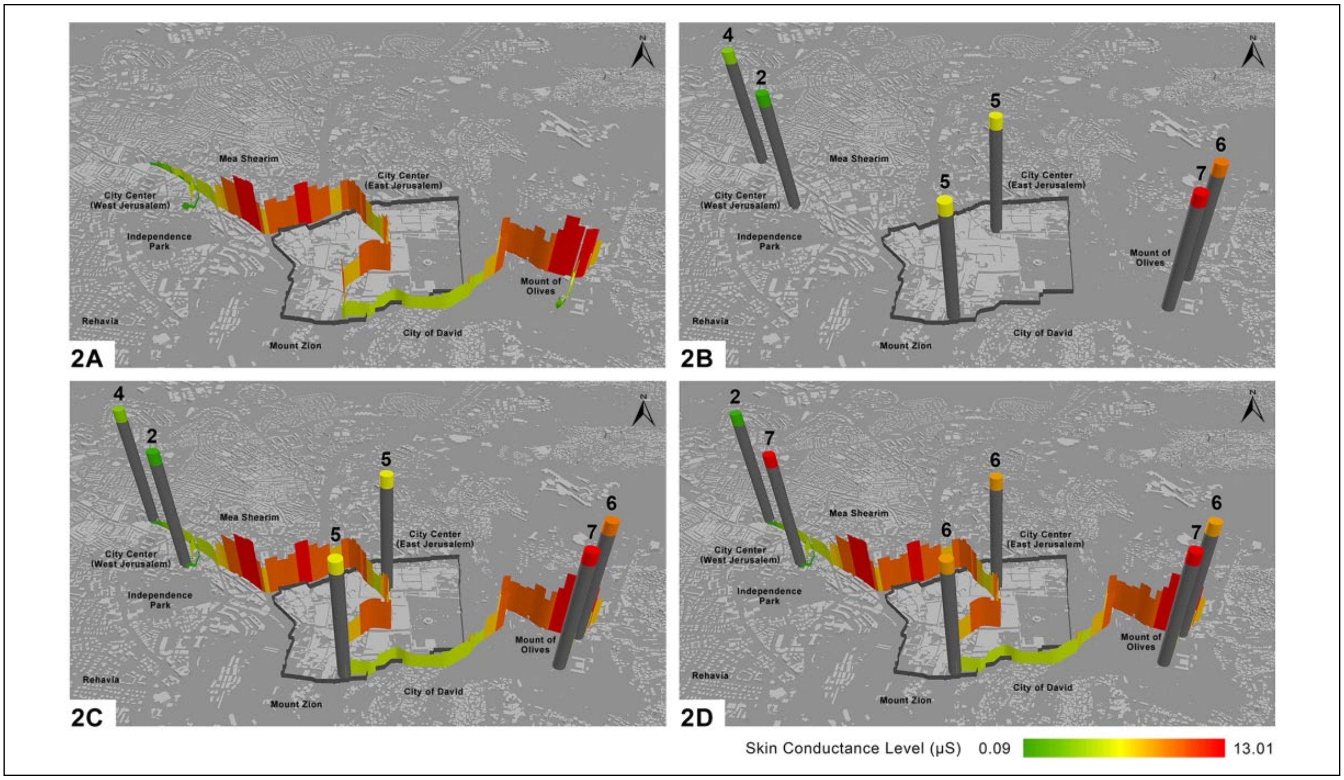

Figure 2. Objective and subjective measures of emotion of a participant along their route.

focusing on the question "How active do you feel?" (rated on a seven-point Likert-type scale from 1 [low] to 7 [high]) we can examine similarities and discrepancies in the objective measurements and subjective reporting. It should be noted that this question was worded in this manner in order to assess subjective emotional arousal without adding the dimension of valence (positive/negative affect). If we were to compare the objective measures to the subjective "level of excitement," it would likely reflect the emotional dimension of valence as well.

It is interesting to compare similarities between objective measures of emotional arousal and subjective reporting. In Figure 2C we have mapped the subjective emotional reports alongside the objective measures of emotion. We can now begin to identify areas of congruence and discrepancies between the results. For the most part, it appears that the subjective answers correspond with the objective measurements; areas of low emotional arousal (measured by low SCL) were also areas that the participant reported lower emotional activation, and areas along the route characterized by high SCL were also subjectively perceived as eliciting high emotional arousal. That said, some discrepancies can be found: the Mount of Olives lookout was not an objectively arousing site, though subjectively the participant stated that he or she felt active there.

This discrepancy is interesting—though, as stated earlier, by examining solely the objective emotional data it is impossible to identify the true emotional context of the experience, and thus we cannot fully interpret this discrepancy. Do the reduced levels of SCL at the Mount of Olives lookout point to calmness? Boredom? Possibly happiness? Are the heightened levels of SCL on the lower part of Jaffa Street an expression of excitement or fear? Thus, a third objective/subjective comparison can be conducted: In Figure 2D we present the participant's answer to the question "How pleasant do you feel?" (rated on a seven-point Likert-type scale from 1 [low] to 7 [high]). By combining the objective measure of emotional arousal with the two (subjective) answers to survey questions, we can gain a broader understanding of the individual's emotional experience. For example, although objectively the upper areas of Jaffa Street and the Mount of Olives lookout show similar patterns of emotional arousal, the subjective answers allow us to differentiate between these areas; one (Jaffa Street) was perceived subjectively as evoking low levels of pleasure and activity, whereas the other was perceived as a highly pleasant and active location. Another example can be seen in the differences in the subjective reporting of two consecutive surveys along Jaffa Street. Again, although the SCL levels are similar, the subjectively reported level of pleasure changed significantly over the course of only a few hundred meters. This shift may be explained by the fact that the participant chose to "detour" off Jaffa Street and dine at a restaurant nearby.

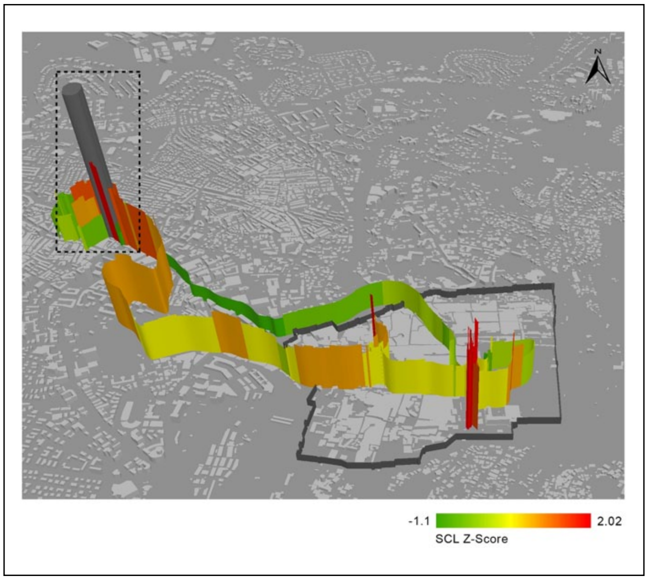

Figure 3. An example of an undesired reporting pattern by a participant.

One important drawback of ESM collection techniques is demonstrated in Figure 3. Similar to the first case presented, the participant's objective measure of emotion is symbolized along the route; however, in contrast to the first case where the participant completed surveys immediately as they were prompted on the app, in this case the participant completed all surveys (time-triggered and location-triggered) in a single location, one after the other, all within a period of a few minutes. This case is an extreme example of a participant's undesirable reporting patterns, though it is not unique; in some cases individuals completed multiple surveys in a single location for a variety of reasons. This case highlights that while ESM methods can be useful in elaborating on behaviors, there is the possibility that the individual will not respond to surveys in the desired location or at the desired time—even if a study is designed with triggered surveys at predefined locations/time intervals. This may lead to recall and other potential biases. Thus, we cannot conclude that ESM eradicates recall biases, only that it reduces them.

Comparing Individual-Level Data

A second interesting technique that can be employed when investigating individual-level data is comparing individuals who express similar spatial and temporal patterns. Such a comparison can be conducted between individuals with a prior acquaintance (who traveled together) or between individuals who did not travel together but show similar spatial patterns.

Choosing whether to compare individuals who were prior acquaintances traveling the same route on the same day or individuals without a prior acquaintance who traveled the same route on different days may seem irrelevant, but this decision has important methodological implications that should be addressed. The chief implication is controlling for intervening variables, a highly criticized aspect of ecological studies (Hairston 1989; Tilman 1989). When comparing routes of individuals with a prior acquaintance who traveled the same route together, one could argue that one individual's emotional experience is not entirely independent of the other's—perhaps the emotional state of one individual is acting as an intermediate variable affecting the emotional state of the other individual, rather than the shared environment affecting them independently. Thus, this comparison may not accurately reflect the effect the environment has on emotions. In contrast, when comparing routes of individuals without a prior acquaintance, the "emotional spillover" effect is controlled for, but the shared environment is not; slight differences in weather, noise, or a random event experienced along the way may cause two identical routes to be experienced differently on two different days (even by the same person). It seems that there is no right or wrong answer. Both types of comparisons can be conducted, and patterns of similarity or dissimilarity shed light on different aspects of emotional experience and spatial behavior.

We chose to compare two routes of two individuals (without a prior acquaintance) on two different days, as presented in Figure 4. Although these routes are not identical, both individuals visited many of the same sites throughout their tour of the city—Jaffa Gate, Church of the Holy Sepulchre, markets of the Old City, the Western Wall, Jaffa Street, and the Machne Yehuda market. Some similarities in objective emotional arousal can be observed; both individuals had high SCL at the Church of the Holy Sepulchre and at the entrance to the Western Wall and a low SCL in both cases at the Machne Yehuda market.

Differences in objective emotional arousal are evident as well; the area surrounding the hostel evoked high levels of SCL for participant A, compared to low levels of SCL for participant B. In addition, walking down toward the Old City was not an emotionally arousing experience for participant A, whereas for participant B higher emotional arousal can be observed. If similar time-space patterns are expected to have a similar effect on emotion (when other factors are controlled for), differences rather than similarities should be of interest, as they may point to unique individual experiences. A good example of this is demonstrated in the follow-up interview conducted with participant B upon returning from a tour of the city. The participant stated that on the walk down to the Old City she accidentally took a wrong turn and wandered into an ultra-Orthodox neighborhood, and the fear of getting lost in an unfamiliar environment caused stress and anxiety. This testimony sheds light on why differences in SCL levels were observed on the walk down to the Old City in the different cases.

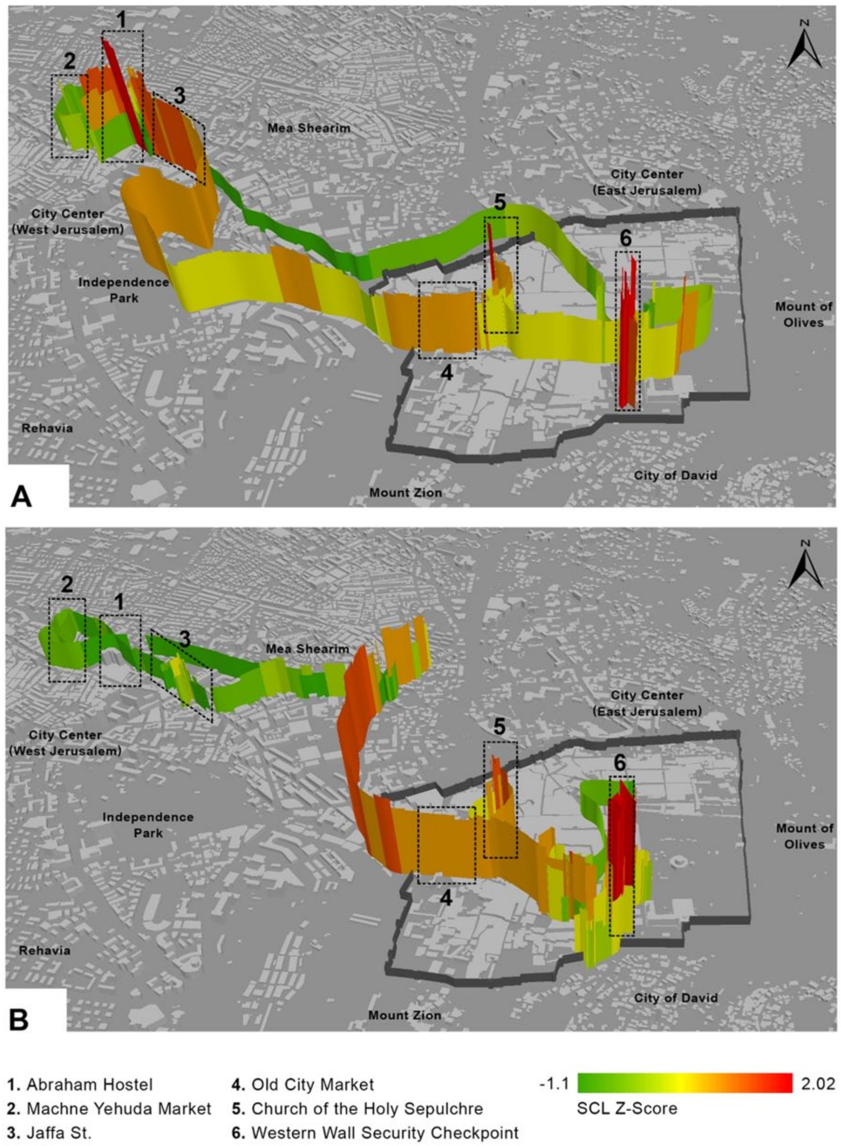

Figure 4. Comparison of SCL along a similar route of two individuals.

This case also demonstrates that additional contextual information is often needed in order to contemplate why these differences occurred and what their significance is. Additional contextual information can also help us conclude that patterns of similarities indeed reflect the shared environment experienced by both individuals.

Comparing the routes of two independent individuals is useful for inferring why differences in emotional experience occur and what they mean. But, as stated above, patterns of similarity between two individuals cannot simply imply emotional characteristics of a site. In order to conclude that a location in the city, in general, has specific emotional characteristics, multiple individuals need to express similar emotional reactions when visiting the location.

Aggregative Spatial, Temporal, and Emotional Data

By combining the spatial and emotional data of 68 participants, we were able to identify emotionally evocative areas in the city. To analyze the data, the central areas of Jerusalem were divided into cells of 20 m × 20 m. For each cell, the average Z-SCL scores of all participants who passed through the cell were calculated (again, SCL scores were normalized in order to attain a measure of SCL that can be compared between individuals). Figure 5 presents the results of this calculation.

Some interesting observations can be drawn from the "emotional map" of central Jerusalem. Overall, it seems that

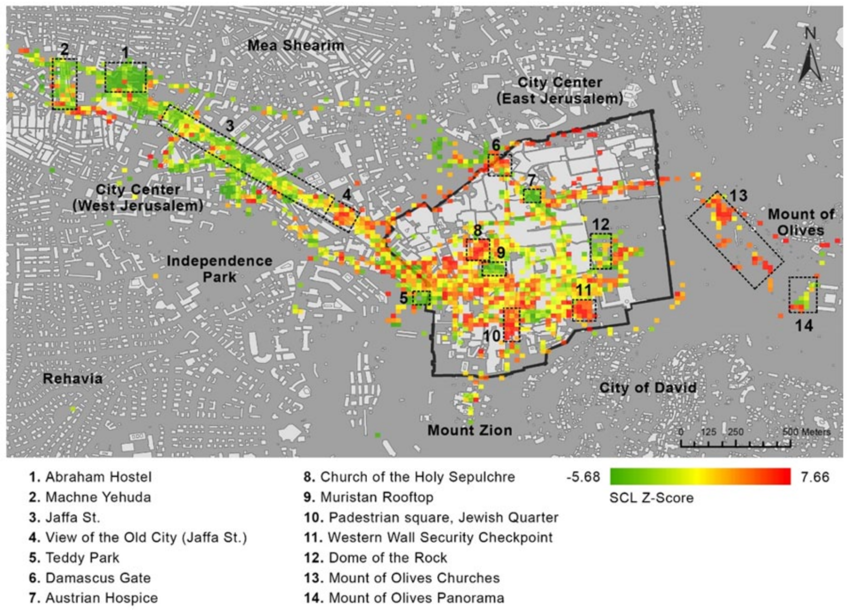

Figure 5. Emotionally evocative areas in Jerusalem.

the sites characterized by heightened levels of SCL fall into two general categories: sites of religious importance (to the Christian faith, as most of our sample identified as Christian) and sites perceived as places with a potential security risk. The areas of the city characterized by predominantly high SCL were the Church of the Holy Sepulchre, the security checkpoint at the entrance to the Western Wall, and Damascus Gate (the northern entrance to the Old City which has seen ongoing security tension in recent years), a pedestrian square within the Jewish Quarter, and the Mount of Olives churches.

Sites with reduced SCL levels also fall into two general categories: sites characterized by visual or aesthetic pleasure and leisure areas/rest stops along the way. One predominantly low-SCL area of the city is Jaffa Street—the central artery of the western part of the city. In recent years, the location has enjoyed a great deal of investment and renovation; today, it functions as a mixed-use pedestrian street with a light rail line running down its center. Interestingly, a point of heightened emotional arousal was observed toward the southeastern end of Jaffa Street—where the Old City becomes visible. Although we cannot rule out alternative explanations, we believe that the heightened SCL in this location reflects the excitement upon viewing Jerusalem's Old City for the first time. Other areas of the city characterized by low SCL are the Austrian Hospice (a popular café and restaurant among tourists); a rooftop near the Muristan (often used as a scenic viewpoint overlooking the Dome of the Rock); Teddy Park, a small park adjacent to the Old City/Jaffa Gate area; and the areas surrounding the Dome of Rock—all known for their aesthetic value.

Another interesting observation relates to the locations in Jerusalem that were not visited by participants in our sample: not a single participant visited the residential neighborhoods of Rechavia, Mea Shearim, or Nachlaot, despite the fact that these neighborhoods are adjacent to the hostel and the city center. The East Jerusalem city center and the City of David area were also not visited by a single participant, despite their proximity to the Old City. It goes without saying that these sites are of central importance to the cultural fabric of modern-day Jerusalem. It thus came as somewhat of a surprise to us that such a limited area of the city was visited, considering the fact that the majority of participants did not participate in a guided tour, had adequate time to explore the city, were located in a highly central and accessible part of town, and were characterized largely as backpackers, who tend to explore sites that are also off the beaten path. It seems that Jerusalem's potential as a tourist destination still largely rests on the Old City and the holy sites in its vicinity, despite efforts to brand the city as a modern multicultural metropolis.

These findings may seem trivial for people who know the tourism geography of Jerusalem, but it is quite clear that certain sites possess a set of attributes that evoke a consistent and recurring emotional response from a large number of individuals ranging in personality, age, ethnicity, religion, and gender.

Discussion and Conclusions

The study of tourists' experiences in time and space has become a crucial field within tourism scholarship during the last decades. However, most evaluations of tourist experiences have been limited to one-time measurements at the end of a visit in a destination through traditional post-visitation surveys. In recent years, thanks to the development of digital platforms, some pioneering efforts have examined real-time or near-real-time experiences, though only a handful of these studies have used digital tracking technologies to accurately anchor the experience in time and space. A common feature of these studies is that they all assess the subjective experience of the participants, through analysis of their impressions in visitor books, interviews, questionnaires, and recently different digital platforms.

In a groundbreaking paper, Kim and Fesenmaier (2015) recently presented the feasibility of studying the objective emotions of tourists visiting a destination by tracking their EDA over time and space. However, this innovative work only demonstrated the feasibility of the idea by applying the concept to two participants. Moreover, their study presented EDA over time and the participants' routes separately; the spatial resolution was thus low, as the physiological data was not fully coupled with GPS data.

In the present paper, four data collection techniques were employed simultaneously in order to conduct a comprehensive and integrative investigation of tourism experience in time and space: high-resolution locational data derived from GPS and cellular network locations; real-time surveying techniques employed through the ESM, including location-triggered and time-triggered surveys; physiological measures of emotion (SCL); and traditional surveying techniques such as questionnaires.

This rigorous research design contributes to tourism scholarship in a number of ways. First, it moves beyond merely presenting the technical proof of concept of a research method. It does this by investigating concrete aspects of spatial behavior and experience in a sample of almost 70 tourists visiting Jerusalem, using ambulatory sensing techniques including objective measures regarding their emotions during their visit. Second, it uses, among other research tools, real-time questionnaires that are triggered by a participant's specific location in the city and/or by time intervals. The questionnaires were delivered to the participants' smartphones in real time and provided an understanding of their subjective emotions. Third, it enables scholars to integrate subjective and objective measures in order to obtain a richer and fuller understanding of the experiences of the individual. By combining and comparing multiple forms of data both at the individual level and within the group of participants, patterns of similarity and dissimilarity can be found. Similarities over multiple individuals are of interest as they may point to a common factor that characterizes a location/environment. Dissimilarities at the individual level are no less important: they point to differences in unique and often singular experiences. Fourth, for the first time, this method allows us to compile multiple sets of individual physiological data (synchronized with locational data) and provide meaning to patterns of similarity across a sample, as well as to identify consistent and recurring emotional responses evoked in a location/tourist attraction in the city. We note that additional contextual information (such as ESM surveying techniques) is often necessary in order to consider why differences in physiology occurred and what they mean.

Theoretical and Methodological Reflections

In our view, the ability to attain a complex understanding of the individuals' subjective and objective tourism experience by receiving high-resolution data in terms of time (seconds) and space (meters) presents new opportunities for tourism research. From the theoretical perspective, the possibility of combining and comparing different types of data that are collected in real time can clearly assist us in answering existing research questions. For example, this type of data can improve destination and attraction management; facilitate the creation of more accurate and sophisticated marketing campaigns in real time, ones that are geared toward the specific characteristics and emotions of the potential consumers visiting the destination; and can allow us to track different interventions conducted in a destination and monitor their impact on users. The combination of sensor data with the precise location of tourists is also useful for collecting data about the environment visited, moving beyond the experience of the individual tourist. In this sense, the tourists themselves serve as sensors, helping us to understand their impact on the environment they visit.

Adding objective measurements to the subjective ones can create "complications," as subjective responses may differ from objective physiological readings. We see these "complications" as opportunities to obtain a richer appreciation of human experience. This is certainly new terrain in tourism research, and probably other fields as well—psychology and geography, for instance.

An additional dimension that should be addressed in the future is the potential Hawthorne effect. Tracking the mobility of tourists (among other things) can in turn influence their mobility in the destination and may impact the experience itself. Scholars should seek out ways to decrease or control this effect.

Alongside its contribution to existing research, does this abundance of new high-resolution data about a tourist's whereabouts constitute a leap forward by enabling us to ask new questions thanks to the new types of data available? Could the potential impact of tracking technologies in the spatial sciences be compared one day to the impact of the introduction of high-resolution digital platforms in other fields, such as MRI in medicine, the electron microscope in chemistry and biology, or the Ikonos earth observation satellite in remote sensing? Perhaps this "prophecy" is a truly wild exaggeration; perhaps not.

Limitations and Challenges

The large amounts of data from different sources that are accumulated when using these novel methods require the development of complex algorithms and automatic scripts; otherwise, they cannot be analyzed in a fast and efficient way. The world of research would benefit greatly if software being developed today by different academic research teams and private companies around the globe on an ad hoc basis could be standardized at some point so that common measures, standards, and protocols for data analysis were created. More importantly, this could lead to an increase in the number of researchers in the field. Today's challenge of analyzing data grows as additional sensors emerge; this no doubt limits the number of prospective users of these methods.

Another challenge for widespread implementation of these novel methods relates to the high roaming prices for phones crossing international borders. Until recently, the use of such data by tourists was relatively limited. Growing use of local SIM cards and attractive international roaming programs, however, are making smartphones more and more relevant for tourists.

One challenge in interpreting data from physiological sensors used outside controlled environments such as laboratories is the unknown impact of external environmental stimuli. This will always remain a challenge; however, the difficulty can be overcome by creating large samples, so that such biases will not significantly impact the overall results.

Finally, the question of privacy arises. The increasing daily use of devices such as cell phones—which are inherently, and among other things, tracking devices—has made the privacy dilemma more pronounced over the course of the past decade (Curry 2000; Fisher and Dobson 2003). This question has been widely debated by the popular media, academia, courts, and lawmakers. However, in most countries, legal systems have thus far failed to tackle the question fully and, as such, the question is of considerable and global importance. Advanced tracking technologies, together with various additional sensors embedded in smartphones or external to them, have the ability and potential to be used in tourism research. However, the use of such technologies, which can obtain exact locations of research participants at any given moment, can infringe on the privacy of the participants in different ways and adds a geographical dimension to the *surveillance society* (Lyon 2001) and the ability to better track the *digital individual* (Curry 1997). This raises different ethical and moral issues. One of the most prominent among these issues is whether, and to what extent, such research projects impinge on their participants' right to privacy.

The past decade has witnessed dramatic growth in the use of various tracking technologies in tourism studies. These methods can provide a richer understanding of the mobility patterns of tourists in time and space, the tourist experience, and tourists' impact on destinations. The rate of papers published annually on the subject has grown in recent years and it is clear that this novel field is further expanding. The incorporation of data derived from physiological sensors demonstrated in the present study has the potential to develop tourism scholarship even further into new, unexplored territories.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was supported by the Israel Science Foundation (Grant No. 832/03).

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