UNDERSTANDING TOURISTS' EMOTIONS IN TIME AND SPACE: COMBINING GPS TRACKING AND BIOSENSING TO DETECT SPATIAL POINTS OF EMOTION

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ABSTRACT

The main contribution of the study is to provide a new methodological and analytical approach in conceptualising and measuring spatial points of emotion (SPoE). It contributes to the further development of mobile methods in applied tourism geography. A mixed-methods design, including georeferenced biosensing data and contextual information, such as video data and ex-post interviews, was used to examine positive SPoE. A conceptual framework was developed for measuring SPoE. The results showed that georeferenced biosensing indicators can be used to identify SPoE in a tourism setting. Using a data-driven and episode-driven approach, visitors' points of relaxation at the beach can be identified. However, there are some limitations to the method, as the interpretation of biosensing signals in a real-world situation needs further clarification. Validly identifying positive valences should be a focus in future tourism research.

Keywords: GPS Tracking, Biosensing, Spatio-Temporal Behaviour, Emotion, Tourism Experience, Mixed-Methods.

JEL Classification: Z30, Z32, Z39

1. INTRODUCTION

Emotions fundamentally shape the tourist experience (Aho, 2001; Tussyadiah, 2014; Kim & Fesenmaier, 2015; Bastiaansen et al., 2019). Recently, smart wristbands with improved measurement methods and automated data transmission have made these instruments increasingly suitable for measuring tourists' emotions outside a laboratory. Researchers from geography (Shoval, Schvimer, & Tamir, 2017), tourism (Scuttari, 2019), and spatial planning (Zeile, Resch, Loidl, Petutschnig, & Dörrzapf, 2016) are beginning to exploit these new possibilities to analyse the spatio-temporal behaviour of tourists and their destination experiences. They aim to better understand the interplay between the body and the environment (Shoval & Birenboim, 2019). In this context, people serve as sensors (Goodchild, 2007) as their body functions (e.g. skin conductance) can be read as indicators of emotional arousal. By georeferencing those body functions, new insights into the spatio-temporal behaviour of tourists can be gained on an objective level. Emotional maps of tourist destinations created this way (e.g., Shoval et al., 2017) can provide insights for the design of visitor experiences, for example. These approaches have so far not been widely adopted in tourism research.

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Biosensing methods, understood as methods which capture the unaltered somatic responses to external stimuli, are considered to have great potential for tourism research (Li, Scott, & Walters, 2015; Bastiaansen, Oosterholt, Mitas, Han, & Lub, 2020) and for exploring the tourist experience holistically with innovative methods. Shoval and Birenboim (2019) recently called for a paradigm shift, making use of new digital tools and sensors with a high spatial resolution to understand tourists' on-site experiences. However, research seems to be dominated by studies focusing on human stress and negative responses to the natural and built environment (Pykett et al., 2020). However, happiness and positive emotions are common during the main phases of the tourist experience (Filep & Deery, 2010; Nawijn, 2010; Mitas, Yarnal, Adams, & Ram, 2012; Carneiro & Eusébio, 2019). Hence, further research is needed to better understand if and how positive emotions can be identified from biosensing data. At the same time, there is still a need for research to check whether the data collected with current mobile methods and the data analysis conducted are valid and reliable.

Taking a mixed-methods approach, this paper contributes to the understanding of the interplay between the body and the environment in a tourism context. It improves the use of mobile methods in tourism geography research by using georeferenced biosensing data to advance the understanding of the tourism experience in real-world situations. A mixed-methods research design, combining GPS tracking, biosensing, eye-tracking video, and ex-post interviews, is used to detect spatial points of emotion (SPoE). Like points of interest (POI), which are usually defined based on their status (sights), their function (gastronomy), or visitor interest, SPoE are defined as points in space that trigger positive or negative emotional arousal in tourists. This paper focused on positive SPoE, which are defined as points that have a positive valence.

2. LITERATURE REVIEW

2.1 Emotions and the Tourism Experience

Defining emotions is a difficult task (Scherer, 2005). A large body of literature from different research disciplines investigates emotions. Especially in human geography, the interaction between human senses and space is not a new topic. Researchers investigate in the study of "sense of place experiences" (Tuan, 2001), a "sensuous geography" (Rodaway, 1994) or an "emotional geography" (Davidson, Bondi, & Smith, 2017). One of the earliest attempts to capture perceptions of urban spaces is the work of Lynch (1960), who used cognitive maps to determine the spatial perception of cities. According to his results, sensory perception plays a major role in image formation.

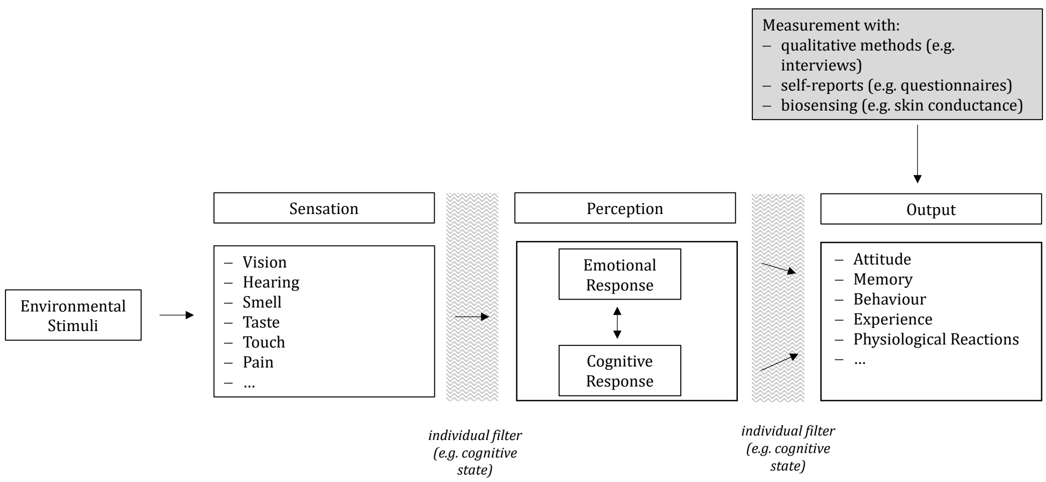
In tourism, which "involves *corporeal* movement" (Urry, 2002, p. 152), the whole body experiences the destination. Human senses are therefore important for the experience and perception of the world (Agapito, Mendes, & Valle, 2013). In addition to the tourist gaze, other scapes must be added to get a holistic idea of the emotional on-site experience. These include sensescapes such as smellscapes (Xiao, Tait, & Kang, 2020), soundscapes, tastescapes, and geographies of touch (Urry, 2002). These strong connections between space, emotions, and the human being can lead to the development of a deep relationship with destinations (Yuksel, Yuksel, & Bilim, 2010) or can even end up in "topophilia" (Tuan, 1961). These few examples from the past show that the study of emotions in tourism is of great importance. The memorable or extraordinary experiences that are becoming increasingly important in the context of an experience economy (Pine & Gilmore, 2011) or a society of singularities (Reckwitz, 2018) and the associated need to create new attractions and positive experiences, make it more important today than ever before to investigate in the emotions of tourists.

From a theoretical point of view, two different approaches are predominant in tourist studies to conceptualise emotions: categorical (or basic emotion) approaches and dimensional approaches (Kim & Fesenmaier, 2015; Li et al., 2015). While the categorical approach tries to conceptualise basic emotions (e.g. joy, love, fear) as distinct categories, the dimensional approach locates emotions in a two-dimensional valence–arousal space, where arousal indicates the emotional intensity (Walters & Li, 2017) and valence indicates the pleasure experienced. The most prominent example is the circumplex model of affect, also known as the pleasure–arousal–dominance model of emotion (Russell, 1980) (Figure 2). The model was applied in tourism research (Chebat & Michon, 2003; Bigné, Andreu, & Gnoth, 2005; Yuksel, 2007) and in studies applying mobile methods (Matsuda et al., 2018; Paül i Agustí, Rutllant, & Lasala Fortea, 2019), and it was shown to be a fruitful framework for categorising emotions based on biosensing (Osborne & Jones, 2017).

Tourist experiences were considered to be individual, socially constructed events (Larsen, 2007) shaped by cognitions and emotions (Kim & Fesenmaier, 2015). Emotions, as the affective component, can be considered the core component of tourist experiences (Bastiaansen et al., 2019). Furthermore, generating tourist experiences can be interpreted as a process (Figure 1): Tourists perceive different environmental stimuli, which, considering several individual filters, induce emotional and cognitive reactions and subsequently influence their attitudes, memories, and behaviour (Kim & Fesenmaier, 2017). In the literature there is largely consensus that

1. Emotions "consist of shortlived responses to situations that are seen as personally relevant" (Bastiaansen, Straatman, Mitas, Stekelenburg, & Jansen, 2020, p. 2);
2. Emotional responses consist of three different elements: (1) subjective experiences, (2) expressive components and (3) physiological arousal (Kleinginna & Kleinginna, 1981); and
3. Physiological arousal comes with subliminal reactions such as facial expressions and electrodermal activities (Li, Walters, & Scott, 2017). The latter can be measured with biosensing methods.

Figure 1. The Role of Emotions in Generating Tourist Experiences



Source: Own Elaboration based on Bastiaansen et al. (2019), Kim and Fesenmaier (2017) and Krishna (2012).

2.2 Measuring Emotions using Georeferenced Biosensing Data

Besides traditional measurements of tourists' emotions based on self-reports (e.g., Nawijn, Isaac, Gridnevskiy, & van Liempt, 2015), which have their limitations (Scuttari & Pechlaner, 2017), attempts were recently made to use research approaches such as mobile biosensing to detect tourist emotions. However, self-reported measurements remain the most widely used method to detect tourist emotions (Li et al., 2015), usually using Likert scales (Hosany & Gilbert, 2010). In contrast to traditional data collection methods, four major advantages of using mobile psychophysiological measures (e.g. skin conductance, facial electromyography, heart rate, eye tracking) to detect human emotions (Birenboim, Dijst, Scheepers, Poelman, & Helbich, 2019) can be identified:

1. Biosensing data are more objective than self-reports, which could include socially desirable responses.
2. The temporal resolution is more precise, allowing researchers to analyse data on a second-by-second basis or even shorter timespans.
3. Wearable devices reduce the burden on the participants.
4. Applications could be used in real-life situations, "to capture the 'unadulterated' emotional response […] during the experience" (Prayag, 2020, p. 80).

However, biosensing methods cannot be regarded as a substitute for self-reports (Caruelle, Gustafsson, Shams, & Lervik-Olsen, 2019). In a direct comparison between subjective (mental maps) and objective (heart rate variation) measures, Paül i Agustí et al. (2019) concluded that none of the approaches alone can capture the complexity of spatial perception.

From a tourism geography perspective, emotions can be seen as spatio-temporal variables; they are "an affective phenomenon which is associated with a specific time and space and this opens the doors to its study as a mappable spatial variable" (Paül i Agustí et al., 2019, p. 2). Biosensing data can also be enhanced with geoinformation, allowing location-based emotions to be analysed and providing a new level of understanding of the spatio-temporal behaviour of tourists and their interactions with the environment. However, only a few researchers have made use of these new possibilities, especially in tourism research. One of the earliest attempts to measure real-time emotions with skin conductance was the explorative approach by Kim and Fesenmaier (2015). They investigate the electrodermal activity of two female tourists during different activities in Philadelphia and combine these results with retrospective interviews to facilitate data interpretation. However, they do not georeference their data. Georeferencing physiological data was the focus in the studies of Shoval et al. (2017); they combined four methodological approaches to reveal the interplay between emotions and the city of Jerusalem. These are the most complex and, in terms of the number of cases ($n=68$), the largest studies to date in which real-time emotions were recorded with the aid of biosensing in urban areas. They used locational data, real-time surveying techniques via smartphones, skin conductance and traditional surveying techniques. They conclude that religious sites and areas with security risks seem to be the most emotionally evocative areas.

2.3 Understanding Biosensing Data

Following Osborne and Jones (2017), the term *biosensing data* is used as an umbrella term for different somatic responses to external stimuli, such as electrodermal activity, blood volume pulse and electroencephalograms. Because the research interest is the identification of SPoE in real-world situations, the measurement of biosensing data is restricted through wearable devices. This study focuses on skin conductance, skin temperature and heart rate.

> 1) Skin conductance: The electric conductivity of the skin, known as electrodermal activity (EDA) or skin conductance (SC), measured in microsiemens (μS), is regulated by the sympathetic nervous system. When stimulated by emotional

arousal, sweat glands produce sweat, which is reflected in increased skin conductivity (Dawson, Schell, & Filion, 2017). Skin conductance is divided into two elements: (1) the tonic skin conductance *level* (SCL) reflects the skin conductivity over a specific period of time and (2) the phasic skin conductive *response* (SCR) represents event-related responses in skin conductivity (Stadler, Jepson, & Wood, 2018). Tonic skin conductance can be interpreted as a fixed baseline (e.g. skin conductance when beginning the measurement without the presence of any stimuli), but also as a moving baseline reflecting slow changes over time, independent from ad hoc stimuli. Variations can be direct results of environmental influences; however, non-event deflections are also common in the data (Birenboim et al., 2019). Depending on individual-personal conditions, SCL usually has a value between 2 and 20 microsiemens (Dawson et al., 2017).
2) Heart rate and heart rate variability: While the heart rate (HR) is the number of heart beats per minute, the heart rate variability (HRV) is the variation in the beat-to-beat time (Ernst, 2014). While HR can be derived from summing up beat-to-beat latencies over a given time, HRV is the variation between the beat-to-beat latencies in a given period. It is usually computed based on the time between heart beats (inter-beat interval, IBI, which is either the time between two R-spikes in the QRS complex, RR, or the time between two R spikes, but filtered for normal values, NN) (Appelhans & Luecken, 2006).

To understand the measurement of emotions based on biosensing, it has to be differentiated between two types of data streams:

1. *Static data* represent a measurement *at* a given *time* and *point in space*, such as the skin conductance in μS. Static data can be represented by a simple vector of all measurements at a given time, in this case, SC, skin temperature (ST) and HR.

$$\overline{S_t} = (SC, ST, HR)$$

2. *Dynamic data* represent a measurement *over* a given *spatial–temporal period*, such as the drop in ST in °C. Dynamic data need a time window with a defined start (t_0) and end (t_1) to represent changes in the biosensing data, resulting in a function representing the data dynamic over time. This function could be a simple difference between the vectors in t_0 and t_1, but also a moving average of data between t_0 and t_1 or a regression-based trend line for all the data between t_0 and t_1.

$$\overline{D_t} = f(\overline{S_{t0}}; \overline{S_{t1}})$$

This study employs both, the dynamic and the static approach to measure emotions.

To relate the above-presented measures to the theoretical background of generating tourist experiences, it is helpful to integrate them into the above-mentioned circumplex model of affect (Hogertz, 2010; Osborne & Jones, 2017). The aim here is to use the biosensing data as indicators of valence and arousal. A finding that is generally accepted in the literature is that rising SC can be interpreted as a rising level of arousal, whereas decreasing SC indicates lower arousal levels (Hogertz, 2010). Furthermore, there is consensus that when SC increases and shortly afterward ST decreases (cold sweat), a negative experience has occurred (Kreibig, 2010; Da Silva, Zeile, Aguiar, Papastefanou, & Bergner, 2014; Osborne, 2019). The stress indicator developed by Bergner, Zeile, Papastefanou, and Rech (2011) goes in the same direction: Falling ST together with rising SC is interpreted as stress. The interplay between SC and ST can thus be read as an indicator of a negative valence. With reference to older studies (Harris, 2001; Calderon & Thompson, 2004), Osborne and Jones (2017) also give an indication of the emotional meaning of combining two dynamic indicators:

"Where EDA response indicates arousal, a small rise in skin temperature (flushing) suggests a positive emotional response, whereas a small drop in temperature (cold sweat) can indicate a negative response" (Osborne & Jones, 2017, p. 162). However, this indication is rather weakly based on empirical data and not very detailed. Paül i Agustí et al. (2019) used another approach, measuring arousal by HRV and obtaining the valence using mental maps from the participants.

In a comprehensive bibliometric review, Kreibig (2010) gives an overview of the interplay between different psychophysiological measures and the response to different emotional experiences. She provides a systematic overview of emotion recognition based on physiological signals. 22 emotional states or combinations thereof are discussed and related to four areas of physiological signals: (1) cardiovascular (including HR, HRV and finger temperature), (2) electrodermal (including SC response, nonspecific SC response rate and SCL), (3) respiratory and (4) autonomic nervous system activation components. The responses of indicators of the emotional states are presented below (Table 1).

Table 1. The Relationship between Emotions and Physiological Features (Extract)

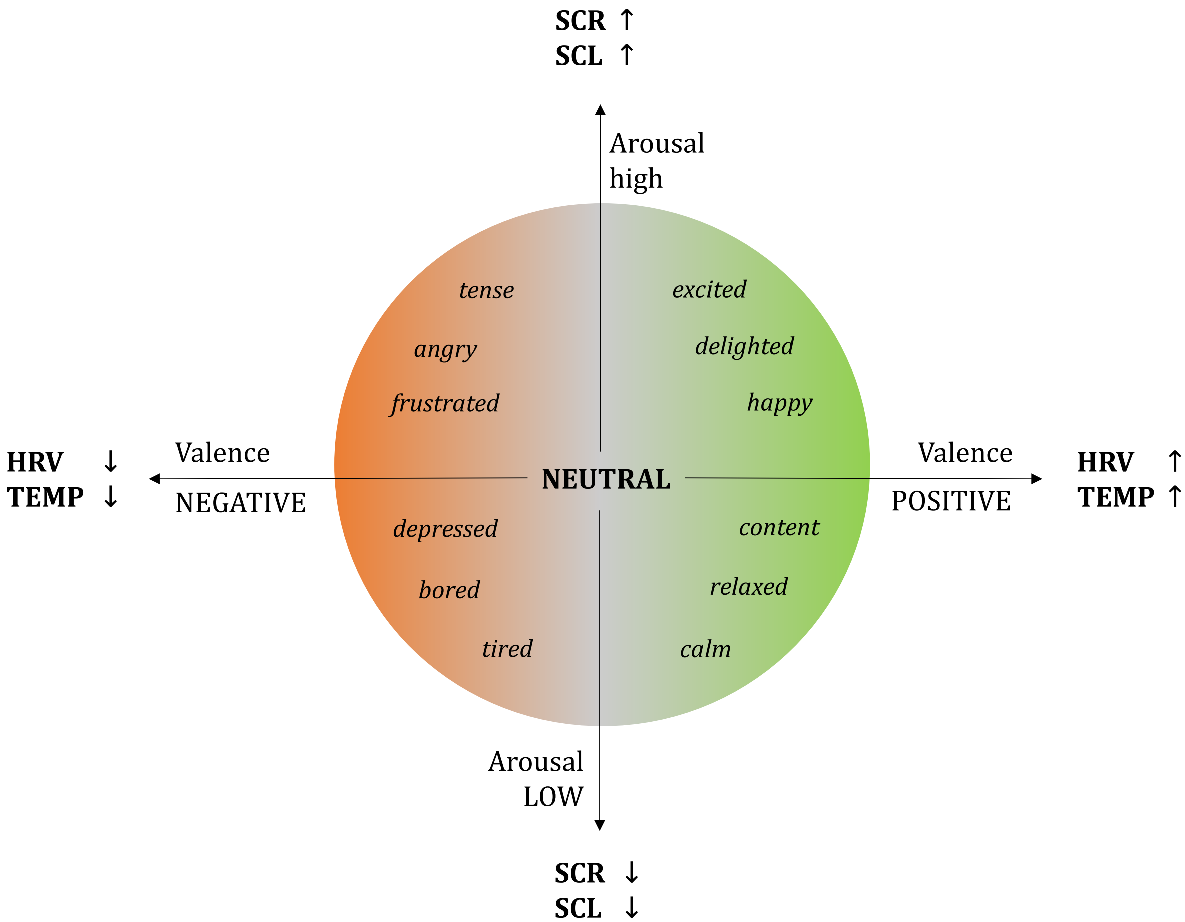
	HR	HRV	FT	SCR	nSRR	SCL
Anger	↑	↓	↓	↑	↑	↑
Anxiety	↑	↓	(↓)	↑	↑	↑
Disgust, contamination	↑--	↑	↓↑	↑	↑	↑
Disgust, mutation	↓	--	↓↑	↑	↑	↑
Embarrassment	↑	(↓)				(↑)
Fear	↑	↓	↓	↑	↑	↑
Fear imminent threat	↓	(--)		↑		↓
Sadness, crying	↑	--	↓		↑	↑
Sadness, non-crying	↓	↓	↓		↓	↓
Sadness, anticipatory	↑	(↓)	↓↑		↑	↑
Sadness, acute	↓	↑ --	↓	↓	↑--	↓
Affection	↓					(↑)
Amusement	↑↓	↑	(--)	↑	↑	↑
Contentment	↓	↓↑		(--)		↓
Happiness	↑	↓	↑		↑	↑--
Joy	↑	(↑)			↑	--
Antic. Pleasure, visual	↓	(↑)	(↑)	↑		↑
Antic. Pleasure, imagery	↑				↑	
Pride	↑↓	(--)				↑
Relief	↑--			↓	(↓)	↓
Surprise	↑		↓↑			(↑)
Suspense	(↓)				(↑)	(↑)

Note: HR=heart rate; HRV=heart rate variability; FT=finger temperature; SCR=skin conductance response; nSRR=nonspecific skin conductance response rate; SCL=skin conductance level. (↑) increase; (↓) decrease; (↓↑) increase and decrease; (−) no change in activation from baseline.

Source: Extract from Kreibig (2010), transposed.

It is evident that EDA related indicators do not seem to differentiate very well. All positive emotions usually involve an *increase* in EDA values (except contentment and relief) and an *increase* in HRV and FT (except happiness). On the contrary, negative emotions usually coincide with a *decrease* in HRV and FT (except disgust and acute sadness). It is noteworthy that identical observations of the data can lead to different interpretations of the emotional meaning. As a preliminary conclusion, there are relatively weak signals for identifying arousal and valence from the physiological data available. Figure 2 shows the result: An increase in phasic or tonic SC (SCR/SCL) indicates a high level of arousal, while an increase in HRV or ST indicates positive valence. The validity and reliability of these indicators could be disputed. Hence, the indicators in Figure 2 might be simplified and may not fully reflect the complexity of measuring the whole range of the valence–arousal continuum.

Figure 2. Selected Physiological Indicators of Emotional Arousal and Valence



Source: Own Elaboration based on Kreibig, 2010; Russell, 1980; Staudt, Grushetskaya, Rangelov, Domanska, & Pinkwart, 2018.

As the valence (e.g. positive or negative) and the present emotion (e.g. tense or excited) are not reflected unambiguously in the biosensing data, other sources must be considered to assess these (Figner & Murphy, 2011; Osborne, 2019). In other words, "biosensing can capture the *what* but not the *why*" (Osborne & Jones, 2017, p. 160). A key takeaway from this is that using additional data sources and combined qualitative methods is fundamentally important for an in-depth understanding of the valence of the tourist emotions measured using biosensing.

3. RESEARCH FRAMEWORK

3.1 Research Questions

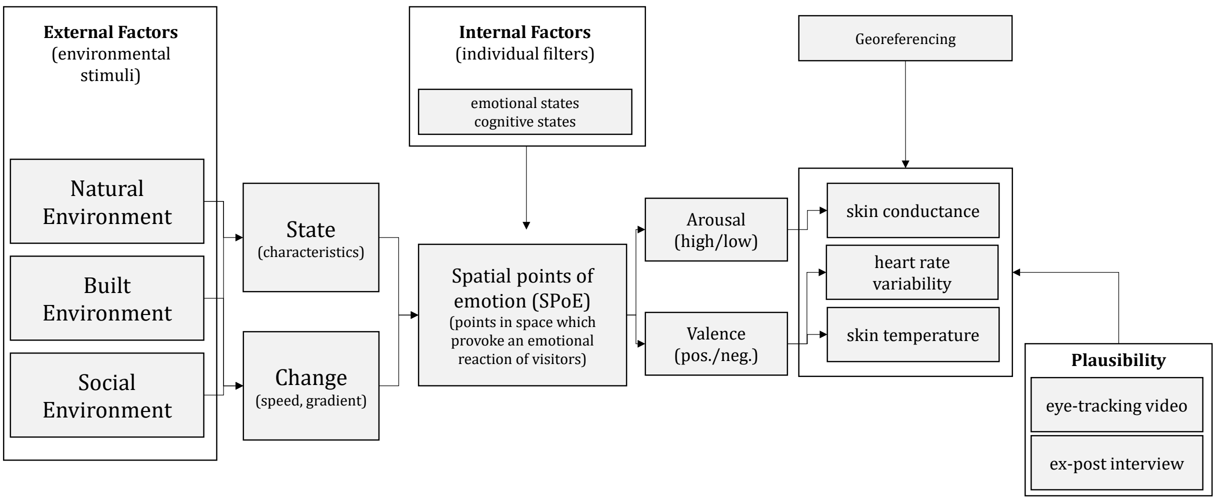
Currently, it is no clear from the literature (a) which data dynamics in the valence–arousal model represents positive emotions, (b) whether mobile measurements in real-world situations are valid and reliable indicators of data dynamics and (c) whether the combination of existing measurement methods is sufficient to capture tourists' emotions in a real-world situation. Against this background, there are three main research questions:

1. How can SPoE be measured in a conceptual framework?
2. What are the limitations of measuring SPoE?
3. What findings can the mixed-methods approach described here contribute to the further development of biosensing methods?

3.2 Conceptual Framework for Measuring Spatial Points of Emotion

The conceptual framework puts the SPoE construct in the centre. On the structure side (left side), it shows that SPoE depend on external factors (primary factors) such as the natural environment (e.g. sea), the built environment (e.g. tourist infrastructure) and social circumstances (e.g. crowding). A distinction can be made between static factors (state), such as the emotional state in a certain environment (e.g. at the sea), and dynamic factors (change), such as the transition between two environments (e.g. the transition between two zones). The focus here is on static factors. On the measurement side (right side) SPoE are operationalised and relate biosensing data to the valence–arousal model. Tourist arousal is measured using SC, while valence is measured by the interplay between HRV and ST. Eye-tracking video and ex-post interviews are used to validate the results (Figure 3).

Figure 3. Conceptual Framework for Measuring Spatial Points of Emotion



Source: Own Elaboration

3.3 Study Design and Data Collection

To detect tourist emotions in a real-world situation, a mixed-methods design was used, combining GPS tracking, biosensing, eye-tracking video and ex-post interviews in a tourist setting. The sample consists of eight female participants who were recruited via an announcement from an academic environment (convenience sample). A small number of test participants is common in psychophysiological studies, given the high effort involved (Bastiaansen, Straatman, et al., 2020). Participants were almost the same age and with the same cultural background. This was necessary to keep the influence of personal aspects on the measured biosensing data as low as possible. However, results cannot be generalised and are therefore not representative of the tourist experience. Data collection took place in June 2019 with excellent weather conditions (barely cloudy and a maximum temperature of 22.1°C). A pre-test was conducted to check the functionality of the sensors. Participants were equipped with a GPS tracker (QStarz BT-Q1000XT), a biosensing wristband (Empatica E4) and mobile eye-tracking glasses (Tobii Pro 2).

Participants were asked to go for a walk along a pre-defined itinerary through Büsum, a small seaside resort on the North Sea coast of Germany. After a short introduction, all the devices were switched on simultaneously to ensure that the time stamp of each device could be used for data matching. Starting the route at the train station, participants were instructed to act tourist-like and stroll through the city, buy an ice cream and go to the dyke and waterfront. On their way back, they had to pass the harbour and walk through a small residential area back to the train station. The itinerary is separated into eight spatial zones (Figure 4). The boundaries of the zones follow different built and natural environments provided within the zones. "Station" is the starting and end zone including the railway station, while "Transition Zone" is a zone of transition into the pedestrian area. There are two sectors in the pedestrian zone: one is a calmer ("Shopping Street (calm)") and the other is a more frequented zone ("Shopping Street (lively)"). The area extending from the passage between two buildings and opening to the dyke and the beach is "Dyke/Beach/Sea". "Museum harbour/Sea" is an area on the land side of the buildings, but passing along the museum harbour with views of the sea. This is followed by "Fischerkai", a street along another dyke with a view to a part of the harbour. The last zone ("Residential Area") mostly includes residential areas used to get back to the railway station. After finishing the tour, each participant was interviewed (semi-structured interviews). The interview focused on their emotions during the itinerary, their perceptions of the town, any critical incidents during their stroll and where they experienced stress or relaxation.

Figure 4. Stills of the Different Spatial Zones from the Eye-Tracking Videos

Source: Own Elaboration

3.4 Data Processing and Analytical Perspectives

As there are no standardised and generally accepted research standards (Paül i Agustí et al., 2019) or even standardised analytical procedures for combining biosensing data with GPS tracking and other contextual data, the following approach is proposed. Data processing involves the following basic steps, resulting in a tidy data file with georeferenced (z-)values of SC, HR, ST and video codings, where each observation (23,375 seconds) forms a row:

1. Extracting the raw data from the three devices (GPS tracker, Empatica E4 and eye-tracking glasses).
2. Matching biosensing data (SC, ST, HR) and geodata. As GPS trackers usually need some connectivity time, an external trigger after a short time (handclap in front of the test person's eyes) was set, which then was used as a matching reference. After converting all data from Unix time to Coordinated Universal Time, the biosensing data had to be aggregated by calculating the arithmetic mean, as geodata were sampled every second (10 Hz) and the E4 recorded biosensing data four times per second (4 Hz).
3. Following Shoval, Schvimer, and Tamir (2018), z-scores for all the biosensing data were compiled to better compare the participants' measurements.
4. Using an inductive approach, video files were coded by content analysis (Mayring, 2010). Besides personal criteria (e.g. personal disruptive factors, speed of movement), possible irritations (e.g. groups of people, passing cars) and codes that describe the orientation in space (e.g. looking around) were generated out of the material. Altogether, the video material had a total of 3,421 codings.
5. Calculating HRV. HRV can be derived from IBI/RR/NN values using either time–domain or frequency–domain calculations. Time–domain calculations can use a succession of RR intervals and compute (a) the root mean square of successive differences or (b) their standard deviations. The Empatica E4 wristband produces an IBI dataset to produce HRV values in the time domain or in the frequency domain, using specialised software such as Kubios HRV or employing own algorithms. However, the IBI data are the only data produced by the Empatica system that are not sampled. Therefore, in this case, it would have been problematic to match the resulting HRV values to the data format (one line per second). Instead, the already available HR data was used and a moving standard deviation score for every second was calculated. The calculation was done along the lines of moving averages, but the empirical standard deviation was computed instead of the mean value only. A window of nine seconds was used so that not too much information was lost in the beginning and at the end of each sequence.
6. The last step to get the working data is matching the z-scores of biosensing, geodata and HRV with the video codings. Each video code is binary coded (0-1) and, using a syntax script, attached to the existing data file compiled in step (2).

Following the literature review and the conceptual framework, rising values of HRV and ST are interpreted as positive valence indicators. On the contrary, decreasing values of HRV and ST serve as a negative valence proxy. Following a similar approach to that used to identify stressful situations (Bergner et al., 2011) HRV and ST are analysed on a five-second basis and two ternary variables, HRV_TERN and TEMP_TERN, with the values -1 (decrease), 0 (constant) and +1 (increase) were created. Finally, a new binary variable VALENCE was created with 0 = no positive indicator and 1 = positive valence indicator. Since this procedure did not provide any new and statistically significant findings, only HRV was considered as a positive valence indicator in the analysis below.

In line with previous research (Osborne & Jones, 2017; Winz & Söderström, 2020), using both quantitative and qualitative perspectives to examine biosensing data proved to be a fruitful approach. Therefore, a data-driven approach, searching for remarkable patterns in the data, and an episode-driven approach, where video files were coded to identify sequences that would indicate changes in emotional state was used (Table 2). Using a static data approach, a Tourist Arousal Map was created (section 4.2) and the eight spatial zones are used to obtain the psychophysiological differences in the different zones (section 4.3).

Using the video codings, the differences in emotional state during different spatio-temporal settings were analysed.

Table 2. Analytical Perspectives

Analytical Step	Perspective	Data Approach	Biosensing Indicators			Contextual Information		
			(Change in) SC	(Change in) ST	HR/ HRV	GPS location data	Video	Ex-post interview
Tourist Arousal Map	Data-driven	Static	X			X		X
Spatial Analysis	Data-driven	Static	X	X	X	X		X
Spatio-temporal Analysis	Episode-driven	Dynamic	X	X	X	X	X	X

Source: Own Elaboration

4. RESULTS

4.1 Characteristics of the Sample

The eight female participants had an average age of 21.9 years (*SD*=2.20). Six out of the eight participants had already visited the destination before, and an average stroll lasted about 49 minutes. Table 3 shows the means of each participant, showing that the mean EDA of all participants is 2.30 μS and never exceeds the maximum mean of 3.50 μS, the average ST (TEMP) is 30.49 °C and the mean HR is 101.57 Hz.

Table 3. Means of Skin Conductance, Skin Temperature and Heart Rate of each Participant

Subject	Observations	EDA		TEMP		HR	
	(seconds)	Mean	*SD*	Mean	*SD*	Mean	*SD*
#1	3,265	0.83	*0.51*	29.75	*1.25*	100.47	*10.51*
#2	2,568	2.52	*0.73*	29.17	*0.53*	104.84	*15.12*
#3	4,683	2.73	*1.08*	31.14	*1.33*	97.88	*10.47*
#4	1,747	3.31	*1.11*	32.64	*0.34*	89.30	*6.94*
#5	3,684	3.26	*1.24*	29.93	*0.92*	97.38	*8.17*
#6	2,463	1.85	*0.31*	32.22	*0.71*	110.70	*13.85*
#7	2,143	1.02	*0.91*	30.17	*1.15*	105.07	*12.66*
#8	2,822	2.62	*0.41*	29.54	*0.65*	108.40	*15.11*
All	**23,375**	**2.30**	**1.23**	**30.49**	**1.47**	**101.57**	**13.14**

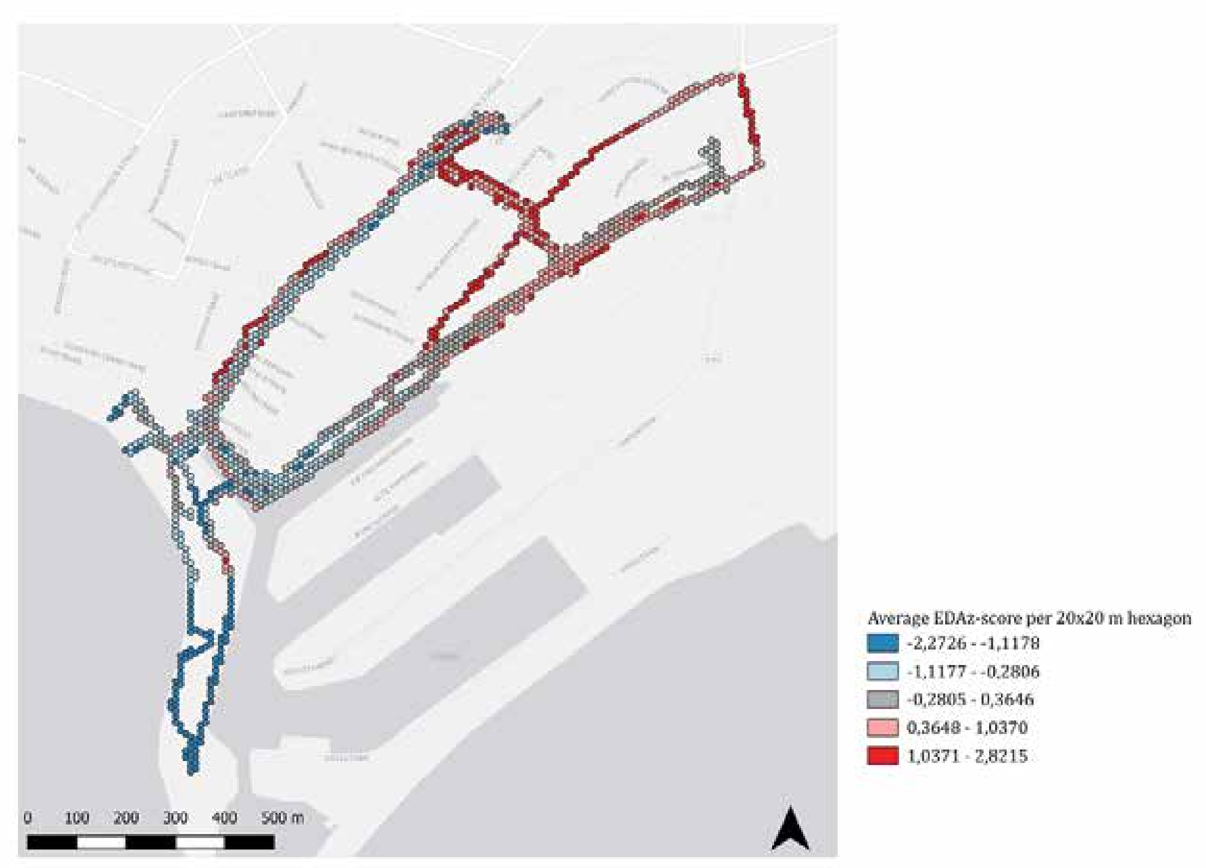
Source: Own Elaboration

The three biosensing indicators are only weakly correlated and correlations are erratic and non-systematic between subjects, with the highest correlations appearing between EDA and ST, while correlations with HR never exceed .5 (All subjects (z-scores): n (obs.) = 23,375; SCL-TEMP $r= +.235$, $p < .001$; SCL-HR $r= +.153$, $p < .001$; TEMP-HR $r= +.137$, $p < .001$). Therefore, there is no reason to believe that the three indicators measure the same or similar conditions, but rather three different dimensions, which is in line with findings from the literature (Kreibig, 2010).

4.2 Tourist Arousal Map

To get a first impression of the emotionally evocative areas during the stroll, a Tourist Arousal Map was plotted (Figure 5). As SC can be read as a proxy for arousal, static data of the z-standardised EDA scores of each participant were used. Based on a hexagon grid with a size of 200 square metres, the average EDA z-score was calculated for all participants crossing the respective polygon. Similar to other studies (Shoval et al., 2017), the map shows where in space people have high or low arousal. The areas during the stroll can be separated from each other relatively clearly. Areas with lower arousal can be found at the sea and harbour (zones: "Dyke/Beach/Sea" and "Museum harbour/Sea"). Areas with higher arousal can be observed on the way back in the residential areas and at the station. However, in the other zones, both high and low arousal hexagons can be identified from the EDAz values.

Figure 5. Tourist Arousal Map of Büsum



Note: Classification—Natural Jenks.

Source: Own Elaboration

What this plot cannot show is whether areas with low arousal signals positive (e.g. relief) or negative valence (e.g. boredom). However, the subjects' statements in the interviews support the idea that there was a form of relaxation in the waterfront areas. Seeing water elicited some kind of relief, as participants #6 and #8 noted for the zone "Dyke/Beach/Sea" (GEO5):

> #6: "I definitely slowed down when I was standing by the sea. I really love that. And then taking a breath, taking in this North Sea air or this wind in general,

and then moving on. But that was somehow a small, beautiful moment of peace that I had then".
#8: "When you come down the shopping street and then just walk towards the water, then you already see it and think like this: Yes! And then I went up there and thought it was something nice. Then I sat on a bench, ate my ice cream, looked out at the water".

On the contrary, areas of high emotional arousal, especially in the "Residential Area", can be interpreted in two ways. Subjects had to walk a predefined path that was marked on a map. On the way back along the dyke and through the residential area, several participants reported that they got lost and thus felt stressed.
#1: "I was walking somewhere in the back where it says 'wedding'-something and then I was at a crossroads and a woman came and helped me because I thought I was in the wrong place and didn't know where to go".

However, another possible explanation for the increase in SC in this area is that the walk was coming to an end and the subjects had to overcome a slight uphill slope (dyke), which was reflected in exertion and sweating that consequently increased SC.

4.3 Spatial Analysis

To obtain statistically significant differences in biosensing indicators besides the areas of high and low arousal, geostatistical analysis was applied. The eight different geozones were used for this purpose. Table 4 shows the descriptives of the main biosensing indicators for the different spatial zones. The data reveal that in the waterfront areas (GEO5 and GEO6), EDAz values are the lowest and HRV is among the highest, indicating areas where the subjects experienced some form of relaxation or contentment. Non-parametric ANOVA tests revealed that the level of the four biosensing proxies differed significantly (EDAz: *Welch's* $F(7)$ 1772.505, $p < .001$; TEMPz: *Welch's* $F(7)$ 1398.238, $p < .001$; HRz: *Welch's* $F(7)$ 513.959, $p < .001$; HRV: *Welch's* $F(7)$ 207.778, $p < .001$). Additionally, post-hoc Scheffé tests were calculated to examine the differences between each of the zones. The results showed statistically significant differences between almost all zones in terms of all four indicator variables. However, between the two waterfront zones GEO5 and GEO6, the results were not significant.

Table 4. Descriptives for Biosensing Indicators by Geozone

Spatial Zone	Code	Observations (seconds)	EDAz (Mean)	TEMPz (Mean)	HRz (Mean)	HRV (Mean)
Station	GEO 1	1,942	0.265	0.796	-0.130	0.527
TransitionZone	GEO 2	2,143	-0.288	0.705	0.477	0.440
Shoppingstreet (calm)	GEO 3	828	-0.302	0.474	0.503	0.234
Shoppingstreet (lively)	GEO 4	4,212	-0.042	0.170	-0.253	0.464
Dyke/Beach/Sea	GEO 5	3,238	-0.933	-0.594	-0.415	0.579
Museum harbour/Sea	GEO 6	1,824	-0.333	-0.610	-0.472	0.557
Fischerkai	GEO 7	3,092	-0.037	-0.697	0.209	0.416
Residential Area	GEO 8	6,031	0.706	0.161	0.240	0.397
All zones		**23,375**	**0.000**	**0.000**	**0.000**	**0.458**

Source: Own Elaboration

4.4 Spatio-temporal Episodes

In a last analytical step, episodes or walking segments during the participants' stroll that allowed a positive or negative emotional reaction to be expected according to the initial results from the Tourist Arousal Map, the spatial analysis and the ex-post interviews were classified. Using the video codings, the focus here was on events where participants saw the sea ("Watching the sea") or had problems finding the way ("Wayfinding").

Table 5 shows that observations where participants watched the sea had lower EDAz, TEMPz and HRz values, but higher HRV values than observations where this was not the case. Non-parametric tests (Mann-Whitney-U) were calculated to show differences in the biosensing indicators between observations with and without watching the sea codings (EDAz: $U = 5486617.500$, $Z = -31.866$, $p < .001$; TEMPz: $U = 8721627.500$, $Z = -17.222$, $p < .001$; HRz: $U = 90001111.000$, $Z = -15.957$, $p < .001$; HRV: $U = 10112228.50$, $Z = -10.794$, $p < .001$). The findings were in line with the results above: Watching the sea and walking along the seaside bring relief and contentment.

On the contrary, statistical results from the wayfinding episode do not support the idea that people experience stress in trying to find the right way back (EDAz: $U = 29305324.50$, $Z = -19.465$, $p < .001$; TEMPz: $U = 31346141.50$, $Z = -14.065$, $p < .001$; HRz: $U = 30056388.00$, $Z = -17.478$, $p < .001$; HRV: $U = 33835389.50$, $Z = -7.184$, $p < .001$). Therefore, high values at the end of the tour are probably caused by other reasons (e.g. sweating, exhaustion).

Table 5. Descriptives for Spatio-Temporal Episodes

Watching the sea	Observations (seconds)	EDAz		TEMPz		HRz		HRV	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
True (1)	1,126	-0.931	0.730	-0.453	0.479	-0.402	0.849	0.589	0.459
False (0)	22,249	0.047	0.989	0.023	1.014	0.020	1.003	0.452	0.419
Wayfinding									
True (1)	3,733	-0.331	1.114	-0.234	1.014	-0.237	0.928	0.483	0.405
False (0)	19,642	0.063	0.964	0.045	0.989	0.045	1.007	0.454	0.425

Source: Own Elaboration

5. DISCUSSION

Although psychophysiological measurements are already frequently used in laboratory settings (Li, Walters, Packer, & Scott, 2018), those methods have so far only been used sparsely in real-world situations (Shoval et al., 2018). There are various reasons for this:

1. First, sufficient quality ambulatory assessment of biosensing data in real-world situations has only recently become possible, since the development of high-end wearables used for medical reasons.
2. The quality of the biosensing data is reduced when people move, as movement can cause errors in the physiological data.
3. The need to capture contextual information to adequately interpret biosensing data complicates the research design (Birenboim et al., 2019).

These challenges were also evident in this study. Great care was taken to ensure that the wristband fit closely on each participant's wrist; nonetheless, it is possible that motion affected the data. Furthermore, data evaluation and interpretation for tourism purposes (i.e.

positive valence) are associated with significant uncertainties. These result from possible measurement errors of the apparatus in a real-world situation and from the fact that the valence of the measured deflections in biosensing data cannot be assigned unambiguously. Referring again to the quote from Osborne and Jones (2017, p. 162)—"biosensing can capture the *what* but not the *why*"—even understanding the "what" seems to be a challenging task. This study identifies the main challenge and a major drawback of biosensing methods: Signals can be measured reliably, but not validly. Since the algorithm for identifying positive valence from the interaction of HRV and ST did not produce significant results (section 3.4), future research should focus on these "data dynamics" to facilitate the interpretation of biosensing data.

Although the biosensing wristband used in this study is designed for use outside an experimental laboratory setting, the criticism of the method (Jones & Osborne, 2020) is supported. An application of this method in areal-world situation is regarded as critical. People's physical fitness and the weather conditions demonstrate this: People who climb up a dyke can sweat, as in this study here. In this case, the ability of the skin to conduct electricity increases significantly without an emotional event behind it (Osborne, 2019). Additionally, standing at the waterfront, exposed to the wind which cools the skin, can lead to a reduction in sweat production and the corresponding values in the psychophysical data. Furthermore, the use of ST in a real-world setting as opposed to finger temperature in a laboratory setting seems to be another crucial point to discuss in future research.

Possible solutions to overcome the drawbacks identified here could lie in data calibration of each participant before starting data measurement in order to get a baseline. Different impulses such as videos and music can be used. The use of mobile eye-tracking equipment proved to be very invasive. Furthermore, not all potential emotional stimuli in the urban context can be captured by the eye-tracking equipment, especially when stimuli are not in the visual field of the tourist. Smaller, high-resolution cameras or, even better, 360° cameras should be considered for future research in this field. In the case of eye-tracking, the potential of eye movements should be used. In this study here, this was not pursued further, as not all eye movements could always be tracked due to the increased sunlight. As a further method of validating the biosensing data, subjective statements on the emotional state of the participants could be used. In addition to subjective queries about emotional state in the context of push messages via smartphones, participants could use the point of interest button on the GPS tracker to mark particularly relaxing or exciting moments in the data.

6. CONCLUSION

This work contributes to the further development of mobile methods in applied tourism geography by exploring the interplay between the body and the environment using a new methodological and analytical approach. A mixed-methods design, including georeferenced biosensing data and contextual information such as video data and ex-post interviews, was used to examine positive SPoE.

This study found that data from biosensors in combination with location sensors can be used to identify SPoE in a tourism setting. Furthermore, combining these data sources with qualitative data (videos and interviews) can add context to content to enable a better understanding of what the biosensing signals mean. Using this setup, points of relaxation at the beach can be identified. However, the results also show that there are significant limitations to this setup. First, the interpretation of biosensing signals needs further clarification and validity testing. This is true specifically when it comes to validly identifying positive valences, but also when it comes to assessing the reliability of measurements in a real-world setting. Second, the study did not actually use tourists as subjects, but rather a small ad hoc sample of humans moving in a real-world tourism setting. Using real tourists as subjects and employing larger sample sizes could help to further clarify the questions arising from this setup. Third, a conceptual framework for measuring SPoE was provided and an explorative approach to measure them was used. To support this approach, data were analysed from two angles: data-driven (where can structures in the data and corresponding real situations be identified?) and episode-driven (where can structures be expected in the data if the search is limited to predefined episodes or locations?). Using binary-coded video codings and connecting them to the biosensing data is a promising approach to work with in the future. The recommendation for future research is to focus more on this episode-driven approach, build hypotheses about potential SPoE (e.g. relaxation or stress) and test the data against the hypotheses.

Many new digital methods are still in their infancy and several problems with application occur. Nonetheless, the many studies on the use of Big Data in tourism, the diverse discussions on digital tracking and visitor management solutions during the Covid-19 pandemic and the use of mobile biosensing methods in space and time discussed here illustrate that tourism geography is on the verge of digitalised and data-driven science. Further research is necessary, especially to exploit the potential of the new technical possibilities.

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