Effects of traffic noise and relaxation sounds on pedestrian walking speed

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Background. Exposure to noise in everyday urban life is considered to be an environmental stressor. A specific outcome of the reaction from environmental stress is a fast pace of life that also includes a faster pedestrian walking speed. There is a limited amount of experimental evidence that people tend to walk faster in an environment with dense traffic and traffic noise. On the other hand, listening to nature relaxation sounds may decrease actual walking speed. The present study examined an effect of listening to annoying acoustical stimuli (traffic noise) compared to relaxation sounds (forest birdsong) on walking speed in a real outdoor urban environment.

Methods. The participants (N=83) walked along an urban route of 1.8 km. The first part of the route was a street with driving cars, the second part was a dense oak alley that led out of the noisy street with traffic. There were three conditions in the experiment. The participants listened either to traffic noise or to forest birdsong; they walked without listening to any acoustical stimuli in the control condition. Their walking speed was measured for certain parts of the route. After completing their walk, participants were asked to describe their experience during the walk.

Results. A mixed ANOVA indicated a significant between-subjects main effect of the condition ($F_{2,160}$ = 14.80, p <.001, η2 = 0.16), significant within-subjects main effect of the section walked ($F_{2,320}$ = 103.28, p <.001, η2 = 0.39), and significant interaction between the section walked and direction of the walk ($F_{2,320}$ = 11.76, p <.001, η2 = 0.09). A post hoc test showed that participants listening to traffic noise walked significantly faster on the route than participants listening to forest birdsong sounds and participants in the control condition. Participants who listened to forest birdsong walked slightly faster than those under control condition; however, this difference was not significant. Analysis of the walk experience showed that participants who listened to forest birdsong during the walk liked the route more than those who listened to traffic sounds.

Conclusion. The study demonstrated that exposure to traffic noise led to an immediate increase in walking speed. It was also shown that exposure to noise may influence perception of an environment. The same environment may be more liked in the absence of noise or in the presence of relaxation sounds. The study also documented the positive effect of listening to various kinds of relaxation sounds while walking in an outdoor environment with traffic noise.

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Abstract

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Results. A mixed ANOVA indicated a significant between-subjects main effect of the condition ($F_{2,160} = 14.80$, $p < .001$, $\eta 2 = 0.16$), significant within-subjects main effect of the section walked ($F_{2,320} = 103.28$, $p < .001$, $\eta 2 = 0.39$), and significant interaction between the section walked and direction of the walk ($F_{2,320} = 11.76$, $p < .001$, $\eta 2 = 0.09$). A post hoc test showed that participants listening to traffic noise walked significantly faster on the route than participants listening to forest birdsong sounds and participants in the control condition. Participants who listened to forest birdsong walked slightly faster than those under control condition; however, this difference was not significant. Analysis of the walk experience showed that participants who listened to forest birdsong during the walk liked the route more than those who listened to traffic sounds.

Conclusion. The study demonstrated that exposure to traffic noise led to an immediate increase in walking speed. It was also shown that exposure to noise may influence perception of an environment. The same environment may be more liked in the absence of noise or in the presence of relaxation sounds. The study also documented the positive effect of listening to various kinds of relaxation sounds while walking in an outdoor environment with traffic noise.

Subjects Psychiatry and Psychology, Public Health
Keywords Noise exposure, Walking speed, Stress, Relaxation, Urban nature

Introduction

Negative health consequences of noise exposure have been studied frequently (e.g., Evans, Bullinger, & Hygge, 1998; Passchier-Vermeer & Passchier, 2000; Stansfeld, Haines, & Brown, 2000; Haines et al., 2001; Babisch, 2006). Exposure to noise in everyday urban life is considered an environmental stressor (Evans, 1984). One specific reaction to environmental stress is a fast pace of life, as defined several decades ago by Werner, Altman, and Oxley (1985, p. 14) to be the "relative rapidity or density of experiences, meanings, perceptions and activities". A fast pace of life also includes a faster pedestrian walking speed that may be a response to stimulatory overload and various urban stressors, including crowding and traffic noise (e.g., Bornstein & Bornstein, 1976). Some studies showed that people walk faster in large cities when compared to smaller towns (Levine & Norenzayan, 1999). More detailed analysis showed that people tend to walk faster in urban streets with dense traffic and traffic noise (Franěk, 2013) when compared to calmer streets. This suggests that the fast pedestrian walking pace may be a spontaneous reaction to traffic noise. The present study examined an effect on walking speed of listening to annoying acoustical stimuli (traffic noise) compared to relaxation sounds (forest birdsong) in a real outdoor environment.

Investigations of pedestrian walking speed documented the phenomenon of a fast pedestrian speed in main downtown areas, as well as the negative health consequences of the fast pace of life in large cities. A pioneering study by Bornstein and Bornstein (1976) reported high positive correlations between the walking speed of pedestrians and the size of the city. This finding repeatedly was supported in subsequent studies (Lowin et al., 1971; Walmsley & Lewis, 1989). There is also evidence that the faster pace of life in large cities is associated with a greater likelihood of heart attacks (e.g., Levine & Bartlett, 1984; Levine & Norenzayan, 1999). Levine, Lynch, and Lucia (1989) interpreted movement speed and the speed of other daily activities as being parallel to Type A behavior patterns (a potential risk factor for heart disease) and even suggested using the term "Type A city". More recently, Wiseman (2007) compared the walking speeds of inhabitants of 32 capital cities. Surprisingly, the walking speed in large cities increased by approximately 10% when compared with previous data found by Levine and Norenzayan (1999) in the early 1990s. Thus, a fast pace of life, including fast walking speed, in today's cities could represent a potential risk factor that may negatively affect the wellbeing and health of their dwellers.

Although some authors suggested (e.g., Bornstein & Bornstein, 1976) that traffic noise may be one factor that influences walking speed, this proposition has not been tested adequately. In our previous studies, we examined the effects of visual and acoustical environmental features of surrounding environments on walking speed (Franěk, 2013; Franěk & Režný, 2014; Franěk, van Noorden & Režný, 2014). It was observed that participants tended to walk significantly faster in sections without greenery and with more traffic, higher perceived noise, and more people than in sections with greenery and with less traffic, perceived noise, and fewer people. However, the effect of traffic noise was based only on the subjective estimation of acoustical characteristics of particular locations. Recently, Maculewicz, Erkut, and Serafin (2016) experimentally examined how sound characteristics for specific environments affect walking pace. The participants listened to sounds of a seashore, busy street, restaurant, and busy offices and simultaneously walked at their own preferred pace on an aerobic stepper. Their results indicated that sounds of

the seashore and restaurant provoked a significantly slower pace than sounds of streets and offices. The study documented not only the effect of traffic noise on walking pace but also showed that listening to nature sounds may result in a decrease in walking speed.

Although traffic noise may cause perceived stress, there are opposite studies that show a restorative effect from urban nature. Some research demonstrates that living in areas with large amounts of urban greenery or only exposing individuals to a natural environment either in a visual or acoustic form results in decreased stress. It is known that residents of neighborhoods with a greater percentage of greenery have lower chronic stress (e.g., Hartig et al., 2011; Nilsson & Berglund, 2006; Ward Thompson et al., 2012). Stress recovery, measured through a variety of physiologic measures, was more rapid in the group that viewed natural scenes compared to the group that viewed urban scenes (e.g., Ulrich et al., 1991). A large number of studies have documented that viewing surrogate nature (photographs, slides, paintings, window views, videos, and virtual computer-generated nature scenes) results in decreased stress, increased positive emotions and decreased negative emotions (e.g., Ulrich et al., 1991; Hartig et al., 1999; Ulrich et al., 2003; de Kort et al., 2006; Valtchanov et al., 2010; Brown et al., 2013; Valtchanov et al., 2010; Jiang et al., 2014; Felnhofer et al., 2015). In accordance with these findings, our recent study showed that the presentation of photographs of nature scenes prior to an outdoor walk decreased walking speed when contrasted to priming with photographs of shopping malls and a control condition without any priming (Franěk & Režný, 2017).

Although a large amount of studies examined the positive effect of viewing nature scenes, the effect of natural sound has been experimentally explored less substantially. It was confirmed that natural sounds tend to be evaluated as pleasant and support recovery, while technological sounds tend to be experienced as disturbing (e.g., Cerwén, Pedersen & Pálsdóttir, 2016). The exposure of natural sounds led to greater mood recovery after presentation to annoying stimuli in contrast to human-caused sounds (Alvarsson, Wiens & Nilsson, 2010; Annerstedt et al., 2013; Saadatmand et al., 2013; Benfield et al., 2014).

A further question is the interaction between the effects of greenery and environmental sounds. The results of several studies suggested that visions of nature from a window or easy access to nearby green areas may reduce the negative impact of traffic noises, which makes the sound be perceived as less annoying (e.g., Van Renterghem & Botteldooren, 2016; Gidlöf-Gunnarsson & Öhrström, 2017). Interestingly, Lee and Jeon (2014) showed that the noise from high speed train was estimated as less annoying if the sound was presented with a picture containing a higher percentage of natural features. Viollon, Lavandier, and Drake (2002) reported that birdsong and traffic noise were judged significantly more negatively where they were presented together with more urban visual scenes.

Moreover, congruency between a specific environment and sound also may play a role because people expect appearance of specific sounds in each environment, congruent with the physical features of the environment (e.g., Bruce & Davies, 2014). Brambilla and Maffei (2006) demonstrated that the level of annoyance is lower and acceptability is higher when the sound is more congruent with the listener's expectation. Jahncke, Eriksson, and Naula (2015) examined the combined effect of diverse acoustical stimuli (nature sounds, quiet broadband noise and office noise) and visual settings (office and urban nature environment) on perceived restoration.

They found that a picture of nature was more sensitive to the influence of auditory stimuli than an office picture.

The present study continues our previous investigations of pedestrian walking pace in a real outdoor urban environment (Franěk, 2013, Franěk & Režný, 2014, Franěk, van Noorden & Režný, 2014, Franěk & Režný, 2017). To systematically examine the effects of different environmental sounds on walking speed, we asked participants to listen either to traffic noise or to relaxation nature sounds while walking on an outdoor route. As previously demonstrated, certain features of the physical environment can also influence walking speed, namely, the presence or absence of urban greenery. People tend to walk slower in an environment with higher perceived natural characteristics (Franěk & Režný, 2014). It is yet to be determined whether particular environmental sounds (traffic noise vs. forest birdsong) may have the same effect on walking speed in different environmental settings, specifically on streets with traffic noise and a small amount of greenery or on a route with greenery without any noise.

The aim of the present study is to investigate the effect on walking speed of listening to diverse environmental sounds while walking in a real outdoor environment. It is supposed that listening to traffic noise increases walking speed, while listening to nature sounds decreases walking speed. Furthermore, the interaction between the effect of environmental features and sound will be examined.

Materials & Methods

Participants

Eighty-three undergraduates participated in the study. The students were young adults aged from 19 to 25 years (*M* age = 21.36 yr., *SD* = 1.48), with 48 men and 35 women. They were recruited from a range of fields of study (informatics, financial management, and tourism) at the University of Hradec Králové. They were compensated by partial course credit. Ethical approval for the experiment was obtained from the Department of Management at the University of Hradec Králové. The participants provided written informed consent in which they declared that they were voluntarily participating in the experiment and that they were informed about the experimental procedure.

Design

A between-subjects design was employed. Participants walked under three conditions: forest birdsong, traffic noise, and a control condition without hearing any sounds. The type of sound (forest birdsong, traffic noise, or no sound) and type of environment (seven sections of the route) were selected as the independent variables; walking speed was selected as the dependent variable.

Stimulus material

There were two conditions with diverse sounds; the participants did not listen to any sound under the control condition. A track with relaxation sounds or a track with traffic noise were selected as

the acoustical stimuli. The soundtrack from the video "Forest Birdsong - Relaxing Nature Sounds - Birds Chirping", available on YouTube (https://www.youtube.com/watch?v=Qm846KdZN_c), was selected as the relaxation sound. The track consists of the sound of birds singing (Nightingale, Blackbird, Chaffinch, Cuckoo and others) and a calm forest river. The soundtrack from the video "Hectic Kolkata (Calcutta) – India", available on YouTube (https://www.youtube.com/watch?v=IFc2KhKLiho), was selected as the traffic noise. The track contains traffic noise and noise from motorized vehicles, engine sounds, intense automobile horns, and human voices. The second track had to be modified because of its short length (9 minutes and 40 seconds), which did not correspond with the length of the participants' walk. The track was modified using the software Audacity to have the length of 38 minutes by repeating it four times in succession. Participants listened to the tracks, which were played on Nokia Lumia 520 with operating system Windows Phone 8.1, using Nokia Music application, version 3.10.822.0.

The sounds were listened to through lightweight Genius HS-M200C headphones. Sounds were adjusted to a comfortable level. For safety reasons, headphones did not entirely masked sounds from the outside. Participants walked without headphones in the control condition.

The participants were randomly assigned to a specific condition. There were 17 males and 14 females in the forest birdsong condition. In the traffic noise condition, there were 14 males and 12 females, and in the control condition, there were 17 males and 9 females.

Walking route

The walking route was a circuit in the central area of Hradec Králové. This city is located in the northeastern part of the Czech Republic and has approximately 100,000 inhabitants. The first part of the route was a street with driving cars; the second part was a dense oak alley that led out of the noisy street with traffic. To compare walking speed in different locations on the route, we chose seven sections to measure walking speed (see Table 1). The sections were selected to provide a direct route and avoid crossing an intersection or similar obstacles. The participants first went from the university building to the starting point of the route, which was located approximately 300 meters from the building. When they reached the end of section 7, they returned back and went along the same route in the opposite direction. The circuit from the starting point to the final point was 1.8 km.

Measurement of walking speed

The participants walked with a small video camera (i.e., a Sony Bloggie MHS-PM5K) on a belt around their waist (size 19 x 108 x 55 mm, weight 110 g). The environment, the participant's feet, and the participant's arms were captured through a fish eye lens. Each section of the route had its beginning and end clearly indicated by a line drawn with intense color on the sidewalk. An evaluator marked two frames of the video recording to create the beginning and end of the annotation for each particular track section. Each frame corresponded to a time when a participant entered or left the section. The evaluation procedure consisted of annotating the video recordings in the software *Elan* (see https://tla.mpi.nl/tools/tla-tools/elan/). Annotations included the name of the track section and were time aligned to the video recordings. Every annotation represented the entire section of the track, so that the extent of time subjects spent there could be

determined. This enabled us to calculate the average speed reached by the participants in all sections. The video recordings were processed by a team of research assistants.

Evaluation of walk experience

The participants rated their experience during their walk and their enjoyment of the environment using the following five items: (1) I was fine during the walk, (2) It was a pleasant time, (3) I liked the route I went through, (4) While walking, I often observed the surroundings, and (5) The sounds I listened to from my headphones bothered me. They were required to rate agreement or disagreement with these items using a 7-point Likert-type scale with anchors 1 = absolutely disagree and 7 = absolutely agree.

Procedure

The participants individually walked around the route. They were sent successively to the route in periods of five minutes. Participants were instructed to walk through the route with their normal walking speed. We used the description "normal" to discourage participants from walking as fast as possible to pass the route in the shortest possible time or, on the other hand, to move too slowly, such as walking for restorative purposes. Further, they were asked to not stop their walk and not call or speak with other people. The route was marked by noticeable orange arrows painted on the surface of a sidewalk to make orientation easier. Participants were asked to complete a questionnaire describing their evaluation of the walk experience after the walk. Participants were not informed about the goal of the study.

The study was conducted in 2017 on three workdays at the beginning of May. The grass along the route was already green, and the trees were light green with sparse foliage. The time schedule was balanced by gender and the conditions across day and time.

Data analysis

The walking speed was calculated for specific sections of the route. A mixed analysis of variance (ANOVA) was conducted to analyze the effects of acoustic conditions (birdsong, traffic noise, or control condition), the route's environmental properties (the section of the route), and the direction of the walk (from section 1 to section 7 or from section 7 to section 1) on the walking speeds in the specific sections. Because some sections on the walking route had similar environmental features and because participants walked in them at roughly same walking speed, we joined similar sections into three groups (i.e., sections 1+2 = group 1, sections 3+4 = group 2, sections 5+6+7 =group 3) to give the analyses more power to detect a significant interaction. The score for each group was the mean across included sections. Differences between reported evaluations of the walk experience under particular conditions were compared by using a one-way ANOVA or t-test for independent samples. Statistical analyses were conducted using the *Statistica 12* software (Stat Soft, Inc.).

Results

Analysis of walking speed

The results revealed an overall faster walking speed under the traffic noise condition (mean = 1.65 m/s, SD = 0.11) and a slower walking speed under the control condition (mean = 1.58 m/s, SD = 0.13); the slowest walking speed was under forest birdsong sounds (mean = 1.53 m/s, SD = 0.12). The average walking speeds in the particular sections of the route are shown in Figure 1 and Table 2.

A mixed ANOVA was conducted to access the effects on walking speed of the condition and direction of the walk on the route. The condition (forest birdsong, traffic noise, control condition) and direction of the walk (from section 1 to section 7 or from section 7 to section 1) were chosen as the categorical predictors; the section of the route (group 1 = sections 1+2, group 2 = sections 3+4, group 3 = sections 5+6+7) was chosen as the within-subject (repeat measures) factors. The speed of walking was used as the dependent variable. The ANOVA indicated a statistically significant between-subjects main effect of the condition ($F_{2,160} = 14.80$, $p < .001$, $\eta 2 = 0.16$), statistically significant within-subjects main effect of the section walked ($F_{2,320} = 103.28$, $p < .001$, $\eta 2 = 0.39$), and statistically significant interactions between the section walked and the direction of the walk ($F_{2,320} = 11.76$, $p < .001$, $\eta 2 = 0.09$). However, the interaction between the section walked and the condition was not significant ($F_{4,320} = 0.49$, $p = .741$).

A post hoc Tukey test showed that the participants listening to traffic noise walked significantly faster on the route than participants listening to forest birdsong sounds and that the participants listening to traffic noise walked significantly faster than participants in the control condition. Post hoc analysis also revealed significant differences between walking speed in particular sections of the route. The participants walked the slowest in the group of sections 5+6+7, faster in sections 3+4, and the fastest in sections 1+2. The absence of significant interactions between the condition and the section of the route indicated that the acoustic stimuli heard by the participants had a similar effect in all sections of the route. The significant interaction between the direction of the walk and the sections of the route reflects that the participants walked faster in the group for sections 1+2 and 3+4 in the direction from section 1 to section 7, and then in the direction from section 7 to section 1.

Evaluation of walk experience

The scores for particular items are in Table 3. It was examined how agreement with the statement “I was fine during the walk” was related to the type of acoustic stimulus to which participants listened. One-way ANOVA indicated a statistically significant effect of the type of condition ($F_{2,80} = 3.986$, $p < .001$, $\eta 2 = 0.17$). A post hoc Tukey test indicated significant differences between the conditions of forest birdsong and traffic noise and between traffic noise and the control condition. The participants listening to forest birdsong sounds were more fine during the walk than those listening to traffic noise. The participants listening to traffic noise were less fine during the walk than those under the control condition.

One-way ANOVA indicated that agreement with the statement “It was a pleasant time” was statistically significantly influenced by the type of acoustic stimulus ($F_{2,80} = 11.273$, $p < .001$, $\eta 2 = 0.22$). A post hoc Tukey test indicated significant differences between the conditions of forest birdsong and traffic noise and between traffic noise and the control condition. The walk was a

more pleasant experience for participants listening to forest birdsong sounds than for the participants listening to traffic noise. The walk was a less pleasant experience for the participants listening to traffic noise the walk than for those under the control condition.

One-way ANOVA indicated that agreement with the statement "I liked the route I went through" was statistically significantly influenced by the type of acoustic stimulus ($F_{2,80} = 4.705$, $p < .05$, $\eta 2 = 0.11$). A post hoc Tukey test indicated significant differences between the forest birdsong and traffic noise conditions. Participants listening to forest birdsong liked the route more than those listening to traffic noise. However, the type of acoustic stimulus did not significantly influence agreement with the statement "While walking, I often observed the surroundings." ($F_{2,80} = 1.295$, $p = .280$).

T-test for independent samples indicated significant differences between the level of agreement with the statement "The sounds I listened to from my headphones bother me" in both conditions with acoustic stimuli. The traffic noise bothered participants more than forest birdsong sounds ($t = 4.077$, $p < .001$, Cohen's $d = 1.15$)

Discussion

The study examined the effects on walking speed of listening to diverse environmental sounds while walking in a real outdoor environment. As expected, the results showed that listening to traffic noise significantly increased participants' walking speed on the urban route. In contrast, listening to relaxation sounds of forest birdsong made the walking speed slightly slower.

Verbal description of participants' walking experiences revealed negative evaluations of various aspects of the walk while listening to traffic noise. Listening to traffic noise was annoying; participants who listened to traffic noise estimated their walk to be less pleasant and they liked the route less than the participants who listened to relaxation sounds or the participants under the control condition. This further supports the existence of an association between negative reactions to traffic noise and faster walking speed.

There is much research indicating that exposure to a natural environment in a visual form results in decreased stress, increased positive emotions, and decreased negative emotions. In our experiment, listening to natural sounds decreased walking speed, but the difference between the effect of natural sounds and the control condition was not significant. It seems that exposure to a natural stimuli in acoustic form may have no such effect similar to the exposure to natural stimuli in a visual form. In our previous experiment (Franěk & Režný, 2017), participants who were primed with pictures of trees walked on the route and were compared to a condition in which they were not primed. Environmental sounds probably do not offer a similar amount of unambiguous information about the natural environment as visual stimuli do. We used birdsong as the stimuli in our experiment because it was found that this type of natural sound is most commonly associated with perceived stress recovery and attention restoration (Ratcliffe Gatersleben, & Sowden, 2013); it are associated with green spaces, spring, and summer (Ratcliffe Gatersleben, & Sowden, 2016). The natural environment soundscape is more complex; it may contain wind blowing and rustling leaves, etc. The problem is that those sounds may not

be easily separated from some technical sounds. For instance, Haga et al. (2016) showed that participants perceived an ambiguous sound consisting of pink noise with white noise interspersed either as a nature sound (waterfall) or as an industrial sound in accordance with instructions given prior to the experiment.

In contrast to the traffic noise, participants listening to relaxation sounds liked the route more and evaluated their walk as more pleasant than those who were under a traffic noise condition and under the control condition (although statistically non-significantly). In addition to previous studies that reported that visual natural stimuli may make traffic noise perception less annoying (Van Renterghem & Botteldooren, 2016; Gidlöf-Gunnarsson & Öhrström, 2017), we observed that acoustic natural stimuli resulted in a higher level of liking visual properties of the environment when compared to acoustic stimulation with traffic noise.

Further, we examined the interactions between the effects of a specific environment and the sound. Although we did not find statistically significant interaction between section walked and acoustic condition, we registered a faster speed in sections 1-4, along the street with car traffic under the condition with forest birdsong. Birdsong may be perceived in this environment as an incongruent, inappropriate acoustic background. In contrast, we registered slower walking speeds in section 5-7, situated in a dense alley, where birdsong and a calm atmosphere of a forest would be more appropriate and congruent with acoustic stimuli. Although it may speak to the effect of congruency/incongruency between listening sounds and the environment, the same patterns of walking speed in these sections of the route were found when participants listened to traffic noise and were under the control condition. Moreover, our previous walking experiments conducted on the same route (Franěk & Režný, 2014) without listening to any acoustic stimuli indicated roughly identical patterns of walking speed in particular sections with similar effect size, specifically the slowest walking speed in sections 5-7, faster walking speed in sections 3-4, and the fastest walking speed in sections 1-2. Clearly, differences in walking speed between particular sections of the route probably are caused by the previously registered effects from environmental features. They were not modulated by interactions between sound and perceived environment; instead, the type of acoustic stimuli influenced the overall walking speed on the whole route in a similar way. It seems that mentioned tendencies found in noise annoyance studies ((Brambilla & Maffei, 2006; an Renterghem & Botteldooren, 2016; Gidlöf-Gunnarsson & Öhrström, 2017) could influence subjective estimation of an environment, but they are too small to affect motor behavior.

The study has some limitations. First, the headphones did not entirely mask outdoor sounds due to safety reasons. Thus, participants also slightly heard noise from outside the experiment under the nature sounds condition. Although this arrangement may reflect real situations, when people are walking outdoor and simultaneously listening to music or relaxation sounds from headphones, it did not entirely change the soundscape of the environment. Second, although there was car traffic in sections 1, 2, 3, and 4 of our walking route, the street was not a typical example of a busy urban highway. Thus, it is possible that phenomena associated with the observed effects of congruency/incongruency between the environment and sound (Brambilla & Maffei, 2006; Bruce & Davies, 2014) would be less pronounced.

Conclusions

In conclusion, our study convincingly showed that exposure to traffic noise led to immediate walking speed increases. Of course, a faster walking pace is not an undesirable behavior of urban pedestrians, if it is, for instance, a part of sport or recreational activity. However, as previously demonstrated, a fast walking speed in the context of the overall fast pace of life as a response to stressful environmental stimuli may have negative health consequences. Moreover, it was also shown that exposure to noise may influence perception of an environment. The same environment may be more liked in the absence of noise or in the presence of relaxation sounds. Finally, the study also documented the positive effect of listening to various kinds of relaxation sounds while walking in an outdoor environment with traffic noise.

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References

Alvarsson, JJ, Wiens S, Nilsson ME 2010. Stress recovery during exposure to nature sound and environmental noise. *International Journal of Environmental Research and Public Health* 7:1036-1046. DOI 10.3390/ijerph7031036

Annerstedt M, Jonsson P, Wallergard M, Johansson G, Karlson B, Grahn P, Hansen AM, Wahrborg P. 2013. Inducing physiological stress recovery with sounds of nature in a virtual reality forest - Results from a pilot study. *Physiology & Behavior* 118:240-250. DOI 10.1016/j.physbeh.2013.05.023

Babisch W 2006. Transportation noise and cardiovascular risk: updated review and synthesis of epidemiological studies indicate that the evidence has increased. *Noise & Health* 8:1.

Bornstein MH, Bornstein HG 1976. Pace of life. *Nature* 259:557-559. DOI 10.1038/259557a0

Brambilla G, Maffei L 2006. Responses to noise in urban parks and in rural quiet areas. *Acta Acustica united with Acustica* 92:881-886.

Brown DK, Barton, JL, Gladwell, VF 2013. Viewing nature scenes positively affects recovery of autonomic function following acute-mental stress. *Environmental Science and Technology* 47:5562-5569. DOI: 10.1021/es305019p

Benfield JA, Taff BD, Newman P, Smyth J 2014. Natural sound facilitates mood recovery. *Ecopsychology* 6:183-188. DOI 10.1089/eco.2014.0028

Bruce NS, Davies, WJ 2014. The effects of expectation on the perception of soundscapes. *Applied Acoustics* 85:1-11. DOI 10.1016/j.apacoust.2014.03.016

Cerwén G, Pedersen E, Pálsdóttir AM 2016. The role of soundscape in nature-based rehabilitation: A patient perspective. *International Journal of Environmental Research and Public Health* 13:1229. DOI:10.3390/ijerph13121229

de Kort YAW, Meijnders A L, Sponselee A A G, IJsselsteijn WA 2006. What's wrong with virtual trees? Restoring from stress in a mediated environment. *Journal of Environmental Psychology* 26:309-20. DOI:10.1016/j.jenvp.2006.09.001

Evans GW ed, 1984. *Environmental stress*. Cambridge: Cambridge University Press.

Evans GW, Bullinger M, Hygge S 1998. Chronic noise exposure and physiological response: A prospective study of children living under environmental stress. *Psychological Science* 9:75-77. DOI 10.1111/1467-9280.00014

Felnhofer A, Kothgassner OD, Schmidt M, Heinzle AK, Beutl L, Hlavacs H, Kryspin-Exner I 2015. Is virtual reality emotionally arousing? Investigating five emotion inducing virtual park scenarios. *International Journal of Human-Computer Studies* 82:48-56. DOI:10.1016/j.ijhcs.2015.05.004

Gidlöf-Gunnarsson A, Öhrström E 2017. Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas. *Landscape and Urban Planning* 83:115-126, DOI 10.1016/j.landurbplan.2007.03.003

Haga A, Halin N, Holmgren M, Sörqvist P. 2016. Psychological restoration can depend on stimulus-source attribution: a challenge for the evolutionary account? *Frontiers in Psychology* 7:1831. DOI 10.3389/fpsyg.2016.01831

Hartig T, Nyberg L, Nilsson LG, Gärling T 1999. Testing for mood congruent recall with environmentally induced mood. *Journal of Environmental Psychology* 19:353-367. DOI:10.1006/jevp.1999.0142

Hartig T, van den Berg AE, Hagerhall CM, Tomalak M, Bauer N, Hansmann R, Ojaj A, Syngollitou E, Carrus G, van Herzel A, Bell S, Podesta MTC, Waaseth G 2011. Health benefits of nature experience: Psychological, social and cultural processes. In Nilsson K. et al., eds *Forests, Trees and Human Health.* Springer: Dordrecht. 127-168.

Haines MM, Stansfeld SA, Job RS, Berglund B, Head J 2001. Chronic aircraft noise exposure, stress responses, mental health and cognitive performance in school children. *Psychological Medicine* 2:265-277. DOI 10.1017/S0033291701003282

Jahncke H, Eriksson K, Naula S 2015. The effects of auditive and visual settings on perceived restoration likelihood. *Noise & Health* 17:1-10. DOI 10.4103/1463-1741.149559

Jiang B, Chang CY, Sullivan WC 2014. A dose of nature: Tree cover, stress reduction, and gender differences. *Landscape and Urban Planning* 132:26-36. DOI:10.1016/j.landurbplan.2014.08.005

Lee PJ, Hong JY, Jeon JY 2014. Assessment of rural soundscapes with high-speed train noise. *Science of the Total Environment* 482:432-439. DOI 10.1016/j.scitotenv.2013.07.026

Levine RV, Bartlett K 1984. Pace of life, punctuality, and coronary heart disease in 6 countries. *Journal of Cross-Cultural Psychology* 15:233-255. DOI: 10.1177/0022002184015002009

Levine RV, Norenzayan A 1999. The pace of life in 31 countries. *Journal of Cross-Cultural Psychology* 30:178-205. DOI: 10.1177/0022022199030002003

Levine RV, Lynch K, Miyake K, Lucia M. 1989. The type A city: coronary heart disease and the pace of life. *Journal of Behavioral Medicine* 12:509-524. DOI: 10.1007/BF00844822

Lowin A, Hottes JH, Sandler BE, Bornstein M 1971. The pace of life and sensitivity to time in urban and rural settings: A preliminary study. *Journal of Social Psychology* 83:247-253. DOI: 10.1080/00224545.1971.9922469

Nilsson ME, Berglund B 2006. Soundscape quality in suburban green areas and city parks. *Acta Acustica United Acustica* 92:903-911.

Maculewicz J, Erkut C, Serafin S. 2016. How can soundscapes affect the preferred walking pace? *Applied Acoustics* 114:230-239. DOI 10.1016/j.apacoust.2016.07.031

Passchier-Vermeer W, Passchier WF 2000. Noise exposure and public health. *Environmental Health Perspectives* 108(Suppl 1):123-131.

Ratcliffe E, Gatersleben B, Sowden, PT 2013. Bird sounds and their contributions to perceived attention restoration and stress recovery. *Journal of Environmental Psychology* 36: 221-228. DOI 10.1016/j.jenvp.2013.08.004

Ratcliffe E, Gatersleben B, & Sowden PT 2016. Associations with bird sounds: How do they relate to perceived restorative potential? *Journal of Environmental Psychology* 47: 136-144. DOI 10.1016/j.jenvp.2016.05.009

Saadatmand V, Rejeh N, Heravi-Karimooi M, Tadrisi SD, Zayeri F, Vaismoradi M, Jasper M 2013. Effect of nature-based sounds' intervention on agitation, anxiety, and stress in patients under mechanical ventilator support: A randomised controlled trial. *International Journal of Nursing Studies* 50:895-904. DOI 10.1016/j.ijnurstu.2012.11.018

Stansfeld S, Haines M, Brown, B 2000. Noise and health in the urban environment. *Reviews on Environmental Health*, 15:43- 82. DOI 10.1515/REVEH.2000.15.1-2.43

Ulrich RS, Simons RF, Losito BD, Fiorito E, Miles, MA, Zelson M 1991. Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology* 11:201-230. DOI: 10.1016/S0272-4944(05)80184-7

Ulrich RS, Simons RF, Miles MA (2003). Effects of environmental simulations and television on blood donor stress. *Journal of Architectural and Planning Research* 20:38-47.

Valtchanov D, Barton KR, Ellard C (2010). Restorative effects of virtual nature settings. *Cyberpsychology, Behavior, and Social Networking* 13:503-512. DOI:10.1089/cyber.2009.0308

Van Renterghem T, Botteldooren D 2016, View on outdoor vegetation reduces noise annoyance for dwellers near busy roads. *Landscape and Urban Planning* 148:203-215. DOI 10.1016/j.landurbplan.2015.12.018

Viollon S, Lavandier C, Drake C 2002. Influence of visual setting on sound ratings in an urban environment. *Applied Acoustics* 63: 493-511. DOI 10.1016/S0003-682X(01)00053-6

Walmsley DJ, Lewis GJ 1989. The pace of pedestrian flows in cities. *Environment and Behavior* 21:123-150. DOI: 10.1177/0013916589212001

Ward Thompson C, Roe J, Aspinall P, Mitchell R, Clow A, Miller D 2012. More green space is linked to less stress in deprived communities: evidence from salivary cortisol patterns. *Landscape and Urban Planning* 105:221-229. DOI 10.1016/j.landurbplan.2011.12.015

Werner CM, Altman, I, Oxley D 1985. Temporal aspects of homes: A transactional perspective. In Altman I, Werner CM, eds. *Home environments. Vol.8. Human behavior and environment: advances in theory and research*. New York: Plenum Press. 1-32.

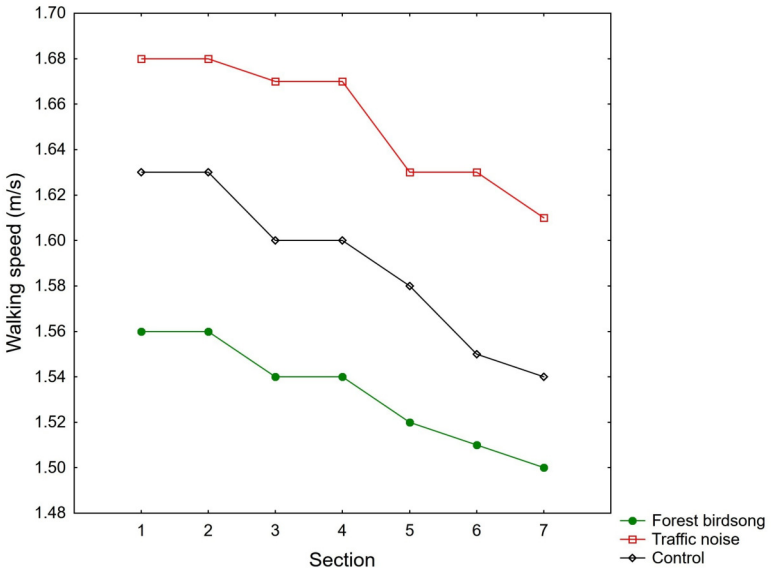
Wiseman R 2007. *Quirkology. How we discover the big truths in small things*. New York: Basic Books.

Table 1(on next page)

Figure 1a, 1b

Figure 1. Average walking speeds (m/s) in particular sections of the route. A: The direction of the walk from the section 1 to the section 7. B: The direction of the walk from the section 7 to the section 1

A



B

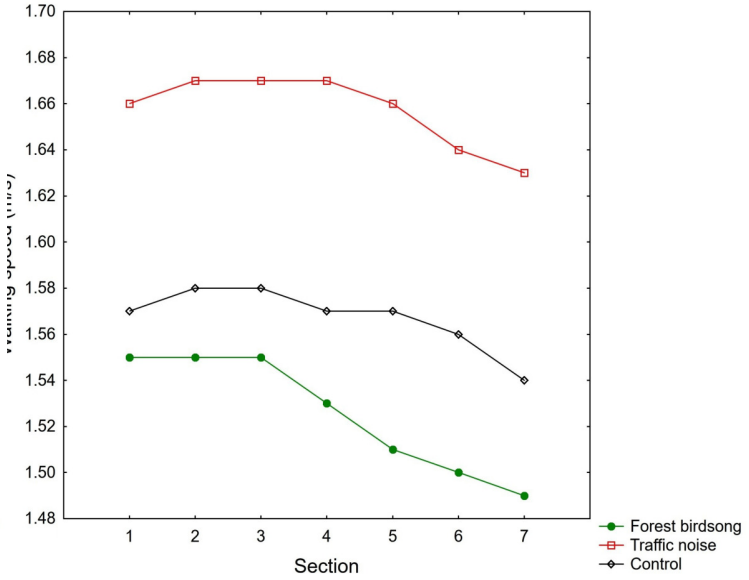


Table 2(on next page)

Table 1

Table 1. Walking route. The description of particular sections where walking speed was measured. For additional route details, see https://maps.google.com, location: Hradec Kralove, Czech Republic, *Orlicke nabrezi*.

Section	Length (m)	Environmental layout	Street
1	60	grass, trees, buildings, traffic,	*Brno Street - Technical High School*
2	55	grass, trees, buildings, traffic	*Brno Street - Business High School*
3	100	grass, trees, traffic,	*Brno Street - Business Center*
4	100	grass, trees, traffic	*Brno Street - Botanical Garden*
5	60	dense oak alley, no traffic	*Brno Street - Malšovická Street*
6	75	dense oak alley, no traffic	*Flošna - tree alley*
7	90	dense oak alley, no traffic	*Flošna - parking*

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Table 3(on next page)

Table 2

Table 2. The average walking speeds (m/s) in specific sections of the route for the two experimental conditions (forest birdsong, traffic noise) and the control condition for both directions of the walk. Direction 1 is from the section 1 to section 7, and Direction 2 is from section 7 to section 1.

Section	Forest birdsong		Traffic noise		Control		Forest birdsong		Traffic noise		Control	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	Direction 1						Direction 2					
1	1.56	0.13	1.68	0.12	1.63	0.15	1.55	0.12	1.66	0.11	1.57	0.11
2	1.56	0.13	1.68	0.12	1.63	0.15	1.55	0.13	1.67	0.11	1.58	0.12
3	1.54	0.12	1.67	0.12	1.60	0.15	1.55	0.13	1.67	0.13	1.58	0.13
4	1.54	0.13	1.67	0.13	1.60	0.15	1.53	0.13	1.67	0.11	1.57	0.13
5	1.52	0.13	1.63	0.12	1.58	0.15	1.51	0.12	1.66	0.12	1.57	0.13
6	1.51	0.12	1.63	0.12	1.55	0.15	1.50	0.12	1.64	0.12	1.56	0.12
7	1.50	0.12	1.61	0.13	1.54	0.15	1.49	0.13	1.63	0.12	1.54	0.13

Table 4(on next page)

Table 3

Table 3. Evaluation of the walk experience. The level of agreement with particular items. The scale ranged from 1 to 7.

Item	Forest birdsong		Traffic noise		Control	
	Mean	SD	Mean	SD	Mean	SD
I was fine during the walk.	6.42	0.62	5.38	1.39	6.12	0.86
It was a pleasant time.	5.71	1.13	4.27	1.22	5.23	1.11
I liked the route I went through.	6.29	0.82	5.65	1.02	6.20	0.57
While walking, I often observed the surroundings.	6.16	1.19	5.65	1.44	5.77	1.14
The sounds I listened to from my headphones bother me	2.45	2.10	4.81	2.26	-	-