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Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas

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Abstract

A growing body of literature indicates that contact with nature influence people's health and psychological well-being both directly and by moderating processes. A questionnaire study was conducted in urban residential settings with high road-traffic noise exposure ($L_{\mathrm{Aeq,\,24\,h}} = 60$–$68$ dB). Out of 500 residents, 367 lived in dwellings with access to a quiet side ($L_{\mathrm{Aeq,\,24\,h}} \leq 45$ dB free field value; "noise/quiet"-condition) and 133 had no access to a quiet side ("noise/noise"-condition). The present paper examines whether perceived availability to nearby green areas affects various aspects of well-being in these two noise-condition groups. For both those with and without access to a quiet side, the results show that "better" availability to nearby green areas is important for their well-being and daily behavior by reducing long-term noise annoyances and prevalence of stress-related psychosocial symptoms, and by increasing the use of spaces outdoors. In the process of planning health-promoting urban environments, it is essential to provide easy access to nearby green areas that can offer relief from environmental stress and opportunities for rest and relaxation, to strive for lower sound levels from road traffic, as well as to design "noise-free" sections indoors and outdoors.

Keywords: Road traffic; Noise annoyance; Nature; Green space; Restorative environments

1. Introduction

For many urban residents, everyday life is filled with stressful situations. Demands from work and family and harmful/adverse environmental conditions raise the needs of restoration periods. Increasing empirical evidence indicates that nature provides restorative experiences that directly affect people's psychological well-being and health in a positive way (e.g., Ulrich, 1981; Kaplan and Kaplan, 1989; Ulrich et al., 1991; Hartig et al., 1996; Herzog et al., 1997; Kaplan, 2001; Hartig et al., 2003). There are also indications that access to nearby nature can act as a buffer or moderator of adverse conditions (Evans, 2003; Wells and Evans, 2003).

A great and growing environmental problem in urbanized areas is noise from transport. It has been estimated that about 80 million (approximately 20%) of the European Union's population suffer from noise levels considered unacceptable (above 65 dB in so-called "black areas") and an additional 170 million are living in "grey areas" exposed to noise levels between 55 and 65 dB (EC, 1996). Findings from a large body of studies show that traffic noise causes non-auditory stress effects such as changes in the physiological systems (e.g., elevated blood pressure), various cognitive deficits (e.g., poor sustained attention, memory/concentration problems), sleep disturbances, modifications of social behavior, psychosocial stress-related symptoms, and emotional/motivational effects (e.g., annoyance, learned helplessness) (e.g., WHO, 2000; Öhrström, 2004; Babisch et al., 2005; Stansfeld et al., 2005; Bluhm et al., 2007). The psychological stress construct has helped to identify these stress-related outcomes and to improve our understanding of how chronic noise exposure from traffic affects human health. However, it is necessary to extend current stress models to identify and include also environmental factors that may moderate the exposure-effect relationship by promoting health and well-being (Evans, 2001). Some previous studies indicate that presence of natural

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elements in noise exposed sites have a moderating influence on people's noise responses. In a large survey on nearly 3000 people in 53 residential sites of the Greater London Council, Langdon (1976) found that high neighborhood quality in terms of attractive appearance, presence of parks and green spaces lowered dissatisfaction with traffic noise to a significant degree. Similar findings are reported by Kastka and Noack (1987). Therefore, our interest in the present study is to examine the potential role of nearby green areas in traffic-noise exposed residential areas.

In a comprehensive review, Kaplan and Kaplan (1989) stressed the importance of nature in urban settings. The availability of nearby trees, opportunities for gardening, and places for taking walks (within 3 min) were highly valued components of urban nature and increased satisfaction and well-being in urban residents. Findings from recently conducted research programs within EU on urban green spaces confer their role as improving people's life quality (BUGS—Benefits of Urban Green Space, 2003; Priestley et al., 2004). Furthermore, significant relationships exist between urban design and public health (e.g., Handy et al., 2002; Frank et al., 2003; Humpel et al., 2004; Hoehner et al., 2005). In a longitudinal cohort study, Takano et al. (2002) showed that the longevity of urban senior citizens increased if they had local availability of walkable green spaces. Findings also indicate associations between nature and stress responses. More frequent visits to urban open green spaces were significantly related to less self-reported experiences of stress in a study by Grahn and Stigsdotter (2003). An important factor was the distance from home to the nearest green space: closer green spaces were associated with more visits (see also De Vries et al., 2003; van Herzele and Wiedemann, 2003; Jim and Chen, 2006). Results from a combined experimental/quasi-experimental field study in which subjects were exposed to stressing cognitive demands support the beliefs that "natural surroundings aid the physical and psychological restoration of people living in cities" (Hartig et al., 2003, p. 119). Hartig and his colleagues showed that contact with natural as compared with urban field settings has the ability to significantly affect physiological systems (reduced blood pressure), cognitive abilities (improved performance on an attentional test), and emotional states (increased feelings of happiness and declined feelings of anger/aggression). The important role of urban nature is also emphasized in a recent state-of-the-art document on urban design and human condition (Jackson, 2003). In this document, access to greenery, visually and physically is identified as the principal key element in healthful urban design.

The present study formed part of the large research program "Soundscape Support to Health" (Phase 1, 2000–2003), which among other things has investigated the relationships between soundscapes (acoustical and perceived) in urban residential areas and effects on health and well-being (Berglund et al., 2004; Öhrström and Skånberg, 2004; Öhrström et al., 2006). An important knowledge established in the project is the understanding of how the soundscape in urban residential settings influence various health outcomes. For example, having access to a quiet side of one's dwelling in traffic noise exposed areas lower noise annoyance, disturbed day-time relaxation, stress-related psychosocial symptoms, as well as improves sleep (Öhrström et al., 2006). Although the "quiet side concept" has important implications for achieving health-promoting soundscapes in urban residential settings, the additional effect of availability to nearby green areas has not yet been taken into account. Can availability to green areas act as a moderator and furthermore attenuate the adverse stress effects of noise, over and beyond the effect of access to a quiet side? What effect has green-area availability on noise responses for those who have no access to a quiet side? Does the effect of green-area availability vary with these two noise conditions? What specific factors might be involved and what potential mechanisms would support the interpretation of the data?

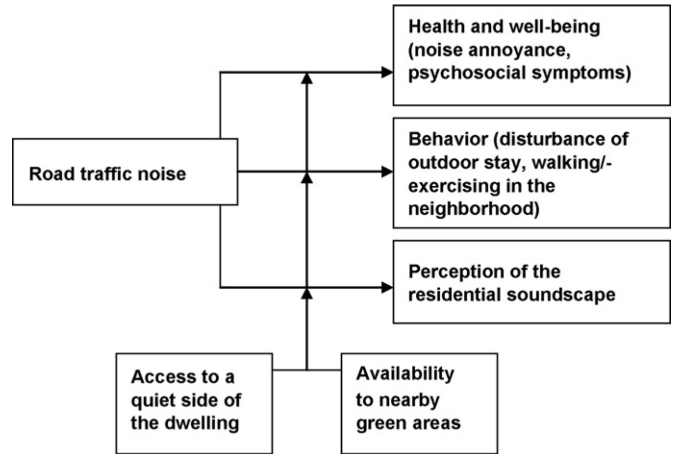

Fig. 1. A conceptual model of the assessed variables and their hypothesized associations.

The main objectives of the present study are, firstly, to explore whether green-area availability moderates resident's noise responses and secondly, whether the potential effect of green-area availability varies depending on access or not to a quiet side of the dwelling. Fig. 1 presents a conceptual model of the assessed variables in the present study and their hypothesized associations. It shall be noted that this is a simplified schematic model of the relationships between noise exposure (the stressor), the modifiers, and adverse effects—the model does not show other potential moderating factors such as noise sensitivity (e.g., Job, 1988; Lercher, 1996), although this factor was assessed and analyzed in the present study. As can be seen in the figure, both availability to green areas and access to a quiet side are assumed to moderate the noise responses, but in the present study, the green-area availability is at focus.

2. Method

2.1. Study design

A cross-sectional questionnaire study was conducted in residential city areas in Stockholm (Södermalm and Hägersten) and Göteborg (Johanneberg), Sweden. Great care was undertaken in designing the empirical field studies and in selecting the different study sites. The latter was based on a number of criteria, for example: similar noise exposures, no other dominating noise source than road traffic, similar houses according to height and type (three to five storied apartment buildings), similar dwellings according to layout (at least two rooms in addition to a kitchen, access to a balcony/outdoor space), and similar population characteristics (for more details, please consult Berglund et al., 2004; Öhrström et al., 2006).

2.2. Sound exposure

Sound levels were determined outside both sides of each dwelling by long- and short-term measurements. Calculations of traffic noise levels (e.g., $L_{\mathrm{Aeq,\,24\,h}}$ = the equivalent A-weighted sound pressure level integrated during 24 h) were based on traffic input data and geometrical data of the field site. Measurements of traffic data (number of vehicles, %heavy vehicles, and motorbikes) were also included. The road traffic speed limit was 50 km/h in the study sites (see also Berglund et al., 2004; Öhrström et al., 2006).

Half of the dwellings in the study areas had access to a quiet side and the other half of the dwellings had similar sound levels at the most exposed side but had no access to a quieter side of the dwelling. A dwelling with access to a quiet side was defined as a dwelling facing at least one side of the building where the total $L_{\mathrm{Aeq,\,24\,h}}$ sound level dB caused by ground traffic and other disturbing noise sources 2 m from the façade (façade reflection included) is less than 48 dB (corresponding to less than 45 dB free field value, i.e., level on the façade minus 6 dB; for more details, please consult Berglund et al., 2004; Thorsson and Ögren, 2004; Ögren and Kropp, 2004; Öhrström et al., 2006).

2.3. Participants

The dataset utilized in the present study (n = 500) is based on questionnaire data obtained from 956 residents (59% response rate). One individual between 18 and 75 years of age in 1625 households were originally selected. If there were two or more persons in the household, the one who was closest to the date of the first distribution of the questionnaire was chosen. The restricted dataset of 500 residents were all exposed to high road-traffic noise exposures, i.e., $L_{\mathrm{Aeq,\,24\,h}}$ = 60–68 dB at the most exposed facade of the dwelling (dB mean = 62, S.D. = 2.14; free field value). The remaining residents with lower sound levels were excluded from further analyses. Out of 500 residents, 367 lived in dwellings with access to a quiet side (“noise/quiet”-condition) and 133 lived in dwellings with no access to a quiet side (“noise/noise”-condition).

2.4. Questionnaire

The participants answered a questionnaire designed to assess adverse health effects of noise (e.g., Öhrström, 1989) and perceptions of soundscapes (Berglund and Nilsson, 2001). The questionnaires were sent by post together with an introductory letter that presented the study as a study on well-being and the general living environment. One or two reminder letters were sent to those who did not answer within 10 days. For the present paper, only the following data were utilized from the questionnaire (for detailed descriptions of the questionnaire, please consult Öhrström et al., 2006): (1) *Perceived availability to green areas*. According to a Swedish dictionary (Malmström et al., 1991), a green area refers to an area in city plans with green surface, trees and so on. In the present study perceived availability to green areas was assessed with the following question: “Do you have access to green areas close to your dwelling?” Three response categories were used: “no access”, “rather good access”, and “very good access”; (2) *Longstanding illness* was assessed as frequencies of “yes/no” responses; (3) *Sensitivity to noise* was assessed by asking the respondents how they in general describe their sensitivity to noise. A four-point category scale was used ranging from “not at all sensitive” to “very sensitive” (cf. Öhrström et al., 1988); (4) *Noise annoyance*. Road traffic noise annoyances when being “at home” and “outdoors close to the dwelling” (last 12 months) were assessed on numeric 0–10 scales with verbal endpoints (“not at all annoyed” and “extremely annoyed”); (5) *Perception of noise as a problem in the neighborhood* was assessed as frequencies of “yes/no” responses; (6) *Use of outdoor spaces*. For use of outdoor spaces, the residents were asked to report on how often they were walking/exercising in the neighborhood (“every day”, “one/few times per week”, “one/few times per month”, and “seldom/never”). They also responded to a question on how often (“never”, “sometimes”, and “often”) road traffic disturbed their desire to stay outdoors; (7) *Identification of sound sources*. Sound-source identification is valuable when describing perception of soundscapes. The concept of soundscape refers to the sound variations in space and time caused by the topography of the natural environment, the buildings and their different sound sources. Acoustical soundscapes are described with the aid of acoustical variables and perceived soundscapes with perceptual variables (Schafer, 1994; Berglund and Nilsson, 2001; Axelsson et al., 2005). A list of 14 sound sources common outdoors in residential environments was provided to the residents (private cars, trucks, buses, motor cycles, aircraft, railway, gardening machinery, ventilation, TV/radio, sound of steps, dogs/other pets, birds, children playing, and people talking). The residents were asked to report on how often (during the last 12 months) they usually heard the listed sounds when they were outdoors close to their dwelling. For each sound source, a four-point category scale was used ranging from “hear seldom/never” to “hear almost always” (Berglund and Nilsson, 2001, 2004); (8) *Stress-related psychosocial symptoms*. Out of eight physiological and psychological symptoms, three were used as indicators of stress-triggered reactions: feeling “very tired”, “irritated and angry” and “stressed” (Öhrström, 1989; Grahn and Stigsdotter, 2003; Öhrström et al., 2006). The respondents were asked to assess each symptom on a four-point category scale according to how frequently the symptom was experienced (“seldom/never”, “once or a few times each month”, “once or a few times each week”, and “every day”). Analyses of the original sample (n = 956), indicated that these three symptoms were significantly lower in prevalence among subjects exposed to the lowest sound levels (45–46 dB) compared to those exposed to the highest sound levels (63–68 dB) (Öhrström et al., 2006). Similar results were found in an intervention study

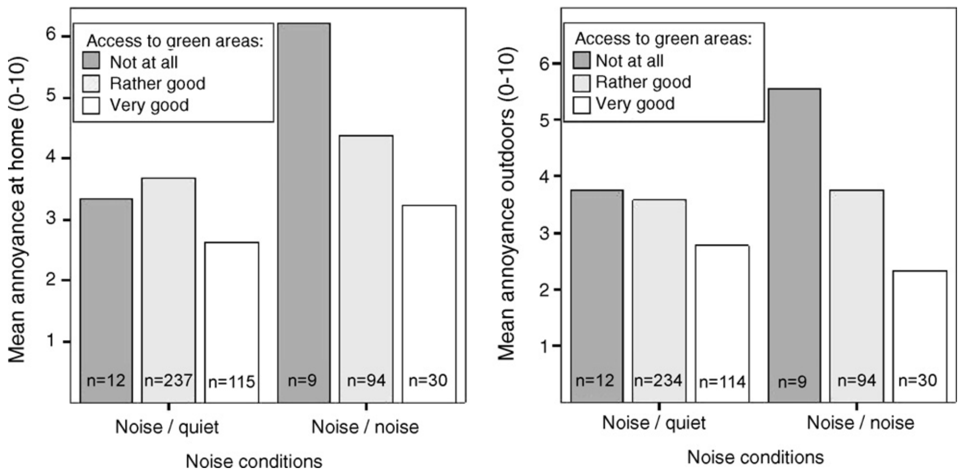

Fig. 2. Mean road traffic noise annoyance “at home” (left) and “outdoors close to the dwelling” (right) in relation to perceived availability to green areas (“not at all”, “rather good”, and “very good”) and noise condition (“noise/quiet” and “noise/noise”).

in which road traffic noise exposure was lowered by changes in the road system and construction of a new tunnel (Öhrström, 2004).

2.5. Availability to green areas

Univariate analyses were performed to examine the frequency of responses on self-reported perceived availability to green areas in each noise condition. For the “noise/quiet” and noise/noise conditions, very few reported “no access” (3 and 7%), a majority reported “rather good access” (65 and 71%), and 32 and 23% reported “very good access” to green areas, respectively. To ensure that the each group has sufficient sample size for further analyses (univariate and multivariate) the possibility to create only two green-area groups was examined by comparing mean scores regarding long-term noise annoyance “at home” and “outdoors close to the dwelling” (see Fig. 2). For the “noise/quiet condition”, mean scores are more closely between those reporting “not at all” and “rather good” access to green areas than with those reporting “very good” access to green areas. For the “noise/noise” condition, the differences in mean scores between the three green-area groups were more equal. Based on

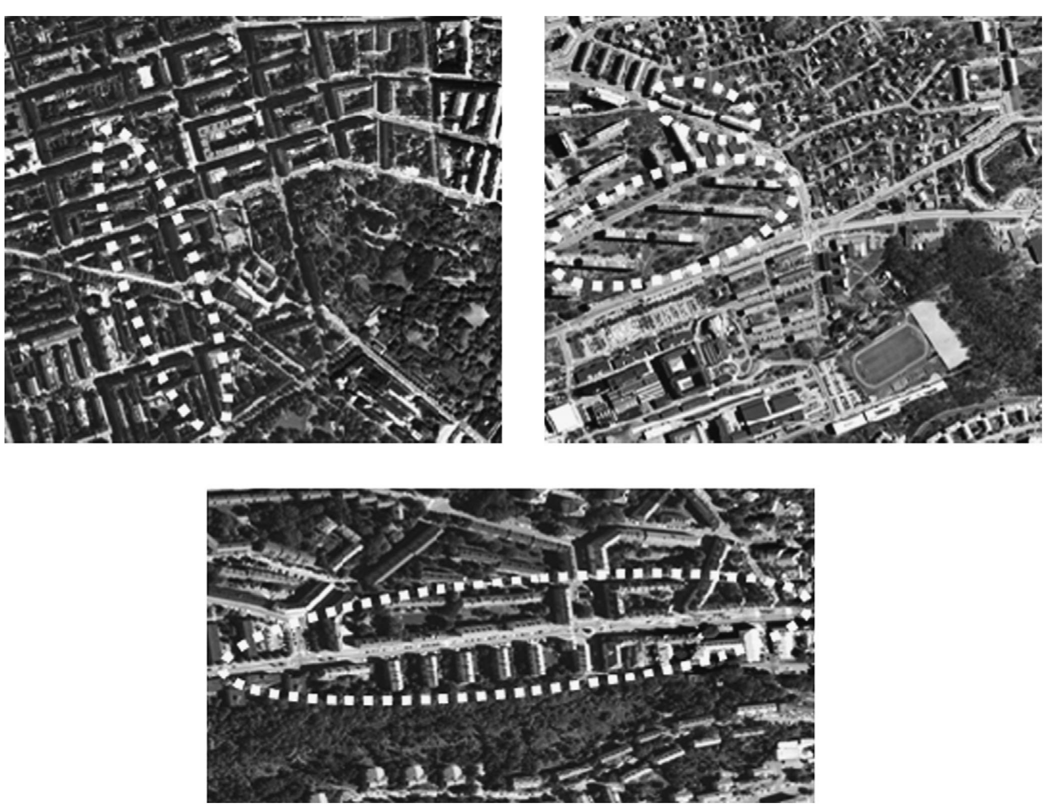

Fig. 3. Aerial photographs of the residential settings (marked with white dotted lines): Södermalm in the city of Stockholm (left panel), Johanneberg in Göteborg (right panel), and Hägersten in Stockholm (lower middle panel).

these initial analyses, two groups were formed: residents with "poorer" availability (i.e., response categories no/rather good) to green areas ($n = 354$) and residents with "better" availability (i.e., response category very good) to green areas ($n = 146$). To validate the construction of these two green-area groups, we examined recent aerial photographs over the study sites and their surroundings (Fig. 3) and approximately judged the distance between each of the sites and the nearest green area. Most of the residents in Hägersten (lower panel) had green areas directly available from their apartments (approximately 10–200 m, i.e., within a 5 min walk) and a majority (65%) of those with "better" availability to green areas resides in this study site. For residents living in Södermalm and Johanneberg (upper panels), the distance to nearest green area was clearly longer (approximately 600 m)—74% of the residents with "poorer" availability to green areas resides in these two study sites. The above results indicated that our green-area group definition was sufficiently valid for further analyses. Table 1 shows the distribution of residents in the two green area and two noise condition groups.

Table 1
Distribution of residents (frequency) in two green-area groups ("poorer" and "better" perceived availability to green areas) and two noise conditions ("noise/quiet" and "noise/noise")

Noise conditions	Green-area groups		Total
	Poorer access	Better access	
Noise/quiet	251	116	367
Noise/noise	103	30	133
Total	354	146	500

3. Results

3.1. Demographic and personal factors and noise levels

Across the two noise conditions ("noise/quiet" and "noise/noise") the green-area groups did not differ significantly ($p > 0.05$) in sex, civil status, age group, occupation, time of residency, long-standing illness, sensitivity to noise, or sound levels from road traffic at the exposed side of the dwelling (see Table 2). We compared the current sample with the excluded sample and found that the excluded sample (<60 dB) were significantly ($p < 0.05$) older (≥46 years of age = 54% versus 41% for the excluded and current samples, respectively). Because of this, more respondents in the excluded sample had longstanding illness, were divorced, widow/widower, had retired, and had longer time of residency. There were no differences in sex and sensitivity to noise ($p > 0.05$). However, the differences between the current and excluded samples should not affect the results of our study. The important issue is if the green-area groups differed within each condition, and this was not the case.

Table 2
Questionnaire responses on demographic and personal variables and measured sound levels ($L_{\mathrm{Aeq,\,24\,h}}$, dB) at the exposed side of the dwelling for two green-area groups ("poorer" and "better" availability to green areas) in two noise conditions ("noise/quiet" and "noise/noise")

Variables	Noise/quiet condition			Noise/noise condition		
	Poorer green-area access	Better green-area access	p^a	Poorer green-area access	Better green-area access	p^a
Women (%)	55	56	0.80	58	63	0.62
Civil status (%)			0.65			0.72
Married or de facto	52	46		50	56	
Living alone	35	34		43	33	
Divorced	10	17		4	11	
Widow/widower	3	3		3	0	
Age group (%)			0.42			0.18
<30	24	18		30	18	
31–40	26	22		35	27	
41–50	18	19		14	13	
51–60	16	23		12	30	
61–70	10	9		5	7	
>71	6	9		4	7	
Occupation (%)			0.68			0.11
Employed	68	61		67	63	
Studying	12	12		20	8	
Unemployed	4	4		1	7	
Retired	14	19		9	17	
Other	2	4		3	7	
Time of residency (mean, S.D.)	8.6 (9.5)	10.4 (11.9)	0.11	7.0 (8.9)	9.4 (11.4)	0.22
Longstanding illness (%yes)	30	32	0.73	27	40	0.18
Sensitivity to noise (%rather/very sensitive)	36	32	0.09	44	43	0.25
Sound levels in $L_{\mathrm{Aeq,\,24\,h}}$ (dB) (mean, S.D.)	62.2 (1.9)	62.2 (1.6)	0.97	61.8 (2.0)	62.0 (1.9)	0.78

Values within parenthesis are standard deviations (S.D.).
[a] Differences between the two green-area groups were determined by χ^2-tests of percentage and by t-tests on mean scale values.

Table 3
MANOVA analysis: main effects of green-area availability and access to a quiet side on noise annoyance (the correlated measure of annoyance "at home" and "outdoors")

Variables	Pillai's trace	F-Value	d.f.	p	Effect size (η^2)
Green-area availability	0.034	8.60	2488	0.000	0.029
Access to a quiet side	0.030	7.52	2490	0.001	0.023

Table 4
Univariate analysis: main effects of green-area availability and access to a quiet side on noise annoyance "at home" and "outdoors", respectively

Variables	F-Value	d.f.	p
Green-area availability			
Annoyance at home	11.54	1487	0.001
Annoyance outdoors	13.14	1487	0.000
Access to a quiet side			
Annoyance at home	4.85	1487	0.028
Annoyance outdoors	0.05	1487	0.827

3.2. Annoyance due to road-traffic noise

A two-way MANOVA was conducted to examine the independent and joint effects of perceived availability to green areas and access to a quiet side of the dwelling on long-term noise annoyance ("at home" and "outdoors close to the dwelling"). Several assumptions need to be met in MANOVA. First, the Box's M-test indicates that the observed covariance matrices of the dependent variables are equal across groups ($p = 0.19$). This allows for a direct interpretation of the results without having to consider group sizes, level of covariances in the group, and so forth. The second assumption to test is the correlation among the dependent variables. In this case the Bartlett's test of sphericity has a significance level of 0.001, satisfying the necessary level of intercorrelation to justify MANOVA (Hair et al., 1995). No interaction effect was observed indicating that the differences between green-area availability are roughly equal across the two noise conditions ("noise/quiet" and "noise/noise"). With a non-significant interaction effect, the main effects can be interpreted directly.

As seen in Table 3, significant multivariate main effects emerged for availability to green areas ($p < 0.001$) and for access to a quiet side ($p = 0.001$), however, the effect sizes were low (partial $\eta^2 = 0.029$ and 0.023, respectively). The partial effect size reflects the amount of variance in noise annoyance that is explained by green-area availability when the effect of access to a quiet side has been taken into account, and vice versa. According to Cohen (1988), a partial η^2-value of 0.03 and below is considered a small effect size, a value of 0.06 and above is considered a moderate effect size and a value above 0.14 is considered a large effect size. The results show that both availability to nearby green areas and access to a quiet side significantly decrease long-term noise annoyance, however, the values of the effect sizes indicate that the influence of the two independent variables on noise annoyance is modest. Analyses of variance (ANOVA) on each dependent variable were conducted to follow up the MANOVA (see Table 4). The non-significant interaction effect holds for each dependent variable separately.

With regard to green-area availability, residents with "better" access to green areas are significantly less noise annoyed due to road traffic both when being "at home" ($p < 0.01$) and "outdoors close to the dwelling" ($p < 0.001$) than respondents with "poorer" access to green areas (Fig. 4, left and right panels, respectively). A significant main effect for access to a quiet side was only observed for annoyance "at home" ($p < 0.05$).

3.3. Perception of noise as a problem in the neighborhood and use of outdoor spaces

As can be seen in Fig. 5, when residents have "better" availability to green areas fewer of them perceive noise as a neighborhood problem (12% points less, $\chi^2_1 = 4.55$, $p < 0.05$ and 18% points less, $\chi^2_1 = 3.06$, $p = 0.08$ for "noise/quiet" and "noise/noise" condition, respectively).

When availability to nearby green areas is "poorer" a higher percentage (sometimes/often) reports that noise frequently dis-

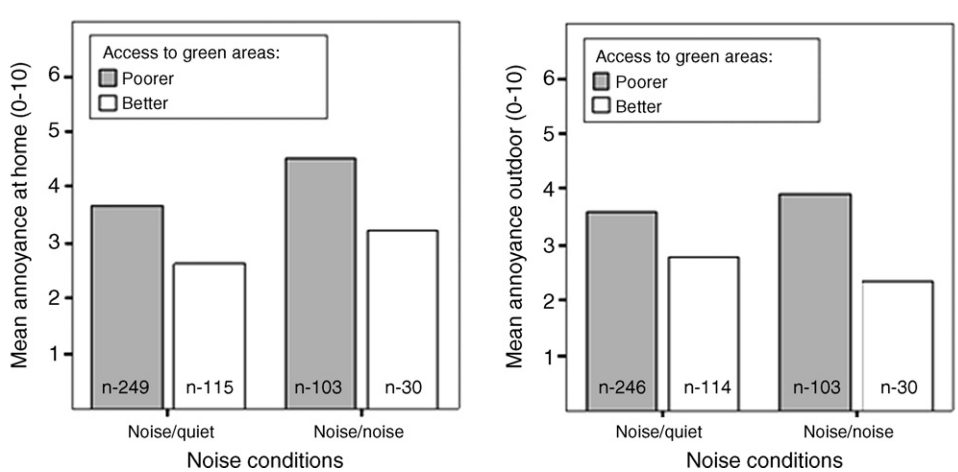

Fig. 4. Mean road traffic noise annoyance "at home" (left) and "outdoors close to the dwelling" (right) in relation to perceived availability to green areas ("poorer" and "better") and noise condition ("noise/quiet" and "noise/noise").

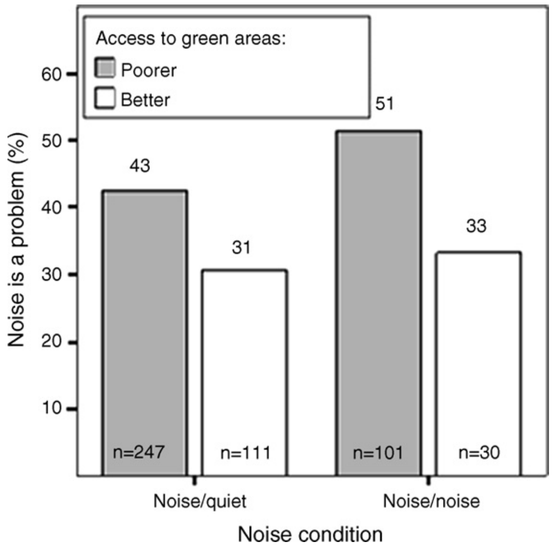

Fig. 5. Frequency of perceiving noise as a problem in the neighborhood in relation to perceived availability to green areas and noise condition.

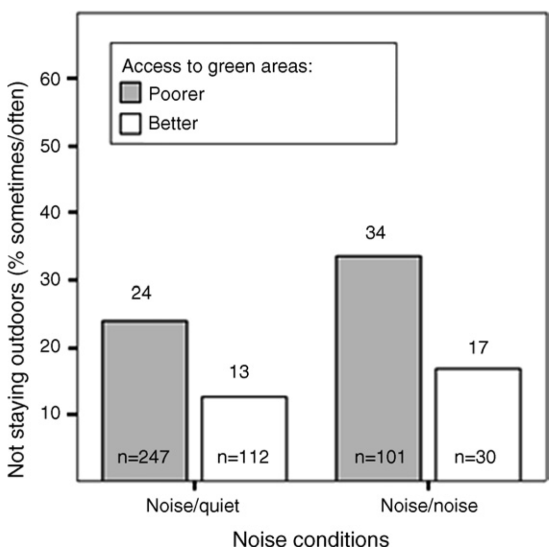

Fig. 6. Influence of noise condition and perceived availability to green areas on residents' desires to stay outdoors.

turb their desire to stay outdoors (Fig. 6). Thus, disturbance is approximately two times greater in residents with "poorer" than with "better" access to green areas ($\chi_1^2 = 6.17$, $p = 0.01$ and $\chi_1^2 = 3.20$, $p = 0.07$ for "noise/quiet" and "noise/noise" condition, respectively). In addition, "better" availability to green areas is associated with a higher amount of residents (%) walking and exercising in the neighborhood every day or once/few times

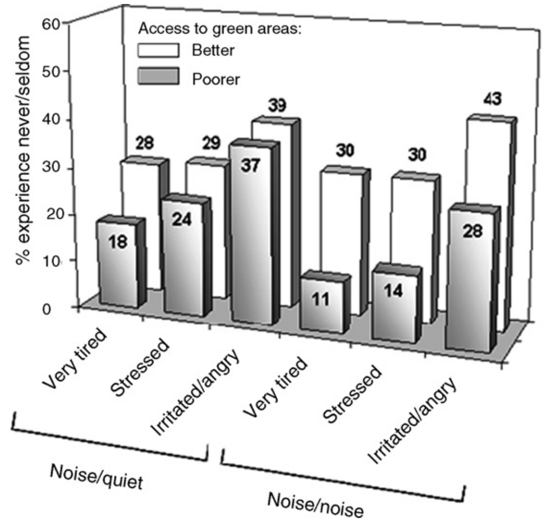

Fig. 7. Prevalence of stress-related psychosocial symptoms in relation to perceived availability to green areas and noise condition.

each week and the results indicate that residents with no access to a quiet side of the dwelling benefit most of availability to green areas (69% versus 78%, $\chi_1^2 = 3.10$, $p = 0.08$ and 58% versus 79%, $\chi_1^2 = 3.80$, $p = 0.05$ for "noise/quiet" and "noise/noise" condition, respectively).

3.4. Identification of sound sources

Table 5 shows the distribution of residents hearing sounds from nature and human sounds when being outdoors in close vicinity to their dwelling. The difference in percentage between the two green-area groups is shown in the column "difference". In both noise conditions, residents with "better" availability to green areas hear birdsong significantly more often than those with "poorer" availability ("noise/quiet"-condition $\chi_1^2 = 5.73$, $p < 0.05$; "noise/noise"-condition $\chi_1^2 = 5.15$, $p < 0.05$). This was also true for human sounds (children playing), but only in the "noise/quiet"-condition ($\chi_1^2 = 7.36$, $p < 0.01$). There were small differences in hearing traffic, people talking, garden machinery, ventilation, and TV/radio sound sources.

3.5. Stress-related psychosocial symptoms

Fig. 7 shows percentage of residents experiencing ("never/seldom") three stress-related psychosocial symptoms in two green-area groups ("poorer" and "better" availability to green areas) and two noise conditions ("noise/quiet" and "noise/noise"). Significant green-area differences were

Table 5
Perception of sound sources (%hear often/almost always) in relation to noise condition and perceived availability to green areas

Sound sources	Noise/quiet condition			Noise/noise condition		
	Poorer green-area access	Better green-area access	Difference	Poorer green-area access	Better green-area access	Difference
Birdsong	42	56	+14*	34	57	+23*
Children playing	35	50	+15**	43	50	+7

*$p < 0.05$; **$p < 0.01$.

Table 6
Associations (r[a]) between stress-related psychosocial symptoms and road traffic noise annoyances at home and outdoors close to the dwelling

Psychosocial symptoms	Annoyance at home	Annoyance outdoors
Very tired	0.28	0.23
Irritated and angry	0.23	0.20
Stressed	0.20	0.20

[a] Pearson's product moment correlation coefficient; correlations are significant at the 0.001 level.

only found in the "noise/noise" condition. Thus, compared to "poorer" green area availability, "better" green area availability was associated with less symptom prevalence regarding "very tired" ($\chi^2_3 = 10.13$, $p < 0.05$), "stressed" ($\chi^2_3 = 8.04$, $p < 0.05$), and "irritated/angry" ($\chi^2_3 = 11.06$, $p = 0.01$). Table 6 shows that the three psychosocial symptoms correlated significantly with noise annoyance "at home" and "outdoors" ($r = 0.19$–0.28). The symptoms correlated also closely with each other ($r = 0.39$–0.55).

4. Discussion

Overall, the results in the present study indicate that the degree of perceived availability to nearby green areas affected the resident's responses to road traffic noise. For both those with and without access to a quiet side of their dwelling, "better" availability to green areas decrease long-term noise annoyance experienced during the last 12 months, reports of noise as a neighborhood problem, and noise disturbance of outdoor stay. For the latter, the number of disturbed residents is approximately two times greater in the condition of having "poorer" than "better" availability to green areas. Additionally, compared to "poorer" green-area availability, "better" green-area availability is linked to a higher number of residents walking and exercising in the neighborhood and to a larger group of residents hearing natural and human sounds very often, which indicate the presence of a positively perceived soundscape. We also found indications that nearby green areas influenced resident's psychological distress: significantly less residents with "better" availability to green areas exhibited stress-related psychosocial symptoms than residents with "poorer" availability to green areas. These symptoms were significantly linked with annoyances caused by road traffic noise to similar strengths as has been found in previous studies (Öhrström, 2004). Furthermore, compared to the influence of having access to a quiet side of one's dwelling, green-area availability seems, in general, to have a similar moderating effect on resident's noise responses, and this effect did not varied significantly with the two noise conditions (i.e., no interaction effects). As demographic/person attributes and residential features of the sample did not differ between the green-area groups within the noise conditions, it is suggested that availability to nearby green areas may be a potential protective factor that partially can moderate the adverse impact of road traffic noise on urban residents.

Noise effects on human health and well-being is commonly described and explained by utilizing stress models (Lercher, 1996). For example, the model developed by Lazarus' and colleagues (e.g., Lazarus and Folkman, 1984) is focused on the transaction between the person and the environment and when applied to the noise situation, it describes the process of stress due to noise exposure (i.e., appraisal, coping, reappraisal). The model also takes into account various mediating/moderating factors related to the person (e.g., noise sensitivity, coping style), the situation (e.g., predictability and control of the noise), and the environment (e.g., simultaneous vibrations), which potentially can influence this stress process and the impact of noise on stress responses. According to the model, the modifying effect of having access to a quiet side of one's dwelling can be interpreted in terms of increased perceived control of the noise exposure by providing an opportunity to reduce the amount of time the individual is exposed to noise, including possibilities for non-noise disturbed sleep, relaxation, opening of windows, etc. (Lercher, 1996; Gjestland and Stofringsdal, 2001; Öhrström et al., 2006). This modifying effect is understandable and straightforward, but how shall we interpret the influence of nature on noise responses in the present study? Those few studies that have investigated the influence of natural elements on noise reactions (Langdon, 1976; see also Lercher, 1996) suggest a link to a more attractive visual appearance at the noise-exposed site and thereby also a higher perceived neighborhood quality. An experimental study by Johansson (2005) confirms this result. He found that adding presence of vegetation positively affected the perceptions of a ventilation noise-contaminated environment (for studies on audio-visual interactions, see also, e.g., Anderson et al., 1983; Carles et al., 1999; Viollon et al., 2002; Champelovier et al., 2005). The moderating effect of green-area availability on noise responses in the present study is in line with findings in the above-mentioned studies. Although the modifying effect of natural elements on noise responses is linked with perceived site quality and satisfaction, we believe that a better understanding of what factors might be involved and possible mechanisms through which such modification occurs, can be fruitfully sought in theories on restorative environments.

4.1. Restorative environments

Findings from research within environmental psychology has shown that exposure to nature contributes to restorative processes. The attention restoration theory (ART, see Kaplan and Kaplan, 1989) suggests that restorative environments (particularly natural as compared with man-made or built environments) have abilities to provide relief and recover from cognitive mental fatigue when the information process or the directed attentional capacity has been overused (e.g., Herzog et al., 1997). Natural environments are thought to encompass "qualities/components" important for recovery or recharging of this capacity: "fascination" involves effortless attention, "being away" permits a sense of rest from daily concerns, "extent" supply sufficient content that can engage the mind, and "compatibility" affords one's purposes. The theory suggested by Ulrich (1981, 1983) is based on well-established stress theory and empirical research. Thus, situations perceived or appraised as stressful commonly evoke psycho-physiological responses such as anxiety, anger and coping, as well as cardiovascular and other bodily responses.

Following a stressor, it is hypothesized that contact with nature can contribute to stress recovery by evoking positive-toned emotional feelings (e.g., pleasure and calm), blocking unpleasant thoughts, and positively change the physiological activity level. Introducing these theories into the area of noise research could be one possible approach to broaden the conceptual framework and give a better understanding of how positive properties in noise-exposed residential environments influence health and well-being.

4.2. Nearby green areas buffer the adverse health effects of exposure to road traffic noise

The results of this study suggest that availability to nearby green areas can moderate or buffer the effects of chronic-noise exposure on health and well-being. As was shown in Fig. 4, exposure to road traffic noise has less impact on long-term noise annoyances under "better" than "poorer" green-area availability. This result is in line with findings from previous studies, in which neighborhood quality due to elements of nature (e.g., presence of parks/green spaces) lowered dissatisfaction with traffic noise (Langdon, 1976; Kastka and Noack, 1987). Furthermore, consistent with previous research (Grahn and Stigsdotter, 2003; De Vries et al., 2003), we found indications that nearby green areas moderated resident's health and well-being with respect to their psychological distress—significantly less residents with "better" availability to green areas exhibited stress-related psychosocial symptoms than residents with "poorer" availability to green areas. How can the role of nearby nature (green areas) as a moderator of noise-related adverse health effects be interpreted? Although the data does not allow for determining causal links, prior empirical research within the area of restorative environments might provide a useful framework for exploration and speculations of important factors and potential underlying mechanisms. Applying the ART approach (attention restoration theory; Kaplan, 1983; Kaplan and Kaplan, 1989; Kaplan, 1995), green areas in close proximity to where people reside may provide an important place for urban residents to escape from stressful and challenging situations, such as chronic noise exposure (e.g., Chiesura, 2004), together with a sense of "being away" (physically, psychologically) from everyday thoughts and experiences that tap attention (Kaplan and Kaplan, 1989). With respect to the "fascination" component of ART, contact with nature may assist in shifting noise-exposed resident's attention from effortful (e.g., focus on traffic noise) to effortless (e.g., experiences of tranquility, positive feelings). This can also be achieved in activities, such as promenades, exercise, and relaxation that an individual can be engaged with when visiting the nearby green area. Trafficked streets are not only noisy; they might also be visually complex. Thus, a majority of the resident's apartments were situated along roads with approximately 9000 vehicles passing per 24 h—more vehicles passing during rush-hours in the morning and afternoon. As a contrast to this traffic-dominated environment, nearby green areas can offer a setting that is sufficiently complex with respect to content and structure (i.e., the "extent" component of ART) and in which the directed attention is allowed to rest and restore (Kaplan and Kaplan, 1989; Kaplan, 1995; Hartig et al., 2003; Berto, 2003). If green areas are perceived as visually attractive, they may also help to reduce stress (e.g., due to traffic noise) by creating feelings of pleasantness and calmness (e.g., Ulrich, 1981, 1983).

The distance from the noise-exposed residential setting to a green area appears to be an important aspect of how it can function as a restorative environment. Our data indicates that green areas directly available or within a few minutes walk from the apartments influenced resident's daily activities in that residential setting—fewer persons reported that traffic noise disturbed their wish for staying outdoors and more persons reported that they frequently walked or exercised in the neighborhood. This is consistent with prior studies which shows that nature within a 5 min walk (corresponding to a maximum of 400 m from the home) encourage the use of outdoor spaces and the occurrence of health-promoting activities (Kaplan, 1985; Kaplan and Kaplan, 1989; Takano et al., 2002; Bonnefoy et al., 2003; Grahn and Stigsdotter, 2003; van Herzele and Wiedemann, 2003; Humpel et al., 2004; Jim and Chen, 2006). Another essential aspect of nearby green areas is the ART-component named "compatibility", which refers to how well the environment meets what one wants to do. Studies have shown that a main reason for visiting green urban natural areas is to escape environmental stressors (e.g., Kaplan, 1983; Kaplan and Kaplan, 1989; Takano et al., 2002; Jim and Chen, 2006; Tyrväinen et al., 2007). In a survey among park visitors, Chiesura (2004) found that motives for visiting the park were primarily related to desires to rest and relax, to escape from the stressful rhythm of the city, and to observe and listening to the nature (see also Guastavino, 2006). The latter leads us in to the potential influence of perceiving a positive soundscape when living in a noise-polluted environment.

4.3. Positive soundscapes

Although we did not specifically examined how the residents perceived the soundscape in the green areas, we found that that "better" green-area availability was linked to a higher percentage of residents hearing natural and human sounds (birdsong, children playing) when they were outdoors. This may indicate that there exist a (positive) soundscape in the nearby neighborhood (potentially in the nearby green areas) that is not dominated by road traffic noise. Opportunities to experience quietness – or more accurate – to experience freedom from unwanted sounds and a natural soundscape has shown to play an important role in recreation experiences (e.g., Kariel, 1980; Kaplan and Kaplan, 1989; Grahn, 1994; Hedfors and Grahn, 1998; Tyrväinen et al., 2007). Natural sounds like birdsong, wind in trees, and sounds from water seem to have the ability to evoke pleasant feelings. Sounds from nature are also much more positively judged and preferred than mechanical sounds (e.g., road traffic, machinery, mobile phone), which mostly are rated as unfavorable and annoying (Tamura, 2002; see also Anderson et al., 1983; Nilsson and Berglund, 2006; Yang and Kang, 2005; Guastavino, 2006). Furthermore, the more often heard sounds from children playing when availability to green areas was "better" compared to "poorer" indicate that nearby green urban areas may have potentials to fulfill important social (and stress-reducing) functions by providing places for children to play, adults to meet, and possibilities to strengthen social ties (Cohen and Wills, 1985; Coley et al., 1997; Wells and Evans, 2003; Chiesura, 2004; Sullivan et al., 2004). Thus, opportunities to easily escape a heavily trafficked and noisy surrounding and to perceive a more positive and tranquil sound environment (Guastavino, 2006) might help to reduce noise-induced stress and other adverse effects of traffic noise exposure.

The above-mentioned findings imply that green areas located close to residential settings areas may be one among potential protective factors that can buffer against the adverse health effects due to chronic traffic-noise exposure. One possible explanation links this buffering effect with the promotion of restorative processes.

4.4. Limitations

Some limitations in this study need to be acknowledged. First, the study was originally designed for investigating the effects of having access to a quiet side of the dwelling on resident's health and well-being. The selection of the residential building areas was, therefore, based on the presence of a quiet side as well as several other criteria (e.g., similarity in noise exposures, house types, population characteristics, etc.). This may have reduced the variation in access to green areas. However, the consistent associations between green-area availability and aspects of health and well-being, the non-significant influences of demographic and person factors (which initially was controlled in the selection of the study sites), and the fact that we found an association between the self-reported availability to green areas and the objective information provided by the photographs of the residential settings validate our assessment of the green-area concept and support our results. Second, because of its cross-sectional character the potential causal sequences between assessed variables cannot be determined. However, a main advantage of this type of study design is that data are assessed from persons in realistic conditions. Third, although the results in this cross-sectional study are promising, it does not allow for far-reaching conclusions about the effects of nearby green areas on health and well-being in other urban residential settings exposed to noise from road traffic. Thus, it is possible that there exist differences due to cultural or environmental context. However, regarding urban nearby green areas and health effects, there seems to be similar results in European and Asian countries (e.g., Takano et al., 2002; Jim and Chen, 2006). For noise responses, previous studies indicate that noise may be better tolerated in certain cities and countries than in others (e.g., Wong et al., 2004). Taken together, well-designed longitudinal studies can give valuable knowledge of potential cause-effect relationships and long-term health effects of nearby green areas in noise-polluted environments.

5. Conclusions

In contrast to many other environmental problems, noise pollution is still growing and it is the only environmental impact for which the public's complaints have increased during the last 10 years (European Report, 1996). Correspondingly, between 30 and 50% of the residents in the present study view noise as a problem in their neighborhood. Thus, persistent road traffic noise is a psychosocial stressor – a daily hassle – that affects people's everyday life (e.g., DeLongis et al., 1988; Lercher, 1996; Babisch, 2005). The research program "Soundscape Support to Health" has previously shown that the "quiet side concept" is a factor of significance for moderating the adverse health effects of road traffic noise (Öhrström et al., 2006). Within this program, the present study makes an additional contribution to the literature on noise and health and the influence of natural environments by showing that good availability to nearby green areas furthermore can enhance the positive effects of access to a quiet side, but also that nearby green areas has an important role by itself for moderating the adverse effects of traffic-noise. However, the results also indicate that access to "quietness" or nearby green areas alone or in combination is not completely effective in minimizing the noise problem in our sample of highly traffic noise exposed residents.

To achieve a long-term sustainable and health-promoting urban residential environment it is essential to strive for lower sound levels at the residencies but also in the close neighborhood (Klaeboe et al., 2005), to assure access to "noise-free" places or a quiet side, as well as to protect, preserve and increase the supply of nearby green areas. These suggestions are supported by the EU Directive 2002/49/EC on the assessment and management of noise (CEC, 2002), which states that noise pollution of residential and recreational areas is an important environmental topic and that "quiet" areas must be mapped in the future. In Sweden, the environmental quality objective "A Good Built Environment" stresses that green spaces close to built-up areas should be protected in order to meet the need of recreational/physical activities and play. It is furthermore expressed that residential and recreational environments should fulfill the society's demands of freedom from noise (Governmental proposition, 2000). In this work, it is necessary that local authorities involved in city planning and the protection of citizen's health (e.g., town/traffic planners, building/landscape architects, specialists in environmental medicine) co-operate and that research knowledge in affected disciplines guides the formation of action plans. For example, with respect to lowering citizen's noise burden, noise control measures implemented in cities should preferably focus on applying the "quiet side concept", traffic-volume reduction, use of low noise asphalt, tyre/road and engine noise reduction (e.g., Sandberg, 1999), and "Ecodriving" (smooth driving, use of the highest gear possible; van Leeuwen, 2006). However, many of these measures are difficult or impossible to implement, mainly for political reasons (Kihlman, 2006). With regard to this, it is momentous to maintain and further develop accessible "noise-free" urban greenery within and close to residential areas so that people easily can get away from environmental stress, perceive a positive sound environment, relax and recharge their batteries, and be physically active (e.g., Kaplan, 1983; Burgess et al., 1988; Grahn, 1994; Handy et al., 2002; Chiesura, 2004). It is suggested that the process of planning, design, management, and conservation of green areas should be directed by elaborated approaches. Examples are, interactive planning with users (e.g., Luymes and Tamminga, 1995; Jim and Chen, 2006) and application of various tools such as, evaluation of green space quality and attitudes, GIS techniques for green-space accessibility (e.g., van Herzele and Wiedemann, 2003; Balram and Dragicevic, 2005; Tyrväinen et al., 2007), and soundscape design and assessment (e.g., Berglund and Nilsson, 2006; Nilsson and Berglund, 2006; Schulte-Fortkamp and Fiebig, 2006; Zhang and Kang, 2007).

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