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Hot or not – identifying emotional "hot spots" in the city

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ABSTRACT:

Cities become increasingly populated, which calls for new approaches to ensure that cities continue being viable places for citizens to live in. The focus of these approaches should be on understanding citizens regarding their feelings, needs and behaviours. This includes an understanding of the perception of and the emotional reactions to urban structures from citizens' points of view. Following the approach of urban emotions (Zeile et al., 2005), different objective physiological and subjective self-report measures were used in an experimental study in order to capture these emotional responses and to visualize the data in an emotional map. A small sample (N=13) of students was asked to collect positive as well as negative *hot spots* in a park area in the city centre of Stuttgart, i.e. spots that elicit positive or negative reactions. The results show the general potential of the park to function as a recreational area, but also identify room for improvement (e.g. concrete structures in the park). While physiological measures are useful to capture subtle emotional responses in larger areas, subjective measures seem to be more useful for understanding the reasons of the emotional responses by identifying positive as well as negative *hot spots*. A visualization tool introduced in this paper allows urban planners and other stakeholders (e.g. citizens, tourists) to view the results and analyse the data in an accessible way.

1. INTRODUCTION

With a growing world population there is a growing attraction of urban areas (United Nations, 2017). As a consequence, the urban settlements are getting closer to reaching their limits and it stands to question, how citizens react to this development. Since different groups come together in urban settlements, it is important to understand their different needs. Otherwise, urban areas could cease to function as viable, attractive living spaces. An important first step is to understand how the people in cities perceive and emotionally react to their surroundings. This "may enable professionals to design more sustainable, pleasant, happy and therefore smart places." (Poplin, Yamu and Rico-Gutierrez, 2017, p. 74).

Thus, in the present study we are focussing on the perception and emotional reactions of citizens in order to identify *hot spots* in selected areas. With *hot spots*, we mean selected spots that elicit positive or negative affective reactions among citizens. With our current study, we want to describe and compare different approaches to capture affective reactions by using objective physiological as well subjective self-report measures.

In addition, the current paper presents an approach to visualize the results in a way accessible to different stakeholders (e.g. urban planners, citizens, tourists). The solution presented is built around the concept of emotional city mapping (c.f. Zeile, Höffken and Papastefanou, 2009) and tries to combine expertise from psychology and geo-informatics.

The presented study adds insights on different methods useful for capturing and analysing affective reactions of citizens. This is necessary because "the use of emotions in urban design is not well-established and far grown (Zeile, Resch, Exner and Sagl, 2015, p. 212). Urban design needs reliable and valid methods to assess emotions in order to answer the following question: What factors make future cities a good place to live in? The novelty of our study is that we focus on the strengths and weaknesses of different methods to assess affective reactions. This may help to combine these different methods for a more comprehensive measurement and visualization approach in the future.

1.1 Evaluating places

If one is interested in understanding the affective reactions of citizens in urban areas, it is necessary to build a methodology that focuses directly on citizens themselves. In new, so-called *smart cities*, real-time data need to be collected in order to understand how a city is functioning (c.f. Zeile, 2017). This also includes a focus on citizens of a city and their needs (Resch, Summa, Sagl, Zeile and Exner, 2015). The idea of a *smart city* from a human-centred viewpoint is getting more and more important: the hope for a more liveable, more efficient and greener city (Zeile et al., 2009).

The approach of Poplin and colleagues (2017) follows this logic. In their study they wanted to identify *power places* in selected areas (i.e. "favourite outdoor locations that evoke positive emotions, and are conducive to relaxation and reduction of stress" Poplin et al., 2017, p. 73). Instead of consulting experts (e.g. urban planners), they used an approach they called "participatory place-making" (Poplin et al., 2017). They asked participants to mark and describe their personal *power places* directly on a map. Based on these data, a space syntax analysis was conducted. Since they were focusing on (positively connoted) *power places*, they did not assess any places eliciting negative emotions. Secondly, they used a memory-based approach, since participants were not in the *power places* while describing them. This may be a good approach to identify outstanding *power places*, but other places eliciting emotional reactions might be missed this way.

Another approach described by Zeile (2017) also focuses on reactions of citizens, but tries to measure emotions more directly during or close to the actual experience. This bottom-up approach as basis for participatory spatial planning is called *urban emotions*, a term introduced by Zeile and colleagues (2015). It is based on the idea that "feelings or perceptions are important key factors and not negligible aspects in urban planning." (Zeile et al., 2009, p. 211) and includes different aspects:

Citizens are used directly as part of the measurement, which is called "people as sensors" by Zeile et al. (2009). Their

perceptions of and (emotional) reactions to urban (spatial and social) structures are assessed while passing through the city (Zeile, 2017).
Emotional responses should be gathered using different approaches, subjective ratings as well as objective physiological measures (such as skin conductance, temperature and cardiovascular activity).
The collected data should be mapped in the end to give urban planners and other stakeholders in a city a viable tool to deduct conclusions from it. Therefore, geo-referenced data needs to be collected as well.
This *urban emotions* approach calls for interdisciplinary or even transdisciplinary expertise, e.g. from the fields of urban planning, geo-informatics, and psychology.
Following the call of Zeile et al. (2009) for intensified research in this field, we conducted a field study using the *urban emotions* approach. Adopting the idea of *urban emotions,* we wanted to test different parameters based on cardiovascular activity for their potential to function as objective physiological measures. These measures were combined with subjective self-reported measures to identify *hot spots* in a selected area, i.e. places that lead to positive or negative emotional reactions while passing by. The subjective ratings were assessed using an app for experience sampling that allows capturing the ratings directly in the field, with no time lag between experienced affect and response to the questionnaire. This minimizes the problems usually found, when people are asked to give ratings in retrospect (Shiffman, Stone, Hufford, 2008).
We were especially interested to see the respective additional benefit of both classes of measures in our study. The collected emotional data were visualized in an emotional city map (Zeile et al., 2009). As a case study, we wanted to investigate a park in the centre of Stuttgart for its potential to function as a recreational area and to identify positive and negative *hot spots* that may support or hinder this function. We selected a park area for our study, because natural settings may have positive effects on citizens (Korpela, Hartig, Kaiser and Fuhrer, 2001; Poplin et al., 2017).

2. METHOD / STUDY

In June 2016 and December 2017, a study at *HFT Stuttgart* (university of applied sciences) was conducted to identify spots that elicit positive or negative affective reactions (so called *hot spots*) in the *Stadtgarten*, a park located at the inner-city university campus. This location is in the heart of the (busy) city centre of Stuttgart and could function as a low-stress retreat for students, employees of nearby organizations as well as other citizens. However, it stands to question whether it already lives up to this potential. Assessing the park in summer and winter gave a more comprehensive picture of the parks hot spots. While the participants explored and rated the area, cardiovascular data and mood were measured. Following the *urban emotions* idea (Zeile et al., 2015), we assessed emotional reactions by using objective physiological measures as well as subjective self-report measures. Varying the approach of Zeile and colleagues (2009) who focused on skin-conductance, we used psychophysiological measured based on cardiovascular activities (heart rate and heart rate variability) as an alternative. Therefore, this study not only evaluated the emotional content of the park area and developed a tool for visualizing the results, but also investigated a different approach to assess affective reactions.

2.1 Sample / Participants

16 business psychology students participated in the field study for course credit. They were recruited via a distribution list. Due to missing values in either the questionnaires or physiological measures (for tracking the heart rate), data from three participants was excluded after the study. The errors from the questionnaire stem from technical problems of the experience sampling application used (these data were not saved). Regarding the sensor used to track the heart rate: it shifted for some participants leading to a large amount of missing data. Thus, data of 13 participants remained, one of which was male.

2.2 Measures / Materials

For collecting objective physiological as well as subjective psychological data, participants were equipped as follows: a map of the area the study was conducted in (including instructions which path to follow), a movisens ecgMove 3 chest belt and a tablet computer (Samsung Galaxy Tab3 10.1) with movisensXS application as experience sampling tool.

2.2.1 Physiology: Cardiovascular measures were continually collected using the movisens ecgMove 3 sensor – a psychophysiological ambulatory measurement system. The raw data was processed with movisens DataAnalyzer into secondary parameters like heart rate (HR), heart rate variability (HRV) and a stress index (SI). HRV was measured in Rmssd as it is seen as the most suitable measure when it comes to connecting it with subjective feelings (Levenson, Lwi, Brown, Ford, Otero and Verstaen, 2017). The stress index (or index of regulation strain) was introduced by Baevsky (e.g. Baevsky and Chernikova, 2017). Physiological parameters are best at identifying the extent of negative emotional responses that can be described as stress (Zeile et al., 2005).

2.2.2 Subjective data: General mood of participants was assessed using items of the German version of the Multidimensional Mood Questionnaire (MDBF; Steyer, Schwenkmezger, Notz and Eid, 1997). Four items for each bipolar scale were chosen in the following order: good-bad (content, happy, unhappy, discontent), awake-tired (wide-awake, alert, tired, sleepy), calm-nervous (calm, relaxed, tense, nervous). Following the instruction “We would like to know how you momentarily feel”, all items were rated on a 5-point Likert scale ranging from *not at all* (1) to *extremely* (5).
The selected *hot spots* were rated on a visual analog scale from *do not like it at all* (0) to *like it very much* (8) following the question “How much do you like the selected hot spot?”. Participants were also asked to describe briefly the identified *hot spot* in an open text field. All ratings were assessed via the movisensXS application.

2.2.3 Location: The GPS position of the participants was continually tracked via the movisensXS application.

2.3 Procedure

The study was run individually for each participant in order to avoid mutual influence of results. The laboratory of the business psychology department served as starting point. After giving informed consent, participants put on the chest belt sensor. They were then informed about the different measures and thoroughly instructed how to use them. Being additionally equipped with a map (see figure 1) and a tablet computer (with the movisensXS app) participants started with a trial task to make sure the application worked and was understandable (note: none of the participants did have any problems with the application; this may be due to psychology students being used to the role of participants in different experimental settings). The trial task also included the first assessment of mood as a benchmark measure. Afterwards, the participants followed the marked way on the map and the instructions from the tablet computer, which came up via notifications from the app. The way was not physically challenging and participants were instructed to walk at a normal pace.

Figure 1. Map of path during the study

The investigator followed participants with some distance in order to help in case of upcoming technical problems. As soon as participants entered the *Stadtgarten* (park) they were asked by notification of the app to explore the area and identify positive and negative *hot spots*, i.e. places they especially liked or did not like. While in the area of the park, the app offered a questionnaire in which a *hot spot* could be documented by taking a picture, saving the corresponding GPS position, rating the *hot spot* and describing why it was chosen. The questionnaire was only available to participants while inside the park. In case the participants left the park without recording any *hot spots*, they were asked to go back and fulfill the task by the investigator. After recording a number of *hot spots* (freely chosen by participants), participants continued to follow the path on the given map. When exiting the park, their mood was assessed for a second time via the app. After a few minutes' walk, participants entered a different part of the park and were again asked to identify positive and negative *hot spots*. When exiting the park for the second time, the mood was assessed again. The walk ended after approx. 45 minutes at the starting point where the study was also finished.

3. VISUALIZATION: TECHNICAL IMPLEMENTATION

As the collected data is dependent on a position we decided to use a server- and map-based visualization.

3.1 Minimum Viable Product/prototype

Our first approach was to set up a Minimum Viable Product (MVP), a prototype with the minimum requirement to visualize the collected data on a map. For data collection of the participants we used the movisens ecgMove 3 sensor which also tracked the position via GPS. Besides the collected data, the participants were asked to take pictures of their personal *hot spots* and allocate an affective evaluation on a scale between 0 and 8. The evaluations are visualized color-coded within an ascending colour gradient between red (*do not like it at all*) and green (*like it very much*).
For the implementation we used the open-source JavaScript library Leaflet to visualize the data and provide a graphic user interface to select the participant. Overall there were five participants available in the MVP. Each participant can be chosen individually or altogether. The graphic layer was placed on OpenStreetMaps. By choosing any participant a polyline will be drawn on the map representing the walked path of the particular participant. Furthermore, the corresponding *hot spots* will be shown as color-coded markers. If clicked, further information of the *hot spot* will be shown such as a picture and respective notes (see figure 2).

Figure 2. Screenshot of the MVP

3.2 Implementation

3.2.1 Data pre-processing: The collected data of movisens was stored in various files and formats. The GPS data was provided in Keyhole Markup Language (KML or KMZ) which is an Extensible Markup Language (XML) notation and an international standard of the Open Geospatial Consortium (OGC). To extract the GPS coordinates and timestamps a PHP: Hypertext Pre-processor (PHP) parser was implemented. After assigning unique identifiers (ID) the data was stored in a Structured Query Language (SQL) database. Further sources provided HR, its corresponding timestamp and the affective evaluation in the comma-separated values (CSV) format. The evaluation was stored as a numeric value between zero to eight. The pictures of the *hot spots* were added to the database in a JPEG format.

3.2.2 Visualization: Besides OpenStreetMaps, Google Maps was added as a further option. To represent the physiological emotional reactions (based on HR) a heat map was used, which simplified the visualisation of the combined emotions of all 13 participants. The emotions were color-coded between the colour gradient of red (high values) to green (low values). Further options of displaying the heat map are inverting the colours, changing the radius and opacity. The *hot spots* were also added as coloured markers. By clicking on a marker, a thumbnail of the location as well as the participant's ID, the corresponding notes are shown. If HR is above 90 bpm the marker will start an animation of going up and down (see figure 3). The mood ratings as well as the HR can also be shown optionally as a bar or line chart. By selecting a specific part of the walked path on the map, the HR values will be displayed in a separate line chart next to the map.

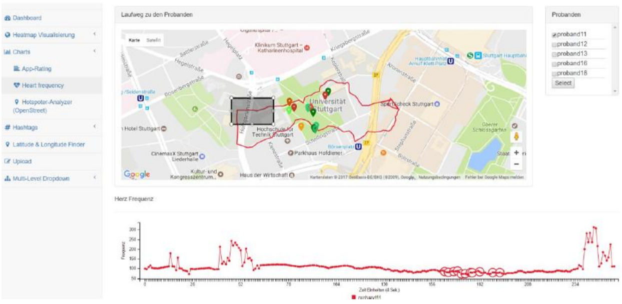

Figure 3. Screenshot of visualization tool

Additionally, the ratings of the mood questionnaire of all participants can be shown as a bar or pie chart at specific moments (beginning and the end of the survey).

3.3 Website

The application requires an Apache server and the open-source relational database management system MySQL. The PHP script is using Ajax calls and the JSON format.

After setting up the website all features are accessible through the GUI. The data of the participants can be replaced, further information uploaded or new participants added. No coding nor technical adjustments are needed for usage.

4. RESULTS

4.1 Hot spots

In total 42 *hot spots* were documented (i.e. 42 spots selected by participants that lead to a positive or negative emotional reaction), on average each participant identified M = 3.23 (SD = 1.46) *hot spots*. Data were analyzed quantitatively as well as qualitatively, focusing on aggregated as well as individual results. 15 *hot spots* are negatively ranked (0 to 3 on a 9-point scale) and 27 *hot spots* are positively ranked (5 to 8). No *hot spot* is categorized in the middle of the scale (4), i.e. participants correctly followed the given instructions. The proportion of positive to negative *hot spots* (about 2:1) is in line with the park functioning as a possible retreat for relaxation-seeking citizens. The comments given and pictures taken of the *hot spots* show that negatively rated areas are those, which include grey and bleak surfaces (e.g. an empty fountain, walls) or buildings (next to the park), concrete and graffiti. The park includes a fitness-trail, which is rated positively by some and negatively by some other participants. Clearly positive locations in the park are the green lawns, colorful flowers (during summertime), the marble statues and the historic buildings of the university campus on the edge of the park.

4.2 Mood

The three subscales of the MDBF (good-bad, aware-tired, calm-nervous) show satisfactory to high reliabilities (Cronbach's α between .73 and .89).
There are no significant differences in the twelve MDBF items between the three times of measurement: beginning of the study, first exit of the park, second exit of the park. This indicates that the short visit of the park did not strongly influence participants' mood during the study.
Mood items (after exit of park) were also analyzed in combination with the number of positive and negative *hot spots* identified by each participant. There is a substantial negative correlation between the number of negative *hot spots* and the mood item "content" (r = -.73, p < .05). The correlation between the number of negative *hot spots* and the mood item "discontent" was positively correlated, but not statistically significant (r = .27, p > .05). Thus, participants were feeling less content when identifying negative *hot spots*. Therefore, the negative *hot spots* should be considered in order to further improve the park area.

4.3 Physiology

In addition to self-reported subjective data, objective physiological data of the participants were analyzed and connected to the rated *hot spots* and subjective mood ratings. Values of eight to nine participants were considered for the general analysis of HR (nine participants) and HRV (eight participants), since recordings for these participants showed a continuous track of physiological parameters. The other participants showed too many gaps in recordings of physiological parameters and were, thus, excluded from this part of physiological analysis. This may be due to not proper adjustment of sensors to participants' body or to the problem of continuously tracking physiological data while moving outside the laboratory. In consequence, the stress index showed many gaps and was therefore not used for this global analysis.
First, physiological parameters (HR and HRV) and mood values were correlated using data from eight (HRV) and nine (HR) participants. HR shows no significant correlations with mood ratings. However, HRV is correlated negatively with the items "tense" (r = -.66, p < .05) and "nervous" (r = -.68, p < .05), i.e. lower HRV-scores are an indicator for negative affect or stress.
Secondly, the average of physiological values (HR and HRV) of each participant was calculated. The average HR (but not HRV) values while being inside the park differed from the values while participants were walking outside of the park area (see table 1).

Participant	Inside the park				Outside the park			
	HR		HRV		HR		HRV	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
5	82	9	44	10	87	11	34	16
6	104	7	14	3	109	11	15	5
7	105	9	15	4	109	9	15	5
9	76	8	23	2	86	9	23	8
11	133	32	-	-	117	37	-	-
12	102	9	20	4	102	13	20	8
13	117	9	8	3	118	10	8	4
14	101	32	10	4	104	10	10	6
16	106	11	16	7	111	6	19	6

Table 1. Means (M) and Standard Deviations (SD) of HR and HRV inside and outside the park area

Seven out of nine participants have lower HR values while being inside the park area. Only one participant shows increased HR in the park (see figure 4).

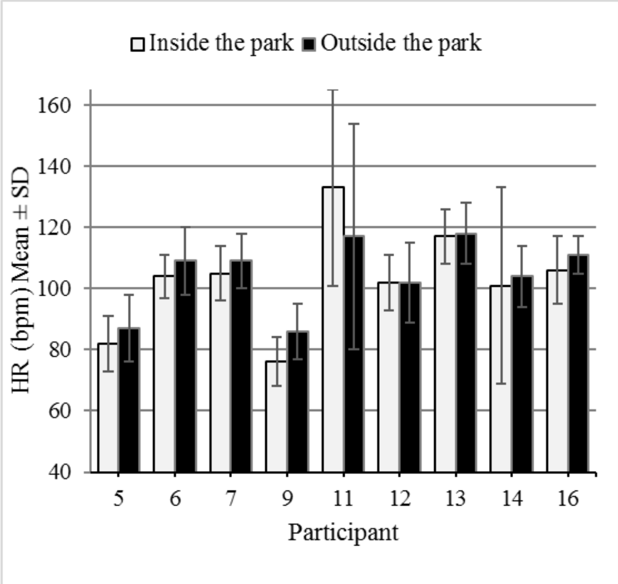

Figure 4. Means and SD of HR inside and outside the park area

The visualization heat map of HR values (see figure 5) illustrates that participants have higher physiological arousal outside of the park area. This can be interpreted as a generally lower stress level among participants while inside the park.

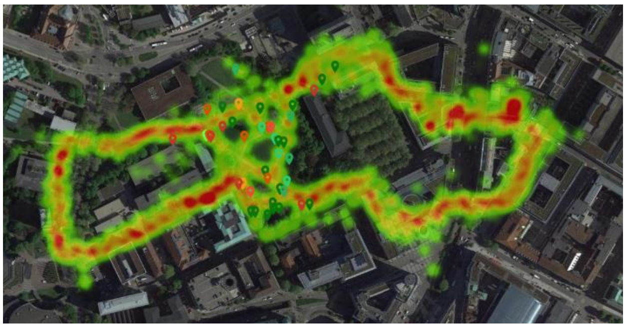

Figure 5. heat map of heart rate (all participants)

4.3.1 Physiology and *hot spots*: Not all of the 42 *hot spots* documented by participants were used for this part of the analysis, as there were too many missing values in the secondary physiological parameters for some of them. We included 33 *hot spots* for analysis with HR, 26 for analysis with HRV and 19 for analysis with the stress index. For the latter 19 *hot spots*, all three physiological measures (HR, HRV and stress index) are highly correlated (all $r \geq |.74|$, $p < .05$). HRV is strongly negatively correlated with HR ($r = -.74$, $p < .05$) and the stress index ($r = -.78$, $p < .05$). HR is strongly positively related to the stress index ($r = .81$, $p < .05$). However, there are no significant correlations between the three physiological parameters and the subjective evaluations of the *hot spots* (HR, $r = -.02$ and HRV, $r = -.13$, both $p > .10$). The correlation between stress index and evaluation of *hot spots* is marginally significant with a medium effect size of $r = -.32$ ($p < .10$), i.e. more positively evaluated *hot spots* correspond with a lower level of stress (and vice versa). Analyzing individual participants illustrate this: One participant for example has a lower value on stress index ($SI = 319$) at the positively rated *hot spot* (8) and a higher value ($SI = 365$) at the negatively rated *hot spot* (0).

5. DISCUSSION

The target of the *urban emotions* approach is to capture and visualize perceptions of and emotional responses to certain structures within urban areas (Zeile et al., 2005). In the current study, we combined different affective measures in order to reach this goal: objective physiological data (based on cardiovascular activity) as well as subjective self-reported ratings (of *hot spots* and general mood). Participants had to identify positive as well as negative *hot spots* in an area of interest (a park) and were asked about the mood state after visiting the park. In addition to these data, participants took pictures of *hot spots* and their GPS-coordinates were tracked. In this case study of the park *Stadtgarten* in the centre of Stuttgart we were interested to test these different measures in order to understand their respective advantages and limitations in order to capture *urban emotions*. We also wanted to understand as a case study, whether the park serves as a recreational area for citizens – and to identify ways how to improve it.

Overall, participants found more positive (e.g. green lawns) compared to negative *hot spots* (e.g. concrete structures) in the park. This shows the overall potential of the park located within the busy city centre of Stuttgart to offer citizens an area of stress relieve and recreation. However, participants' overall mood was not influenced by the visit of the park during the study. There are different possible explanations for that. First, the visit may have been too short for participants to positively affect their mood. In addition, since participants were following a task, they were not really using the park for recreational purposes. Second, the park might (still) have too few positive and too many negative *hot spots* as it is today. As the results show, the fewer negative *hot spots* participants encounter the more content they are feeling. One third of *hot spots* was rated as negative, which might be a number too high for a recreational area to have a positive effect on visitors. A third explanation is that people are not fully aware of their emotional states or may be unable to report them in self-reports (Weinberger, Kelner, McClelland, 1997), especially if these are not strongly experienced (such as moods compared to emotions) and if they are not used to pay attention to their emotional states. In this case, objective physiological measures might have an advantage and give additional insights. Physiological parameters such as HRV and HR may be good additional indicators of these minor changes in mood. HRV for example seems to be a good indicator of experienced stress, even if people are not aware of this themselves, proving its incremental value in capturing *urban emotions*. The results show a correlation of HRV with the level of self-reported nervousness and tenseness. However, even if all parameters deducted from cardiovascular activity were highly correlated with each other, only HR showed a somewhat lower stress level for participants while walking inside the park area compared to areas outside the park. Physiological measures seem also to be correlated with different *hot spots*, but they seem to be more reliable to identify larger areas of high and low stress levels compared those single spots.

However, the sensors used in this study let to quite some amount of missing data. This may clearly be a downside for using these kind of data (c.f. Zeile et al., 2009) and needs to be closely explored in future studies. Another problem is the interpretation of the different physiological parameters. Even though the different physiological parameters are highly correlated with each other, they show different correlational patterns with the subjective self-report measures. In addition, HR showed the expected differences for participants while being inside compared to outside the park area, but HRV did not. Thus, apart from the measurement problems regarding the reliability of physiological measures used in this study, the construct validity of these measures is an open question. Here, further research with larger samples, long-term measurements and consideration of other physiological parameters is necessary. It might be useful to assess the heart rate during a neutral task upfront for all participants allowing for individual calibration. Also, the walking speed and walk acceleration could be used to this effect. Apart from other physiological measures it could be worthwhile to integrate other measures as well in order to get a better understanding of the emotional reactions of people in urban areas (e.g. from social media posts, such as tweets; c.f. Resch et al., 2015) and its triggers (e.g. by using an action camera, or a mobile eye-tracking device). In addition, other factors that influence emotional responses, such as weather conditions, should be tracked in future studies. For example, it would be interesting to investigate, how the different appeal of the park area over the course of the year would influence emotional reactions (the sample in our study was too small to investigate this question).

Taken together, subjective self-report measures used as experience sampling proved to be helpful to identify outstanding negative as well as positive *hot spots* in the park. Objective physiological measures add information by capturing more subtle emotional experiences (such as mood) and seem to be useful to evaluate areas (as opposed to certain spots) within a city.

In addition to the assessment of emotional responses, we were also interested in developing a visualization tool in order to display these data in a way easy to understand for different (non-scientific) target groups, such as citizens and tourists as well as people working in urban development. The tool introduced in this study had the ability to analyse physiological data as well as data from self-report measures, both for individual participants and on an aggregated level, in a way that is easy to comprehend for all target groups. Above that, for each hot spot rich information was offered (e.g. description and picture of spots), that may be especially interesting for tourists, visiting the town. With tools like this "the extraction of georeferenced emotions could be used to identify areas where the citizens' well-being is not optimal and where urban planning actions are necessary." (Resch et al., 2015).

6. OUTLOOK

Overall, our study sets another example of how to assess and display *urban emotions* in a larger city (Resch et al., 2015). To achieve an understanding of how citizens are feeling in over-growing cities is a very important issue for politicians, urban planners and citizens themselves. It is extremely important to use reliable and valid measures for assessing these emotional variables. Following an experiencing sampling approach helps to minimize error, as does the use of different classes of measurement (self-report as well as physiological measures). Physiological measures may be useful to identify areas of interest for urban planners that elicit positive or negative affective reactions among citizens. To get a better understanding of the reasons for these reactions, subjective self-reports seem to be a good complementary approach. In future research, it is important to find self-report measures that are most informative for urban planners. In addition, it is also important to understand the problem with reliability and validity related to physiological data in the field.

For the next iteration of the software solution, we aim to use the OGC standard SensorThings API. Furthermore, additional sensors such as thermometer or other sensing devices can be added and interconnect more easily. The goal is to establish an online tool for emotional mapping where participants as well as sensors can be added and managed using a GUI. Through storing the collected data on a server first, the information should be called and visualized in almost real-time. In addition, The usability of the visualization tool for different target groups (e.g. urban planners, citizens, tourists) needs to be considered in future development.

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