🏆 *reviewed paper*

Crowding Density in Urban Environment and its Effects on Emotional Responding of Pedestrians: Using Wearable Device Technology with Sensors Capturing Proximity as well as Psychophysiological Emotion Responses while Walking in the Street

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Keywords: stress, biometric sensor, psychophysiology, urban crowd density, restoration

1 INTRODUCTION

Worldwide urbanization in many areas leads to very high urban density livingconditions, for example, in Hong Kong, there are about 40,000 people per km2 (Berlin:4000 p/km2).

Beside many other factors of urban infrastructure, pollution, transportation congestion etc. high urban population density feeds in an urban environment which is characterized by large pedestrian crowding in streets. Peen, Schoevers et al. (2010) could show that mood disorders and anxiety disorders are more prevalent in urban than in rural areas. Furthermore, stress recovery is faster and more complete when people are exposed to videos of natural rather than urban environments (Ulrich, Simons et al. 1991).

As this might be a pervasive feature of shortening social distance and recurrent invasion to personal space, it seems to be prevalent risk high urban density. Tost (2015) underlined that mental health is impaired by shortening social distance and invasion to personal space as one main featureof high density urban environment, beside high level of socio-spatial complexity and heterogeneity. Cox, Houdmont et al. (2006) propose a model of the effects of high density. They suppose that high density leads to the perception of crowding which evokes an experience of stress. This stressful experience has a negative impact on individual and organizational health. As one of the moderators of the relation between high density and the perception of crowding they propose a lack of control over the situation, i.e. the ability to control the proximity to others which can reduce stress.

While the covariaton of crowd density and stress load seems quite obvious, only few studies can be found which examined this relationship with empirical data on an individual level. High density often leads to the perception of limited space which can also be called crowding (Walden and Forsyth 1981). In a crowded situation, people feel uncomfortable, stressed, tense, annoyed and frustrated. This is also physiologically measurable – crowded conditions are related to decreased skin resistance, increased respiratory rate and cortisol level, higher blood pressure and an overall increased stress-related arousal (Aiello, Nicosia et al. 1979, Walden and Forsyth 1981).

Aiello, Nicosia et al. (1979) point out that children are more competitive, more aggressive and less motivated under high density. According to them, the increased aggression might be a result of frustration and competition that occurs when resources are scarce which is more likely the more people are present.

For a deeper understanding of these findings the concept of personal space seems to be quite helpful.

According toSommer (1959), personal space is an area with invisible boundaries which is surrounding a person's body. Unlike a territory, personal space is not stationary, but rather carried around by the person whose body is building the center of this space. Wabnegger, Leutgeb et al. (2016) point out that personal space might be a phylogenetically acquired trait which has evolved throughout evolutionary history to prevent aggression within and between species or groups. Personal space usually determines interpersonal distance and its effects on psycho-physiological responses to varying distances.

In his Proxemic Theory, Hall (1966) distinguishes four different zones of interpersonal distance: intimate, personal, social and public distance (each with close and far phases). People seek to maintain these distances from other people to prevent unsolicited touch by strangers (Vine 1982) and they form the personal space. Entering sombody's personal space is usually a sign of familiarity or intimacy.

However, in urban high density living conditions, it can proof difficult to maintain everybody's personal space, for example when walking in a crowded street. This physical proximity and intrusion into personal space (especially the personal or intimate distance) by strangers are experienced as being uncomfortable anddisturbing by many people.When somebody intrudes into someone else's personal space the results are anxiety, stress, flight, aggression and negative mood (Allekian 1973, Efran and Cheyne 1974, Altman 1975, Smith and Knowles 1978, Kanaga and Flynn 1981).

Smith and Knowles (1978) could show in their study that short distances (i.e. personal space invasion) lead people to crossing the street faster and having more unpleasant, rude and aggressive impressions of the intruder than with long distances. Moreover, subjects were less likely to help another person recover a lost object after this person has been invading their personal space(Konečni, Libuser et al. 1975). Kaya and Erkip (1999)demonstrated in their study that people in the high-density condition showed more withdrawal behaviors than people in the low-density condition which indicates that they felt more intrusion into their personal space under the high-density condition because the interpersonal distance was shorter. Such withdrawal behaviors are a means to protect one's personal space in crowded situations. Examples are nonverbal behaviors like avoiding eye contact, increasing interpersonal distance and moving or turning away (Hall 1966, Demian 1978).

From this background it seems reasonable to assume that everyday walking in highly crowded streets means to experience a trajectory of mostly involuntary intrusions of the own and others' extrapersonal space causing momentary stress responses. But if assuming with Wabnegger, Leutgeb et al. (2016)that personal space is an evolutionary acquired disposition to respond emotionally when other people are crossing one's ambient space, it seems necessary to widen the scope of its efficacy by connecting to biopsychological findings of emotional responding. According biopsychological emotion theory (Panksepp 1982, Ekman 1992, Izard 1993, Panksepp and Watt 2011, Levenson 2014) there are separate basic appraisal-reaction sets, which developed as functional systems for survival in an evolutionary process (Izard 1993, LeDoux 1998, Levenson 2014). Even if there is no consensus of how many elementary or prototypical emotional systems there are, (see Von Scheve (2014) for an overview), it seems that fear, anger, sadness, joy, disgust and curiosity make the core of elementary emotional responses to internal and external stimuli (Turner, Doxa et al. 2001).

There seem to be also consensus, that the core mechanism evoking emotional response syndromes consists of a non-voluntary, continuous neural appraisal process of internal and external stimulation (Ortony and Turner 1990, Izard 1993, LeDoux 1998, Scherer 2001, Lang and Bradley 2010, Levenson 2014). According to a standard psychobiology textbook (N. Birbaumer and W. Jänig 2010) an emotional response is triggered by the outcome of neuro-affective appraisal process, with appraisal being an automatic, non-deliberate, namely non-conscious process (Zajonc 1980, N. Birbaumer and W. Jänig 2010), by which features of situational stimuli are matched with prototypes like danger, reward expectation, novelty and loss/separation.

This neural emotional reaction to stimuli then unfolds on several dimensions, namely as changes in physiological functions, in muscular-skeleto system (posture, gesture and facial expressions), as well as in motivational tendency and subjective feelings(Levenson 2003, Levenson 2014).

In sum, one can assume that walking and moving in higly crowded streets in high-density urban areas, which means to encounter people by crossing their personal space as well as having them crossed the own personal space will elicit emotional response in real-time, presumably aversive, but maybe also appetitive. We will examine this question by applying an unobtrusive wearable sensor technology capturing the flow of personal space intrusions by passive infradredbodysensorfusioned with psychophysiological signal data, by which emotional responses are identified in real-time on a second-by-second resolution. Our leading questions are: Does random involuntary crossing of personal space while walking in crowded streets evoke emotional responses? Does the trajectory of personal space crossings and their accumulation have an impact on short term psychological attentional impairment respectively restorative need?

2 DATA AND METHOD

2.1 Sample

The subjects (n=30, age mean= 24.77, age sd= 0.718) are Chinese people studying and living in Hong Kong, but no longer than 5 years. These people are relatively familiar with Hong Kong living surroundings but would still keep curiosity to the environment. Additionally, they have no heavy mental illness history, no symptom systemic sweating (secondary) and no experience of suffering from accident events in the past month.

2.2 Design

The study uses a within-subject and between-subject measurement design. Subjects weretold to walk a selected route consisting of two parts: the district ofTsimShaTsui and Kowloon Park. TsimShaTsuidistrict is is a commercial center in Hong Kong with very high pedestrian density.

The sample was split into groups, with one group of subjects starting the route either by walking the park path first and then the street part. The other groups of subjects walked the same route but started street path first and then the park path.

All subjectscame to a predefined at meeting point, where body sensors were attached. Before starting the walk they went through a smartphone app with specifictests and questionnaires. After having walked the first route part (park path or street path), they return to meetingpoint a and repeated went through the smartphone app. After having walked the second part of the total route they again returned to the meeting point, where they went through the app questionnaire a third time.

At selected predefined spots, subjects were told to orient themselves in specific direction and then using the smartphone app to answer several questions about their subjective evaluation of the visible environment. At the end of the route walking socio-demographic information and general urban attitudes were collected by the smartphone app.

For city street part of the route at the four corners indicating begin of each street path, subjects were asked to suspend walking to experience the coming streetscape for ten seconds and answer the questionnaire in the mobile phone.

Group A			Group B		
Park	T(Pre-test)	• ***Skin Conductance*** • Questionnaire • Attention Blink test • Hearing test • Sound test	T(Pre-test)	• ***Skin Conductance*** • Questionnaire • Attention Blink test • Hearing test • Sound test	**City**
	1-2-3-4	• Experiencing • Restorative Component Scale • Thermal Perception	5-6-7-8	• Skin Conductance • Experiencing • Restorative Component Scale • Thermal Perception	
Middle Test	T(Middle-test)	• ***Skin Conductance*** • Questionnaire • Attention Blink test • Hearing test • Sound test	T(Middle-test)	• ***Skin Conductance*** • Questionnaire • Attention Blink test • Hearing test • Sound test	**Middle Test**
City	5-6-7-8	• ***Skin Conductance*** • Experiencing • Restorative Component Scale • Thermal Perception	1-2-3-4	• ***Skin Conductance*** • Experiencing • Restorative Component Scale • Thermal Perception	**Park**
	T (Post-test)	• ***Skin Conductance*** • Questionnaire • Attention Blink test • Hearing test • Sound test	T (Post-test)	• ***Skin Conductance*** • Questionnaire • Attention Blink test • Hearing test • Sound test	

Table 1: Study Desing

2.3 Walking Path

The predefined urban street walking path is in TsimShaTsui, Hong Kong. TsimShaTsui is a famous commercial center in Hong Kong. In addition to a big shopping mall, there are lots of retails, restaurants and exhibition areas. Its pedestrian volume is huge every day.

The urban street path encompasses four roads: Nathan Rd (streetpath 1), Peking Rd (streetpath 2), Hankow Rd (streetpath 3) and Haiphong Rd (streetpath 4). These four roads are different from many perspectives. Nathan Rd is a city main road with four lanes separated by central isolation greening zone. Peking Rd has two lanes in same direction, without greening on any sides. An entrance of a shopping mall is on the right side of Peking Rd, which forms a big public space for people activity. The width of Hankow Rd is equal to two lanes, but utilization of one of them is parking, and the other side planted with street trees. Haiphong Rd

ISBN 978-3-9504173-4-0 (CD), 978-3-9504173-5-7 (print)
Editors: M. SCHRENK, V. V. POPOVICH, P. ZEILE, P. ELISEI, C. BEYER, G. NAVRATIL

located between the city part and the man-made park, therefore, old and tall trees in the park could be observed on Haiphong Rd.

Figure 1: Map of walking route with 4 street paths

Data collection was conducted during April 2017. On each experimental day, two to four subjects were asked to experience the predefined city walking path around mid-noon separately. The instructor gave the basic experimental introduction to the subjects at the meeting place whose location is near the man-made park.

2.4 Psychophysiological signals and emotion responses

The smart-band which was used in this study was developed by the company Bodymonitor, a spin-off from Gesis Leibniz Institute for the Social Sciences, as tool to measure peripheral body signals like electrodermal activity and skin temperature as indicators of primary emotional responses like stress and interest.

Figure 2: sensor wristband

The sensor wristband captures and saves locally skin conductivity and skin temperature at a rate of 10 HZ with 10 Bit resolution. Besides these psycho-physiological informative parameters, skin contact quality as well as ambient temperature are measured simultaneously. This enables the detection of crucial artefacts in skin conductivity and skin temperature caused by changing contact quality of skin and transducers.

Validity of capturing electrodermal arousal was confirmed by experimental research (Papastefanou 2013), as well as by several field studies (Hogertz 2010, Bergner et al. 2011, Bergner et al. 2013, Hijazi et al. 2016, Steinitz et al. 2014).

The sensor wristband comes with a classification algorithm, which was developed by Papastefanou (2016) from the background of the biopsychological framework of emotion described above. In this framework of basic emotions(Ekman 1992, Levenson 2003)physiological responses are seen as a central dimension in manifestation of neuro-affective appraisal of stimuli.Levenson, Carstensen et al. (1991) and atmostKreibig's (2010, 2014) review have shown that specific emotional states are correlated with specific physiological arousal reflected in peripheral parameters like skin conductivity, skin temperature, heart rate variability. This means that a kind of elementar valence (aversive vs. appetitive) of physiological emotion responding can be identified.

EDA based emotion response type	„feelings" connotations
appetitive arousal „orientation, surprise, expecting reward"	joy, curiosity, suprise, newness
aversive arousal („Flight-Fight-Response, expecting loss")	fear, anger, tension, stress, discomfort
Balance	Vigilance, well-being, hedonic pleasure
Retraction	Shut-off, dis-interested, mental witdrawal, tired, deeply relaxed

Table 2: typology of aversive and appetitive EDA emotions

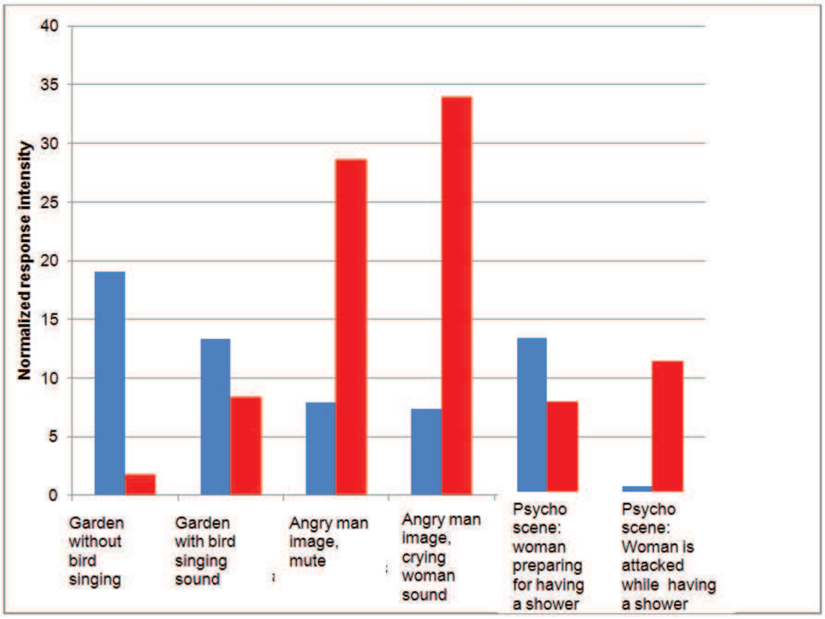

Figure 3: Intensity of aversive and appetitive EDA-response by ground truth emotion induction stimuli. Notes: Blue denotes appetitive responses, red denots aversive responses, n=30, own calculations.

Rainville, Bechara et al. (2006)report that basic emotions like anger, fear, happiness and sadness are also associated with distinct patterns of physiological changes.

From these studies electrodermal activity (EDA, also known as galvanic skin response GSR or skin conductivity) seems to be the most simple and effective indicator of emotional arousal. Electrodermal activity reflects directly sweat gland activity, which is directly enervated by neural signals of sympathicus nervous systems, while sympathicus nervous excitation is closely connected to brain structures of neuro-affective negative (avoidance) or positive (approach) appraisal (Boucsein 1995, Boucsein and Backs 2009). While it is experimentally verified by (Setz, Arnrich et al. 2010) and (G. Papastefanou 2013), that EDA as a single parameter allows to identify stress reactions, Hijazi et al. (2016) also showed that EDA changes cleaned for artifacts and noise can be used validly for identifying emotional responses to aversive stimuli as

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well as emotional reactions to appetitive stimuli. For further corroboration we calculated mean response strength for aversive and appetitive responses to different audiovisual stimulation (based on images and sounds of the IAPS and IADS). Results in figure confirm once again, that

As this classification is based on signal data with a 10 Hz resolution, we finally get a database with moments of a 10th of a second as basic observation units. Thereby the whole data set is hierarchically level data set with subjects and their moments of time over the whole observation period. For each moment of time there is information available about the emotional class of a given arousal response. This data on emotion reaction occurrence can be used as binary (yes vs no occurrence) as well as metric information (momentary strength of the response).

2.5 Indicating crossing personal space by passive infrared sensor

In addition to psychophysiological sensors, by way of a hardware interface the sensor-band was extended by a motion infra-red sensor, whose technical design and body positioning allowed for detecting people crossing the personal space of walking subject at varying distances.

We used the slight motion type ofpassve infrared sensor by Panasonic (NaPiOn) designed to cover a wide area, to detect human presence in an ambient space of up to 2 m distance from sensor position (see figure). The sensor, rather than emitting light such as from LEDs, detects the amount of change in

infrared rays that occurs when a person (object), whose temperature is different from the surroundings, moves. 1. As this sensordetects temperature differences, it is well suited to detecting the motion of people by their body temperature (see figure below). The infrared sensor was positioned about the level of the subjects sternum. So the sensor responds with a signal, when a human body moves through the conical space area of the sensors sensitivity (figure).

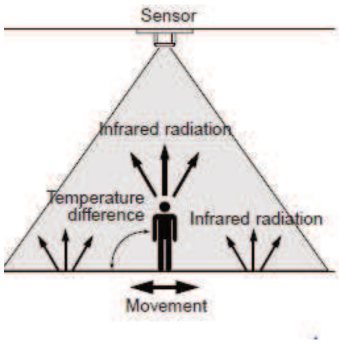

Figure 4: Movement detection mechanism by passive infrared sensor

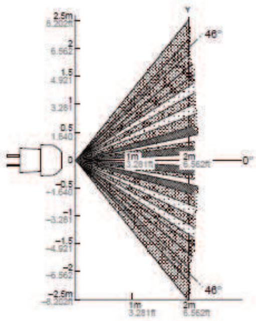

Figure 5: Detection sensitivity space of slight movement detection PIR

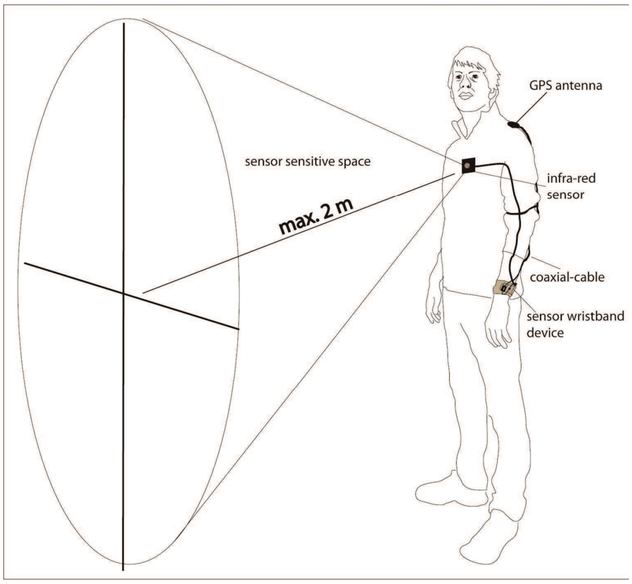

Figure 6: Sensors and wristband body positioning and indication of sensor-based person space

When human bodies moved through the sensor sensitive space, the sensor output a signal, which is stored locally in the wristband (along with signals of the other sensors). This signal was transformed into yes/no information for each moment of data collection. The data collection moments were given by 10 Hz recording, which means a 10th of a second. These moments are the units of observations in a hierarchically structured data set with subjects as top level.

2.6 Data set and statistical analysis

The data set is build up by psychophysiological as well as passive infrared motion sensor signals at a rate 10 Hz. So after emotion classification of electrodermal signals and motion detection signals, for each 10th of a second over the whole observation period of walking the urban street route, we reduced the data to binary information about occurrence of an emotional response as well as on occurrence of motion in the 2 m personal space.

As we are dealing with a hierarchically structured data set, we run multilevel statistical analysis by modeling the covariation of personal space movement as mixed regression model with random intercept. As EDA phasic responses typically show a bell curve shape over time, we choose the amplitude maximum as binary indicator of emotion response occurrence. For dealing with binary dependent variable we use the logit model. In this model binary information about moving through 2-m personal space is incorporated as independent variable. As we do not have information about distance of to persons entering the personal space we used as a proxy additional lagged information about personal space crossing. In an exploratory manner we included five lagged entery variables, namely in the moment simultaneously with emotional response, moments 1 second , 2 seconds, 3 seconds, 4 seconds and 5 seconds before. Finally, to control for accumulation of emotional responsivity over the street paths we included path duration information for each

3 RESULTS

3.1 Crossing personal space as crowd density indicator

When we look first on how much time subjects needed to walk down the pre-defined streets of the urban we find clear differences between the street paths, with street path 3 which subjects needed most time to walk down and street path 4 with least walking time (see table 3). This walking duration differences are due to physical length of the street paths as well their crowdedness.

Using the signal data of the motion sensor we find different frequencies of having had people crossing the personal space while walking the street path (see Table 4). Taking the ratio of mean number of person space crossing to the length of the street path (metres) we get an indicator of crowd density as being experienced by pedestrians walking through the streets. We see that streetpath 2 and streetpath 4 could be labeled as mostly crowded.

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citypath	mean duration in minutes	Physical length (meters)
streetpath 1	4.2	178
streetpath 2	4.8	96
streetpath 3	5.4	178
streetpath 4	3.5	96

Table 3: Mean duration of walking in different street paths

Urban streetpath	Mean number of personal space crossings	mean personal space crossings per meter
streetpath 1	36.4	0.20
streetpath 2	24.1	0.25
streetpath 3	38.8	0.22
streetpath 4	25.2	0.26

Table 4: mean number of personal space crossings while walking in different street paths

To analyze the relationship between personal space crossing and subsequent emotional responding while subjects walk in crowded streets we estimated the odds ratios of emotional response occurrence at each measured moment of time (namely a 10^{th} of a second), predicted by preceding occurrence of personal space crossing by other pedestrians. In table 5 results for aversive emotional responses are reported. We find for the model 1, which is based on data of the whole walking route, that subjects, who experience personal space crossings subsequently - namely in the next 2 seconds – will have an increased probability to elicite an aversive emotional response.

But obviously this holds true only for street paths 1 und 4. For street path 2 and street path 3 we do not find any significant effect of personal space crossing on subsequent emotional responding. Interestinglyin street path 1, the aversive emotional response occurs simultaneously with personal space crossing, whereas in street path an aversive response is elicited even 1 or 2 seconds after personal space crossing.

	Model 1	Model 2	Model 3	Model 4	Model 5
VARIABLES	Total route	Street path 1	Street path 2	Street path 3	Street path 4
Crossing Personal Space (PS) (no lag)	1.183***	1.351**	1.051	0.943	1.273*
	(0.077)	(0.169)	(0.153)	(0.115)	(0.171)
CrossingPS 1-second lag	1.139**	0.94	1.212	1.061	1.188
	(0.0751)	(0.133)	(0.168)	(0.125)	(0.163)
CrossingPS 2-second lag	1.146**	1.221	1.17	0.856	1.270*
	(0.0755)	(0.158)	(0.165)	(0.108)	(0.171)
CrossingPS 3-second lag	1.012	0.979	0.942	0.901	1.084
	(0.0696)	(0.136)	(0.143)	(0.112)	(0.153)
CrossingPS 4-second lag	1.04	1.182	0.951	0.81	1.128
	(0.0708)	(0.155)	(0.145)	(0.104)	(0.157)
CrossingPS 5-second lag	1.093	1.057	0.913	1.027	1.178
	(0.0732)	(0.143)	(0.141)	(0.121)	(0.162

Subjects variation	1.200***	1.629***	1.275***	1.296***	1.220***
	(0.057)	(0.211	(0.082)	(0.0883)	(0.0648)
Constant	0.0752***	0.0754***	0.0604***	0.0669***	0.0669***
	(0.00593)	(0.00983)	(0.00568)	(0.00643)	(0.00577)
Observations	287,641	54,941	80,790	93,140	58,740
Numberofsubjects	30	30	30	30	30

Table 5: Effects of crossing personal space on occurrence of aversive emotional response while walking in urban street paths (odds ratios, mixed effects logit models). Notes: SE of logit coefficients in parentheses, models controlled for momentary duration of path. *** p<0.01, ** p<0.05, * p<0.1

Crossing one's personal space means that people are getting aware, that other people are getting close to oneself, so out of the crowd they got specific attention attention as thei approach. Finding in table 10 show, subjects automatically respond with aversive arousal. But from a theoretical point of emotional responding, approaching people, who get close by crossing the personalspace, might also elicit an response of curiosity or interest, generally appetitive. As we have also data available about non-aversive, appetitive responses we can examine, if person space crossing also triggers appetitive responses. In table 6 results are reported for the whole route (model 1) and for the four street paths separately (models 2 -5).

For the whole route moments we find no significant relationship between crossing personal space and appetitive responding. This seems due to heterogeneity between the street paths. Namely, we find a significant effect of personal space crossing on appetitive response when walking in street path 1 or in street path 2, but not in street paths 3 or 4. For streetpath 2 we even find a prolonged effect of personal space crossing up to second 3 after crossing. This lag effect means, that as people come closer to the subject they even got more interesting. For streetpath 1 we find a significant increased appetitive response probability at those moments when others a crossing personal space.

VARIABLES	Appetitive response Total route	Appetitive response Street path 1	Appetitive response Street path 2	Appetitive response Street path 3	Appetitive response Street path 4
Crossing Personal Space (PS) (no lag)	1.061	1.287*	1.428***	0.818	0.848
	(0.0784)	(0.18)	(0.196)	(0.12)	(0.155)
Crossing PS 1-second lag	0.979	0.972	0.947	1.074	0.934
	(0.0746)	(0.151)	(0.151)	(0.141)	(0.164)
Crossing PS 2-second lag	1.104	0.953	1.314*	1.182	0.995
	(0.0804)	(0.15)	(0.186)	(0.149)	(0.17)
Crossing PS 3-second lag	1.05	0.86	1.371**	1.087	0.93
	(0.078)	(0.141)	(0.191)	(0.142	(0.163)
Crossing PS 4-second lag	1.033	1.134	1.111	0.995	0.952
	(0.0771)	(0.167)	(0.168)	(0.134)	(0.165)
Crossing PS 5-second lag	0.860*	0.699**	0.85	0.897	1.075
	(0.0691)	(0.125)	(0.143)	(0.126)	(0.178)

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Subjects variation	1.086***	1.129***	1.423***	1.104***	1.158***
	(0.0237)	(0.0392)	(0.14)	(0.0301)	(0.0477)
Constant	0.0838***	0.0857***	0.0694***	0.0751***	0.102***
	(0.00451)	(0.00585)	(0.00775)	(0.00468)	(0.00763)
Observations	287,641	54,941	80,790	93,140	58,740
Numberofsubjects	30	30	30	30	30

Table 6: Effects of crossing personal space on occurrence of aversive emotional response while walking in urban street paths (odds ratios, mixed effects logit models). Notes: SE of logit coefficients in parentheses, models controlled for momentary duration of path. *** p<0.01, ** p<0.05, * p<0.1

4 DISCUSSION AND CONCLUSIONS

From the background that personal space seems to be an important concept for understanding emotional dynamics in crowded streets, we first time used a sensor device to indicate dynamically personal space of subjects walking in an urban street. Personal space operationally is thereby defined as the sensitivity area of a passive infrared sensor for slight motions with max. 2 m distance from the subject. Crossing this sensitive area means that somebody gets into or close the subjective personal space. Our findings show that this sensor approach is feasible and provides meaningful results: it can be used to calculate an indicator of experienced crowd density. Difference of experienced crowd density ratio between the different street paths of the test route is a preliminary result which support its validity.

We further examined the relationship between personal space crossings – indicated by signals of motion in an area distance of 2 m or less – emotional responding. We find significant effects of personal space crossing on aversive and appetitive emotional responses, based on EDA arousal classification. This means that walking in crowded streets as they are typical for a business district like TsimShaTsui, leads to a series of involuntary personal space crossing, which then evokes aversive emotions, as assumed by proximity theory. But finding that personal space crossing also leads to appetitive emotional response points to some neglected aspect of the functioning of personal space: namely its meaning as area/space which defines the subjective relevance of encountering other people by chance. When people come close into one's ambient personal space arousal processes start and lead to aversive responses but also to appetitive response. Obviously the urban context plays a significant role to when an occurrence of personal space crossing is emotionally evaluated as negative or positive (in the meaning of interest).

By the present analysis we can not uncover the specific aspect of the different street paths of the test route, to make personal space crossing eliciting aversive or appetitive responses.

But as the data of the Hong Kong study also measured geo-position on a second-by-second level, a further step in analyzing urban antecedents of personal space emotion effect could be done. Dynamic geo-position data of longitude and latitude can be used to operationally define small urban spatial segments of walking in the street. Then the relationship between personal space crossings and emotional response could be examined for specific street segments and their urban structural characteristics.

Showing that personal space can be validly be measured by body sensors, opens up further analyses about how moving in crowded streets elicits emotional responses, whose accumulation over the path walked might add to what people finally feel as stress load in high density urban areas. As data on psychological outcomes after having walked in urban streets are available by the Hong Kong study, an another analysis can focus on how over the sequence of involuntary and non-controllable aversive reactions they do accumulate and determine subjective feelings of reduced attention performance and heightened stress load.

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