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# Human exposure to environmental health concern by types of urban environment: The case of Tel Aviv

Izhak Schnell [a], Oded Potchter [a, b, *], Yaron Yaakov [a], Yoram Epstein [c]

[a] Department of Geography and Human Environment, Tel Aviv University, Tel Aviv, Israel
[b] Department of Geography, Beit Berl Academic College, Beit Berl, Israel
[c] Heller Institute of Medical Research, Sheba Medical Center, Tel Hashomer and The Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel

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ABSTRACT

This study classifies urban environments into types characterized by different exposure to environmental risk factors measured by general sense of discomfort and Heart Rate Variability (HRV). We hypothesize that a set of environmental factors (micro-climatic, CO, noise and individual heart rate) that were measured simultaneously in random locations can provide a better understanding of the distribution of human exposure to environmental loads throughout the urban space than results calculated based on measurements from close fixed stations. We measured micro-climatic and thermal load, CO and noise, individual Heart Rate, Subjective Social Load and Sense of Discomfort (SD) were tested by questionnaire survey.

The results demonstrate significant differences in exposure to environmental factors among 8 types of urban environments. It appears that noise and social load are the more significant environmental factors to enhance health risks and general sense of discomfort.



## 1. Introduction

Over the last decade the combined effects of a set of environmental factors on subjective sense of discomfort and health concern have received growing research attention, given mounting awareness of the risks posed by urban heat islands, concentrations of air pollution, noise, visual and social loads, and similar phenomena (Ulrich et al., 1991b; Peschardt and Stigsdotter, 2013). Studies in this field tend to define as dependent variables either their subjects' accounts of subjective sense of discomfort (SD) (Toftum, 2002; Fang et al., 2004; Schnell et al., 2012) or physiological indices such as Heart Rate Variability (HRV) (Schnell et al., 2013), Salivary Cortisol (Van den Berg and Custers, 2011) and cognitive tests (Kaplan, 1995).

Most studies have focused on the effects of one or two environmental factors on health. Several studies focused on the effects of thermal loads and noise on subjective sense of discomfort (Epstein et al., 2000; Toftum, 2002; Pellerin and Candas, 2004; Candas and Dufour, 2005). Other studies have focused on the effects of thermal load and air pollution on subjective sense of discomfort (Poupkou et al., 2011). Recently, more comprehensive studies are considering four factors (CO, thermal load, social load and noise) (Schnell et al., 2012, 2013). While most studies focused on the effects of environmental factors on subjective sense of discomfort, a growing number of studies measure the effects of environmental factors on HRV (Sawasaki et al., 2001; Kurosawa et al., 2007; Bjor et al., 2007; Liu et al., 2008; Rashid and Zimring, 2008; Schnell et al., 2013). All of the studies noted above found significant effects of all these environmental factors on risk for health and subjective sense of discomfort.

In studying variations in concentrations of environmental risk factors within indoor and outdoor urban types of environments, most studies use mathematical models based on measurements extracted from a small number of fixed climatic monitoring stations distributed around the city and extrapolations of these results based on few factors like distance from pollution sources, volume of risk at the source and intervening variables that affect patterns of distribution like wind direction and velocity, urban morphology, etc (Gu et al., 2011; Sun et al., 2012). Such models are vulnerable to several critiques. First, numerous studies show that monitoring stations located in cities tend to underestimate concentrations of

* Corresponding author. Department of Geography and Human Environment, Tel Aviv University, Tel Aviv, Israel.
*E-mail address:* potchter@post.tau.ac.il (O. Potchter).

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pollutants to which residents are exposed in practice (Duci et al., 2003; Gullver and Briggs, 2003; Kaur et al., 2005; Potchter et al., 2014). Second, studies show that the pollutant distribution patterns in urban spaces are highly complex, to an extent that makes it difficult to accurately model them (Zwack et al., 2011). Third, using data from fixed outdoor monitoring stations does not enable comparison between indoor and outdoor environments.

Previous studies have focused on the differences in subjective sense of discomfort and health risks that different types of environments pose. Such studies aim to expose the environmental risk factors in inner city environments while highlighting the restorative power of green areas (Ulrich et al., 1991a; Kaplan, 1995; Kaplan and Kaplan, 1989; Hartig et al., 2001; Parsons et al., 1998; Korpela et al., 2008; Staats et al., 2008). However, they suffer from three major shortages. First, they focus almost exclusively on the contrast between the busiest central urban environments and the green environments at cities' outskirts, ignoring the 'mid-urban' environments in which most people reside and act. We study diverse human exposures to environmetal discomforts and health risks in different types of urban environments. Second, since other studies measure exposure to environmental discomforts and health risks without controlling the concentrations of environmental risk factors in the measured sites, we added simultaneous measurements of environmental risk factors (thermal load, air pollution, noise and social load) that might affect the subjective sense of discomfort and health risk. Third, no agreed upon measurements or associations exist between subjective sense of discomfort and HRV; former studies tend to apply the more frequently used measures, with the exception of Park et al. (2010) and Schnell et al. (2013), which show discrepancies among the results for subjective psychological and physiological measurements. We suggest comparing the results for both subjective sense of discomfort and HRV and exposing the causes for differences between them.

Schnell et al. (2012; 2013) offered a new methodology to monitor the effects of a set of environmental factors on subjective sense of discomfort and health, by HRV. In these studies, individuals' exposure to environmental variables such as noise, CO and micro climate as well as individuals' heart pulse rates were monitored by mobile micro-sensors carried on the subjects' bodies while they were performing their daily life in the city. This quantitative assessment was followed by questionnaires assessing the subjects' social loads and subjective senses of discomfort.

This study aims to classify urban environments in which measurements were taken into types characterized by different combinations of exposure to environmental risk factors and to measure average levels of subjective sence of discomfort and HRV produced in each of these types of environments. We hypothesize that a set of measurements taken by the same individuals in different types of urban environments in a random way can provide a better understanding of the distribution of human exposure to environmental risk factors throughout the urban space than results calculated based on measurements from close fixed stations.

## 2. Research methods

### 2.1. Methodological approach

This study adopts an urban ecological approach based on three domains: 1. Spaces investigated: urban environments that are frequented by those ascribing to the young 'Urbanite' socio-spatial lifestyle. 2. Independent variables: exposure to noise, CO, thermal load and social stress as a set of environmental factors. 3. Dependent variables: HRV and subjective sense of discomfort (SD) as the results of this set of environmental factors. These independent variables were chosen since the human body responds immediately to these factors and this response can be seen in the heart rate variability (Schnell et al., 2013).

### 2.2. Study area

The study was conducted in the city of Tel Aviv, Israel, located at 32°06′ N 34°47′ E, situated along the eastern coast of the Mediterranean Sea. The climate of Tel Aviv is defined as Subtropical Mediterranean, Csa according to the Köppen classification (Potchter and Saaroni, 1998), characterized by a mild, wet winter and a hot, humid, summer (Bitan and Rubin, 1994).

Tel Aviv, the core of the largest metropolis of Israel, with population of 3.46 million, has a population of 414,600 (Statistical Abstract, 2012).Tel Aviv is a modern city that passes an accelerating growth over the last 100 years, demonstrates the activity phenomenon that characterizes any modern city.

### 2.3. Research subjects and experimental course

Thirty-six subjects participated in the study (22 males and 14 females). The subjects were healthy people between the ages of 23 and 40, who avoided smoking throughout the course of the experiment and 72 h prior to the experiment. None of them were regular users of drugs and alcohol or any medication.

The subjects followed a pre-determined daily route starting from the university in northern Tel Aviv to Jaffa at the southern end of the city and back. Each experiment lasted for two sequential days, including six subjects following the same route. Two such experiments took place during the winter, two during the summer, one during the autumn and one during the spring. All 36 subjects followed the same route. Along the route, the subjects stopped at approximately 10 sites every day. The investigated sites included indoor sites such as shopping malls, student dormitories or apartments and pubs; as well as outdoor areas, including open markets, main streets, side streets and parks. Between the sites, participants used busses for longer distances and walking for shorter ones. The subjects spent about 45 min in each site; they spent at least 15 min at each site, adjusting, before measurements were taken (Fig. 1).

### 2.4. Measurements techniques of personal exposure to independent set of environmental factors

In order to evaluate the personal exposure to an independent set of environmental factors in the micro urban environment, four methods were used: (1) measurements of micro-climatic and micro-environmental variables, (2) calculations of thermal sensation, (3) calculation of Heart Rate Variability (HRV) and (4) a questionnaire survey.

Three fix environmental monitoring stations of the Israeli ministry of environmental protection are situated along the predetermined daily route and used as a background information data.

The subjects wore a suit with portable measuring equipment that measured in-situ climatic and environmental variables, using mobile micro-sensors that continuously measured noise and CO levels, as well as climatic variables. CO Levels were measured and recorded using the portable Drager Pac III logger with CO sensor once every 60 s throughout the experiment.

The instruments were calibrated both with 25 ppm CO calibration gas and fresh air before each experiment, and compared to CO data collected by one of the monitoring stations of the Israeli Ministry for Protection of the Environment. The correlation coefficient (R) was determined to be 0.79, with the Pac III more sensitive to immediate changes than the Ministry's recordings. Noise measurements were recorded with a Quest pro DL dosimeter ranging from 40 to 110 dB, with resolution of 0.1 dB. The noise sensors were