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Access to urban green spaces and behavioural problems in children: Results from the GINIplus and LISAplus studies

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ABSTRACT

Aim: We investigated whether objectively measured access to urban green spaces is associated with behavioural problems in 10-year old children living in Munich and its surrounding areas.
Methods: Behavioural problems were assessed in the GINIplus and LISAplus 10-year follow-up between 2006 and 2009 using the Strengths and Difficulties Questionnaire. Access to green spaces was defined using the distance from a child's residence to the nearest urban green space. Associations between access to urban green spaces and behavioural problems were assessed using proportional odds and logistic regression models in 1932 children with complete exposure, outcome and covariate data.
Results: The distance between a child's residence and the nearest urban green space was positively associated with the odds of hyperactivity/inattention, especially among children with abnormal values compared to children with borderline or normal values (odds ratio (OR) = 1.20 (95% confidence interval (CI) = 1.01–1.42) per 500 m increase in distance). When stratified by sex, this association was only statistically significant among males. Children living further than 500 m away from urban green spaces had more overall behavioural problems than those living within 500 m of urban green spaces (proportional OR = 1.41 (95% CI = 1.06–1.87)). Behavioural problems were not associated with the distance to forests or with residential surrounding greenness.
Conclusion: Poor access to urban green spaces was associated with behavioural problems in 10-year old children. Results were most consistent with hyperactivity/inattention problems.

1. Introduction

Currently, more than half of the world's population lives in urban settings (United Nations, 2011). An increasing number of children grow up in cities and often have limited access to green spaces. The effects of urbanisation on the well-being of children have not been adequately investigated. Further insight into the effects of urban green space access on children's health is needed to inform efficient city planning and the development of effective health policies (Kyttä et al., 2012; Lee and Maheswaran, 2010).

Green spaces appear to have positive effects on human psychological health (Bowler et al., 2010; Lee and Maheswaran, 2010). However, with only a few exceptions, most studies examining associations between green spaces and mental health have been conducted among adults (Bowler et al., 2010; Lee and Maheswaran, 2010). Moreover, objective measurements of green space access have rarely been used in these studies (Annerstedt et al., 2012; Kyttä et al., 2012; Lee and Maheswaran, 2010; Stigsdotter et al., 2010).

Several hypotheses have been proposed to explain how green spaces may have a beneficial effect on mental health and well-being. There is mounting evidence supporting the restorative and stress reductive effects of green spaces (Fan et al., 2011). Better access to green spaces is also hypothesised to promote physical activity, which

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could ultimately lead to improved mental functioning (Fan et al., 2011; Lee and Maheswaran, 2010). Finally, green spaces might also improve psychological health by encouraging the development of social contacts (Maas et al., 2009).

We investigated whether objectively measured access to urban green spaces was associated with behavioural problems in 10-year old children living in Munich and its surrounding areas.

2. Materials and methods

2.1. Study population

The "German Infant Study on the Influence of Nutrition Intervention plus Environmental and Genetic Influences on Allergy Development" (GINIplus) study and the "Influence of Life-Style Factors on the Development of the Immune System and Allergies in East and West Germany plus the Influence of Traffic Emissions and Genetics" study (LISAplus) are ongoing population-based birth cohorts. Both cohorts have a similar study design and recruited healthy full-term neonates with a normal birth weight. GINIplus participants were recruited in the cities of Munich ($n = 2949$) and Wesel ($n = 3042$) between 1995 and 1998. This cohort consists of two study groups: one is an observation group and the second includes a nutritional intervention conducted during the first four months of life, in which a randomised, double-blind controlled trial compared the effect of three hydrolysed formulas versus cow's milk formula on allergy development. Newborns with a family history of allergy were selected for the intervention group. Participants with a negative family history or a positive family history but who declined to participate in the intervention trial were included in the observation group. LISAplus participants were recruited in the cities of Munich ($n = 1467$, but two participants withdrew their consent to participate), Leipzig ($n = 976$), Wesel ($n = 348$) and Bad Honnef ($n = 306$) between 1997 and 1999. The GINIplus and LISAplus studies were approved by the local ethics committees and informed consent was obtained from all parents of participants. More detailed descriptions of these cohorts have been published elsewhere (Heinrich et al., 2002; von Berg et al., 2003, 2013; Zutavern et al., 2006).

The current analyses are restricted to participants residing in the city of Munich and its surrounding areas from the time of recruitment until the 10-year follow-up ($n = 1700$ from GINIplus and $n = 940$ from LISAplus), as land use data at a high resolution was only available for this study centre. The analyses were also restricted to children for whom information on behavioural problems ($n = 1478$ from GINIplus and $n = 792$ from LISAplus) and other covariates ($n = 1303$ from GINIplus and $n = 742$ from LISAplus) was available. Children who reported living at their current address (at the 10-year follow-up) for less than one year were excluded ($n = 85$ from GINIplus and $n = 28$ from LISAplus). Thus, the final study population comprised 1932 participants ($n = 1218$ from GINIplus and $n = 714$ from LISAplus).

2.2. Access to urban green spaces

The following land use types were considered as urban green spaces: "Friedhof" (cemetery), "Gartenland" (garden), "Grünanlage" (park) and "Gärtnerei" (plant nursery). The shortest distance between each child's place of residence at 10 years of age and the nearest urban green space (in metres) was used as a surrogate for urban green space access. Data for these calculations were obtained from the local Bavarian land use dataset (vector with spatial resolution of <5 m) from the Bavarian Survey Office for the year 2008. The land use data covers the entire study territory (27,521.66 km^2), which includes two administrative regions of Bavaria state: Upper Bavaria and Swabia. Data management and calculations were performed in ArcGIS 10.1 Geographical Information System (GIS) (ESRI, Redlands, CA).

2.3. Behavioural problems

Behavioural problems in children were assessed using the German version of the Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997; Woerner et al., 2004). Parents completed the SDQ on behalf of their child at the 10-year follow-up. The SDQ is an internationally disseminated and validated screening instrument used to identify behavioural problems in children and adolescents. In a recent review, the psychometric characteristics of the SDQ were reported to be strong (Stone et al., 2010). Good psychometric properties were also reported for the German version of the parent-reported SDQ in terms of reliability, based on internal consistency (Rothenberger et al., 2008; Woerner et al., 2004), and validity, based on the SDQ's ability to discriminate between clinical and community samples (Becker et al., 2004; Klasen et al., 2000).

The SDQ comprises five subscales for five items (25 items in total): emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems and prosocial behaviour. To score each item, a three-point scale ("not true", "somewhat true" and "certainly true") is used. Subscale scores and the total difficulties score were derived following the standard scoring instructions (http://www.sdqinfo.com/) and subsequently grouped into normal, borderline and abnormal categories, according to cut-off points recommended for a German population (Woerner et al., 2004). According to the standard scoring instructions, SDQ subscale scores were first prorated (mean substitution) when at most two out of five scale times were missing. Overall mental health was assessed by the total difficulties score, which was estimated by summing all subscale scores except for the prosocial behaviour score. As our study was focused on behavioural problems (i.e. difficulty subscales), the prosocial behaviour subscale (i.e. strength subscale) was not included in the analyses.

2.4. Covariates

Potential confounders were selected a priori, mainly based on our previous studies of behavioural problems in children (e.g., Tiesler et al., 2013). The following covariates were extracted from parent-completed questionnaires and considered in the current analyses: study (GINIplus observation group/GINIplus intervention group/LISAplus), sex (male/female), exact age at the 10-year follow-up (years), parental level of education (both parents with <10 years of school (low)/at least one parent with 10 years of school (medium)/at least one parent with >10 years of school (high), classified according to the German education system), age of mother at time of birth (≤30 years/>30–35 years/>35 years), single parent status at the 10-year follow-up (yes/no), time spent in front of a screen (<1 h per day in summer and ≤2 h per day in winter (low)/≥1 h per day in summer or >2 h per day in winter (high)) and time spent outdoors (≤4 h per day in summer and ≤2 h per day in winter (low)/>4 h per day in summer or >2 h per day in winter (high)).

2.5. Statistical analyses

Associations between access to urban green spaces and behavioural problems in children were assessed using proportional odds models. The proportional odds ratio (pOR) is a summary of odds ratios obtained from logistic regression models using incremental cut-points to dichotomise ordinal outcomes (Scott et al., 1997). Possible dichotomizations for the SDQ scales are (i) abnormal/borderline vs. normal and (ii) abnormal vs. borderline/normal. The assumption of homogeneity of the pOR over these two cut-points was tested with a score test. As proposed by Bender and Grouven (1998), when this assumption was violated in either crude or adjusted models, logistic regression models for the above-mentioned dichotomizations were applied and odds ratios (OR) are reported. Effects are reported per 500 m increase in the distance between a child's residence and the nearest urban green space.

All statistical analyses were performed in SAS (version 9.2; SAS Institute Inc., Cary, NC, USA).

2.6. Sensitivity analyses

As study participants were spatially spread over the inner city of Munich and its surrounding areas, we explored potential effect modification by urbanisation using an interaction term between distance to urban green spaces and whether a child lived in the inner city of Munich (yes/no) and by stratifying the main analyses by whether or not a child lived in the inner city of Munich. Since the prevalence of behavioural problems was higher among boys than girls for the total difficulties score (9.7% abnormal and 8.6% borderline in boys, 5.1% abnormal and 5.5% borderline in girls; Chi-square $p < 0.01$) and for all SDQ subscales except for emotional problems (e.g., for the hyperactivity/inattention subscale: 11.5% abnormal and 5.7% borderline in boys, 3.6% abnormal and 4.3% borderline in girls; Chi-square $p < 0.01$), we also tested for effect modification by sex using the same procedure as aforementioned.

In order to explore whether physical activity mediates the association between access to green spaces and behavioural problems, models which contained no physical activity-related covariates were compared to the main models (in which two physical activity-related covariates are included: time spent outdoors and time spent in front of screen) and to models adjusted for parent-reported child physical activity (available for 1625 children).

To test the robustness of our primary exposure variable, we conducted some further sensitivity analyses. First, access to urban green spaces was defined as the presence of urban green spaces (yes/no) in a 500-m buffer around each child's place of residence, rather than as a linear distance. A 500-m buffer, which was assumed to be a proxy for a child's neighbourhood, should represent a distance reachable within 10 min of walking (Villeneuve et al., 2012) as children have limited mobility compared to adults (Duncan et al., 2011). Previous studies examining the effects of green spaces on children and adult health have also used this buffer size (Dadvand et al., 2012; Kyttä et al., 2012; Villeneuve et al., 2012). We repeated this analysis using a 300-m buffer, which is in-line with the European Commission's recommendations for access to green spaces (Ludlow et al., 2003).

Second, to examine whether the size of an urban green space is an influential factor on the studied associations, we limited urban green spaces to those with a land area greater or equal to 5000 m^2, as has been recommended by the European Commission (Ludlow et al., 2003).

Third, we repeated the main analyses after excluding cemeteries and plant nurseries from the urban green spaces definition.

Fourth, we assessed associations using the distance between a child's residence to the nearest forest as the exposure. Forests, in contrast to artificial urban green spaces, represent natural green spaces.

Finally, we assessed associations using residential surrounding greenness, defined by the mean value of Normalized Difference Vegetation Index (NDVI) in a 500-m buffer around each child's place of residence, as the exposure. NDVI is a commonly used indicator of green vegetation. We derived NDVI from Landsat 5 Thematic Mapper (TM) satellite images from the Global Visualisation Viewer from the U.S. Geological Survey (http://earthexplorer.usgs.gov/) for the year 2003 (two images from the 14th of July and one from the 24th of August were merged to cover the study area). A detailed description of the NDVI assessment has been previously published (Markevych et al., 2014).

3. Results

The socio-demographic characteristics and exposure levels of study participants are presented in Table 1. The age of children ranged from 9.4 to 11.7 years and 51.4% of them were male. The median distance to the nearest urban green space was 289.1 m and the interquartile range was 368.1 m. The prevalence of behavioural problems among the study participants, as measured by the SDQ subscales, and the total difficulties scores are presented in Table 2. The internal consistency of the SDQ subscales and the Total Difficulties Score expressed as Cronbach's α (Cronbach, 1951) were comparable to the values obtained for the German validation sample (Woerner et al., 2004): Total Difficulties Score: 0.81; emotional symptoms: 0.68; conduct problems: 0.54; hyperactivity/inattention problems: 0.80; and peer relationship problems: 0.64.

Table 1
Characteristics of the study participants ($n = 1932$).

	Total *n* (%) or mean ± SD[a] or median (IQR[b])
Study	
GINIplus observation group	683 (35.4)
GINIplus intervention group	535 (27.7)
LISAplus	714 (37.0)
Sex	
Male	994 (51.4)
Female	938 (48.6)
Age (years)*	10.1 ± 0.2
Parental level of education[c]	
Low	96 (5.0)
Medium	350 (18.1)
High	1486 (76.9)
Age of mother at birth	
≤30 years	584 (30.2)
>30–35 years	921 (47.7)
>35 years	427 (22.1)
Single parent status at the 10-year follow-up	
No	1715 (88.8)
Yes	217 (11.2)
Time spent in front of a screen[d]	
Low	1451 (75.1)
High	481 (24.9)
Time spent outdoors[e]	
Low	1307 (67.7)
High	625 (32.4)
Distance to the nearest urban green space (m)**	289.1 (368.1)

[a] Standard deviation.
[b] Interquartile range.
[c] Definition based on highest parental level of education: both parents with less than 10 years of school (low), at least one parent with 10 years of school (medium), at least one parent with more than 10 years of school (high), classified according to the German education system.
[d] "Low": defined as less than 1 h per day in summer and 2 h or less per day in winter.
[e] "Low": defined as 4 h or less per day in summer and 2 h or less per day in winter.
* Mean ± SD.
** Median (IQR).

Table 2
Behavioural problems assessed by the Strengths and Difficulties Questionnaire (SDQ).

	n (%)
Total difficulties score	
Normal	1651 (85.5)
Borderline	137 (7.1)
Abnormal	144 (7.4)
Emotional symptoms	
Normal	1591 (82.4)
Borderline	130 (6.7)
Abnormal	211 (10.9)
Conduct problems	
Normal	1685 (87.2)
Borderline	162 (8.4)
Abnormal	85 (4.4)
Hyperactivity/inattention	
Normal	1687 (87.3)
Borderline	97 (5.0)
Abnormal	148 (7.7)
Peer relationship problems	
Normal	1771 (91.7)
Borderline	86 (4.5)
Abnormal	75 (3.9)

Table 3
Associations between the distance to the nearest urban green space and behavioural problems assessed by the Strengths and Difficulties Questionnaire (SDQ). Results are presented as proportional odds ratios (pOR) or odds ratios (OR) with corresponding 95% confidence intervals (CI).

	Crude pOR or OR[a] (95% CI)[b]	Adjusted[c] pOR or OR (95% CI)
Total difficulties score	1.05 (0.91–1.21)	1.07 (0.92–1.23)
Emotional symptoms	0.96 (0.83–1.11)	0.96 (0.83–1.11)
Conduct problems	1.04 (0.89–1.21)	1.03 (0.89–1.20)
Hyperactivity/inattention		
Abnormal/borderline vs. normal	1.11 (0.97–1.28)	1.13 (0.98–1.30)
Abnormal vs. borderline/normal	**1.18 (1.00–1.39)**	**1.20 (1.01–1.42)**
Peer relationship problems	**1.18 (1.01–1.38)**	**1.20 (1.02–1.40)**

Bold text indicates statistical significance at the 5% level.
[a] Proportional odds ratios are homogenous across the cutoffs of the ordinal SDQ variables. If the crude or adjusted models violated this assumption, cutpoint-specific odds ratios are reported.
[b] Effects reported per 500 m increase in the distance to the nearest urban green space.
[c] Adjusted for study, sex, age, parental level of education, age of mother at time of birth, single parent status at the 10-year follow-up, time spent in front of a screen and time spent outdoors.

Associations between access to urban green spaces and behavioural problems are reported in Table 3. A larger distance to the nearest urban green space was statistically significantly associated with an increased risk of hyperactivity and inattention problems, especially among children with abnormal SDQ values compared to children with borderline or normal values (OR = 1.20 (95% confidence interval (CI) = 1.01–1.42)). There was also an association with peer relationship problems (pOR = 1.20 (95% CI = 1.02–1.40)). For overall behavioural problems and for conduct problems, associations were similar in trend but not statistically significant. Finally, a larger distance to an urban green space was positively but not statistically significantly associated with less emotional symptoms.

The interaction term between urban green spaces and urbanisation was not significant. In the stratified analyses, associations between urban green spaces and behavioural problems were slightly stronger for children living in the inner city of Munich ($n = 782$) compared to those living in the surrounding suburban areas ($n = 1150$) (Supplementary Fig. 1).

Associations between urban green spaces with overall mental health and hyperactivity/inattention problems were modified by sex (p-value of interaction terms <0.05). Among males, a larger distance to the nearest urban green space was associated with an increased risk of mental health problems and hyperactivity/inattention problems (analyses stratified by sex presented in Supplementary Table 1). All associations among females were null.

The main findings were robust to the inclusion/exclusion of all physical activity-related variables investigated (data not shown).

Fig. 1 summarises the results of the sensitivity analysis in which behavioural problems are compared between children living closer ($n = 503$) or further than 500 m ($n = 1429$) away from the nearest urban green space. We observed a statistically significant association for hyperactivity/inattention (OR = 1.49 (95% CI = 1.10–1.99) for children with abnormal or borderline values compared to those with normal values; OR = 1.79 (95% CI = 1.24–2.57) for children with abnormal values compared to children with borderline or normal values). There was also a statistically significant association between the absence of urban green spaces in a 500-m buffer around a child's place of residence and greater overall mental health problems (pOR = 1.41 (95% CI = 1.06–1.87)). When we repeated these analyses using a 300-m buffer (937 children reside within 300 m of an urban green space), the association with hyperactivity/inattention problems was similar but weaker (OR = 1.21 (95% CI = 0.92–1.60) for children with abnormal or borderline values compared to children with normal values; OR = 1.45 (95% CI = 1.02–2.04) for children with abnormal values compared to those with borderline or normal values). All other associations were not significant.

The association between access to green spaces and hyperactivity/inattention problems was no longer significant after excluding urban green spaces smaller than 5000 m^2 (OR = 0.95 (95% CI = 0.75–1.19) for children with abnormal or borderline values compared to children with normal values; OR = 1.06 (95% CI = 0.82–1.38) for children with abnormal values compared to children with borderline or normal values). The association between access to green spaces and peer

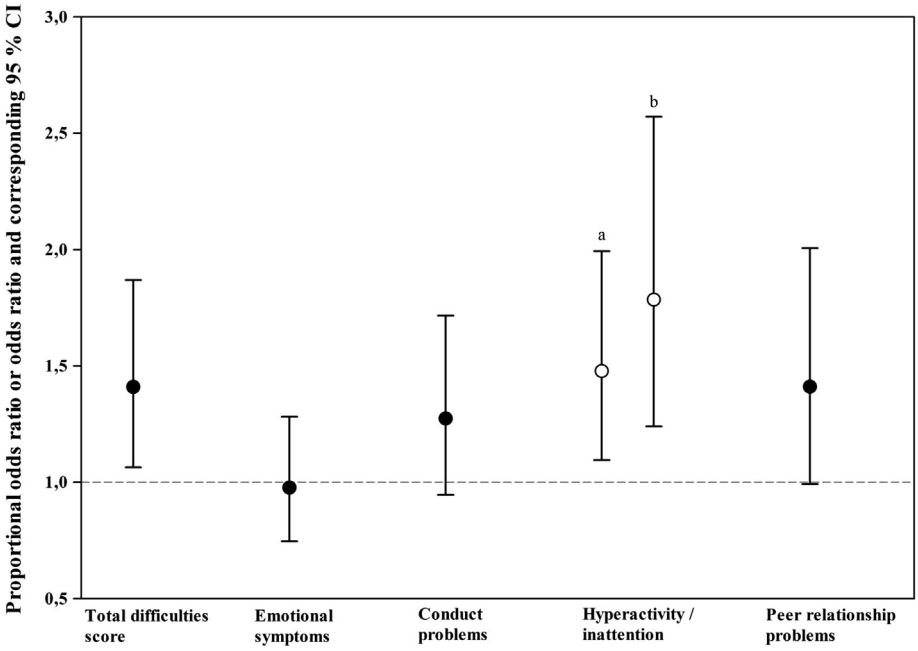

Fig. 1. Associations between urban green spaces within a 500-m buffer around the residential address and behavioural problems assessed by the Strengths and Difficulties Questionnaire (SDQ). All models are adjusted for study, sex, age, parental level of education, age of mother at time of birth, single parent status at the 10-year follow-up, time spent in front of a screen and time spent outdoors. Black circles indicate proportional odds ratios; white circles indicate odds ratios (a — abnormal/borderline vs. normal, b — abnormal vs. borderline/normal).

relationship problems was also attenuated and no longer statistically significant (pOR = 1.11 (95% CI = 0.87–1.42)).

When cemeteries and plant nurseries were excluded from the urban green space definition, a larger distance to urban green spaces remained significantly associated with an increased OR for hyperactivity and inattention problems (1.06 (95% CI = 1.01–1.13) for children with abnormal or borderline values compared to children with normal values; 1.07 (95% CI = 1.00–1.15) for children with abnormal values compared to children with borderline or normal values).

Poorer access to forests and residential surrounding greenness, as measured by NDVI, were not associated with behavioural problems in children (data not shown).

4. Discussion

4.1. Key findings

Hyperactivity/inattention and peer relationship problems in 10-year old children were positively associated with increasing distances to urban green spaces. The effects were slightly stronger for children residing in the inner city of Munich. When stratified by sex, the observed association with hyperactivity/inattention was only statistically significant among males. Children living further than 500 m away from any urban green space had more overall behavioural problems than those living within 500 m of an urban green space. When small (<5000 m^2) green spaces were excluded from the analysis, no statistically significant associations were observed. Finally, behavioural problems were not associated with the distance to a forest or with residential surrounding greenness.

4.2. Interpretation of the results

Hyperactivity and inattention are symptoms of attention-deficit/hyperactivity disorder (ADHD), which is among the most commonly diagnosed child psychiatric disorder. More than 5% of children are affected worldwide (Polanczyk et al., 2007). ADHD is characterised by elevated impulsivity, increased motor activity, impaired concentration and short-term memory deficits, all of which can reduce school performance (Schmiedeler and Schneider, 2013). The observed association with hyperactivity/inattention problems was quite robust in our study, and remained significant in two of the sensitivity analyses (exclusion of cemeteries and plant nurseries from the urban green space definition and dichotomization of the exposure as yes/no urban green space in a child's neighbourhood). However, in these same two sensitivity analyses, associations with peer relationship problems were attenuated. Whether a true independent causal link exists for each outcome requires further examination, especially for peer relationship problems, which were less consistently associated with urban green spaces in our study.

There are several theories which attempt to explain the psychological benefits of green spaces. Among them, is a purported effect of physical activity (Fan et al., 2011; Lee and Maheswaran, 2010). Better access to green spaces is hypothesised to increase the frequency and level of physical activity by decreasing the perception of effort and increasing levels of motivation (Gladwell et al., 2013). Moreover, physical activity conducted outdoors in green environments has been shown to lead to greater feelings of revitalization and positive engagement compared to physical activity conducted indoors (Gladwell et al., 2013). Interestingly, although many studies have recently investigated the link between objectively measured neighbourhood green spaces and physical activity in adolescents and children (Ding et al., 2011; Lee and Maheswaran, 2010), the results remain inconsistent. Unfortunately, we did not have data on objectively measured physical activity or information on whether physical activity was being conducted in urban green spaces. Nevertheless, the results of the two sensitivity analyses we conducted to examine any effect mediation by questionnaire-derived physical activity yielded null findings.

A second hypothesis is that any green space-related benefits may be explained by the restorative and stress-mitigating effects of green spaces, as summarised by the complementing stress reduction theory (SRT) (Ulrich et al., 1991) and attention restoration theory (ART) (Kaplan, 1995). The SRT describes how exposure to nature may activate affective response, behavioural approach orientation and continuously relaxed attention (Ulrich et al., 1991). The ART, on the other hand, emphasises that the natural environment may alleviate recovery from mental fatigue caused by directed attention (Kaplan, 1995). In line with these theories, it has been reported that walking or playing in green environments reduces symptoms of ADHD in children (Kuo and Taylor, 2004; Lee and Maheswaran, 2010; Searight et al., 2012; Taylor and Kuo, 2009; van den Berg and van den Berg, 2010). Both the SRT and ART suggest that contact with any type of green space (even just a physical presence in them) and greenness itself may be beneficial for mental health. However, our results indicate that for our study population of 10-year old children, urban green spaces were most important. All associations with natural green spaces (forests) were null. Unfortunately, we did not have information on the time spent in specific green spaces and activities conducted there. We might suppose that urban green spaces are most attractive for 10-year old children, as they are likely better maintained and may be perceived to be safer than forests. Moreover, due to perceived lack of safety and insufficient maintenance, 10 year-old children might not be allowed to wander alone in forests. The null findings for surrounding greenness may indicate that access to structured urban green spaces is more important for children than having a high level of green vegetation in the neighbourhood.

In line with our primary assumption, we found that effect estimates were slightly stronger in the inner city of Munich compared to its surroundings. We hypothesise that there is a general lack of green spaces in urban areas, and thus parks and gardens play a more important role for urban residents than for those living in suburban or rural areas, in which natural green spaces are more prevalent.

In stratified analyses, the associations with overall mental health and hyperactivity/inattention were significant only among males. It is possible that there may be sex differences in the usage (frequency and type of activity) of urban green spaces. It is also possible that boys may be more likely to be allowed to use neighbourhood green spaces unsupervised than girls. However, we did not have the necessary data to verify either of these assumptions. Nevertheless, this finding suggests that poor access to urban green spaces might affect the psychological health of 10-year-old boys to a greater extent than girls of the same age. This observation may be important when considering that ADHD is more prevalent in males than females (Polanczyk et al., 2007).

The attenuation of the associations after excluding small green spaces from the exposure definition may suggest that small urban green spaces play an important role among children.

The association between an absence of neighbourhood green spaces and worse overall mental health among children, and especially boys, is consistent with previous studies conducted mainly among adults. A recent literature review, which included 35 articles (Lee and Maheswaran, 2010), reported that green spaces may benefit the well-being and mental health of children and adults. A second systematic review, which included 25 studies and focused mainly on the short-term effects of green spaces in different age groups (Bowler et al., 2010), suggested that green environments may have positive effects on well-being and emotional health. In a cross-sectional study conducted in Turku, Finland, which included 1837 children and adolescents, a larger proportion of green spaces in a 500-m buffer around the place of residence was associated with better perceived health. In a large survey conducted in New Zealand (n = 8157), adolescents and adults who lived in neighbourhoods with more green spaces had better mental health than those with less green spaces (Richardson et al., 2013). In a study including 9230 Swedish adults, the risk of having self-reported poor mental health was lower among those with green spaces within a 300-m buffer around the place of residence and

among physically active women (Annerstedt et al., 2012). In a cross-sectional study conducted in Chicago on 1544 adults, green spaces were found to mitigate stress (Fan et al., 2011).

4.3. Limitations

The cross-sectional design of our study is its main limitation. Causal relationships cannot be inferred, and it is not possible to determine whether the observed effects may be due to a lagged association between green spaces and mental health. We are also unable to exclude the effect of any self-selection bias on the associations. That is, that parents from a higher SES are more likely to select living in greener neighbourhoods and to have less behavioural problems. Our results are also prone to attrition bias as GINIplus participants (especially those from the observation group), and those born to young mothers were less likely to be included in the current analyses. Furthermore, families with a lower level of education and income were less likely to be initially recruited and to continue participating in the 10-year follow-up of the GINIplus and LISAplus cohorts. Therefore, as in the case with the Danish National Birth Cohort, children with a lower socioeconomic status are under-represented in this analysis, and the generalizability of our findings is questionable (Jacobsen et al., 2010). Moreover, we did not have data on area-level SES, which could be a source of residual confounding. Neighbourhood SES could be associated with both behavioural problems and access to green spaces, with more deprived neighbourhoods being less green and having a higher prevalence of behavioural problems in children (Kalff et al., 2001). Nevertheless, we cautiously adjusted our models for variables representing socioeconomic status, such as parental education level and single parent status at the 10-year follow-up. Since only 5% of the study participants had parents with a low parental education level, it was not possible to carry out analyses stratified by parental education level. A further limitation is that we were unable to control for parental psychopathology, physical health and activity, as well as parenting methods which may be sources of residual confounding. Moreover, there is a potential for exposure misclassification as we used the linear distance from a child's residence to the nearest urban green space as a surrogate for access to urban green spaces. Unfortunately, we did not have information on which green spaces (the nearest, the second nearest, etc.) each child visits, and how often. However, we conducted an additional analysis using presence or absence of urban green spaces in the neighbourhood as a dichotomous exposure variable, and our main findings remained robust. We also did not have information on quality characteristics of green spaces, such as their accessibility to the public, perceived safety, availability of playgrounds, maintenance, and occurrence of organised events, all of which could result in residual confounding. Moreover, we were unable to control for indoor greenness (i.e. houseplants) and for own (not public) green spaces (i.e. backyards/gardens). Finally, behavioural problems in children were assessed by a screening questionnaire and unfortunately, could not be confirmed by a physician's diagnosis.

5. Conclusions

Our findings suggest that children with poorer access to urban green spaces are more likely to have hyperactivity/inattention problems at 10 years of age. This association was only significant in males. Moreover, the absence of urban green spaces in a child's neighbourhood was associated with poorer overall mental health. Behavioural problems were not associated with the distance to a forest or with residential surrounding greenness. Given the general lack of studies on the influence of green spaces on mental health of children, further research is warranted and our observed associations should be replicated.

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Appendix A. Supplementary data

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