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A Pilot Experiment on Affective Multiple Biosensory Mapping for Possible Application to Visual Resource Analysis and Smart Urban Landscape Design

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1 ABSTRACT

This paper is designed to identify potential stressors as well as negative and positive environmental stimulators in urban landscapes, using wearable physiological sensors and GPS devices. An 8-channeled Procomp Infiniti device was used in this study, recording electrocardiogram (ECG), electroencephalogram (EEG), skin conductance, skin temperature, electromyography (EMG) of facial muscles expression and respiration, with a maximum sample rate at 1024/s. Probands in the pilot experiment were asked to take a 15-minute walk on a designated route for three times. Physiological measures were first filtered and then combined with GPS locations and visual eyesights. Affective mapping analysis based on the collected data allows first conclusions on the responsiveness of probands towards different visual experiences. Further analyses will determine the impacts of urban environments on stressors and what role latest technological advancements in smart landscape design in form of augmented reality can play for improved well-being of city dwellers.

2 ENVIRONMENTS AND WELL-BEING

Research studies revealed that exposure to natural environments would trigger positive affective responses and enhanced cognitive functions (Velarde et al. 2007; Bowler et al. 2010). Therefore, frequent access to nature may enhance human mental health. On the opposite side, city dewellers, with limited access to nature, were found more likely to suffer from mental diseases and poorer psychological well-being (Lederbogen et al. 2011; Tost et al. 2015). Up to now, findings were mostly confirmatory verifying the effect of natural environments on human affective responses. However, a recent study revealed that visual aesthetics may be another important - if not more significant - environmental factor on human health additional to nature (Seresinhe et al. 2015). Seresihe et al. revealed that better scenic view correlated with lower sickness report spatially. Surprisingly, after controlling the health effects from scenic views, they did not find relevant health benefits residual from ecological and envrionemtnal effects produced by green plants. In other words, scenic views may have a significant impact on human well-being, which may be comparable to environmental or ecological effects on health. Following those arguments, the designs of urban landscapes matter, not only in the meaning of functionality and comfort, but also for aesthetics and views.

In China, the past urban development has been criticised for its lack of human scale design (Kögel & Meyer 2000; Chen & Thwaites 2013). Rapid urbanisation and pancake-like urban growth has produced uninviting, car-dependent cities, where only outstanding and sometimes highly exaggerated architectural forms trigger visual responses (Pan 2011; Chen & Thwaites 2013).

Several studies in recent years have discussed the proposals of re-implementation of traditional elements and design aesthetics in Chinese urban and landscape planning for the purpose of creating identities and livable places (Chen & Thwaites 2013; Hassenpflug 2013; Wang & Meng 2015; Wang & Ruan 2015). In the process of smart city approaches of Chinese cities, the understanding of people's well-being and interaction with their urban environments have gained unprecedented importance in planning practice.

3 BIOSENSORY MAPPING

The availability of wearable biosensor devices, such as fitness-wristbands, smartwatches or heart rate monitors have offered new research opportunities for measuring biological data out of the lab, but in practical and natural or urban environments (Bergner et al. 2013; Burke et al. 2006).

Research on the empirical value of emotion mapping have highlighted the opportunities and possible symbiosis of individual perception of urban spaces and urban design (Kwan 2011). Studies on biosensory mapping used different wearable devices (Bergner et al. 2013; Zeile et al. 2013; Zeile et al. 2015), mostly analysing biosensors such as skin conductance and skin temperature, as general indicators for stress reaction. Yet, several evaluations have shown shortcomings of such methods on measuring emotions and in situ environmental perception. One central aspect in this discussion is the one-sidedness of single sensory measurement, which in most cases only depict negative emotions in form of stress levels. Limited indicators could only indicate a certain negative stressor in measured data, but not analyse specific triggers or positive reactions. Further indicators are needed to identify the exact valence of biosensory data.

3.1 Multiple biosensory mapping

Although emotions are complex to understand and therefore difficult to measure, recent developments in cognitive neuroscience offered new opportunities for measurment. Emotions can be understood in several dimensions, i.e. valence (biphasic emotion, whether and how much one likes or dislikes), arousal and arguably a third approaching/avoiding motivation dimension (Bradley & Lang 2006; Mauss & Robinson 2009). Most biosensory measures fell into the valence and arousal dimensions as reported by Lang and his colleagues: for example skin conductance (SCR r =.81), and agruably skin temperature too, were good predictors of self-reported arousal levels based on simple linear regression analysis, while peak heart rate acceleration (r=.76) and facial expression muscle EMG (r=-.90 for corrugator EMG, r=.56 for zygomatic EMG) were good predictors of self-reported biphaisc valence level (Lang 1995).

The state of arousal ranges from neutral to highly aroused or emotionally triggered. The valence level as a biphasic placement of either pleasant or unpleasant reaction, completes a measurable set of indicators for emotional response. For measuring arousal and valence, several indicators, such as skin conductance, skin temperature, ECG, and EMG are being assessed for their value change rates (see Fig. 1).

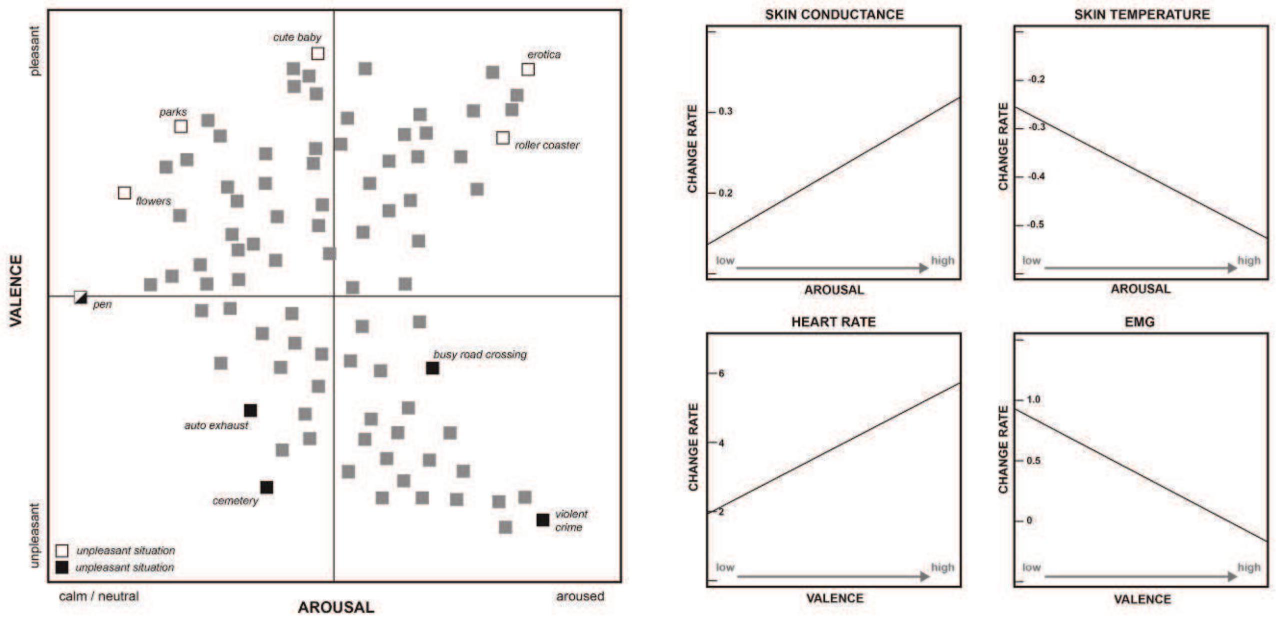

Fig. 1: Arousal and valence indicator assessment (based on Lange 1995) and expected correlation with biomeasures based on exsiting findings

When change rates correlate with each other (compare Bergner et al. 2011; Bergner et al. 2013; Lang 1995; Bradley & Lang 2006), they can indicate emotional reactions towards a specific situation, based on rated multi-sensors. Using multi-bisensory measurement offers an opprotunity to specify emotion in both valence and arousal, which therefore differentiate positive arousal (excitement) from negative one (stress/fear). To landscape architects and urban designers, these different assessments can be crucial to environmental design.

3.2 Technical challenges for multi-sensor mapping

A major obstacle for collecting multi-sensor data lies with available technology. For measuring EEG data for instance, high-technology computal devices attached to the human body are needed, which often don't meet the requirements for portable use (Tost et al. 2015). If portable though, such as the device used in this pilot study (see chapter 4.1), measurements could still hold uncertainties in outdoor environments. The effects of weather conditions, humidity or simply the movement of probands have an influence on recorded data, as could be experienced during first initial test runs. Even though several difficulties could be improved, such as loosening sensors during walks, several obstacles could not be cleared out, yet and will be discussed further.

4 METHODOLOGY

This pilot study was designed to test the feasibility of measuring emotions, affective valence and arousal levels to be specific, using a portable multi-channel physiological device during an uncontrolled in-situ walk in the real environment. As supported by empirical evidences from literature (see chapters 2 and 3), we expected to measure affective valence using heart rate and facial muscle EMG, while to measure affective arousal using skin conductance, skin temperature and ECG based on the findings of Lang et al. 1993; Lang 1995; Mauss & Robinson 2009.

The first phase of this research project, which is described in this paper, neither can nor intends to clarify the central question about the affectiveness of visual perceptions of urban landscapes. At this point, the research focuses on technological reliability and the significance of multi-sensory data.

Therefore following questions are expected to be answered:

(1) Are portable bio-sensory techniques and in-situ walking measures good enough to capture environmental perception?

(2) Is bio-sensory data able to capture specific visual stressors or interest points? Were these results triangulated with narratives provided by participants?

(3) Did bio-sensory data reveal consistent spatial patterns across runs/ individuals?

4.1 Technological devices

For measuring multisensory data, a Procomb Infinity device was used (see Fig. 2). The device can measure 8 channels or biosensors. For the experiment described in this paper, 6 channels were used, including (1) ECG (three sensors measured on wrists, with a sampling rate at 256 per sec), (2) EEG (Fp referenced at Fz, with a sampling rate of 1024 per sec), (3) facial EMG (three sensors at forehead with corrugator muscle, with a sampling rate at 256 per sec), (4) skin conductance and skin temperture (one sensor each, both with a sampling rate at 256 per sec), (5) respiration (measured at abdomen with a sampling rate at 256 per sec). Each biosensor transmits its measurements to an “on-board” recording device (6), which again is linked to an ordinary laptop or computer.

In addition, each proband in the experiment was outfitted with a Garmin eTrex20 GPS device set at a sampling rate of 1 per second, as well as a video camera attached to the proband’s head for capturing a rough visual focus.

The “on-board” recording device was carried by each participant in a bagpack. Even though this resulted in additional weight during the walk, it was made sure for all probands that the devices and measurement parts do not conflict with movement abilities and general comfort. Wires were attached with velcro fasteners to arms or torso, given a certain tolerance for unrestrained movement.

It has to be stated, though that in comparison with wristband devices as used in previous studies (Bergner et al. 2013), the multisensor device has its limitations on practicability. There might always be a specific influence on data collection by wearing it and participants will always have some thoughts about the device during the experiment, as interviews afterwards revealed. Also other external factors, which do not appear with simple wristband devices, e.g. looks and staring from other people towards an unusual outfit, might have additional influences on nervousness and stress reactions.

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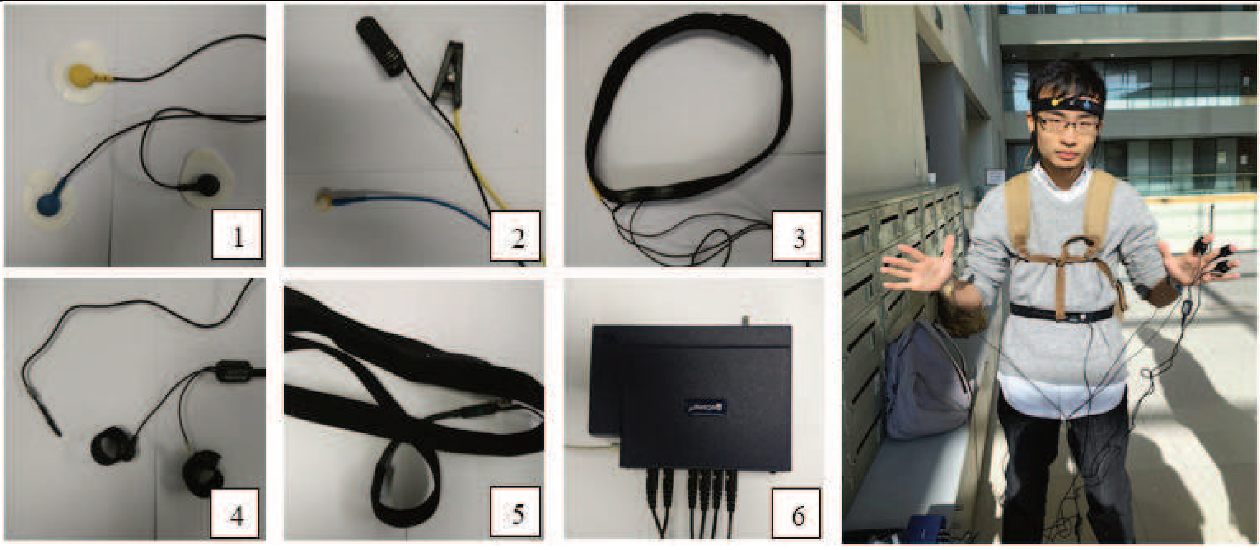

Fig. 2: Biosensor measurement parts & equipped participant (used with permission)

4.2 Visual perception

One of the central aspects of this research study revolves around visual perception and its impact on well-being. At a later point of the project, virutal or augmented reality features will be used as a comparing tool, analysing whether and to which extend design and aesthetic elements of the built environment can improve the well-being of citizens. Even though this question was not the central focus for the initial case study, the reaction and feelings towards the visable built environment shall be recorded and documented for later comparison.

Each participant was asked to write a brief narration for each walk, specifying visual experiences – whether negative or positive – and other happenings or interactions. Participants were also asked to present those specifics by photos or snapshots taken from their video-recordings from each walk.

4.3 Data collection

Data collection with such biomapping devices as presented in chapter 4.1 underly certain preconditions. Usually, multisensory data experiments took place under enclosed (indoor) lab conditions (Tost et al. 2015), where environmental impacts or external effects were minimal on the experiment. For outdoor environments, several aspects have to be named, which interfere with human biological reactions: weather, wind, temperature, air humidity, light/shadow, smell or noise, among others, which can certainly influence well-being and comfort, therefore might have impacts to the collected data. Distortions by such external influences can only be ruled out with a certainly high amount of datasets under different conditions of the outdoor environment.

Another, more difficult obstacle in the data collection is the activity on an outdoor walk itself. An ongoing walk – even just for 10 to 15 minutes – has its effects on heart rate/pulse and other biological indicators used in this study. For example, increases in ECG measurements and stress reactions towards the end of the route, could be very well linked to the activity or even to the proband's knowledge (and arousal) that the „finish line" is coming close. Some test runs also indicated that the walking speed increased after the last turn towards the end of the route for almost all probands, which also depicted effects on arousal measurements.

5 INITIAL CASE STUDY

The purpose of the first multisensory mapping case study was an effective testing of the devices, the practicability of them under outdoor conditions and their reliability as well as collected data consitency. Interviews of all probands were conducted afterwards to identify any difficulties or specifics, which could have affected the biosensory mapping or could play a role for data analysis.

5.1 Location & Route

For the test location, a 15 minute walking route across the Tongji University Campus in Shanghai was chosen. After first trials with different route styles, a clearly defined A to B route was favoured over a round trip, as it resulted in the most reliable data. It has yet to be evaluated, why round trip trial data showed lower quality results and varying consistency.

We intentionally selected a site on the university campus, which varied in self-reported environmental experiences in a walkable range. The proposed route across the campus could be divided into eight varying zones or locations (see Fig. 3). It consists of open spaces as well as dense alleys, green spaces and concrete plazas, busy roads with traffic and pedestrian walkways.

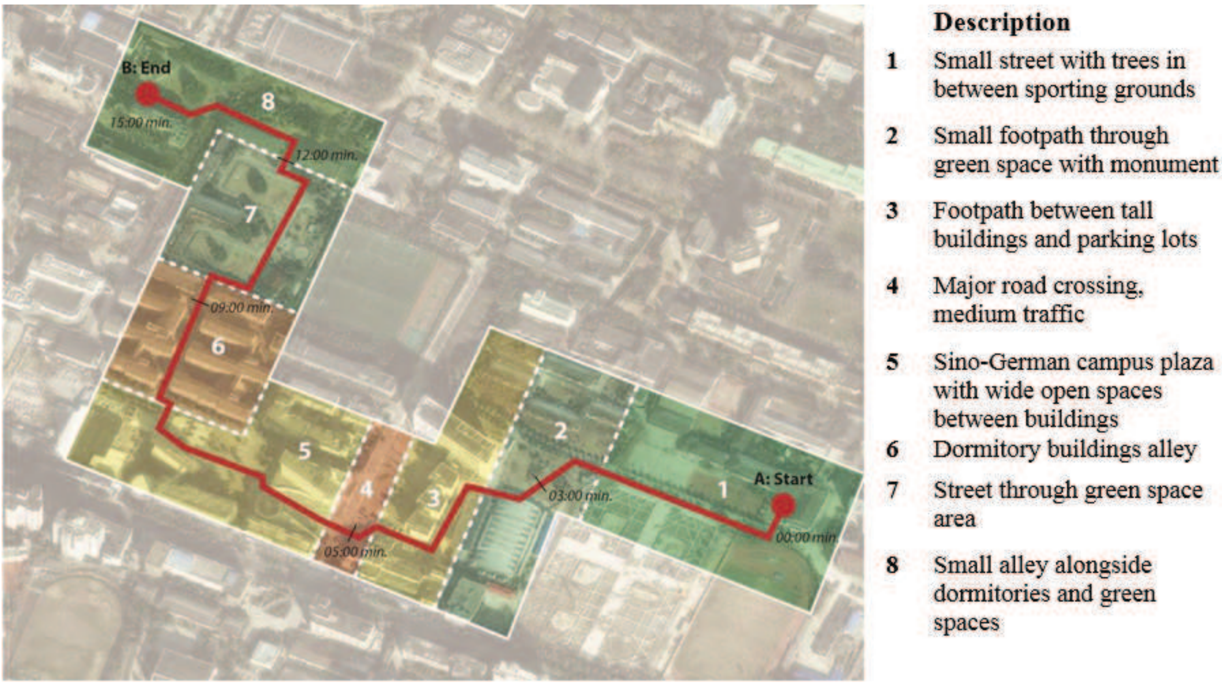

Fig. 3: Chosen route with eight different perception areas

5.2 On site biosensory mapping

Four participants were recruited and asked to walk the selected route in the same direction for three times, with small breaks in between. They were asked to perform the walk in a stable and modest walking speed, so that exhaustion and impacts on measured data were kept on a minimum level.

At each walk, they were carrying a 6-channel Procomp Infifniti device, a video-camera attached to the head gear, as well as a Garmin etrex20 GPS. The whole process of the walks was also video taped by an experiementer behind the participants. All experiements were conducted in November 2015 under varying, but mostly fair weather conditions, mainly at around 10-15°C. None of the participants did report any uncomfortable feeling neither about the outdoor conditions nor the carrying of the devices.

Also, the participants were familiar with the campus before the experiment for several years. The route and walkways were known to all participants. Influences on biosensors, e.g. stress levels, for orientation purposes can therefore be crossed out at this point. Interviews after the experiment confirmed that no participant had any difficulties with the route itself or for orientation during the walk.

All together, 12 datasets were collected from all walks, some of which could not be further analysed, due to lost signals on certain indicators during the run. In the end of the first mapping, 9 datasets could be used for further analysis.

5.3 Data analysis

Before analysing biosensor data, several processes need to be untertaken to make datasets readable and usable for the project's purpose.

In a first step, collected data indicators were avereaged from their individual sample rate to a comparable level of 1 second each. This enables the biosensor data to be synchronized with 1 second interval GPS tracks. The average rates are still consistent and depict data in appropriate precision for the project purpose. However, not all biosensors are possible to be averaged at this stage properly. ECG, EMG and EEG data were recorded on several different frequency channels (see Tab. 1), which need resampling and filtering afterwards.

Biosensor	Channel	Indicator	Sample Rate	Criteria
ECG	A: ECG	ECG	1024	-
	A: ECG HR (smoothed)	Heart Rate	1024	Valence
	A: ECG LF Total Power	In (LF/HF)	16	Arousal
	A: ECG HF Total Power	In (LF/HF)	16	Arousal
	A: ECG HR mean (bpm)	Heart Rate	1024	Valence
	A: ECG peak freq. mean (Hz)	Heart Rate	16	Valence
	A: ECG LF/HF (means)	In (LF/HF)	16	Arousal
EEG	C: EEG ERP N400~700	EEG	256	-
EMG (facial expression muscle)	D: EMG	EMG	256	Valence
	D: EMG mean (uV)	EMG	256	Valence
Skin Conductance	E: Skin Cond	Skin Conductance	256	Arousal
	E: Skin Cond mean (uS)	Skin Conductance	256	Arousal
Skin Temperature	F: Temp	Skin Temperature	256	Arousal
Respiration	G: Abd Resp	Abdominal Respiration	256	Arousal

Tab. 1: Defined and measured channels for the initial case study

EEG datasets were resampled to 256 per second in order be to synchronized with other physilogical data. All raw datasets were prepocessed via BioGraph Infiniti V6.0.4., the software coming with the Infinity device. In-depth filtiering and denosing preprocessing for certain indicators were conducted using Matlab.

After preprocessing, indicators, such as ECG LF & HF Channels, were smoothed and averaged to the GPS sampling rate at one per second. Spatial data then was synchronized with physiological data using the 1-second time stamp.

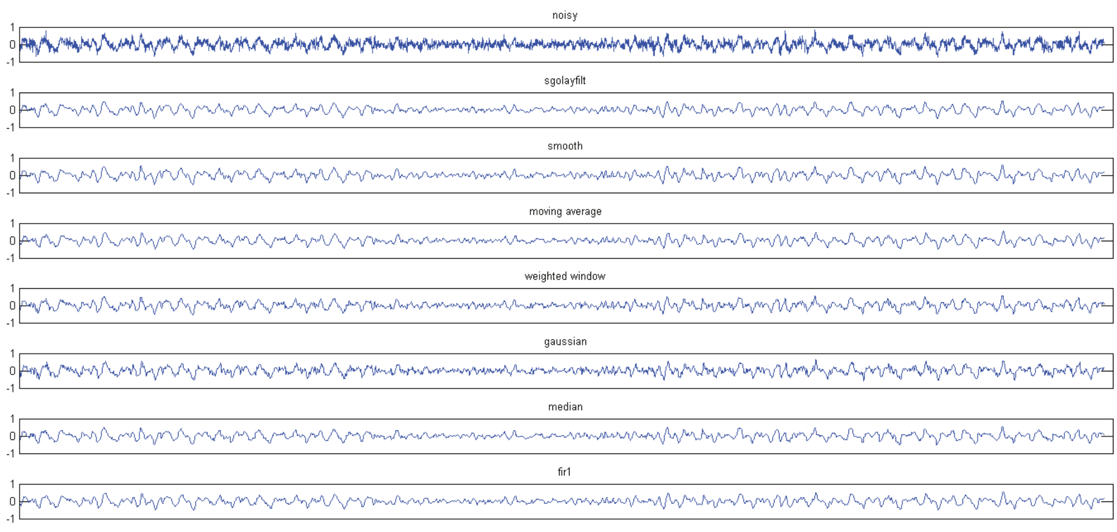

Fig. 4: Denoising of raw ECG data using different methods (a 30-sec sample from data was used to depict the denoising process)

At the time stamp interval, physiological indicators were able to be linked to locations on each GPS route. Based on the findings of Lang et al. 1993 and Lang 1995, certain indicators can depict the two relevant criteria:

- “affective arousal”, indicating biphasic levels of stress (calm/neutral vs. aroused)
- “affective valence”, indicating biphasic valence of emotional reactions (unpleasant vs. pleasant)

For locating arousal and valence in data channels, focus will be put on the change rates of single indicators and their relationship to each other. The correlated increases or decreases for arousal and valence indicators show the emotional responses of either pleasant or unpleasant feelings of the participants. After thorough analysis of the usable datasets of each walk and each participant, they were depicted via the time- and GPS-stamp in a GIS-based heat map (see Fig. 5).

According to this map, seven meaningful hot spots for emotional responses could be indentified alongside the route, three of which with unpleasant and three with mostly pleasant emotional responses. A seventh hot spot (7, see Fig. 5) depicts both a negative response followed by stronger positive responses. This can be explained by the change of environments, as participants walked first in between parked cars and two buildings and after the left turn continued to walk adjacent to a park.

For all identified hot spots, unpleasant emotions show comparably higher magnitudes than pleasant ones. Along the route, further minor responses can be found, both for positive and negative responses, which after viewing video records and interviews can be linked to occasional interactions or in some cases be the result of visual perception, as interviews showed.

To confirm the initial questions of this study (see chapter 4), as expected, unpleasant emotional responses are typically located at spots of high traffic or traffic-related interactions (road crossings, parking lots), while positive emotions or pleasant reactions can be found in rather calm areas along the route.

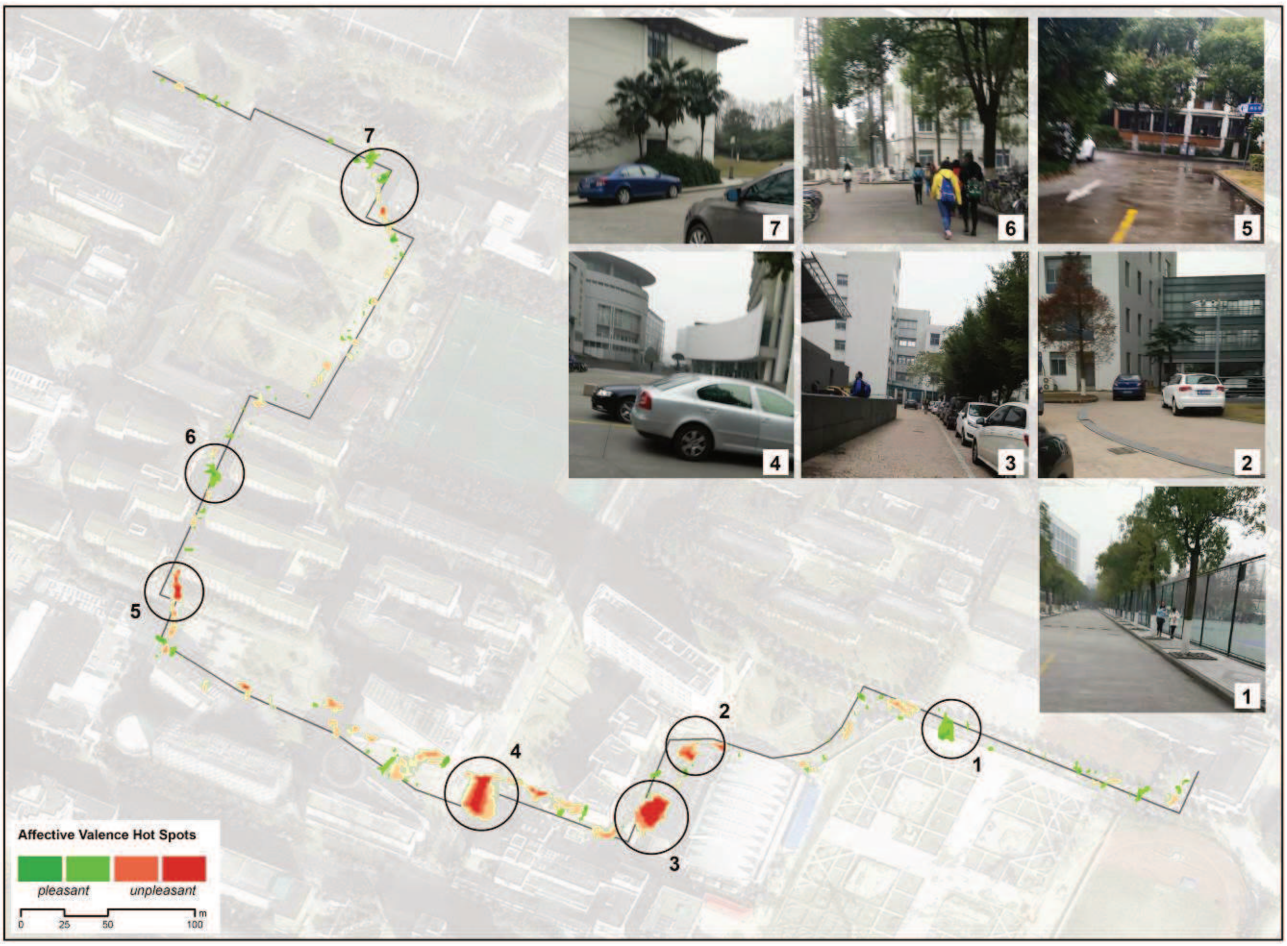

Fig. 5: Affective Valence Heat Map with captured hot spots of pleasant and unpleasant affectiveness and snapshots of the typical views

In comparison with the stated narratives of each participant though, certain spots surprisingly did not match with measured biosensors. Almost all participants named zones 3 and 5 (see Fig. 3) as the most unpleasant, especially from a visual or design point of view. On the opposite side, zones 1, 7 and 8 were named as the most pleasant, both for walkability and visual aesthetics. The measured results depicted in the heat map though, do not confirm strong feelings or emotional responses at all allegedly unpleasant or pleasant locations. Zone 5 on the one hand, was stated as the most negative visual perception by all participants, naming specifically the rather dark walkway in between tall and grey buildings. In data rows and hot spot analysis, slightly unpleasant emotions can be verified, but not to an extend, which would be comparable to other unpleasant hot spots linked to interactions and traffic.

Similar to these findings, zone 7, which was judged as the area with most positive visual aesthetics by the participants, does not show significant impacts on pleasant emotional responses. Minor magnitudes exist after hot spot analysis, but do not correlate with the identified hot spots (1, 6 and 7) and stated narratives.

The results of this initial case study indicate that emotional responses towards urban environments are more likely impacted by interactions to a much larger magnitude than visual experiences. It has to be further evaluated, why in both cases, the visual perceptions seem to play a minor role in comparison with interactions and if there are other calculations needed for extracting visual perceptions from interactions.

A first possible answer can lie within the varying affective responsiveness of the participants towards aesthetics, as this conscious and unconscious judgement is highly individual, while responses towards traffic and interactions might trigger more consistent responses. Further tests and the introduction of virtual features and alterations of the urban environment (augmented reality) could help identifying the impact of visual aesthetics towards the magnitudes of multi-biosensory data.

6 CONCLUSION & OUTLOOK

The case study showed some first possibilites multisensory data analysis can have on the characters of urban spaces. However, many difficulties and challenges exist for proper data interpretation and application. First of all, the tested device produces data of varying quality under outdoor conditions and activities, which has to be reviewed in timeconsuming processes. The devices used in this study, are also not suitable for common data collections, therefore is this study not fully comparable to previous studies based on wristbands or wearables. Many obstacles remain for proper data collection and analysis.

Nevertheless, with the appropriate steps taken, multisensory data is able to not only identify stressors or – in case of urban space – locations with unpleasant emotional reactions, but can also depict possible positive connotations of the built environment. In the first case study presented in this paper, positive and negative triggers could be identified, even though they could not undoubtfully linked to visual perception, yet. There are several additional factors and influences to consider in open or urban environments, which might have a higher impact on emotional responses and biosensory data rather than visual perception.

At this stage of the project, it is crucial that further research has to be conducted in order to better understand the biosensors and their sensitivity towards urban environments and visual aesthetics. For further steps, the influence of visual perceptions on the well-being or stress reactions will be investigated. This also includes further experiments with alterations of existing sceneries by using augmented reality technologies. In addition, other biosensory devices will be tested to analyse and possibly verify the measured data used in this study.

Since technological development and ongoing enhancment of multi-biosensory devices persist, the findings of emotional responses towards environments and sceneries will gain importance and hold their share for designing more livable urban landscapes.

7 ACKNOWLEDGEMENTS

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