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Sensing the City – How to Identify Recreational Benefits of Urban Green Areas with the Help of Sensor Technology

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1 ABSTRACT

Urban green spaces have different benefiting values for urban life. Besides their ecological values, they are important for retreatment and recreation and provide positive contribution for the subjective well-being of the citizens. The EU emphasizes this importance for the urban spaces in various guidelines and directives, like in the Charta of Leipzig with its contents of a vital city. However in terms of a measurable classification, there is just a concentration on the European Union Environmental Noise Directive. Additionally, questionnaires to request personal subjective opinions are used. This research study aims to show if this issue could be reduced to one dominating factor or how the well-being of the citizens could be reflected by more complex correlations. By now, a qualitative and concurrent method to arise the recreation value by the well-being of the citizens is missing. The research approach includes the usage of an ambulatory assessment device (wristband) with psychophysiological measurements. Hence, a wristband (“SMART-Band”) has been developed which can measure unobtrusively emotions in real time as product of unswayable body functions. By this method, subjective feelings and emotions could be transferred into quantifiable values. Furthermore, correlations with these values and the noise level from EU directives are in focus of the research. The study took place in four different urban spaces with specific noise loads and recreational characters. The test persons (n=18) were equipped with wristbands (“SMART-Band”), video cameras and noise detection technologies (instruments of the Laboratory of Monitoring and Spatial Sensing of the University of Kaiserslautern). For supplementary validation, information gained from questionnaires and tagging smartphone technologies are used.

2 INTRODUCTION

Through developments in recent years such as ubiquitous computing and pervasive sensing (Martino et al., 2010), the human environment is increasingly enriched by vice versa connected sensors, which generate spatial planning-relevant data. With the help of new mobile technologies, citizens are more and more integrated in this network of applications and could interact with it in the future. First thoughts on this have been considered some years ago with the theory of "Citizens as Sensors" (Goodchild, 2007) or a “People-Centric Urban Sensing” (Lane et al., 2006). This ensures that citizens, who should be the focal point of any planning consideration, may be considered as active sensor for the urban environment. Pervasive Sensing in its current status is marked by the fact, that the primary external influences singularly are measured, but the direct effects and interactions of the citizens will not be considered. So far, it is important that not only the sensor measurements of the citizen were taken into account, but also into which emotions they were resulting. This study will introduce devices and methods, which will consider the human sensor and its emotional perception. One important influencing factor is urban noise on test persons and the correlation with their emotions. Aim is to define methods and new insights for defining the quality of a place. The study “Sensing the City” shows the potentials of psychophysiological monitoring and prospects for their use in urban planning. The study takes place in three urban areas in the city of Kaiserslautern in which the participants are connected with different kinds of psychophysiological monitoring devices and audiovisual measurements.

3 STATE OF RESEARCH

3.1 Monitoring and Spatial Sensing

Monitoring contains an observation of a phenomenon over a specific period of time, with the result of using the gained forecasts for a reactive or constructive control. Regarding the used data, monitoring needs a systematic collection, analysis and documentation of these data in order to do an analysis over time of quantitative and qualitative entities (Streich, 2011). Charateristically for monitoring methods are very detailed and strictly implemented protocols with exact timestamps and a continuous recording of the observed object or event. Only by using this data collection, it is possible to generate time series, which are the basis for forecasts. Especially in the working field of spatial planning, the accompanying time series analysis was emphasized. With the appearance of Web 2.0 and associated technological opportunities as mentioned in both previous points, many new developments will influence the approach of monitoring. Besides, the empowerment of non-experts to create, analyse, visualize and publish geospatial information will contribute data for monitoring.

Due to the mentioned elaborations, it has to be distinguished between deductive monitoring (top-down) and inductive monitoring (bottom-up). Deductive monitoring is mainly composed of data generated by time series analysis: People collect data sets, with or without the awareness that they wear a sensor device to collect data, or unconsciously, like the connection dataset of cell phones. Regardless of the fact how these monitoring technologies deal with personal data and data security, the continuous recording of these kind of data has a large potential, not only for spatial planning. Inductive monitoring approaches, especially in spatial planning have to be considered in a different way and could be described as a concluding approach from the entirety. It could be seen that the following trend is going to be detected: the growing amount of interest in the use of "Sensing the city". Sensing the city in this case means the combination of georeferenced data with the help of ubiquitous mobile computer systems and sensor technology. Furthermore, in this context, the term "Geoweb" from the British magazine "The Economist" (2007) is mentioned as well as it is metaphorically referred to "Web 3.0" or "GeoWeb" (Batty et al., 2010, p.1). In particular, the GeoWeb phenomenon refers to "the development and changing nature of map-based, data mash-ups. It tries to explain the basic concepts behind map mash-ups, how geospatial data gathering and analysis has changed and how new technologies and standards are impacting on this" (Batty et al. 2010). During the last years, a drastic increase in available GIS-data source and especially rapid developments and price reduction in sensing technologies could be observed. To make use of this immense amount of data within monitoring systems, real-time data integration mechanisms and approaches have to be developed (Resch et al., 2009) and would be desirable in this context. Essential parts of a "Sensing the city" system are (smart) sensors, humans (as sensors) and a monitoring system (Exner et al., 2011).

3.1.1 (Smart) Sensors

"Base-sensors" for spatial planning are sensors for detection of location and direction of an object (Streich, 2011): These sensors can be subdivided in sensors for self-location (for example a GPS-Tracker) or position detecting, how it is used for radar equipment or the detection of Cell-ID in mobile phone networks. With the help of GPS and a compass, it is possible to detect the moving direction. Other available technologies are data collecting devices with the assistance of visual sensors (like digital cameras), audio sensors or in addition sensors for the measurement of the degree of air pollution. A general overview and classification in sensor types could be distinguished: sensors for state variables and material properties, sensors for geometrical and mechanical parameters, electromagnetic and optical sensors and other possibilities for image processing (Schanz, 2007) or, like in the present case, the skin conductance and the skin temperature (Zeile et al., 2011). All the sensors produce mostly quantifiable data and could be used in different planning related issues.

Crucial point is to organize these complex and heterogeneous data sets and new technologies. So it is necessary to develop new methods for its use, administration, organization and management. Basic research for the handling of these data sets is essential in this regard. An interesting approach for this is to use "bikers" as sensors as shown in the Copenhagen Wheel project (Outram et al., 2010), in which environmental conditions like CO and NOx concentration, temperature, noise (dB) and humidity were directly measured by sensors during bicycle rider's tours through the city. Focus in these cases were particularly citywide sensory data, data management, the integrated real time visualization in a top down process with a bottom-up approach. Hence, one of the most important issue in planning processes is "to involve humans into a "sensing process", because they function through their body impressions as a synchronized multi-sensor" (Exner et al., 2011).

3.1.2 Human as sensors

Like above mentioned, it is necessary to integrate people's skills for gathering sensor data. In 2010, "The Economist" stated out to this point: "Everything will become a sensor, and humans may be the best of all". Due to the technological development in smartphone business, the combination of Smartphone - Human Interaction could be a huge potential in planer's everday work if it is possible to use this specific ability of people for monitoring spatial phenomena. Their abilities in terms of sensing will result together through interaction with the user itself in the rise of new planning relevant sensor data. Furthermore, crowdsourcing integrates an entirely new mode of participation in processes of urban discussion for geospatial data gathering" (Exner et al., 2011).

3.2 Noise reduction in spatial planning

Environmental noise may be defined as unwanted sound that is caused by emissions from traffic (roads, air traffic corridors and railways), industrial sites and recreational infrastructures, which may cause both annoyance and damage to health. It is to be considered as one of the main local environmental problems in industrialized countries. Noise in the environment or community seriously affects people, interfering with daily activities at school, work and home and during leisure time. Furthermore environmental noise causes an increasing number of complaints from the public.

Generally, action to reduce environmental noise has had a lower priority than that taken to address other environmental problems such as air and water pollution. However, it has been estimated that around 20 percent of the European Union's population or close on 80 million people suffer from noise levels that are considered to be unacceptable – i.e. that many or most people become annoyed, that sleep is disturbed and that serious long-term health effects like increase of hypertension are to be feared. The European Union calls these 'black areas'. An additional 170 million citizens are living in so-called 'grey areas' – these are areas where the noise levels are such to cause serious annoyance during the daytime – but no serious health damages. Only 150 million Europeans live in 'white areas' that are not seriously affected by environmental noise (EU-WG-AEN, 2003). These are mostly rural areas or privileged places in urban areas.

The reduction of environmental noise is subject to two important restrictions. The first is that spatial systems or infrastructures are to be assessed, not the sources of sound emissions like cars or aircrafts. Therefore, environmental noise assessment and mitigation is not concerned with technical questions, such as constructing cars in a way that makes them quieter, but rather with the question of infrastructure planning and its impact on residential and leisure areas. The second major restriction is that there are some kinds of noise that may not be assessed in the environmental context – the most important one being neighborhood noise, which is a question of architecture, of social behaviour and of legislation, but not of spatial planning – although there are some connections to planning (Rumberg, 2009). A recent goal of noise mitigation according to the European Union Environmental Noise Directive is to protect quiet areas against an increase in noise. Especially in densely populated cities urban parks and green spaces are of great importance. The designation and protection of quiet areas is thus a contribution to maintaining a high quality of life in the cities.

3.3 Emotional Mapping (based on skin conductance and skin temperature)

The human-being has ever been in the focus of any planning consideration. Thus, it is only logical to determine him as sensor and source of individual data concerning its environment. How does a person sense its actual surroundings and how can these impressions and emotions be measured objectively? Recently, a multitude of researchers (psychologists, neuron-scientists, medical scientists, computer scientists, etc.) occupy themselves with these questions. They work in the field of "Affective Sciences" on emotions and their influence on human behaviour and society (NFS Affective Sciences, 2011). The immediate transferability to space is quite obvious. In this context, two main criteria to identify unaffected emotions, which are triggered by the surroundings, have turned out:

- Affective emotions have to be recorded in real-time and for every instant to identify particular on-site situations
- The measurement must not hinder or disturb the individual to avoid the collecting of cognitiv influenced emotions

Considerable research in the field of classical emotion research and the Affective Sciences shows consistently that emotional reactions come along with changes in the activity of the autonomic nervous system. These internal reactions are reflected in specific physiological parameters (e.g. skin conductance and skin temperature) (Kreibig, 2010), which are classified as vital data of the individual. Methodical with regards to content, the recording and analysis of this vital data is called psychophysiological monitoring. “Recent technological developments, such as a sensor wristband, now allow the recording of these parameters outside a lab, even without limiting a test person’s mobility. A wrist-sensor like that is therefore the ideal instrument to record emotional stress reactions one encounters while moving through urban space [...](Bergner et al., 2011, p.249).” One possible approach, in case of outdoor measurements, is the identifying of mental load (stress) with the help of physiological indicators. Stress can be understood as a product of anger and fear - highly negative emotions. The analysis of stress moments especially helps to identify deficits in the urban environment. All these facts favour the usage of psychophysiological monitoring coupled with ambulatory assessment (wearable computers) for real-time studies in space. The combination with the field “Monitoring and spatial Sensing” offers completely new perspectives for the spatial awareness and performance of encompassing spatial analyses. This approach was already pursued in several project studies. First test series were done in the emomap-project (Zeile, 2010). Furthermore the so-called EmBaGIS (Emotional Barrier-GIS)-studies were conducted in the context of urban spatial barriers for handicapped people (Bergner et al., 2011).

4 REPERTOIRE OF METHODS

To capture spatial relevant data, different kinds of methods are combined into an overall approach. Focal point is the comparison of noise measurements and psychophysiological data, which brings the principle of humans as a sensor in the classical consideration of spatial planning data collection.

4.1 Noise measurements

A key method for the assessment of noise load and its effects is noise mapping. Noise mapping is the representation of acoustic data in a cartographical format and the assessment of noise exposure in the context of public health and quality-of-life in a multi-level modelling process. Its benefits are the visualization of acoustic data and, by combination, of the information with a geographical information system (GIS) enabling the correlation of different datasets. Thus population density can be related to noise exposure to generate information about the number of people exposed to noise levels above a certain criteria level. In general, the purpose of noise mapping is to give an accurate statement of sound levels in a location, to provide noise trend data, to establish exposure levels of a population for risk estimation purposes, to identify pollution hotspots and relatively quiet areas for the definition of priorities, to yield information as to the effectiveness of management schemes and to inform as well the public as decision makers (Rumberg, 2009).

To effectively cope with noise problems in spatial planning a quantitative and informative basis-of-discussion is required. Environmental noise in general is not constant over the time but is normally showing a complex time structure. So the instantaneous sound level is no sufficient description for environmental noise, and long-term-descriptors – such a average sound levels, weighted average sound levels such as LDEN (a 24-h hour average level in which evening and night time is weighted) and peak (or maximum) sound levels and NATs (number above a defined threshold) – are complemented. The effects of noise on humans highly depend on this time structure. Strong noise peaks appearing at low background levels are particularly disturbing while generally higher, but constant levels (e.g. near to highways) are perceived less intensely. In comparison to that, other collected data to measure noise exposure and its effects on human beings is generally poor - and data on noise effects is often difficult to compare due to very different measurement and assessment methods.

Generally noise data may be achieved by measurement or prediction. In the majority of cases prediction models based on complex emission and propagation algorithms (e.g. ISO 9613) are used for noise mapping in larger areas and for long-term-description. For these cases noise prediction software (e.g. CadnaA, Lima and SoundPlan) is available. For short-term-monitoring in specific locations measuring the instantaneous sound levels using noise level recorders is more suitable.

4.2 Psychophysiological Monitoring

The recording and observation of changing body functions (physiology) are part of the psychophysiological monitoring, which shows individual emotions localized in real-time. This research focuses on negative emotional reactions, which can be classified as "stress"-reactions. A negative experience is given, if the skin conductibility increases and shortly afterwards, the skin temperature drops (Bergner, 2011). The following graphical curves illustrate this process (Fig. 1).

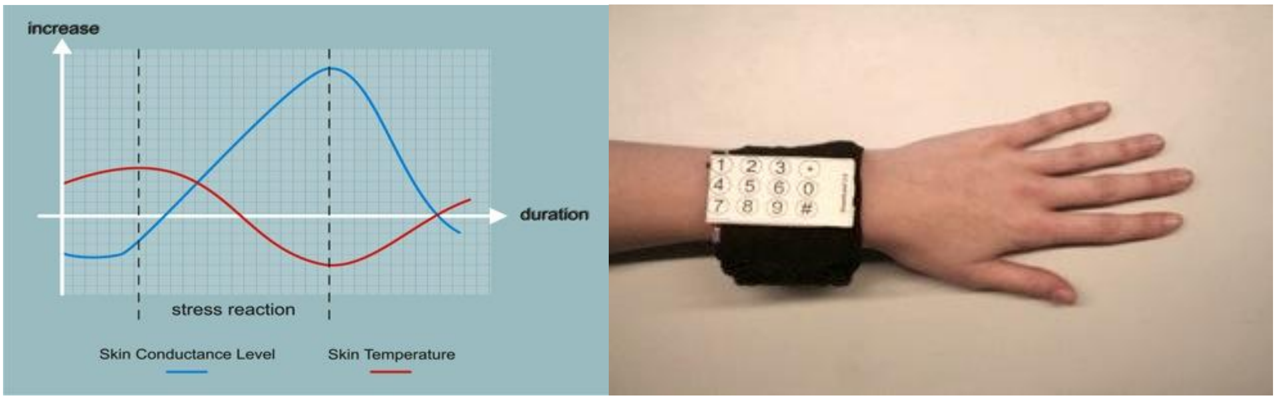

Fig. 1: Stress reaction & SMART-Band (Own source)

It is obvious that the qualitative visual analysis of the physiological data is rather time-consuming. To shorten this procedure, the mathematical function of the mentioned parameters is simplified with the first derivation. Hereby, the slope values of the curves can be used for statistical analysis. The method of using scoring points (increase in skin conductibility = Scoring +1; decrease in skin temperature = -1) was already used in studies before (Bergner et al., 2011). With the help of a sensor wristband (SMART-Band by www.bodymonitor.de) the changing body functions are measured and recorded. This wristband was developed by GESIS, the Leibnitz-Institute for Social Science in Mannheim (Papastefanou, 2009).

5 STUDY "SENSING THE CITY"

The aim of this study was to identify urban retreat and recreational areas against the background of the European Union Environmental Noise Directive with the help of psychophysiological measurements. The idea behind was, that in a city can exist qualitative retreat areas with a high recreational potential, caused by good urban design, although the areas could not be classified as a retreat area by the European Union Environmental Noise Directive. One example for this phenomenon is the fact, that people have the impression that the subjective quality of sojourn is even high on a loud street, if a fountain is located on the street and people can hear the sound of the fountain splashes.

5.1 Study Set-up

During the study, the following parameters were modelled /measured:

- Noise pollution (quantitative modelling with immission control software for location determination)
- Noise pollution (quantitative & qualitative measurement with noise level recorder)
- Subjective perception by using SMART-Bands (and alternative SenseWear devices), recorded through skin conductance level and skin temperature
- Additional geotagging of impressions via RADAR SENSING App via KML
- Traditional 5 level ICBEN-questionnaire (International commission on biological effects of noise), which described the perception of noise pollution.

The test persons (n=18) were a group of students from the local university. Ten were male and eight female with an average age of 25,4 years (m=27; w=23,5). They had the excercise to concentrate on reading a book in the different areas over a time span of 30 minutes.

The test persons were equipped with:

- SMART-Bands for measuring physiological data
- SenseWear upper arm bands for measuring physiological data
- Neck Cameras to identify the individual audio-visual impressions
- Smartphones (with the installed tagging RADAR SENSING App)

Before the setting up the study, first step was the analysis of the city of Kaiserslautern to identify potential areas with high suitability for quiet recreation. The test persons filled in their standardized ICBEN questionnaires on noise pollution, where they wrote down, if they had the impression at this place to be considered a relaxed situation. Following the phase of data collection with Sensewear-Band and SMART-Band in which the subjective physiological responses were measured in fact of rapidly changing situations of noise. Simultaneously, the local sound signals were recorded and measured.

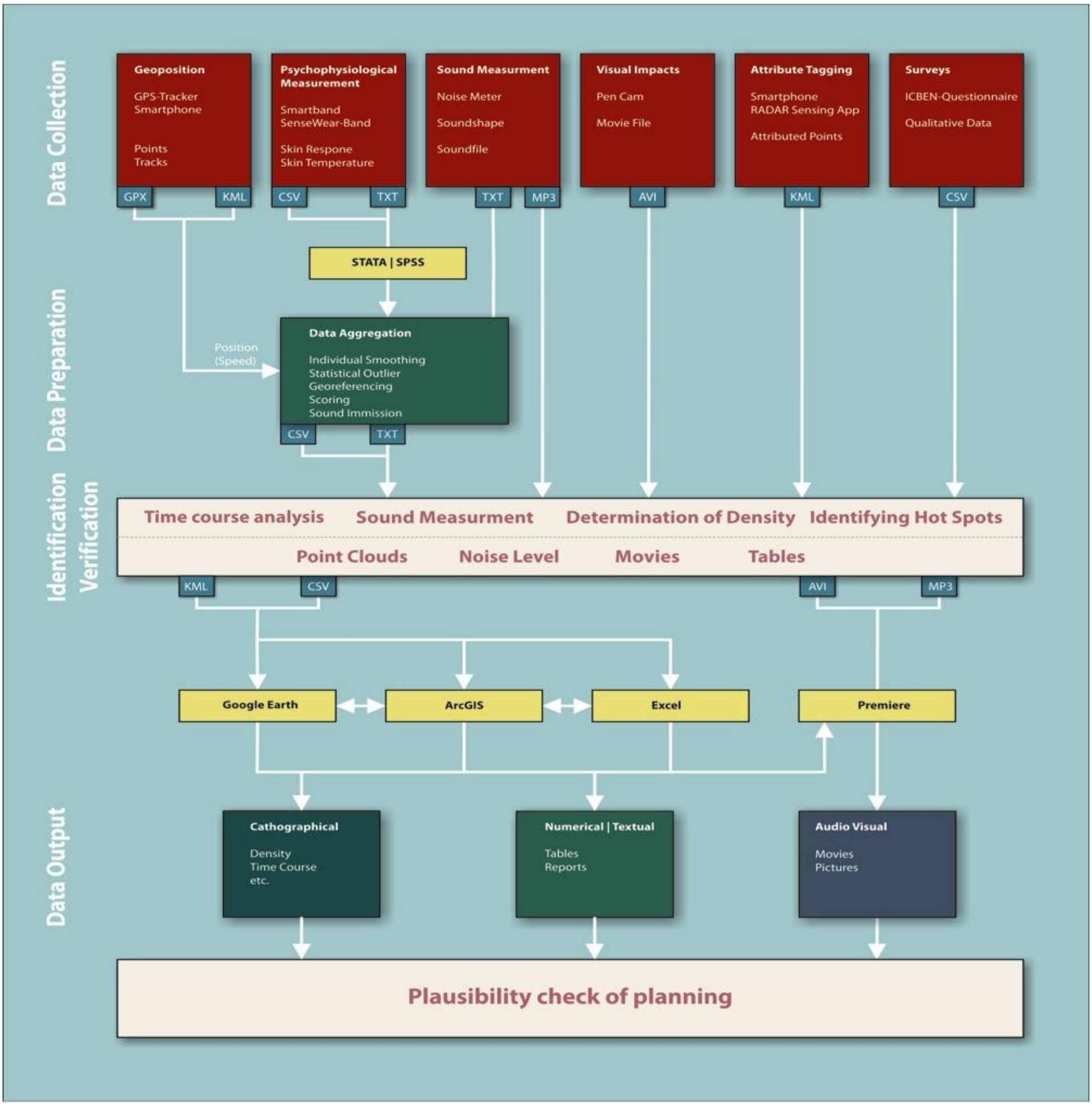

Fig. 2: Study-workflow (Own source)

In order to validate the hypothesis of the connection between different noise levels and the emotions of the test volunteers, four characteristic study locations were identified in the city centre of Kaiserslautern. All four locations have specific characteristics and noise levels:

- Location Volkspark: bigger inner city park, which is mostly calm and has a high potential for recreational purpose – test bed for the visualizations in this paper
- Location Fackelrondell/Stadtplatane: inner city area in an area with an intense surrounding traffic, recreation purpose just for a short-time stay possible
- Location Stadtpark-Straße (street side): inner city area in an area surrounded with medium intense traffic, although the park is mostly calm, the sidelines are strongly influencing by traffic noise.
- Location Stadtpark-Kern (centre): inner city area in an area surrounded with medium intense traffic, the measurement was collected in the calmer centre of the park.

The comparison of the noise levels on an afternoon over the period of a 30 minutes time span reflects the various specifics of all four test beds. It could be seen, that the level on the "Stadtplatane" with an intensive traffic is in average much higher than all other levels. The "Volkspark" for example has a stable level, which was just interrupted by two specific situations, a playing child and a passing lawn mower. Both measurements in the "Stadtpark" also showed differences because of the traffic, though the distance between both measuring sites are less than 100 meters.

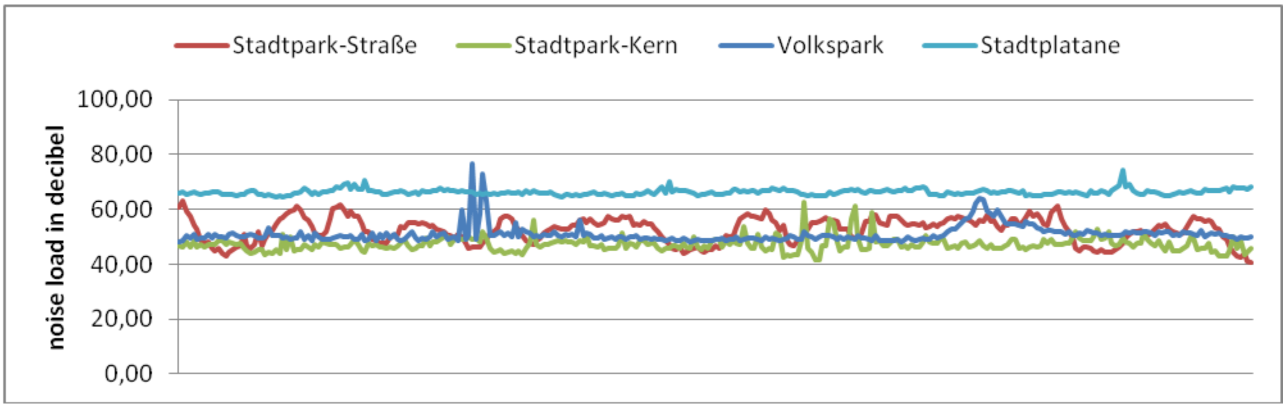

Fig. 3: Comparison of the noise levels from the 4 study locations (Own figure, based on work of Diehl, Michel and Keller for the study project Sensing the City, 2012)

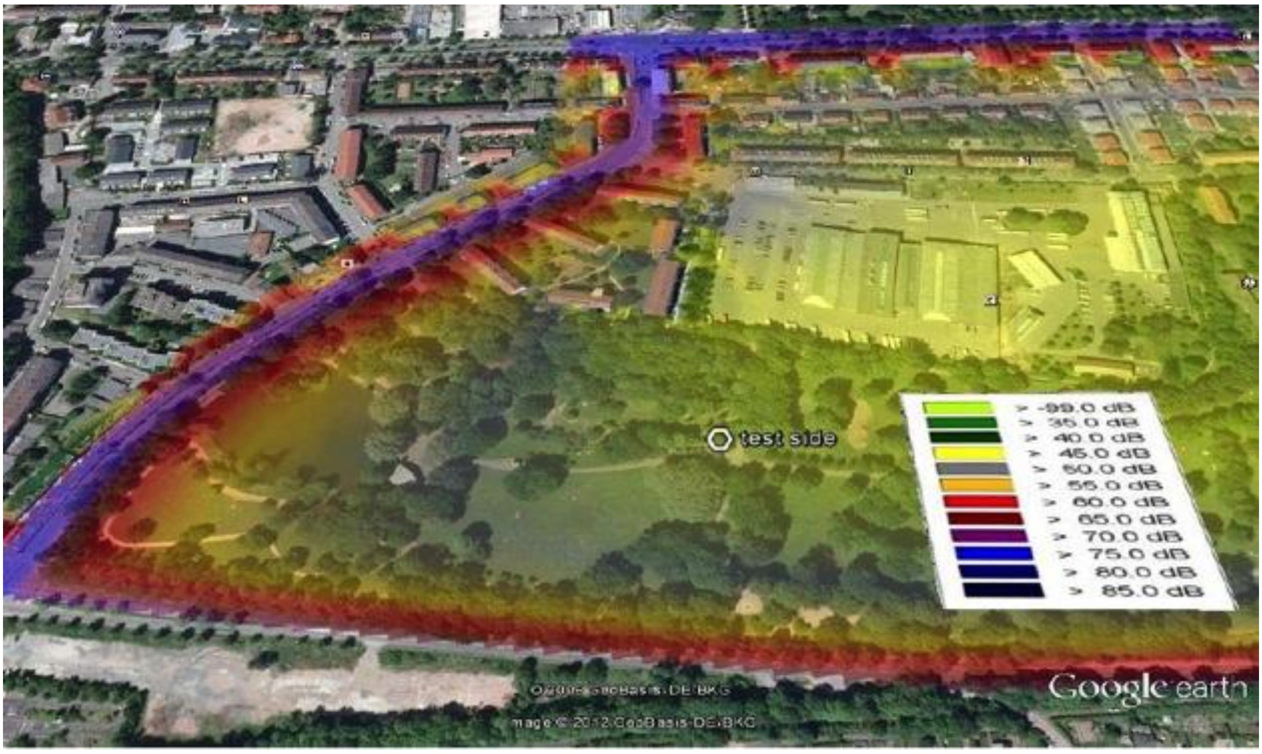

Fig. 5: Test side "Volkspark" (Own source, noise map produced with CadnaA)

Deeper insights of the study in terms of visualisation were given with the results of the test study of the area "Volkspark". The measurement site is directly in the middle of the park and has a comparatively low noise

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level. The test bed and the noise distribution could be seen in the following figure. Due to the calm environment, this spot brings the best circumstances for analysing the reaction of the test person on specific noise incidents.

5.2 Findings and visualization

Emotional mapping is a new field of study for noise effect research in gerneal as well as for the impact of the research in this topic. With this new set of technologies, it will be easier to prove assumptions about the correlation between noise load and subjective well-being. This approach is shown by a combination of quantitative and qualitative analysis. The results of the test persons show a correlation between both entities. The following picture illustrates the decibel level and the number of stress reactions in a time-series chart. The correlation between two specific events (a passing lawn mower and a playing child) could be seen clearly.

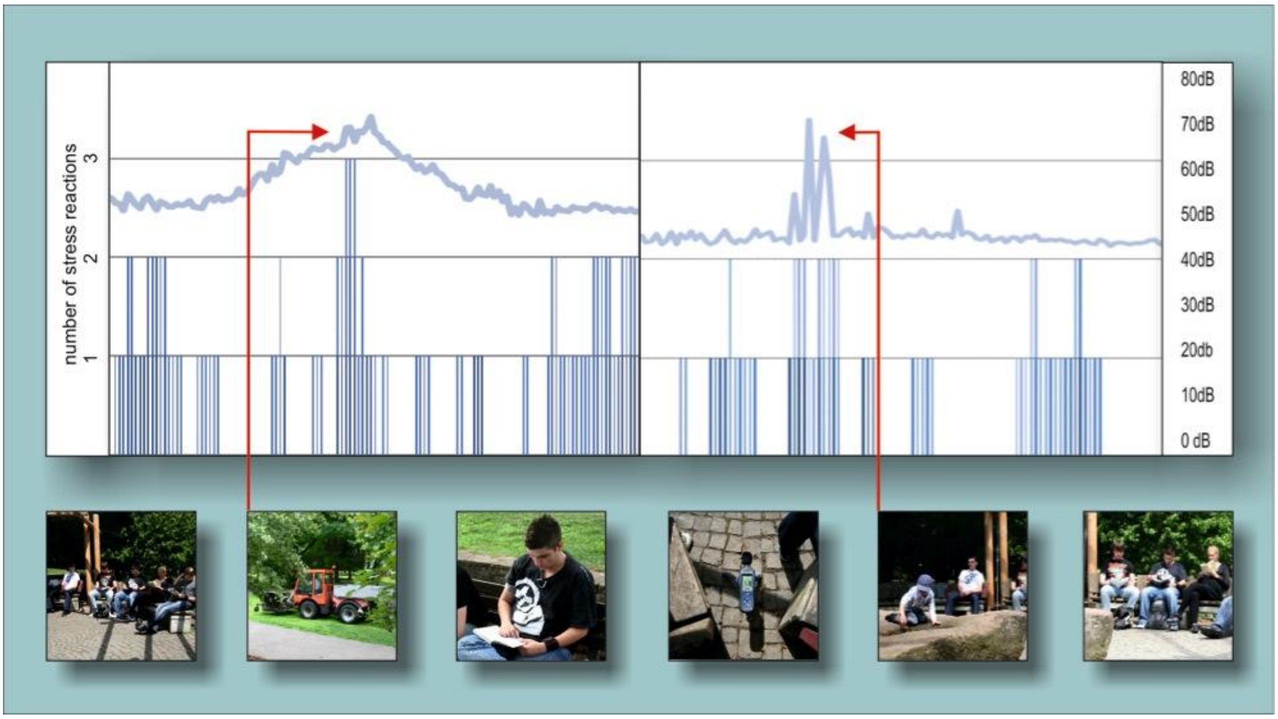

Fig. 4: Qualitative analysis of noise at the location “Volkspark” (Own figure, based on work of Diehl, Michel and Keller for the study project “Sensing the City”, 2012)

The possibility to integrate georeferenced measurement data into Google Earth shows a further potential of this method. The subsequent figure shows an example for a visualisation of emotional data of three test persons during a passing lawn mover. As it can be seen in figure 4 as well, a raising noise level induces a raising stress moment. This raising skin conductibility during stress responses could be visualized with localized vertically moving bullets on a scale as it could be seen in figure 5, which could be considered as a localized “pulse” for the volunteer.

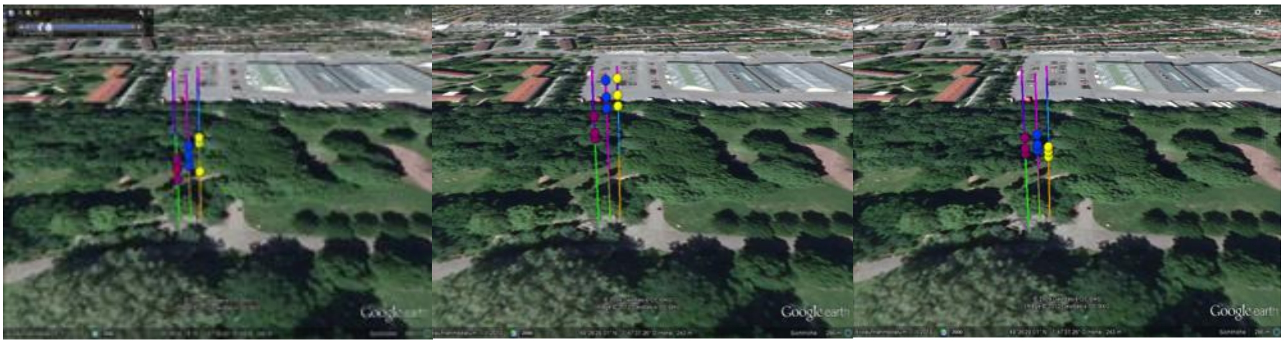

Fig. 5: Different stress emotions of the locations “Volkspark” during a crossing lawn mower (compare figure 3) (Own figure, produced with gpsvisualizer.com, 2012)

6 CONCLUSION

The logical combination of new technical monitoring methods and people centric surveys opens completely new perspectives to capture humans' environment. The knowledge of the perception and feelings of the urban population provides for an improvement of "spatial awareness". In case of recreational benefits of urban green areas, some interesting findings have been outlined. First indications are found that there is correlation between high noise amplitudes and stress of the participants in the study set up. A constant high noise level however is covering people's perceptions of the actual local surroundings and leads to fewer and lower stress reactions. Taken as a whole, in the study is shown that besides the noise level, some other influencing factors on the well-being could be detected (for example awareness of movement around, presence of other people, odors, light, etc.) Hence, the methods to sense urban space have to be extended to determine spatial awareness. The interdependency of the environment and the subjective well-being is obvious and could not be described only with a few selected influencing factors. The approach to combine environmental data with the vital data of people therefore is still a new field of research, which has many advantages in contrast to classical methods of data collection, analysis and their comprehension and could be seen as a scientific enrichment.

One further research task lies in maturing technology and method. The used SMART-Band is presently in the state of prototype. So, there are small deficits in the usability and the data structure. Currently, a next generation of SMART-Bands will be developed, including a new sensor generation for delivering much more reliable data sets. Hence, an automation of the data analysis process is needed. Real-time processing by "the push of a button" is a desirable aim to reduce the dependency on the actually mainly manually analysis.

Furthermore, the consideration of the data at hand was based on static measurement locations and there has to be an enrichment of the emotional data with the use of GPS-data in order to see a pepole's emotions during their movement through urban areas. This topic is going to be considered in our upcoming research project "Sensing in green areas". Another field of research will be the qualitative analysis, in order to find out, which spatial circumstances could lead into which correlating body reactions. In this context, it is necessary to create a comprehensive and synchronized consideration of the various data flows. There will be further insights for classifications of "good" and "bad" stress situations and the different specific personal levels of the physical activity for example. Besides the measured implicit values of the test person, there could be as well an additional examination of own estimations of subjective well-being. That could be measured either in ordinary questionnaires or via special mobile phone questionnaires. More information for this will be provided in the conference paper "A New Urban Sensing and Monitoring Approach: Tagging the City with the RADAR SENSING-App". People are able to use this software to attach locations in the urban environment with either positive, negative or neutral remarks and to tag various values like cleanliness, sojourn quality, urban design/architecture, social environment, accessibility, lighting, seating or for example traffic. As an overall conclusion, these new methods could bring new insights for planners in order to detect time-space-patterns in urban environments and will be a new field of research in the future.

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