The effects of selected urban environments on the autonomic balance in the Elderly – A pilot study

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***Abstract*— A group of Elderly was asked to travel in four urban environments in order to test the effects of a set of four environmental factors: noise, social load, thermal load and CO on their heart rate variability. We asked whether out of home trips in urban any urban environment is recommended regardless in of the environmental conditions outside home. We show that elderly are mainly vulnerable to environmental factors such as social and noise loads that affect their levels of HRV regardless of the type of place they visit including urban parks on the one hand and central city environments on the other one. We find also that although elderly HRV responses are deteriorating with age and reduction in health conditions, it is still a useful indicator of stress and risk for health. Most important it appears that social loads are the main environmental factor influencing HRV. This confirms studies about the vulnerability of elderly to stereotyping and social risks in public spaces and it shows that such fears have physiological effects on the elderly.**

INTRODUCTION

The decrease in engagement with life outside home has been repeatedly demonstrated to be associated with increase in social isolation, and by thus, with negative effects on physical and mental health among the elderly (Nicolson, et al. 2012). The relationship between movement in out of home spaces, social contacts and health deterioration are reciprocal. On the one hand decline in physical functioning may lead to decrease in spatial mobility and increase in social isolation and on the other hand decline in social engagement and spatial mobility leads to deterioration in health (Avlund et al. 2002; Rosso et. al. 2013; Holwerda et al. 2014) Limitation on spatial mobility characterizes between one third and one half of the elderly over the age of 65 (Webber et al. 2010). Although the digital era increases possibilities for social interactions without any need for corporeal spatial mobility, corporeal movement has its own value and is important for the development and maintenance of social networks. Yet, this assertion needs further verification (North and Fiske, 2012; Nicholson et. al. 2012).

Most studies regard the elderly physical and psychological health responsible for deterioration in their spatial mobility (Baker et al. 2003; Nimrod, 2007). Increasing number of studies argue that spatial mobility among the elderly is highly determined by the interplay between elderly physical and mental capabilities and the characteristics of the environment (Gagliardi et. al. 2007). These ecological studies argue that discrepancies between limitations in spatial mobility and the environment may increase stress in the elderly (Kahana et al. 2003). However, there is a shortage in systematic studies that focus on the relationship between mobility in urban environments with different environmental conditions and elderly health. During the last decade several studies highlight the risks posed on elderly in urban environments. These studies focus on elderly exposure to physical barriers (Seamon, 1981), air pollution and thermal load (Schwartz, 2005; Park, et. al. 2005; Adar, 2007). Furthermore, these studies tend to focus on the effects of one or two environ mental factors on elderly mobility and not on the combined effects of major environmental factors. In addition, the impact of noise and social loads on elderly are rarely studied. The impact of social load is particularly important due to elderly vulnerability to being stereotyped or exposed to violence. Several studies expose the prejudices younger people develop towards the elderly deterring elderly from reaching out of home spaces. (Martens et al. 2004; Palmore, 2005; Cathalifaud et. al. 2008; Bodner and Lazar, 2011).

The majority of studies about the effects of human exposure to environmental factors on human stress measure stress in three alternative ways: 1. Subjective sense of discomfort (Fang et al, 2004). 2. Cognitive performance (Kaplan, 1995). 3. Physiological measure of the autonomic nervous system including heart rate variability (HRV) and at times also salivary Cortisol (Kurosawa, et al., 2007; Rashid and Zimrin, 2008; Van der Berg and Custers, 2011). Since stress affect the autonomic system a variety of human functions and physiological systems sub-served by this system are likely to be affected. A reliable measure of autonomic functions and consequently of the stress imposed on the organism is heart rate variability (HRV), (Liew, 2015; Jonsson, 2007). Therefore, HRV analysis and specifically Low frequencies-high frequencies ratio (LF/HF) facilitates an ongoing assessment and documentation of stress response in human beings.

Studies that focus on the elderly found that elderly who routinely visit urban parks are mentally and physically healthier (Hung and Crompton, 2006; Periera et. al. 2012) and live longer (Takano et. al. 2002). Empirical studies found that elderly who visited central city environments experienced significant increase in the levels of stress as assessed by HRV (Adar et al., 2007), while in contrast elderly who visited urban parks experienced significant reduction in stress levels (Maas et al., 2008; Barton and Pretty, 2010). Ren et al (2011) associate increase in stress as measured by HRV to increase in levels of heat load and Ozone and Schwartz et al. (2005) and park et al. (2005) link increased stress to increase in small particles dust and Ozone. The possible role of the perception of parks as relaxing environments as opposed to the improved environmental characteristics in parks has not been fully elucidated. We hypothesize that environmental characteristics and specifically parks effect on the reduction of noise and social load would mediate the effects of urban environments on experienced stress as measured by HRV. In the following study we examine to what extent changes in HRV are associated with different environmental conditions and sites in the elderly.

Studies on young and healthy subjects reveal similar results. In most of them the effects of environmental factors like noise, climatic load and air pollutants on HRV are measured (Ulrich et. al. 1991; Candas and Dufour, 2005; Liu et. al. 2008; Korpela et al. 2008; Poupkou et. al 2011; Kurosawa, et al., 2007; Rashid and Zimrin, 2008; Van der Berg and Custers, 2011; Schnell, 2013). Schnell et al. (2013) found that the higher levels of stress and risk for health in central Tel Aviv among young healthy adults are caused mainly by noise and social load while the restorative power of urban parks stems mainly from the reduction in levels of social load, noise, air pollution and heat load.

We hypothesized that the less hectic and noisy environments would be associated with improved heart rate variability, that this response would be mediated by the two environmental pollutants of noise and social load regardless of their sites.

Research Methods

The participants

We included 26 volunteers that have been recommended by the community center to participate in the study. They were between the ages of 68 and 95 with an average age of 85. Twenty one of them were women and the rest men. All participants demonstrated ability to follow directions, to fill in the questionnaires and to walk the half kilometer needed to cross the distance needed for the experiment without any special effort. Out of this group selected by the head of the community center, six were using medications potentially affecting the autonomic system due to hypertension or arrhythmia and thirteen were diagnosed to be diabetic. Neither of them had a clinical significant heart failure.

The locations

We have performed the study in four sites that represent different types of urban environments. The first site was the community day center that is located in a quiet site with a small garden in front of it. The second site was a busy main street with public transport. The third site was a four acre park with a small water stream at the center of the park. In the park there are many trees, flowers and grasses as well as sites for children and adult sport and sitting banks. The park was spacious. The fourth site was a side street with a two to three stories houses surrounded by green vegetations and trees in an area covering about 25% of the lot.

Procedure

We have defined four environmental factors as independent variables: Thermal load, CO, noise and social load, and two intervening variables: age and use of medication that potentially affect the autonomic nervous system. The dependent variable was the HRV low frequency / high frequency ratio (LF/HF) as a measure of Heart Rate Variability (HRV) reflecting autonomic balance (see instruments).

We have randomly divided the 26 volunteers into five subgroups. Each subgroup took the experiment on a different day. The five experiments took place during the mornings of spring 2015. They wore the devices one and a half hours prior to the experiment as an adjustment period. The measurements of CO, Noise and HRV were taken continuously but we extracted results for the last five minutes they have spent in each site. The elderly calmly walked from one site to the other for about 7-10 minutes and stayed while sitting in each site for thirty minutes. In each site they filed in also the short questionnaire for about three minutes. The researcher walked with them along the route recording any unusual event and taking care that the subjects will not enter into interactions with each other in a way that might affect the results.

Instruments

We measured HRV by Polar 810i device extracting RR for five artifacts free sequential accumulated minutes in each environment while the subjects rested at the site. We used the frequency domain analysis based on the proportion between low frequencies (0.04-0.15 Hz) and high frequencies (0.15-0.4 Hz). Low frequencies (LF) represent mainly sympathetic activity of the autonomic nervous system and high frequency (HF) represents parasympathetic activity. Normalized LF/HF ratios were automatically derived and used for the analysis. Increased ratio represents increased stress and vice versa. Artifacts were removed automatically from the analysis and the analysis was performed employing the Kubios software. Both frequency and time domain analysis were employed.

We measured noise with a Quest pro DL device in the ranges between 40 and 110 decibels. During the experiment we measured the noise the subjects were exposed to continuously

Dry and wet temperatures were measured using Fourier microlog (resolution 0.50c and 0.5%; accuracy 0.60c and 3%) calculating Zohar heat index (1980). Zohar index is simple to calculate and in a pretest comparing results to PET a correlation coefficient of R=0.89 was found.

We measured CO using a Drager Pac III after calibration but since most results were almost zero with few very low measurements above zero we have excluded CO from the analysis. Social load was calculated based on a question posed to the subjects at each site: 'To what extent you feel stressed or relaxed by the present of other people at your vicinity at this moment'. The answers were given on a colored scale from 1-100 with green representing relaxation and red stress. In addition, we recorded all the medications that the elderly have used during the test and a week prior to the test and those medications potentially affecting the autonomic nervous system were identified.

Analysis

Before analyzing results we tested the relevance of four intervening variables: age; well being; medication treatment; and diabetic disturbances. Since only age and use of medications were found to distinguish among elderly levels of HRV we included only them as intervening variables in the analysis. The distributions of the normalized results for each of the dependent, independent and intervening variables was first computed followed by analysis of bivariate correlation coefficients employing Pearson correlation .The correlations were employed to establish the degree of intra-subject and between locations stability of the autonomic responses. At the second stage we analyzed differences among sites in terms of the dependent and independent variables and at the third stage we applied a mixed model for the analysis of associations between the independent and the intervening variables and between the dependent variables LF, HF and LF/HF. Mixed models allowing for repeated measures were employed as we extracted for each subject two measurements in each site or 208 measurements in total (4 sites x 2 measurements per site x 26 subjects)

Results

The distributions (mean and SD) of the different HRV measurements are depicted in table one (Table 1). All measurements demonstrate variations in levels of HRV with pNN50 and LF/HF presenting particularly high standard deviations. Simple binary correlations among the different indices of HRV are relatively high (between 0.50-0.87) in a way that increases the reliability of the results.

Table 1: Total HRV distributions (Mean and standard deviation) HRV

HRV index	Mean	S.D.
SDNN	56.2	45.4
rMSSD	42.5	35.7
pNN50	14.6	21.7
LF/HF	2.3	3.1

Differences between the sites were found to be small with urban parks associated with relatively lower LF/HF values. Unexpectedly, city centers were associated with the second lowest levels of LF/HF whereas the community center for the elderly was associated with high LF/HF ratio (Table 2). However, none of these differences are significant according to paired sample variation analysis (t=0.5; Sig.=0.6).

Table 2: the distribution of mean and standard deviation LF/HF values by site

Site	Mean	S.D.
Elderly community center	2.6	3.2
City center	2.3	3.2
Urban park	2.0	2.5
Residential site	2.5	3.6
Total	2.3	2.1

The distributions of the noise measurements show that the environments in general were extremely noisy with 17dB higher in average from the standard of 65 dB (table 3).. Furthermore, deviations from the average were within one and a half standard deviation.

Levels of social load remained relatively low among the elderly with two third of the participants experiencing levels less than 23 on a scale between 1-100 and only few experiencing levels above 40. Thermal loads were low with average of 200c representing convenient climatic conditions and standard deviations have remained small.

In analyzing differences in levels of exposure to the selected environmental factors among the sites no differences were recorded in terms of Zohar heat index. In terms of noise the noisiest site was the Elderly community center with the central city site presenting the lowest level of noise. The researcher recorded that the main source of noise was human noise created by the subjects themselves and people they have interact with. In terms of subjective social load the Elderly community center was experienced as the most secure and relaxing environment with the park being second one. The other environments out of the community center and in particular the city center exposed the elderly to relatively high levels of social load.

Table 3: Mean and standard deviations of environmental factors as related to sites

Environ. factor Site	Noise in Dbs		Social load		Thermal ^{0c} load		CO_{ppm} concentration	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Elderly community center	87.7	7.0	3.4	11.9	20.1	2.4	0.0	0,0
Central city	80	11.6	9.6	26.0	20.0	2.5	0.23	0.4
Park	82	5.7	5.4	20.0	19.8	2.4	0.0	0,0
Residential	80.4	10.8	8.1	22.6	19.9	2,4	0,0	0,0
Total	82		7.0	16.0	20	2.4	0,06	0.2

Db, decibels

Mean differences among the sites were not significant with the exception of noise in which the elderly community center came out as the noisiest site while levels of noise in the park were as strong as in the other places out of the elderly community center. These mean differences were significant at the level of 0.05. No significant differences were calculated between diabetes and none-diabetes on both time and frequency domains measurements. However, significant differences were measured between age groups (Sig. between 0,02-0.05) and medicine takers (Sig. between 0.02-0.04). Therefore we add the two variables as intervening variables.

In calculating bivariate correlation coefficients among the variables it turned out that LF/HF was significantly correlated only with social load (r=.29; sig.=.0001) and with the two intervening variables of age (r=-.31; sig.=.0001) and medications (r=.28; sig=.0001) . Age affected negatively the autonomic balance, while medications that potentially affect the autonomic system appear to increase the parasympathetic tone. ..

Employing mixed models, including the three environmental factors: thermal and social loads and noise as well as the intervening variables of age and medications and the types of environment are depicted in Tales 4 and 5. Table 4 presents the results for time domain analyses highlighting the salient effect of noise on the elderly with increased levels of exposure to noise increasing stresses among the elderly. At the same time thermal loads were found to significantly affect the autonomic balance in the elderly. It is interesting that types of places do not add any explanation to the variability in time domain indices of HRV beyond the direct effects of noise and thermal load.

Table 4: A mixed model of the effects of the environmental factors on time domain measurements of HRV

Factor	SDNN		rMSSD	
	F	Sig.	F	Sig.
Noise	10.6	0.002	23.9	0.0001
Thermal	7.6	0.007	8.1	0.005
Social	0.26	0.61	1.5	0.23
Age	8.4	0.005	29.0	0.0001
Medication	0.8	0.38	7.9	0.006
Env. type	1.0	0.33	1.5	0.22

Table 5 presents the results for the frequency domain analyses highlighting the dominant effect of increase in exposure to social loads and noise on increases in stresses. In addition both age and use of medicines are affecting all measures of the frequency domain analyses. The effect of medication on frequency domain measurements is particularly strong. However, once again types of environments do not have any effect on HRV beyond their effects on the distribution of the environmental factors in them.

In comparing the results for time and frequency domain analyses it appears that noise is found significantly correlated with HRV in both time and frequency domain analyses. At the same time thermal load and social load are correlated with HRV as analyzed by time domain and frequency domain respectively.

Table 5: Mixed model for the effects of the environmental factors on frequency domain measures of HRV

Factor	HF		LF		LF/HF	
	F	Sig.	F	Sig.	F	Sig
Noise	7.5	0.008	7.6	0.008	6.5	0.013
Thermal	1.2	0.28	1.2	0.28	1.4	0.24
Social	11.8	0.001	12.1	0.001	13.4	0.001
Age	8.2	0.005	7.8	0.006	8.2	0.005
Medicine	18.3	0.0001	18.9	0.0001	19.9	0.0001
Env. type	0.85	0.36	0.89	0.40	1.1	0.3

The type of place does not add any significant contribution to the explained variance in LF/HF. Interactions among the independent variables have remained insignificant.

The studied environmental factors and the intervening variables predict 38 percent of the variability in levels of LF/HF. Twenty four percent are explained by age (8%) and the use of relevant medications (14 %) and 16 percent are explained by social load (11%) and noise (8%).

Discussion

Loneliness and isolation are major factors that lead to elderly deterioration and exhaustion (Nelson et al. 2007). Elderly are advised to reach out of home, to maintain their engagement in outer spaces and to associate with others (Nicolson et al. 2012). However, only limited attention is given to the environmental risks urban spaces pose on vulnerable populations like the elderly as mediated by the the effects of environmental factors such as noise, thermal and social loads. If at all, former studies on elderly exposure to risk for health in cities, focus either on the risk posed by heat waves on mortality or on the effects of air pollution on HRV (Devlin, et al. 2003; Decramer et al 2003; Schwartz, 2005; Park, et. al. 2005; Adar, 2007). We expend these studies to test also the effects of noise and social load on HRV in addition to thermal load and air pollution. The contribution of urban environments per se as opposed to uniquely associated potential pollutants to the sympatho-vagal balance, also have not been determined.

In our study values of LF/HF are relatively low in comparison to young healthy subjects tested in similar environments in Tel Aviv (Schnell et al. 2013). However, the rest of the measurements included in table 1 are about similar to those of the younger healthy people. This means that HRV effectively measures elderly responses to environmental risks for health. Some doubts may be raised concerning the effectiveness of HRV as measurements of environmental stress among elderly who use medicines that may affect the autonomous system.

Overall, it seems that the elderly were exposed to high levels of noise similar to the ones measured in a former study in Tel Aviv (Schnell et al. 2013). However they were exposed to 19 points lower levels of social load but high levels of standard deviations relative to the study in Tel Aviv (Schnell et al. 2013). It seems that the elderly were highly vulnerable to the studied environmental conditions. Their autonomous system responded even to slight increases in their exposure to any of the three studied environmental factors with social loads and noise presenting the dominant environmental factors affecting HRV.

The effect of social loads on elderly autonomous functioning is of particular interest. It confirms the vulnerability of elderly to social stereotyping, violence and alien responses by younger populations (Cathalifaud et. al. 2008; Bodner and Lazar, 2011). This study leads to the hypothesis that elderly stereotyping may have physiological effects on elderly autonomous functioning, a hypothesis that requires further studies in which the direct relations between stereotyping and HRV are tested.

Comparison between results for the analysis of time and frequency domains is worth mentioning. While in time domain analysis thermal load presented significant results in frequency domain analysis thermal load had no effect on levels of HRV. Opposite to it, while in frequency domain analysis social load had a significant effect on HRV in time domain no such associations were found. This result is probably related to the different sensitivities of each of these analysis methods. Time domain analysis expectedly reflects the short term responses while the frequency domain analysis reflects the longer term effects.

Over all, the results are comparable to the responses of young healthy subjects studied by Schnell and his associates (2013) in similar conditions in Tel Aviv. In that study noise and social load also were the dominant factors to predict HRV although in the study of the young healthy subjects in Tel Aviv the two environmental factors have been explaining much higher levels of variability in LF/HF. In addition, the elderly demonstrated higher levels of vulnerability to thermal loads with their autonomous system responding even to slight differences in levels of heat stress. Even differences of 3-40c led to significant increases in levels of SDNN and rMSSD. This is in contradiction to our study on young healthy subjects who did not respond to thermal load except for extreme situations of hot days in winter when their bodies were not adjusted to high temperature (Schnell et al. 2013).

Comparison between results for young subjects studied in Tel Aviv under about similar environmental conditions shows that fluctuations in values of LF/HF remain extremely low among elderly with mean value of 2.3 and S.D of 3.1 compared to mean values of 10.9 and S.D. of 10.8 among the young subjects (Schnell, et al. 2013). These results confirm evidences from various studies who show that aging may be associated with depressed responses to environmental effects as they are measured by HRV (Reardon and Malik, 2006; Almedia-Santos, 2016). However, our study shows that the elderly demonstrated sufficient levels of responsiveness to the environmental conditions they were exposed to including the various levels of noise, thermal and social loads. Despite low variability in levels of thermal load it significantly affected the level of SDNN and rMSSD the subjects have experienced.

Medications that are known to affect the autonomic system and are commonly prescribed to the elderly have tremendously reduced elderly responses to environmental loads. While the levels of LF/HF for medicated participants ranged between 0.6 to 5 the same results ranged between 0.6-20 for the not medicated participipnats. This finding also comes as no surprise. The suppressive effect of cardio tonic medications on the sympatho-vagal balance and particularly among the elderly has been repeatedly reported (Van Zyle et. al. 2008; Garakani, et. al. 2009).

The fact that site did not affect levels of LF/HF are also worth mentioning. On a first glance it seems to contradict many studies that show that busy urban environments increase levels of LF/HF and urban parks reduce levels of LF/HF among young and older people ((Ulrich et. al. 1991; Kurosawa, et al., 2007; Korpela et al. 2008; Van der Berg and Custers, 2011). In our study we found that the urban park had some restorative effect on the elderly but this effect was insignificant. On a second glance, the similar levels of LF/HF are associated with the similar distributions of noise, heat and social loads in the four environments. If compared with Schnell's et al (2013) study among young persons in Tel Aviv the significant differences in levels of LF/HF among busy urban and park sites were associated with significant differences in subjects' exposure to heat, noise and social loads (Schnell et al. 2015). This consistent trend points to the validity of HRV analysis in human subjects regardless of their age. . Furthermore, it means that the sites themselves have only marginal effects on the autonomic balance beyond their mediating effects of thermal, noise and social loads. This means also that the role of expectation to relax in parks as Kaplan (1995) suggests are of marginal relevance relative to the effects of the aforementioned environmental factors.

Despite the significant results of this study it suffers from some shortcomings. First, a volunteering bias should be expected and the possible exclusion of more vulnerable participant might have affected our results. Second, the need to select close sites to each other and to distance ourselves from high voltage electrical lines that distort the measurements of the heart bits, forced us to choose sites that did not present significant differences in exposure to the studied environmental factors. Third, we did not take the risk of taking the elderly to an outdoor trip in hot and cold thermal conditions and therefore, the differences related to sites has been possibly relatively small. It is not inconceivable that out of the city park would be associated with a different autonomic balance than that obtained within the city. Further studies based on a larger sample size, including sites with more diverse levels of environmental pollutions and a longer period of monitoring would lend support to our observations.

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