Defining and assessing walkability: a concept for an integrated approach using surveys, biosensors and geospatial analysis

Abstract
Walking as a transport mode is still often underrepresented in the overall transport system. Consequently, pedestrian mobility is usually not recorded statistically in the same manner as it is performed for motorised traffic which leads to an underestimation of its importance and positive effects on people and cities. However, the integration of walkability assessments is potentially a valuable complement in urban planning processes through considering important quantitative and qualitative aspects of walking in cities. Recent literature shows a variety of approaches involving discrepancies in the definition of walkability, the factors which contribute to it, and methods of assessing them. This paper provides a new understanding of the concept of walkability in the European context. Our approach relies on the extension of methodological competence in transportation, spatial planning and geography by linking new measurement methods for evaluating walkability. We propose an integrated approach to assessing walkability in a comprehensive methodology that combines existing qualitative and GIS-based methods with biosensor technologies and thus captures the perceptions and emotions of pedestrians. This results in an increased plausibility and relevance of the results of walkability analysis by considering the spatial environment and its effect on people.
Introduction

Walking is healthy, promotes social contacts and is a basic requirement of mobility: nearly every change of location begins and ends with a walk (Grob & Michel 2011). At the same time, walking is sustainable and environmentally friendly and thus increases the quality of life for all residents. About 95% of short distances under 100 metres are covered on foot (Schwab et al. 2012). If one considers all stages of people’s mobility, including walking, with other means of transport or ways of transfer, journeys made on foot represent the vast majority. The data situation in Europe is still inadequate and ‘walking had not been seriously considered as a means of transport and, consequently, not been measured’ (Sauter & Wedderburn 2008: 1). This aspect is slowly changing, but there is a lack of sensitivity and political will, resulting in fragmented data collection and inappropriate methods for the assessment of walking. As a conclusion, the need for action arises at the level of intensifying pedestrian research and the development of a comprehensive and high-quality database including subjective perception and emotions which have significant effects on travel behaviour (Ma 2000). Therefore researchers and decision-makers require new methods to collect data.

The concept of walkability supports urban planning processing through considering important quantitative and qualitative aspects of walking in cities. However, a variety of recent literature shows a discrepancy in the definition of walkability, its contributing factors, and methods to assess these factors (Forsyth 2015). One main mismatch exists between the interpretation of walking as a mode of transportation and walking as a social, recreational and healthy activity. However, walking is not only a means of transport and the quality of public space as well as related social activities have to be considered (Gehl 2011). Additionally, methods are needed to capture walking more holistically (Flükiger & Leuba 2015), rather than mere a quantitative analysis of official data sources. This is where the utilisation of subjective bio-sensor measurements together with qualitative surveys and Geographic Information System (GIS) based analysis can be advantageous when combining different data types and qualities.

By analysing these data spatiotemporally and geostatically, the connection and spatial distribution of factors contributing to walkability can be identified and illustrated, including for decision-making purposes. From a methodological viewpoint, biosensors can record the physiological parameters of a person and the changes of these parameters can be used to infer individual responses to the environment and different real-world situations. Through this means, qualitative aspects such as emotions can be transformed into a quantitative measure, bridging the gap between qualitative and quantitative aspects.

This article gives an overview of relevant literature on walkability with a focus on European approaches. Subsequently, we provide a new, multi-faceted definition of walkability and an approach for holistically assessing urban walkability through combining traditional geospatial analysis of spatial data, subjective information gathered through questionnaires, and individual perceptions acquired by wearable biosensors. A small case study illustrates the approach. This new integrative method aims to provide a new understanding of walkability and offers an opportunity to encounter the lack of data on walking – especially on where people prefer to walk and why.

Related work on the definition of walkability

The construct of walkability - conflicting understandings and definitions

A city’s attractiveness or its opportunity for walking is often expressed as ‘walkability’ (Weinberger & Sweet 2012: 22; Tribby et al. 2015: 189). While walkability is a commonly used term, the concept behind it often remains elusive (Dovey & Pafka 2019). There are numerous conflicting definitions, most of which have emerged in planning disciplines in the USA, and the term is rarely defined in dictionaries (Forsyth 2015).

The narrower definition of walkability encompasses an empirical concept and refers to walking as a potential modal choice for a specific purpose (e.g. walking to work, bus/train stop, grocery shopping). The integration of leisure-related mobility into the understanding of walkability has led to a broader understanding of the term, which has also changed the scope of walkability (Bucksch & Schneider 2014). It has resulted in an emerging interest in other disciplines as well, such as social science, cultural geography, anthropology (Middleton 2010; Lorimer 2016) and health (Handy et al. 2002; Saelens et al. 2003; Grasser, Titze & Stronegger 2016). Many publications state that there is a connection between public health and the level of a city’s walkability (Brownson et al. 2009; Grasser, Titze & Stronegger 2016; Sarkar, Webster & Gallacher 2018). In this context, walkability is also understood as an activity-friendly design of public spaces, an important aspect of social coexistence and individual perception (Ewing & Handy 2009; Bucksch & Schneider 2014). The extension of the walkability concept to other disciplines and the integration of leisure mobility, aspects of public space and the pedestrians’ perceptions makes it even more difficult to grasp and define the term (Bucksch & Schneider 2014). However, walkability in its narrow
definition measures opportunities to walk in a particular (urban) environment, and not actual walking behaviour (Weinberger & Sweet 2012). Yet, there is a critical relationship between perceptual qualities and personal reactions in the walking behaviour study (Ewing & Handy 2009). What people perceive is the result of experiences, attitudes and interpretation of the environment. The reactions of pedestrians to a place - such as perceived safety, well-being or interest - are difficult to assess objectively, directly and by external analysts (Ewing & Handy 2009; Talen & Koschinsky 2013).

Evaluation of walkability

When considering walkability as a broader concept, it includes quantitative objective characteristics (infrastructure, land use etc.) as well as qualitative features such as subjective sense of safety, aesthetic sensibility etc. (Ewing et al. 2006; Bucksch & Schneider 2014). These indicators are often evaluated in the form of an index which is critical in terms of data reduction (the values of the individual features usually cannot be reconstructed from the final values of an index). There is weighting of individual characteristics (which is partly at the discretion of the researcher) and it often lacks spatial or socio-demographic differentiation (Rohwer & Pötter 2002). Walk Score® has been widely used as an index for assessing ‘walking potential’, but was often only a part of bivariate correlation models (Hall & Ram 2018: 310).

Furthermore, there are no clearly defined methods for assessing walkability and much research revolves around defining quantifiable indicators and concentrates on aggregated macro-level urban data. This aspect ‘limited researchers’ ability to conduct sensitive disaggregated analyses focusing on individual travel behaviours, and made it difficult to test any potential effect of micro-level walkability’ (Park 2008: 81). Using other methods (see section: Methods of measuring and analysing walkability) such as audits, mixed-methods derived from urban study and biosensors can help improve the accuracy of measuring individual perception and emotions.

Defining walkability for our approach

A more holistic approach on walkability should also consider aspects of overall mobility, and urban and public space research (Gehl 2011; Eckardt 2014; Flükiger & Leuba 2015). In order to implement walkability principles in planning and infrastructure projects, planners and municipalities need data and evidence. We emphasise that these data should rely on the extension of methodological competence in transportation, spatial planning and geography by linking new measurement methods to assess walkability. Furthermore, a methodological discussion is necessary, striving for a foundation of evidence-based data producing increased plausibility and relevance in the analysis results. This can be achieved by considering the spatial environment and its effect on people (including their mobility behaviour and choices).

The spill-over effect of a walkable infrastructure, such as sustainable, liveable and exercise-encouraging environments, often describes the status quo and not an objective of future city planning and potentials for improvement. However, when defining walkability, urban planning processes should also include a discussion about new methods to assess walkability.

Therefore, we suggest that walkability refers to the physical environment with its objective and subjectively perceived characteristics, extending its basic understanding by adding the pedestrians’ perception and emotion. Walkability has to include a fine scale perspective and overcome its understanding as a graduation and description of the status-quo of pedestrian infrastructure. The concept of walkability should rely on the extension of methodological competence in transportation, spatial planning and geography by linking traditional and new measurement methods for the evaluation of walkability.

Methods of measuring and analysing walkability

Since walkability does not only encompass measurable functional and physical requirements, but also qualities that can only be mapped subjectively (e.g. individual perception of the environment, the importance of different aspects of walkability or personal preferences), suitable measurement methods must be selected that can be used at various spatial scales. This section contains a brief explanation of the methods we have identified suitable for this purpose.

Audit-based methods

Audits are a common method for assessing walkability using a rating system (Brownson et al. 2009; Titze et al. 2010; Tran 2017), carried out either in printed or in electronic form (Bucksch & Schneider 2014). Some audits are based on movement-specific models (Giles-Corti & Donovan 2002; Pikora et al. 2003), which examine the individual, social and physical environmental determinants while covering the dimensions of functionality, safety (personal safety and traffic safety), aesthetics, and business or services (Pikora et al. 2003: 1696). These audits aim to quantify (urban) space and thus assess it by, e.g., mathematical weighting of various parameters such as walking distance, proportions of green space, traffic volume etc. (Krenn, Oja & Titze 2015: 453-455).
Sensors for walkability assessment

Combining sensor technology for measuring walkability, or at least for surveying how people use public space, is not a new field of research. Sensors recording physical or chemical values as a technological component are core elements in systems engineering.

In the following, we present some existing examples of sensor technology used for walkability assessment, divided into permanently installed, mobile, and biosensors.

Permanently installed sensors

A promising approach to indirectly assessing walkability through the systematic observation of people’s behaviour in urban space is using a mobile or permanently installed camera. Regarding the topic of walkability and the needs in public traffic environments, which are very heterogeneous, H. Buxton (2003) introduced the method of dynamic scene understanding. In a public place, for instance, it is necessary to understand how objects move according to constraints imposed by: (1) the environment (highway, inner city); (2) the type of interactions they are exposed to (cruise, turning); and (3) their nature or class category (car, pedestrian) (Romero-Cano, Agamennoni & Nieto 2016: 654). Pedestrian detection can improve understanding of the movement of people in special situations (Dehghan et al. 2013) as well as agent-based modelling to visualise and understand pedestrians’ behaviour in order to improve planning processes such as those for the new London Bridge national railway station (Le Glatin, Milford & Hutton 2014).

Mobile sensors

The most evident, but very disruptive, mobile sensor, is the smartphone, combining various sensors like accelerometers, a GPS receiver or a microphone for capturing noise (Maisonneuve, Stevens & Steels 2008), sensors for light intensity and colour (Harari et al. 2016; Gutierrez-Martinez et al. 2017) and even pollutant concentration sensors via the USB interface (Schäfer et al. 2017). In combination with tailor-made apps, it is possible to capture data either indirectly by sensing the surrounding environment (e.g. GPS, temperature) or directly by information provided by users (e.g. surveys, questionnaires) like the eDiary app that is used to acquire subjective perceptions of walkability (Resch et al. 2015). For reasons of completeness, mobile phone data also has to be mentioned. The logsins of the smartphones on the respective transmitter masts are evaluated via the Cell-ID. An example of this is the M-Atlas, which evaluates this for mobile behaviour through temporal changes in logins (Batty et al. 2012). Due to the non-standardised density of mobile phone masts and their decrease in rural areas and the resulting inaccurate location, this approach is not adequate to assess walkability. These data can be helpful for statements about behaviour relating to global or urban mobility. However, these data sets are difficult to access due to data protection.

Biosensors

New wearables and technologies allow one to capture human perceptions and emotions through measuring bio-physiological parameters and thus add additional data to the walkability assessment (Dörrzapf et al. 2015; Zeile et al. 2016). Sensations or emotions are reflected in specific physiological parameters such as skin temperature, skin conductance or heart rate variability (Kreibig 2010; Kanjo, Al-Husain & Chamberlain 2015). These changes in the activity of the autonomic nervous system can be measured with sensors and allow one to identify stressful events. Skin conductance level (SCL) together with skin temperature can, in particular, reveal insights into the emotional state of pedestrians. According to emotion researchers, when a negative experience occurs, the skin conductivity increases and the measured skin temperature decreases (Rodrigues da Silva et al. 2014: 95). Measurements with biosensors can be classed as objective measurements of human science. Objective measurements are methods that are not based on self-reporting of the feature being examined, but rely on outsiders or equipment collecting the data. These measurements allow one to exclude subjective distortions from the participants in the study, which occur in reported data. The main drawback consists in the fact that objective physiological measurement data do not permit direct conclusions on human experience and behaviour, requiring additional reported data (DöRING & Bortz 2016).

Geodata analysis to assess walkability

As opposed to the acquisition of the subjective perception of walkability through questionnaires, interviews and other empirical methods, a well-established and a common approach to assess walkability is analysing traditional urban geodata related to walkability, enabling the spatial (and temporal) reference of data. These geodatasets are aggregated on various spatial units and scales and include population, urban functions, land use categories, the street network, traffic volumes, road widths, greenness indices, and numerous other matters (Bucksch & Schneider 2014).

E. Leslie et al. (2007) propose a walkability index using a combination of tax valuation and cadastral (parcel) data, road networks, land use and zoning data, shopping centre locations and census data. From these data, the authors derived urban characteristics such as dwelling...
density, connectivity (intersection density), net retail area, and a custom land use classification. Similarly, a walkability index called Walk Score® is presented by L. J. Carr, S. I. Dunsiger & B. H. Marcus (2010).

While the analysis of geospatial data has been proven very valuable for assessing urban walkability, many approaches that are based on geospatially analysing ‘objectively-measured’ data (traditional geodata – see above) give insufficient consideration to neglecting more subjective factors such as individual perceptions or emotions. Although these factors are essentially relevant to walkability assessments, they are often challenging to measure or interpret. This issue is potentially rooted in the quantitative nature of geospatial analysis that is, by definition, difficult to combine with more qualitative approaches (Kwan & Knigge 2006).

**Preliminary summary**

The literature chapter provides insights into the challenges of defining walkability, including the latest methods of measuring it, and it illustrates how these different approaches can broaden our understanding. Methods to assess walkability originate from many different disciplines, like transportation planning and geography. Despite significant methodological advances, assessing walkability remains a challenge and the disciplines mentioned address this problem from different angles and with a variety of methods. In particular, sensor technologies are becoming more widely available with the proliferation of smartphones, and this is likely to usher in a new phase of assessment of walkability. Thus, walkability research, and especially the combination of these methods, will lead to more comprehensive but complex datasets which require more differentiated analysis. This is explained in the next chapter.

**Methodology for an integrated approach to assessing walkability**

In order to make progress towards a more holistic understanding of walkability, we propose the following integrated approach to assessing walkability with sensor-based technologies, and thus capture the perceptions and emotions of pedestrians. Figure 1 represents the key elements in our framework, consisting of the collection and analysis of sensor data, the derivation of inferences by combining different data sources, and the evaluation of the results.

**Data Collection and Technical Development**

As a first step, we measure and assess the perceptions and emotions of pedestrians, using wearable biosensors. Based on a technology screening and laboratory tests, we argue that the most suitable for our research are E4 (a wearable wireless device for the wrist which acquires continuous, real-time physiological data like electro dermal activity and skin temperature) and the Zephyr™ BioModule™ Device (a chest strap which measures e.g. heart rate variability). Then, a sensor fusion method extracts emotion information from the measured data (SCL, skin temperature and...
heart rate variability). Second, we use an eDiary app that enables the user to input their subjective perceptions with respect to the environment (Resch et al. 2015), which we developed together with psychologists and urban planners. Finally, the sensor measurements (‘objective’ technical measurement data) and eDiary inputs (‘subjective’ sensations) are related to one another in order to identify and locate the trigger of the human physiological reaction in the physical environment.

The definition and selection of suitable physiological parameters for the determination of emotional states is a critical step beyond the current state of knowledge. This procedure is necessary in order to obtain meaningful and reliable results on human reactions in the urban context and to develop suitable algorithms that enable valid statements even outside the experimental laboratory. This goes beyond the current state of the art since previous research efforts in analysing physiological measurement data to derive individual emotion levels did not permit one to draw unambiguous conclusions. Thus, our approach delivers more reliable results as the parameter definition combines physiological parameters such as skin conductance, skin temperature and heart rate variability in order to be able to derive stress levels and emotions in a reliable fashion. Yet, this is still a substantial challenge and subject to future research.

**Data analysis**

In a second step, we are developing a comprehensive procedure for data processing and analysis. Our approach will combine measurable physiological parameters to derive perceptions and emotions when walking along with a (semi-) automated procedure to identify the reactions of pedestrians.

Moments of stress are detected through an algorithm which applies a sequential filter to the raw data: first, a low-pass filter (cut-off frequency 0.5 Hz) to eliminate high-frequency variations in measurements that may be caused by technical inaccuracies, followed by a high-pass filter (cut-off frequency 0.05 Hz) to filter the tonic skin conductance level (SCL) that is an indicator of the subjective baseline for each test person. Then, it applies a rule-based algorithm that detects patterns in the measurement data: 5 s of GSR increase, lagged (+3 s) increase in skin temperature, a local maximum followed by a local minimum in skin temperature, and a slope steepness of <20° (which may also be an indicator for the intensity of the stress sensation).

The aim is to evaluate physiological data, to derive stress reactions and to validate the results in a broad field study within this project.

**Derivation of inferences**

In a third step, we aim to synthesise the sensor data with the data from the eDiary app to check for inconsistencies (ground-truthing). It allows the identification and spatial location of triggers of the detected perceptions and emotions. Thereby, this step can contribute to the assessment of walkability in a spatial context. Furthermore, it makes it possible to illustrate spatial accumulations of the human physiological reactions of pedestrians as an indicator for walkability.

However, drawing reliable conclusions from physiological data is difficult, despite the maturity of technological developments. On one hand, real-world experimentation compromises reproducibility (compared to lab-based studies), and results in higher complexity due to additional external factors; and on the other hand, the test persons’ awareness of being participants in a study may induce a variety of cognitive biases (Bluemke et al. 2017). Since the analysis of sensor data does not produce unambiguous results (see above), combination with an eDiary app, which acts as a subjective feedback method, is necessary to determine the context and trigger of the pedestrian’s perception or emotion. The eDiary app validates the measurements for each participant, constituting a ground-truthing mechanism for the biophysiological data measured by wearable sensors. Currently, our approach calculates difference maps between the geospatially analysed sensor measurements and the eDiary entries, which are both aggregated in raster cells at a pre-defined size and standardised over that number of measurements and eDiary entries. Although the eDiary entries are not a reliable gold standard per se (because of a number of factors inducing uncertainty, including memory errors, conditioning effects, dilutions due to cognitive processes rather than a spontaneous answer, the illusory truth effect, and others) (Bluemke et al. 2017), they complement the measurements from wearable sensors. A quantitatively accurate measure for both of the data sources, which may require a long-term research effort together with psychologists and medical researchers, is yet to be developed.

**Evaluation of methods and further application**

Thus, the last step of our approach is the evaluation of the benefit compared to conventional methods. A list of criteria for the selection of methods, procedures for data acquisition, evaluation and visualisation provides recommendations for walkability studies and shows the application areas and the potential of the methodology for the design of planning principles and participatory processes.
4.5. Pilot study: walkability in Salzburg and Cologne

In an initial pilot study, we investigated urban walkability using the approach that had been developed, comparing the cities of Salzburg and Cologne. We recruited 56 participants (27 for Salzburg and 29 for Cologne) who were instructed to walk through their respective cities with sensors mounted on their bodies (Empatica e4 wristband, Zephyr BioHarness, plus GoPro ego-video camera) all the while entering inputs into the eDiary app on a smartphone that they carried with them, and to answer a customised questionnaire after their walk. Figure 2 shows the geospatially analysed (Getis Ord Gi*) physiological sensor data for the city of Salzburg – red areas indicating hot spots (spatially clustered moments of stress) and cold spots (spatially clustered moments of relaxation). The results show that suspected stress hot spots (near Hanuschplatz square, in front of Mozart’s birth place – one of the city’s major tourist hubs, or Residenzplatz square) can be identified. Both hot spots and cold spots identified in the human sensor data correlate with the subjective perceptions of the participants provided through the eDiary app and the questionnaire. This correlation is similar in both test cities. The limitations described in the following section of the paper also apply to this field study.

Discussion and limitations

The methods mentioned in the integrated approach have been successfully tested in different research studies, but barely in the context of walkability. Nevertheless, there are still some limitations in the context of research criteria, data analysis, data and privacy issues and their use for walkability studies.

Research criteria in laboratory vs. real-world settings

We have to assume that the sensors measure what they are supposed to measure in a laboratory setting; the transfer to a real-world setting sets of a free debate and reflection on the research criteria. The objectivity should be given through the measurement by instruments and these “are inherently better shielded from both subject bias and experimenter bias than are either reported measures or measures based on behaviour observations” (Meehan et al. 2005: 253). However, it is still a challenge because one cannot completely standardise the test.
situation. It is necessary to avoid outside factors interfering (e.g. building sites, events) and keep interfering factors (weather, noises, daytime) as constant as possible during the field tests.

In our planned field test, we hoped to achieve data samples from 60 test subjects to assess walkability. Even if there are studies which barely meet this sample size, it still lacks representativeness because random sampling is not possible through the recruitment of volunteers in the field tests. In qualitative or quantitative research methods, biases (any influence that provides a distortion in the results of a study) can always occur in all steps involved (planning, data collection, analysis, and visualisation). This confounding effect cannot be completely avoided, but researchers should ‘be aware of all potential sources of bias and undertake all possible actions to reduce and minimise the deviation from the truth’ (Šimundić 2013: 12).

**Determining parameters and analysing biosensed data**

A major challenge in analysing urban walkability using physiological sensors is that no homogeneous literature exists on how to derive stress and emotion levels from psycho-physiological measurements. S. D. Kreibig (2010) performed a systematic literature review on detecting emotions from nervous activity measured by body sensors. While the review is comprehensive, it reveals that the findings of previous studies are not homogeneous and oftentimes contradict each other. This may be because physiological responses are only a surrogate for a psychological process, and not a direct response. Thus, current data analysis algorithms are not unambiguous, i.e., they are partially not validated by medical science or psychology, but they are mostly the result of severely limited empirical studies.

In consequence, the definition of suitable physiological parameters that can be measured for the determination of emotional states and the selection and assessment of specific physiological reactions requires support from medical researchers. A standardisation of the methodology for the collection, evaluation and validation of the measurement data as well as their use in urban planning processes can be ensured by such a process. Yet, despite there being only a small body of literature currently existing, this research area is not new and poses complex problems, mostly relating to the broadly unknown connection between emotional psychological processes and related physiological responses. Thus, reliable results may be subject to rigorous, longer-term research efforts to achieve a more thorough understanding of these relationships.

**Data and privacy issues**

There is an increasing trend towards the use of spatio-temporal data from wearable sensors in science as a result of the rapid development of sensor technology. However, using these data potentially causes significant risks of violating privacy, partially due to their complexity, or because practitioners and the public are not fully aware of the potential disclosure risks linked to these data (Haley et al. 2016). With respect to the use of participatory sensing data in research studies, B. Resch (2013) emphasises the practitioners’ obligation to address several privacy issues such as data ownership, accessibility, integrity, liability, and opportunities to opt-in or opt-out. Although there is a wide variety of problem-oriented publications on geo-information disclosure which are available, no clearly defined solutions have been proposed. O. Kounadi, B. Resch and A. Petutschnig (2018) sketch out a geo-privacy guideline for participatory sensing data, covering the entire process chain of a research campaign.

**Summary of results and outlook**

Our suggested approach advances walkability assessment towards a more holistic understanding and relies on the extension of methodological competence in transportation, spatial planning and geography by linking new measurement methods for evaluating walkability. There clearly is a need for reliable and practicable methods or technologies helping to improve the conditions for pedestrians and quality of life in urban areas. Therefore, it is vital to collect comprehensive and high-quality data as a basis for an accurate evaluation of the quality of walking and to understand the concept of walkability.

Advances in biosensor technology enable us to record and map the changing physiological reactions of pedestrians in specific real-world situations. Based on these human reactions, individual perceptions and emotions can be identified in designated areas. The merging of objective measuring methods and other methods (like audits, questionnaires, feedback via eDiary apps, and geospatial analysis) allows conclusions to be drawn concerning the triggers of emotions or reactions and the specific urban location at which they occurred.

Our approach delivers four main outcomes: firstly, methods for biosensor- and eDiary-based assessment of the perceptions and emotions of pedestrians. Secondly, the data collected are merged, checked, analysed and geospatially visualised (see Geodata analysis to assess walkability). Thirdly, a methodology to derive the triggers of the human physiological reactions of pedestrians is proposed in order to draw conclusions on the walkability of public space. In a final step, an evaluation of methods is conducted.

Conclusions drawn from a discussion of our approach have identified a number of further research needs and issues. We are striving to provide
evidence-based data to underpin an increased plausibility and relevance of the results of our analysis by considering the spatial environment and its effect on people. Determining the parameters for the detection of emotions is a relevant challenge for research. Data and privacy related issues must be taken into consideration and should be addressed comprehensively. Finally, this research will contribute an additional benefit to walkability research by revealing unseen perspectives derived from biosensor data.

**References**


