Umweltstress und Erholung in Wohngebieten
Psychologische Perspektiven zur Optimierung urbaner Entwicklung

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Abstract

City residents are often exposed to multiple environmental burdens that may cause stress and thereby pose a health risk. However, surprisingly little is known about the relative impact of specific stressors on mental health, or the co-occurrence of stressors, and on the potential to compensate for such risks through the inclusion of natural resources such as general vegetation in densely built areas and public green spaces. Moreover, most research has focused on a singular level of analysis, while from a theoretical perspective, the interaction between contextual and individual-level factors is especially critical in regard to mental health. Thus, the aim of this study is to investigate the co-occurrence of multiple environmental burdens and the potential of natural resources with respect to the mental health of city residents. Based on a comprehensive theoretical model of the stress and restoration process three consecutive studies were conducted in Berlin. An online survey facilitated the identification of the most critical local environmental factors. Subsequently a spatial analysis was conducted using a Geographic Information System in order to select two structurally, architecturally and socially comparable neighborhood street blocks with high versus low burden levels in regard to traffic noise, air pollution, and provision of green space. A household survey was conducted in the selected study sites that additionally assessed the perceived level of other locally relevant burdens (litter and dirt in the public space, behavior-related noise, general vegetation). Qualitative data and hair cortisol level as an objective indicator of chronic stress, were supplemented in a subsample. Results showed that either multiple stressors co-occur or multiple resources are co-present. Residents from high-burden blocks behave in a less healthy manner than residents from low-burden blocks, but they do not differ in regard to perceived mental health or cortisol level. However, perceived air pollution is related to perceived health. Moreover, individuals who feel more impaired, annoyed, or at risk by air pollution have higher cortisol levels. This relation exists with a high level of objective air pollution only, while no such relation exists when objective air pollution is low. This finding suggests chronic environmental stress with detrimental health consequences. Finally, residents whose homes have views onto high amounts of diverse kinds of vegetation, as well as who regularly use a park or a vegetated way have lower cortisol levels and partly report higher life satisfaction. The results have implications for public health and sustainable urban development.
Zusammenfassung

1. Einleitung


Das DFG-Graduiertenkolleg Stadtkologische Perspektiven III bringt Optimierungsstrategien für urbane Naturentwicklung in diesen Diskurs ein. Das Hauptziel meines Teilprojekts war zu identifizieren, welche Umweltbelastungen im Hinblick auf die psychische Gesundheit von Stadtbewohnerinnen und Stadtbewohnern\(^1\) am dringlichsten reduziert werden sollten, und welche natürlichen Ressourcen Potential aufweisen, die psychische Gesundheit zu fördern.


\(^{1}\) Ich bitte insbesondere die weibliche Leserschaft um Verständnis, dass ich im Folgenden für eine bessere Lesbarkeit auf weibliche Personenbezeichnungen verzichte.
2. Theoretische Perspektiven


2.1 Von akutem zu chronischem Stress

Akuter Stress ist zunächst eine adaptive Reaktion zur Bewältigung der wahrgenommenen herausfordernden Umweltanforderungen, die auf mehreren Ebenen der Befindlichkeit

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2.2 Zum gesundheitlichen Potential von (Stadt-) Natur

2.3 Zusammenfassung


![Abbildung 1. Theoretischer Rahmen zum Einfluss von Umgebungstressoren und natürlichen Ressourcen auf die psychische Gesundheit (eigene Darstellung). Die Zusammenhänge sind stark vereinfacht dargestellt und auf das Forschungsdesign dieser Arbeit bezogen. Einzelne Bausteine sind beispielhaft zu verstehen.](image-url)
3. Empirische Befundlage

3.1 Umgebungsstressoren und Befindlichkeit

In der Literatur finden sich zahlreiche Belege, dass Umweltfaktoren wie Lärm, Gerüche, soziale und räumliche Dichte oder Temperatur akute Stressreaktionen auslösen können (für Quellenangaben sei auf die angehängten Artikel verwiesen). Entscheidender für diese Arbeit ist aber, welche gesundheitlichen Effekte sich bei längerfristiger Exposition am Wohnort feststellen lassen. Zu dieser Frage dominieren zwei Forschungsansätze. Zum einen wurde gezeigt, dass Anwohner von Stadtteilen, Wohngebieten oder Straßen mit multiplen Stressoren auch unter Kontrolle des individuellen sozioökonomischen Status mehr Stress erleben und eine schlechtere Befindlichkeit aufweisen als Anwohner weniger belasteter Gebiete (z.B. Agyemang et al., 2007; Dalgard & Tambs, 1997; Dupéré & Perkins, 2007; Pacione, 2003; Silver, Mulvey & Swanson, 2002; Thomas et al., 2007). Dabei wurden diverse physische und psychosoziale Stressoren (z.B. Kriminalität, Verwahrlosung der Umgebung) integriert betrachtet, so dass der Beitrag einzelner Stressoren und die Art ihres Zusammenwirkens offen bleiben.


Luftverschmutzung geht älteren Studien zufolge eher mit psychiatrischen als mit somatisch-kardiovaskulären Symptomen einher. So wurden an Tagen mit erhöhter Stickstoffoxid-, Staub- und Schwefeldioxidbelastung erhöhte Einweisungsrate in Psychiatrien festgestellt, wobei für Kohlenmonoxid- und Ozonbelastung uneinheitliche Befunde vorliegen (Briere et

3.2 (Stadt-) Natur und Befindlichkeit


3.3 Integration und Forschungsfragen

Zusammenfassend können multiple Umgebungsstressoren die aktuelle Befindlichkeit negativ beeinflussen und längerfristig zu einem Gesundheitsrisiko werden. Der relative Einfluss spezifischer Stressoren und die Art ihres Zusammenwirkens sind jedoch unbekannt, sodass es an Handlungsperspektiven für die Stadtentwicklung mangelt. Gleichzeitig kann Stadtnatur⁳ in Wohngebieten Potential für die Förderung psychischer Gesundheit aufzuweisen, die Mechanismen sind jedoch unklar.


³ Der Begriff Stadtnatur ist in dieser Arbeit sehr breit gefasst und bezieht sich sowohl auf urbane Grünlagen unterschiedlichster Art, als auch auf diverse Vegetationsarten unterschiedlicher Pflegegrade innerhalb hoch - gradig versiegelter Gebiete im Außenraum. Für Referenzen zu den Befindlichkeitseffekten anderer natürlicher Ressourcen sei auf Artikel IV verwiesen.

1.) Welche Umgebungsstressoren sind im Berliner Stadtgebiet am kritischsten?

2.) Sind Zusammenhänge zwischen multiplen Umweltbelastungen in Wohngebieten und der psychischen Gesundheit von Anwohnern nachweisbar?

3.) Wie wirken multiple Umweltbelastungen hinsichtlich der psychischen Befindlichkeit zusammen?

4.) Inwiefern können allgemeine Vegetation im Wohngebiet und öffentliche Grünflächen eine Ressource für die psychische Gesundheit von Stadtbewohnern darstellen?
4. Methodologischer Hintergrund

4.1 Allgemeine methodische Überlegungen


für chronischen Stress analysiert.


4.2 Methodische Teilschritte

Wie in Abbildung 2 skizziert, dienten vier methodisch-empirische Teilschritte der Beantwortung der Fragestellungen. Zur Identifikation der Umgebungsstressoren mit der höchsten Wahrscheinlichkeit, bei einem Großteil der Berliner Bevölkerung Stress zu erzeugen, erfolgte eine Online-Studie mit multiplen Ein schlusswegen, um eine breite und heterogene Stichprobe zu gewinnen. Es haben sich $N = 763$ Personen aus allen Bezirken Berlins beteiligt.

<table>
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*Abbildung 2.* Methodisch-empirisches Vorgehen der vorliegenden Arbeit und Zuordnung der Forschungsfragen und der im Anhang befindlichen Artikel (eigene Darstellung).


An diesen Standorten erfolgte in einem dritten Schritt eine Fragebogenstudie als Haushaltsbefragung, an der sich \(N = 428\) Anwohner beteiligten. Letztlich schloss sich ein Jahr später in einem vierten Schritt eine vertiefende Interviewstudie an einer Teilstichprobe von \(N = 32\) an, in der auch Haarproben und qualitative Daten erhoben wurden.

Im folgenden Kapitel sind die Fragestellungen und Hauptbefunde der vier Artikel zusammengefasst, die den Kern der kumulativen Dissertationsschrift darstellen. Erkenntnisse, die nicht in den Artikeln beschrieben, aber für den Gesamtrahmen der Arbeit von Interesse sind, werden als Zusatzinformationen beschrieben. Für eine Erläuterung und Diskussion der methodischen Vorgehensweisen sei auf die Originaltexte verwiesen.

\(^4\) Cornelius Senf übernahm die technische Ausführung in ArcGIS.

5. Zusammenfassung der Artikel

5.1 Artikel I: Environmental stress in urban neighborhoods


*Zusatzinformationen.* Die wahrgenommenen Intensitäten aller Faktoren korrelierten untereinander sehr signifikant zu .30 oder höher. In einer Analyse zum Zusammenwirken multipler Faktoren anhand der Wahrnehmungen anstatt Bewertungen zeigte sich ebenfalls wahrgenommene Sauberkeit als einziger und lediglich schwacher Prädiktor der

\(^6\) In dieser Arbeit entspricht der Begriff Wohnzufriedenheit der Zufriedenheit mit der Wohnumgebung und beinhaltet keine Evaluation bezüglich der Wohnung oder des Wohngebäudes.
Wohnzufriedenheit. In dieser Studie wurde Wohnzufriedenheit global durch ein Item erfasst. In der folgenden Studie wurde auf eine differenziertere Skala zurückgegriffen.

5.2 Artikel II: Multiple environmental burdens and neighborhood-related health of city residents


\(^7\) Objektive Belastung bezieht sich in dieser Arbeit auf die im Digitalen Umweltatlas vorliegende Umweltvaluation, die unabhängig von der subjektiven Evaluation der untersuchten Probanden ist. Dass auch der Umweltatlas keine vollständig objektive Belastung abbildet, wird in Kapitel 6.2 diskutiert.
geht nicht auf sozioökonomische Merkmale zurück. Das Gesundheitsverhalten konnte
bei den Berufstätigen und den Personen mit anderem beruflichem Status additiv durch
wahrgenommenen Verkehrslärm und wahrgenommene Luftverschmutzung vorherge-
sagt werden. Die Teilnehmer hoch versus gering belasteter Blocks unterschieden sich
nicht in Lebenszufriedenheit, allgemeiner Gesundheit, Depressivität und Ängstlichkeit –
weder in der Gesamtstichprobe noch bei diversen Zusatzanalysen mit potentiell vulnera-
bleren oder stärker exponierten Subgruppen. Allerdings konnten in der Gesamtstichprobe
diese Gesundheitsindikatoren jeweils zu einem kleinen Anteil durch die wahrgenommene
Luftqualität vorhergesagt werden. Dieses Resultat weist die in Kapitel 3.1 genannten
Befunde zum Zusammenhang zwischen Luftverschmutzung und psychischer Gesundheit
erstmals auf der Ebene von Straßenblocks nach.

Zusatzinformationen. Wahrnehmung und Bewertung der Luftverschmutzung korreli-
erten in den hoch belasteten Straßenblocks höher mit Lebenszufriedenheit, Depressivität und
Ängstlichkeit als in den gering belasteten Blocks. Eine Skala zur Erfassung des Sozialklimas
zeigte, dass die Bewohner der hoch belasteten Blocks das soziale Klima der Nachbarschaft
größtenteils negativer bewerteten als die Bewohner der gering belasteten Blocks.

In der Online-Studie wurde auch Kälte im Winter negativ bewertet. Zudem fand die
Befragung zur kalten Jahreszeit und an einer relativ jungen Stichprobe statt, sodass eine
Unterschätzung des Stresspotentials von Hitzebelastungen nicht auszuschließen war. Daher
wurde ein Datensatz zum Bioklima ebenfalls in die GIS-Analyse einbezogen. Nur einer
der vier gering belasteten Blocks (Kreuzberg) wies auch günstige klimatische Bedingungen
auf. Anwohner dieses Blocks unterschieden sich weder in der subjektiven Bewertung des
Klimas, noch in der Gesundheit von den anderen Teilnehmern.

In einem der vier Gebiete (Treptow-Neukölln) unterschied sich die subjektive Intensität
aller relevanten Umweltfaktoren signifikant und entsprechend der Variation; zudem waren
dort die Effektstärken des Vergleichs der Wahrnehmungen und Bewertungen aller Faktoren
zwischen dem hoch versus gering belasteten Block am höchsten. Daher erfolgte die verti-
efende Interviewstudie dort.

5.3 Artikel III: Residential exposure to multiple stressors and cor-
tisol level: New insights from a Berlin neighborhood study

Fragestellungen. Diese Folgestudie hatte zum Ziel, die Befunde der Fragebogenstudie
durch Analyse des Haar-Cortisols als objektiven Indikator für chronischen Stress zu ergänzen
und mit qualitativen Interviews zu vertiefen. Die erste Hypothese war, dass die Bewohner

**Ergebnisse.** Die beiden Teilstichproben (n = 17 vs. n = 15) waren in soziodemografis- 
Zusatzinformationen. Das Gesundheitsverhalten unterschied sich in dieser Stichprobe nicht signifikant, was auf die kleine Stichprobengröße, einen höheren Anteil Beschäftigungsloser im hoch belasteten Gebiet und auf ein gleiches Niveau an körperlicher Aktivität als Teilaspekt des Gesundheitsverhalten zurückgehen mag.

5.4 Artikel IV: Healthy urban design: Beyond public parks


wöchentlich oder häufiger einen nahgelegenen Park (Görlitzer Park) und einen begrünten Fußgängerweg entlang eines Kanals (Landwehrkanal) nutzten, wiesen signifikant geringere Cortisol-Niveaus auf. Der Effekt des begrünten Wegs war stärker als der des Parks, zudem gaben die regelmäßigen Nutzer dieses Wegs, nicht aber die Nutzer des Parks, eine signifikant höhere Lebenszufriedenheit an. Hinsichtlich des allgemeinen Gesundheitszustands zeigten sich keine Effekte. Der Weg am Kanal verbindet beide Wohnblocks mit anderen Gebieten in mehrere Richtungen, wurde von den Probanden als ein ästhetisch ansprechender Raum wahrgenommen und teilweise allein und für kurzweilige oder längere Erholungsaktivitäten genutzt. Der Park wurde als sozio-kultureller Erlebnisraum, jedoch nicht als natürliche Umgebung geschätzt und nicht zur Erholung, sondern für soziale Zwecke oder zur Durchquerung besucht. Dieser Befund deutet an, dass urbane Grünflächen möglicherweise nicht nur aufgrund der Natur gesundheitliches Potential aufweisen, sondern indem sie Raum für die Befriedigung sozialer Grundbedürfnisse bieten, die mit physiologischer Aktivierung assoziiert ist (Seeman, 1996; Uchino et al., 1996). Die Teilnehmer des nähergelegenen Blocks in Alt-Treptow (geringe Belastung) nutzten den Görlitzer Park häufiger. Die Nutzungshäufigkeit des Weges am Kanals, spezifischer Grünflächen und aller begrünter Flächen (jugliche Grünflächen und begrünte Wege) insgesamt unterschieden sich jedoch nicht zwischen den Teilnehmern beider Blocks. Der Aktionsraum in der Freizeit war weitestgehend auf einen Umkreis von etwa drei Kilometern beschränkt; das Umland wurde selten aufgesucht. Insgesamt kam begrünten und verkehrsberuhigten Wegen für alltägliche Strecken und für aktives und passives Erholungsverhalten eine hohe Bedeutung zu. Dies galt für Teilnehmer aus beiden Blocks und mit unterschiedlichen soziodemografischen Hintergründen. Für die Nutzung begrünter Wege wurden im Alltag Umwege in Kauf genommen, was für den Besuch eines Parks selten der Fall war.

6. Diskussion

6.1 Zusammenfassung der Befunde


Ein positiver Effekt der Nutzung von Stadtparks auf die Befindlichkeit wurde bereits gezeigt (Bowler, Buyung-Ali, Knight & Pullin, 2010; Ward Thompson, Aspinall & Bell, 2010). Das Potential von allgemeiner Vegetation in Wohngebieten für die psychische Befindlichkeit wurde hingegen bislang kaum und lediglich mit subjektiven Indikatoren untersucht (Kuo & Sullivan, 2001b; Sullivan, Kuo & Depoorter, 2004; van Dillen, de Vries, Groenewegen & Spreeuwenberg, 2011). Der Befund zum „grünen Blick“ – im Sinne hoher Quantität unterschiedlicher Vegetationsarten – und dem Cortisol-Niveau entspricht Experimenten aus unterschiedlichen Ländern, in denen eine Reduktion neurophysiologischer Aktivierung durch das Betrachten von lokaltypischen Naturszenen nachgewiesen wurde (Chang et al., 2008; de Kort et al., 2006; Laumann et al., 2003; Parsons, Tassinary,
und Vegetationsformen gelten. Er spricht für einen Effekt durch die permanente visuelle
(oder auch multi-sensorische) Wahrnehmung von Vegetation und einer positiven Bewertung
dieser Perzeption, welche die Befindlichkeit anhaltend positiv beeinflusst. Es ist der bislang
 einzige Befund zum chronischen neurophysiologischen Korrelat der Versorgung mit
Vegetation in einem dicht bebauten Innenstadtbereich. Da aufgrund der kleinen Stichprobe
keine weitere Spezifikation oder Klassifikation der Vegetation möglich war, sind experi-
mentelle Studien zu den neurophysiologischen Effekten spezifischer Bewuchs-Arten und
Spezies wünschenswert.

Die Befunde dieser Arbeit deuten zudem auf ein gesundheitliches Potential begrünter
verkehrsfreier Wege hin, da sie für Erholungsaktivitäten in der Freizeit und für tägliche
Wege genutzt werden. Als Verbindung vom Wohnort zu einem Park machen sie den Besuch
dieses Parks bei manchen Personen wahrscheinlicher, und die regelmäßige Nutzung eines
begrünten Weges ist mit geringerem Cortisol-Niveau und höherer Lebenszufriedenheit
assoziert. Möglicherweise können begrünte Wege fehlende Grünflächen kompensieren,
da die Teilnehmer des hoch und gering belasteten Blocks mit Anschluss an den Kanal
begrünte Flächen insgesamt gleich häufig nutzen und sich nicht im Ausmaß der körperli-
chen Aktivität unterscheiden. Dass die Nutzung des Wegs am Kanal mit der psychischen
Gesundheit assoziiert ist, entspricht der theoretischen Arbeit von Kaplan und Kaplan (1989),
die Erholungseffekte von Natur unter anderem auf eine hohe Kompatibilität mit vielen
Verhaltenszielen, dem Erlebnis räumlicher Ausdehnung und der Möglichkeit, alltäglicher
Routine zu entkommen, zurückführen. Diese Aspekte wurden in den Interviews im Kontext
der Nutzung dieses Weges in der Freizeit und im Alltag angesprochen. Gesundheitspräventive
Maßnahmen sind allgemein besonders effektiv, wenn sie in den Alltag integrierbar sind (Bull,
Giles-Corti & Wood, 2010; Faltermaier, 2005). Das Ergebnis ist weiterhin mit dem von
Grahn und Stigsdotter (2003) publizierten negativen Zusammenhang zwischen der Nutzung
von Grünflächen und stressbezogenen Erkrankungen (Grahn & Stigsdotter, 2003) konform.
Da keine anderen Publikationen zu begrünten Wegen in der Gesundheitsforschung vorzulie-
gen scheinen, ist die Generalisierbarkeit der Befunde schwer einschätzbar. Berlin weist im
europäischen Vergleich überdurchschnittlich viele öffentliche Grünflächen auf (European
Wege ein vergleichbares Potential aufweisen, etwa indem sie fehlende Parks kompensieren
cönnen, muss in weiterführenden Studien untersucht werden.

Die Effekte des grünen Blicks und der Nutzung von Grünflächen sind unabhängig
vom Ausmaß der objektiven Umweltstressoren und von umwelt-unabhängigen Stressoren.
Dies lässt eher auf einen direkten als einen stress-kompensatorischen Einfluss der Stadt natur
auf die psychische Gesundheit schließen und steht damit in Einklang, dass die Präferenz natürlicher Umgebungen universal und auch ohne Stress gegeben ist (Regan & Horn, 2005).


8 Diese Aussage bezieht sich auf einen Vergleich zwischen den deskriptiven Statistiken der Umweltwahrnehmungen und -bewertungen in der Online-, Fragebogen- und Interviewstudie und dem jeweiligen Anteil, der an der Wohnzufriedenheitsvarianz erklärt werden konnte.
Instabilität, einem schlechten Image und höheren Kriminalitätsraten beitragen (Marans & Stimson, 2011). Schließlich stellt die Kovariation dieser Stressoren oder Ressourcen die Interpretation der Befunde aus Feldstudien, die einen spezifischen Faktor isoliert untersuchen (z.B. Lärmwirkungsforschung), infrage. Dies spricht für die ökologische Validität der Forschungsfrage zur Auswirkung multiplier Belastungen auf die Befindlichkeit und unterstreicht den dringenden Forschungsbedarf in diesem Bereich.

6.2 Einschränkungen und Forschungsausblick

Durch die Anwendung neuer und teils explorativer Methoden kann diese Arbeit wichtige Forschungslücken schließen und neue aufzeigen. Das gewählte Vorgehen bringt jedoch Einschränkungen mit sich, die bei der Interpretation der Befunde und bei weiterführender Forschung berücksichtigt werden sollten.


Letztlich mögen in der vorliegenden Arbeit die Freiwilligkeit der Teilnahme und die Beschränkung auf Personen mit hinreichenden Deutschkenntnissen zu einer Überrepräsentation von Personen mit höherem sozioökonomischem Status und zu kulturell homogenen Stichproben geführt haben. Um Personen mit geringem sozioökonomischem Status zu gewinnen, könnte ein partizipativer Forschungsansatz hilfreich sein. Dadurch ließen sich sowohl die Forschungsfragen an den Bedarf sozial schwacher Personen anzupassen, als auch Multiplikatoren (z.B. Mitglieder lokaler Gruppen) in die Datenerhebung einbinden (Bergold & Thomas, 2012; Chavis & Newbrough, 1986). Der in qualitativen Interviews identifizierte Gentrifizierungskonflikt verdeutlicht die Notwendigkeit, eine zuvor definierte Forschungsfrage für zusätzliche lokale Belange zu öffnen, um die ökologische Validität einer Untersuchung zu gewährleisten.

6.3 Praktische Perspektiven


Literatur


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ANHANG

Übersicht der Originalartikel

Manuskript Artikel 1

Manuskript Artikel 2

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Manuskript Artikel 4

Selbständigkeitserklärung


Human perception of urban environment and consequences for its design

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4. Environmental Stress in Urban Neighbourhoods

With regard to sustainable urban development it is of special interest to investigate if, and if yes, how abiotic and biotic environmental factors affect human health and well-being. This question has mostly been addressed within the field of epidemiology and environmental medicine rather than psychology. However, before city dwellers end up suffering from health consequences such as lung diseases caused by fine dust particles or heat strokes in urban heat islands, they may first experience stress induced by such critical factors. This applies to a much larger proportion of urban populations as severe diseases are usually caused by the concurrence of multiple and often independent risk factors rather than just one. In regard to human health, psychological effects do matter. Human health is defined as a “(…) state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (WHO, 1946). At the end of the last century researchers began to put more emphasis on psychological processes as mediators in the relationship between objective environmental conditions and human well-being. This is partly due to the fundamental theoretical work of Richard Lazarus’ research group outlined briefly in the following.

The cognitive-transactional stress theory of Lazarus and colleagues (Lazarus, 1966, 1991; Lazarus & Cohen, 1978; Lazarus & Folkman, 1984; Lazarus & Launier, 1978) explains how stress reactions to environmental stimuli arise by cognitive processes and by a dynamic and interdependent interaction of objective attributes of the environment and personal characteristics. Thus, the theory is most suitable to explain inter-individual differences in reactions to or consequences of stressful environmental conditions. In short, stress is conceptualized as a perceived imbalance between environmental demands and resources to fulfill these demands.

According to the theory, a situation is perceived and evaluated in regard to one’s own well-being (primary or demand appraisal). If it is perceived as potentially endangering well-being, an individual checks if there are sufficient personal and/or situational resources to cope with the situation. This secondary or resource appraisal is more strongly influenced by cognitive structures, personality traits and demographic variables like problem solving competences, optimism, self-confidence, age and education, and by the situational context, such as perceived control over the stimuli, social support or financial resources (Carp & Carp, 1982; Robin et al., 2007). Only when resources are evaluated as insufficient will an acute stress
reaction arise on different dimensions that are not necessarily corresponding. That is to say, stress is reflected in heightened physiological activation, changes in emotional states, at a cognitive-functional level—that is, in attention and performance—and/or in modified social behavior. Subsequently, a strategy to cope with the actual stress is chosen. Coping strategies are cognitive, emotional or behavioral processes aimed at reducing the acute stress by adapting oneself or by changing the situation (Homburg & Stolberg, 2006; Lazarus & Folkman, 1984). Finally, the success of the chosen strategy is evaluated in respect to stress reduction. We refer to this process as reappraisal. If stress was successfully mitigated, the same stimulus is less likely to cause a stress reaction the next time it appears. Otherwise, the stress reaction continues or follows should the stimulus reoccur. In the long run, this can result in various detrimental consequences such as mood disturbances, increased symptom reporting, elevated blood pressure, susceptibility to infectious diseases, use of psychotropic substances, or slower recovery from otherwise induced diseases (Adler & Hillhouse, 1996; Cohen, Evans, Stokols, & Krantz, 1986; Dougall & Baum, 2001; Marsland, Bachen, Cohen, & Manuck, 2001).

4.2. The cognitive stress theory in urban research

Urban research based on the cognitive-transactional model of stress is primarily focused on emotional rather than perceptual-cognitive appraisal. Unfortunately, the reactions studied in the field of “annoyance research” are varied and not clearly distinguished. Appraisal is surveyed using terms as diverse as annoyance, disturbance, bother, anger, displeasure, discomfort, distress, or even concern (Koelega, 1987; Lima, 2004). Thus, it is not surprising that research on the same environmental stressors comes up with enormously different results. Another problem in this field of study is how to determine as to when a person can be considered affected. Do they have to be highly annoyed, or only moderately annoyed? As of yet, there is no conclusive answer in the literature.

Negative environmental appraisal is not only a prerequisite to the experience of stress, it is also associated with social or political actions that support the improvement of the environment (Prester, Rohrmann & Schellhammer, 1987), and with neighbourhood dissatisfaction (Amério & Aragonés, 1997; Kearney, 2006; Marans & Spreckelmeyer, 1981). As neighbourhood satisfaction is related to residential satisfaction and satisfaction with life in general (Amério & Aragonés, 1997; Campbell, Converse, & Rodgers, 1976), we operationalized it as an indicator of well-being in the urban environment. Besides physical factors, it is influenced by other environmental conditions (Francescato, 2002; Hur & Morrow-Jones, 2008), and by demographic variables (Galster & Hesser, 1981).
One of the limitations of the cognitive-transactional stress theory is that predictions of “objective” environmental stressors are impossible. Hence, researchers attempt to identify stimuli that cause stress with a considerable probability in specific populations. The following stressor classification according to Lazarus and Cohen (1978) simplifies this issue. Environmental stressors can be classified as 1.) cataclysmic events that affect large numbers of people overwhelmingly like natural disasters or war; 2.) personal stressors with a powerful and sudden impact like illness or job loss, and 3.) background stressors that bring about less severe and more gradual changes. The latter are subdivided into daily hassles – distinct “events” or instances affecting individuals rather than groups of people – and ambient stressors. Ambient stressors are environmental conditions that are perceptible (although they may go unnoticed), chronically present, negatively valued, non-urgent and intractable, meaning they cannot be altered structurally by an individual (Campbell, 1983), and are the category of interest in the third experiment.

4.3. Empirical findings and research questions
Noise from sources like traffic, industry, crowds, or a high population or building density, air pollutants and ozone, water pollutants, odorous substances, weather conditions like heat waves and cold temperatures, and aspects of visual pollution such as litter, billboards and unaesthetic urban design have empirically been identified as potential ambient urban stressors (Bullinger, 1998; Cohen et al., 1986; Craik & Zube, 1976; Evans, 1982, 2003; Flade, 1987; Glass & Singer, 1972; Husemann, 2005; Robin et al., 2007; Taylor, 1982; Taylor, Repetti, & Seeman, 1997; Walsh-Daneshmandi & MacLachlan, 2000; Zimring, 1982). In the third study, we investigated which of these factors are perceived critically in the metropolitan area of Berlin. Moreover, we explored another, more subtle kind of urban pollution – the urban sky glow at night, or light pollution. Lately, the issue has gotten into scientific and public debate because of its ecological consequences and because it hinders astronomers’ work. It is often argued that light pollution also impacts human well-being. Indeed, constant light exposure has been associated with health consequences such as altered immune functioning or breast cancer (Kloog, Stevens, de Barchana & Portnov, 2008; Navara & Nelson, 2007; Stevens, 2006). However, it is unclear whether these effects are due to physiological or psychological pathways, and epidemiological reports remain inconclusive (de Molenaar, 2003; Langers, de Boer, & Buijs, 2005; Padgham & Saunders, 1995; van Ratingen, 2001).

Most published studies on environmental stress have only investigated exposure to a single stressor. However, in real life people react to combinations of multiple stimuli. As suggested by the literature (Bell et al., 2001; Cohen et al., 1986), we hypothesize that the concurrence of
several critical factors predicts neighbourhood satisfaction better than a singular factor alone. As there is no indication in the literature, we explore whether multiple factors concur in an additive, an exponential or in an alleviative way.

4.4. Method
In order to effectively obtain a geographically wide, demographically diverse and large sample, the third experiment was conducted as an online survey. The questionnaire was developed according to internet research guidelines (see e.g., Gräf, 2002; Tuten, Urban, & Bosnjak, 2002; Sassenberg & Kreutz, 2002) which dictated the questionnaire’s instructions, item wordings and sequences, screen randomization, layout, and the general procedures. Data was collected from February to April 2009.

Questionnaire
We first assessed demographic variables, information about the housing situation and neighbourhood satisfaction by asking how satisfied participants were, generally speaking, with their proximate living environment on a 7-point Likert-scale, with “1” corresponding to extremely unsatisfied and “7” to extremely satisfied. Proximate living environment was defined as the area of a maximum two-minute-walk from participants’ home. The second section of the survey focused on light pollution. Two 7-point scaled items asked for the actual and desired brightness in the proximate living environment, with “1” corresponding to extremely dark and “7” to extremely light. Participants were further presented with a list of various lighting sources to indicate which ones were visible from their homes and to rate how much they felt disturbed by those on a 5-point Likert-scale, with “1” corresponding to absolutely not disturbing and “5” to very disturbing. We also assessed whether the term light pollution was known at all. In the final section the perception and appraisal of various factors was measured by similar 5-point Likert-scales. Appraisal was assessed by impacted well-being as a comprehensive measure for widely-used terms like annoyance, nuisance or disturbance. We also requested participants to indicate which factor disturbed them the most. At the end of the survey respondents were given more detailed information about the overall research project and the purposes of the study, as well as space for remarks.

Participants and procedure
The survey was kept as short as possible to maximize return rates (Bosnjak & Batinic, 1999). It could be completed in 10-15 minutes and it was possible to leave items unanswered. Participation was limited to Berlin residents with sufficient German language skills and internet access. Participants were recruited by emails distributed through personal networks or student and topic-related mailing lists, by notes in newsletters and on websites of local
networks, authorities and initiatives. The only content-related information given was that it was a study on the perception and appraisal of environmental conditions in the urban area of Berlin. As an incentive for participation, participants were offered a report of the results via email. In addition, we promised to forward the outcomes to local authorities.

The survey was completed by \( N = 763 \) residents from all 12 administrative districts of Berlin. Most submissions were obtained from the central districts Friedrichshain-Kreuzberg (22%), Mitte (13%), and Pankow (13%) while residents of the peripheral districts Reinickendorf and Spandau are underrepresented with only 1% each. Sexes were almost equally represented (54% female vs. 45% male participants with 1% not indicating sex). The age range was 9 to 80 with an average age of 31 years. The sample was very well educated with 48% having a school qualification for university entrance and 44% holding a university or a similar academic degree.

4.5. Results

Light pollution. The term light pollution was known by 51% of the respondents. The mean perceived nocturnal darkness in the proximate neighbourhoods was somewhat higher than the desired \( (M = 3.97 \text{ vs. } M = 3.22) \). Commercial lighting visible from rather few people’s homes like illuminated advertisements/ LCD-Displays \( (M = 2.66, SD = 1.42, N = 128) \) and laser lights \( (M = 2.33, SD = 1.45, N = 72) \) were perceived as the most disturbing. More widespread, unavoidable and safety-related light sources like street lighting \( (M = 1.90, SD = 0.95, N = 558) \), traffic lights \( (M = 2.01, SD = 0.99, N = 303) \) and interior illuminations \( (M = 1.59, SD = 0.80, N = 586) \) were least disturbing.

Environmental perception and appraisal. To explore how the quality or intensity of environmental factors was perceived, we computed the mean appraisals as well as the summed percentage of participants choosing the most and second most negative category of the 5-point scale. The results are displayed in Table 1. 32% reported to live in a neighbourhood with quite or very strong traffic noise while the mean perceived traffic noise level is 3.01. In regard to odors, we did not ask participants to rate the perceived intensity and/or frequency as a measure of environmental perception. Instead participants were merely asked if they regularly perceived unpleasant odors. Among the 35% who answered yes, most specified odors from litter and excretions in the public space (31% of this subsample), neighbours (28%), and traffic exhaust emissions (17%).

- Insert Table 1 about here -
Among the factors rated by all participants, traffic noise, litter and dirt are the most critical, as shown by mean appraisal ratings and the percentage of participants who chose either of the two as the most disturbing one. When unpleasant odors are regularly present, however, they are on average rated even more negatively. Among the 27% who indicated that there were other factors in their proximate surroundings which impacted their well-being, most referred to noise from various sources (6% of the total sample), to a lack of public green space and the absence or the cutting down of trees (5%), and to dirt and canine excrements (4%).

As the correlations in the second last column of Table 1 show, environmental appraisal is to a large extent determined by the perceived quality or intensity of most factors except water quality and population density. This implies that the appraisal of these two latter factors is influenced stronger by non-perceptual factors. In other words, the perception of a poor quality of open urban waters or a high population density does not necessarily imply feelings of impacted well-being.

Neighbourhood satisfaction. The correlations of environmental appraisals and neighbourhood satisfaction are displayed in the last column of Table 1. While the majority of the sample (68%) indicated to be at least quite satisfied, 14% of the participants were extremely, very or quite unsatisfied with their proximate neighbourhoods, with another 17% neutral and 1% missing. Concurrence of several potential stressors. Regression analyses were used to test if neighbourhood satisfaction can be better predicted by several concurring factors than by a singular factor alone (see Cohen, Cohen, West, & Aiken, 2003). At first we examined the influence of several control variables including age, gender, education, parenthood, duration of residence, housing type, and time spent at home on average weekdays. Only gender was found to be significantly associated, with women less satisfied with their neighbourhoods ($M = 4.76, SE = 1.36$) than men ($M = 5.08, SE = 1.20$), $t(745) = -3.39$, $p < 0.01$. To reduce the amount of variables for hypothesis testing a multiple forced entry regression was performed with all eleven appraisal variables. We set $\beta = 0.15$ as the minimally required strength of influence. Accordingly, we ran a hierarchical regression with the appraisal of litter and dirt, and industrial noise. In the first step the two variables were entered simultaneously. In the second step the multiplicative term of the two variables was added to test for an interaction effect. The predictors were $z$-transformed to counterbalance different standard deviations and to reduce multicollinearity (Jonas & Ziegler, 1999). We found a small main effect only for the appraisal of litter and dirt ($\beta = -0.29$, $p < 0.001$; $R^2 = 0.09$). It cannot be traced back to gender differences because the respective correlations do not differ significantly between the two
groups \((Z = 0.465)\). The interaction term was not significant, and therefore the main hypothesis of this study could not be confirmed.

4.6. Discussion

Traffic noise, litter and dirt, unpleasant odors, cold temperatures in winter and air pollution were rated the most critical ambient stressors in the urban area of Berlin. Moreover, insufficient public green space and near-by vegetation also seem to influence well-being in neighbourhoods. That is, the survey may have primed subjects to think of stressful conditions when they were asked for other negative factors. As we did not present urban greenery as a factor to be rated, we cannot compare it to ambient stressors at this time, but the indication in an open question should be weighed more than when respondents only react to presented factors.

Better educated people tend to evaluate the environment more critically (Marans, 1976; Robin et al., 2007) and our respondents might have a rather high degree of awareness of pollution as voluntary participation attracts people with interest in a specific topic. However, we suppose that the extent of negative appraisals is rather underestimated here for several reasons: First, the variance in objective environmental loads in our participants’ neighbourhoods may be reduced. The high education degrees in our sample suggest that our participants have a rather high socioeconomic status. However, as discussed in the environmental justice literature (cf., Bolte & Mielck, 2004), it is the lower and middle class groups which usually live in areas with higher degrees of pollution. Second, individuals generally do not like to express negative feelings (Boucher & Osgood, 1969). They might also correct their evaluations unintentionally to reduce cognitive dissonance (Festinger, 1957). For instance, if it is easier for city dwellers to change their attitudes instead of their actions, they might correct their environmental appraisal rather than move away. Similarly, correction of the evaluation may occur when respondents cognitively habituate – that is they become accustomed to – stressful environmental conditions. Habituation – to be distinguished from physiological adaptation – is a mechanism that occurs when no suitable coping strategies are available for constant stress-inducing stimuli. It can also be interpreted as a cognitive reappraisal that the stimulus deserves less attention (Bell et al., 2001). Habituation may avoid breakdowns due to stressful stimuli, however it is problematic as it can deplete resources and result in stress disorders on the long run (e.g., Cohen et al., 1986; Craik & Zube, 1976). The more predictable and the more regular stressful stimuli are, the easier it is to habituate to them (Glass & Singer, 1976). This could be a reason for the highly negative appraisals of unpleasant odors and litter and dirt in comparison to, for example, constant air pollution.
For the same reasons, individuals usually indicate moderate or total satisfaction with their homes, relatively independent of the environment (Marans, 1976). Hence, our finding that one third of the sample is not satisfied might be a conservative estimation, which is an undesirable outcome for Berlin: Neighbourhood satisfaction is not only a desirable state for individuals but also a societal issue. Unsatisfied residents behave less responsibly and are less likely to maintain semi-private areas, display less neighbourly behavior and are more likely to move away (see Flade, 1987; Gärling & Friman, 2002). This can contribute to the impoverishment of residential areas as the people with higher mobility are the ones with a higher income.

We could not confirm that the concurrence of more potential stressors predicts neighbourhood satisfaction better than one dominant factor. At this point we can only speculate why. Koelega (1987) supposed that coping with one stressor may increase vulnerability to other stressors. We intend to test his assumption with more direct stress and health indicators in further studies. As constant environmental loads may cause over-activation and thus enhance vulnerability on a physiological level, we will additionally apply a physiological stress measure and contrast the findings with more subjective stress indices.

*Implications for sustainable urban development*

Neighbourhood satisfaction could be partly predicted by the appraisal of cleanliness of the proximate surroundings, which was also rated the most critical factor besides the well-known problem of traffic noise. Thus, litter and dirt in the public space is not only an aesthetic problem. We suggest that despite the economic problems Berlin is currently facing, the city should allocate more resources to this issue. Besides more frequent cleaning, more and bigger trash bins, or public campaigns and information, more research is needed to understand why people litter and how their behavior can be changed other than by implementing fines. At present, we are going to examine these aspects in more detail.

[...]

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References


Table 1: Descriptive results of the perception and appraisal of environmental factors, correlation between mean perception and appraisal of each factor \((r_{cp-ja})\) and between appraisal and neighbourhood satisfaction \((r_{ja-ns})\).

<table>
<thead>
<tr>
<th>Environmental factor</th>
<th>Environmental perception</th>
<th>Environmental appraisal</th>
<th>Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(M^a)</td>
<td>(SD)</td>
<td>extent(b)</td>
</tr>
<tr>
<td>Traffic noise</td>
<td>3.01</td>
<td>1.07</td>
<td>32%</td>
</tr>
<tr>
<td>Cleanliness resp. litter/dirt</td>
<td>3.01</td>
<td>0.95</td>
<td>28%</td>
</tr>
<tr>
<td>Cold temperatures in winter</td>
<td>n.a.(^e)</td>
<td>n.a.(^e)</td>
<td>n.a.(^e)</td>
</tr>
<tr>
<td>Air quality</td>
<td>3.08</td>
<td>0.82</td>
<td>20%</td>
</tr>
<tr>
<td>Noise by crowds</td>
<td>3.43</td>
<td>0.99</td>
<td>15%</td>
</tr>
<tr>
<td>Heat in summer</td>
<td>n.a.(^e)</td>
<td>n.a.(^e)</td>
<td>n.a.(^e)</td>
</tr>
<tr>
<td>Artificial lighting</td>
<td>n.a.(^e)</td>
<td>n.a.(^e)</td>
<td>n.a.(^e)</td>
</tr>
<tr>
<td>Residential density</td>
<td>2.45</td>
<td>0.79</td>
<td>51%</td>
</tr>
<tr>
<td>Industrial noise</td>
<td>4.58</td>
<td>0.69</td>
<td>2%</td>
</tr>
</tbody>
</table>

Subsample:

- Water quality \((N = 381)\):
  - 2.69  | 0.93  | 40% | 2.18 | 1.03 | 1%         | 0.37** | 0.12* |
- Unpleasant odors \((N = 269)\):
  - n.a.\(^e\)  | n.a.\(^e\)  | n.a.\(^e\) | 2.98 | 0.99 | 4%         | --- | 0.20** |

\(**p < 0.01; \* p < 0.05; \text{not assessed; high mean perceptions indicate positive ratings in regard to noise sources, air and water quality and little population density; extent is the summed percentage of participants who chose the most and 2nd most negative/intense category; high mean appraisals indicate strong impacts on well-being; worst is the percentage of participants disturbed most by the corresponding factor.}\)
Multiple environmental burdens and neighborhood-related health of city residents

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ABSTRACT

Urban living environments are known to influence human well-being and health; however, little is known about the multidimensionality of different environmental burdens. The aim of this study is to examine the relations between multiple burdens and self-rated health of city residents in Berlin. A spatial analysis was conducted to determine neighborhood street blocks with high versus low levels of three environmental burdens (traffic noise, air pollution, lack of public green space) as study sites for a cross-sectional household questionnaire. Burden levels served as dichotomous predictors to compare residents’ self-reports of neighborhood satisfaction, life satisfaction, health behavior, and psychological and physical health symptoms. Residents from high-burden blocks appraised the environmental conditions more stressful, reported poorer health behavior and were less satisfied with their neighborhood than residents from low-burden blocks. However, they did not differ in regard to more general health symptoms. Three other burdens (behavior-related noise, litter and dirt in public space, lack of urban vegetation) which could not be varied objectively, were assessed by their perceived intensity. Regression analyses of the relations between the perceived levels of all six burdens and outcomes in the total sample revealed the following: Neighborhood satisfaction could be predicted from multiple stressors and resources that co-occur independently, while more general health symptoms were related only to perceived air pollution. The results have implications for both urban planning and public health.

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1. Introduction

In the light of rapid world-wide urbanization processes, current public debate and research in multiple disciplines focuses on how to design, develop and manage cities sustainably so as to provide city dwellers with health-supportive habitats. According to the World Health Organization’s definition of health (World Health Organization, 1948), urban neighborhoods must ensure not only the absence of disease or ill health, but also support a state of complete physical, mental and social well-being. Improving habitats within dense urban areas implies the use and increase of benefits from ecosystem services, as well as the reduction of pollution and environmental burdens (Borkard & Hunhammer, 1999; Endlicher et al., 2011). To date, the dominant research approaches have focused on health effects of singular environmental resources (i.e., potentially beneficial factors) or burdens (i.e., potentially harmful factors) and/or on singular levels of intensity (e.g., individual, neighborhood, community). However, the demand for comprehensive research integrating multiple factors and multiple-level approaches to better understand the complexities of environmental factors has recently increased (cf. Galba, Freudenberg, & Vieth, 2005). Consequently, the present paper aims at an integrative understanding of the relations between urban environmental stresses and resources, and neighborhood-related health. After presenting the existing theoretical approaches and empirical results from both research perspectives (environmental stress and environmental resources), we develop an integrative framework that we apply to our empirical study.

1.1. Environmental stress and neighborhood-related health

Many of today’s urban environmental burdens that influence human health can be subsumed by the concept of ambient...
stressors. Ambient stressors are defined as environmental factors that are perceivable (although they may go unnoticed), chronically present, negatively valued, non-organic, and irremovable, meaning to individual cannot alter these stressors structurally (Campbell, 1983). They might impact behavior and health not only by physical, but also subjective means in that they elicit stress reactions through different, context-dependent cognitive and emotional pathways that are illustrated in an eclectic model from Bell, Greene, Fehrer, and Baum (2001). Following this model, environmental stressors, it needs to be noted and appreciated in research to recognize the adequacy of stimulation. These processes – appraisal more than perception – are influenced by physical properties of the stimuli, as well as personal situations and situational conditions. Homeostasis is sustained if stimuli are within the desired range of stimulation, which may contribute to positive affect, neighborhood satisfaction and thus, to life satisfaction (Amir, 2002; Francescato, 2002). However, individuals appraise environmental factors negatively when they perceive a shift from homeostasis toward disintegration (cf. Klu, 1983). Lazarus and colleagues have extensively described and studied this process as stress appraised (Lazarus, 1991; Lazarus & Cohen, 1978; Lazarus & Folkman, 1984; Lazarus & Laun, 1978). Negative appraisal may result in heightened arousal changes in emotional states, in cognitive functions and behavior. Subsequently, a coping strategy (i.e., an intentional behavioral or intra-psychic effort) is chosen to restore homeostasis and accordingly, the stimulus is reappraised. If coping was successful, the same stimulus is less likely to cause negative appraisal and for the corresponding responses the next time it is perceived. Otherwise, heightened arousal continues or stress is even intensified due to unsuccessful coping attempts (model, 1983). Repeated exposure to stressors can enhance the risk of detrimental after-effects such as mood disturbances, social withdrawal, sleep loss or elevated blood pressure (Adler & Hillhouse, 1986; Cohen, Evans, Skodol, & Kranzler, 1986; Doebbel & Baum, 1993; Doebbel & Baum, 1990; Doebbel & Baum, 1980). While the eclectic model is capable of explaining inter-individual differences in reaction to an acute environmental stimulus, it needs to be specified further research on long-term effects of neighborhood burdens in three aspects: the concept of coping, physiological pathways, and the co-occurrence of multiple burdens. Although the model is limited in understanding the complexity of stress reactions, stress mediation is likely to be maintained. While this is a well-adaptive mechanism in most cases, one stress-ameliorating strategy deserves special interest because it poses a health risk on its own: Consumption of psychotropic substances such as alcohol and nicotine. For example, smoking was shown to increase with elevated levels of ambient stress (Cherek, 1985). Conversely, unsuccessful coping efforts are unlikely to be sustained over a longer period of time and may be displaced by passive mindsets (e.g., prolonged concern or resignation; Hemburg & Stolberg, 2004; Koff, 1991). Moreover, two other intra-psychic assimilation mechanisms occurring on a rather unconscious level are plausible with repeated or prolonged exposure to environmental burdens: Cellular adaptation occurs when neurophysiological sensitivity diminishes, resulting in modified perception (cf. Campbell, 1983). Cognitive habituation may occur because stimulus uncertainty is reduced or due to reduction of cognitive disturbance and results in modified appraisal (Festinger, 1957). In short, negative appraisal of permanent environmental conditions and frequent substance consumption can be regarded as a result of the inability to constructively cope with, adapt or habituate to environmental burdens. Both phenomena are a health risk factor and thus, of central interest.

The second aspect in Bell et al.’s (2001) model to be interrogated refers to the finding that subjective stress responses do not always predict the elevation of physiological responses (Kirschbaum, Raudsepp, Gaab, Schommer, & Hellhammer, 1999). Thus, environments with high ambient stressor levels may permanently elicit neural and neuroendocrine responses, regardless of cognitive processes. When this state of “allostatic load” (McEwen, 2000) coincides with other risk factors such as higher age, low social status or low social support (Pincus & Pincus, 2001; Willi & Pagan, 2001), the risk of stress-related symptoms enhanced (e.g., delayed-speed of disease recovery, susceptibility to infectious diseases, hypertension, steroid diabetes, ulcers, etc.) for reviews, see Carton, 2000; Cacioppo & Baum, 2001; Cohen & Kessler, 2000; Marshland et al., 2001).

Finally, the model focuses on how singular stressors act. However, neighborhoods may be confronted with multiple ambient stressors that are present at the same time, as they might vary in spatial and temporal occurrence when emitted from the same source (e.g., road traffic emissions, unpleasant odors, air pollutants at the same time). According to Lepore and Evans (1988), multiple environmental stressors exert independent effects when one stressor does not deplete general coping resources, when it demands a different resource of resources (e.g., social vs. material resources), or different strategies (e.g., mental problem solving vs. passive acceptance) than other stressors. Thus, a potentiating effect is more likely when acute stress elicited by one factor reduces capacity to cope with or adapt to concurrent or subsequent stressors.

In the literature on ambient stressors, traffic noise has received more attention than other omnipresent forms of environmental pollution (e.g., unpleasant odor burdens, litter, heat waves, air pollution, noise from other sources such as industry or human). The more it is researched (cf. Bell, 1993; Bell & Stolberg, 2004; Cacioppo & Baum, 2001), the more it is realized that ambient stressors cannot be considered in isolation. However, it is not clear what types of health effects or mental health effects are less likely to be associated with an elevated risk of hypertension and coronary heart disease. Conversely, air pollution seems to have a high level of genetic factors, some of which are genetically unknown (see Evans, 2003).

In regard to the effects of multiple stressor exposure, interactive effects of one ambient stressor with another kind of stressor (e.g., stressful life events, work and personal stress, etc.) cannot be excluded (Evans, 2003; Wallenius, 2004; for reviews, see also Cample & Matthews, 1989; Lepore & Evans, 1989). However, there are few publications on how multiple ambient stressors co-occur. In experimental studies, an interactive effect was found for noise and social crowding, but not for noise and vibration (Haugset & Nestle, 2007; Martín-García-Granell & Cárdenas-Jacinto, 2005). In neighborhood research, physical ambient and social stressors (e.g., littering, incivility, neighborhood maintenance or structural problems, signs of crime, etc.) are often aggregated into one single stress indicator (Ayres et al., 2007; Bell & Tamir, 1997; Elskow, Maksymyki, & Kears, 2001; Feldman & Steger, 2004; Matheson et al., 2000; Silver, Muly kan, & Swaim, 2002; Weil et al., 2004). According to these studies, neighborhoods with higher stress scores tend to be of lower socioeconomic status than areas with lower stress scores. Moreover, their residents tend to report lower neighborhood satisfaction and poorer physical and mental health, controlling for individual-level socioeconomic status. These studies implicitly assume additive stressor effects, but the relative contributions of single stressors to overall effects and their interplay remain unexplained (see also Winkel, Saeger, & Evans, 2009).
1.2 Environmental resources and neighborhood-related health

In addition to the impact of urban environmental stressors on human health, the beneficial effects of urban ecosystems have recently received growing interest (e.g., Ward Thompson, Aspinall, & Bell, 2010). There are two main research positions that argue for evolutionary-based benefits of natural environments: a psycho-physiological approach and a cognitive mechanisms approach. In short, the first tradition arose from Ulrich's stress reduction theory (1983) and focuses on the capacity of natural environments to foster restoration, that is, recovery from environmentally and otherwise induced stress (Ulrich, 1983). According to SRT, natural environments provide restoration by visual characteristics that signal resources relevant to survival and well-being. Due to an inherited tendency of humans to respond to such cues with positive affect, these environments aid recovery to moderate levels of autonomic arousal (see alsoOntko & Heerwagen, 2002). The other tradition is based on Kaplan and Kaplan's attention restoration theory (ART, 1988). ART assumes natural environments enable recovery from directed attention. This capacity is explained by specific qualities inherent in natural environments that allow for effortless attention. Kaplan (1985) suggests an integration of these two perspectives. Specifically, as stress reduction might enhance attention capacity, restored attention might contribute to stress reduction, or positive effects of natural environments on both functions could be plausible. Beyond these pathways, urban green spaces may support health in additional, indirect ways (cf. De Vries, 2010). That is, they might stimulate physical activity, which is in turn beneficial to health (see Phillips, Kliemt, & King, 2001, for a review). Moreover, they might enable or facilitate social contact and thus help gaining social support, which protects against poor health, as discussed in Section 3.1.

Numerous studies have shown greater beneficial effects of natural vs. non-natural environments. Public green spaces in close proximity to home buffer the impacts of stressful life events (Vander Meer, Maas, Verheij, & Groenewegen, 2010; Weble & Egan, 2003). They are related to enhanced neighborhood satisfaction, self-reported physical health and longevity, and to reduced anxiety and depression (Maas, Verheij, Groenewegen, de Vries, & Spreeuwenberg, 2006; Maas et al., 2009; Takano, Nakamura, & Watanabe, 2002). While research has mainly focused on the use of green spaces, the frequency of visiting these areas does not fully explain such effects (Nielsen & Hansen, 2007). Some authors suggest that visual exposure to shared natural space or vegetation in general might explain the health effects of these resources (e.g., Ainslie, Vetten, & Neesham, 2009; Hu, Han, & Chien, 2010; Kaplan, 2001; Kourany, 2006; Kuo & Sullivan, 2001). Moreover, small patches of green and vegetation may stimulate the use of outdoor spaces and social activities (Sullivan, Kuo, & Depoorter, 2004).

1.3 Integrative framework and overview of the present study

In light of the beneficial health effects of natural elements, urban neighborhoods with few health-relevant resources offer fewer opportunities for recreation. Thus, inadequate availability of urban vegetation and public green spaces can be considered environmental burdens and, therefore, potential health risks. These kinds of burdens might often co-occur with the health risks arising from ambient stressors. For example, as the number or size of urban green spaces increase in neighborhoods, physical environmental quality improves by function of air pollutant absorption, noise reduction and microclimate regulation (Robards & Hunteram, 2009; Konarz et al., 2011; Lungner, Kull, & Endlicher, 2011). Moreover, research findings suggest that such resources may counterbalance the psychological effects of ambient stressors in urban neighborhoods (see Cerdà et al., 2004, for a review; Leslie & Corin, 2008). For example, perceived availability of nearby green areas was found to decrease annoyance reactions to traffic noise (Cerdà-Camposani & Öhman, 2007). Therefore, we argue for an integrative framework (see Fig. 1) that takes into consideration both ambient stressors and lack of natural resources, as well as their interplay, in order to enhance ecological validity of research on neighborhood health effects.

To our knowledge, this is the first study to assess and compare the relative relations and interplay of multiple ambient stressors and lack of natural resources in regard to self-rated neighborhood-related health outcomes. Using Geographical Information Systems (GIS), we analyzed the spatial variability of two ambient stressors

![Diagram](image)

Fig. 1. Framework of the present study on multiple co-occurring neighborhood-level burdens (i.e., ambient stressors and lack of natural resources) and neighborhood-related health outcomes. Potential interactions among multiple burdens are investigated in an exploratory way.
(traffic noise, air pollution) and one ecological resource (provision with public green space) in order to identify inner-city neighborhood street blocks in Berlin with high and low burden levels. These factors were selected because, as the above-discussed literature suggests, they are the factors with most probable singular health effects. Moreover, a household questionnaire survey was conducted among residents of these sites. The perceived levels of these other ubiquitous and locally relevant environmental burdens (van der Meer et al., 2011) were assessed as additional predictors for which no suitable GIS-data exist: litter and dirt in the public space, behavior-related noise and lack of urban vegetation. We hypothesize that objective variations of environmental burdens are reflected in subjective environmental evaluations and in neighborhood-related health indicators. Moreover, we consider perceived levels of additional non-varied environmental burdens for new insights regarding the multiple-hazard framework. Predictions of either independent or interactive effects of multiple co-occurring burdens, as Lepore and Evans (1986) suggest, are impossible due to a lack of literature on burden-specific coping strategies. Thus, we investigate the relative strength of each of the factors, the potential interactions among them, and their combination in an exploratory way.

2. Method

2.1. Study areas

Our study was conducted in the German capital of Berlin, which is divided in 12 districts and populated by about 3.4 million inhabitants. As in most European cities, inner-city areas are compact and densely populated by residents with varying levels of social status. Late 19th-century block developments dominate the layout of these areas in Berlin. They consist of uni-story housing units with a front house, two side wings and a rear building with an enclosed backyard. Street blocks were chosen as an appropriate geographical neighborhood scale of analysis (cf. Dupré & Perkins, 2007; Goldstein, 1989) in a four-step procedure. First, the latest versions of appropriate datasets on road traffic noise, traffic-related air pollution and provision with public green space were selected from a Digital Environmental Atlas. Second, we conducted a spatial analysis using a Geographical Information System (ArcGIS). The three datasets were classified into four levels of burden intensity each, then combined in a dataset, summed, and visualized in a map covering the entire urban area of Berlin. This allowed identification of inner-city blocks with a combination of the highest and lowest burden level in each of the three factors. The combination of environmental data is referred to as “high-burden” and “low-burden” street blocks throughout the paper and serves as a dichotomous neighborhood-level predictor. In addition, a dataset on various urban structure types was included in order to select street blocks with comparable structural aspects (e.g., architectural properties of housing and within-block population density).

The Berlin Senate Department for Urban Development (SenStadt, 2011) provides the Digital Environmental Atlas and comprises street block level data on various environmental burdens and resources. Most of these data cover the entire urban area.

Most of the data are environmental quality evaluations in nominal or ordinal scale level with varying amounts of levels. Evaluations are scored at human health and correspond to legal bases. Identifying exposure levels were not available for interested readers; more detailed information on the spatial analysis and the datasets used is available from the authors.

2.2. Sample

From 2000 surveys distributed to all eight street blocks, 428 residents returned a completed questionnaire (21.46% response rate). Submissions were balanced between high-burden (n = 215, 50.28%) and low-burden blocks (n = 213, 48.18%). Participants ranged from 16 to 81 years in age (M = 38.5, SD = 14.3). Tables 1 and 2 provide further information on the sample characteristics. As displayed, women and highly educated people are overrepresented. However, education degrees in the population of Berlin are above German average (Kühle, Pant, Bohle, Rockmann, & Werdin, 2009). According to the Federal Statistical Office (Destatis, 2010), the degree of unemployed almost matches the city’s actual unemployment rate of nearly 14.5% in 2007, while the 2008 unemployment rate of 14.6% in Berlin is underrepresented. Among those who indicated either less German national representation, reported being European. Thirty-five percent of all participants indicated that they suffer from one or more chronic stress-related physical symptoms such as pain symptoms (18%), gastrointestinal diseases (9%), hypotension, coronary heart diseases (14%), and asthma (16%), whereas only a few participants reported frequent infectious diseases, cancer, diabetes mellitus and rheumatism. The mean individual raw scores of psychological symptom scales are displayed in the last two rows of Table 3. Al linger those scores with the gender-specific norms (Hanklo, 2000), 3.5% reported a clinically relevant score in depression, and 30% in anxiety. Comparisons of self-reported symptoms with officially diagnosed prevalence rates are certainly problematic. However, the rates of participants’ stress-related physical symptoms

The air pollution dataset contains evaluations for PM10 and NO2, based on traffic counts and classifier streets into four levels from mildly burdened to heavily burdened. In Berlin these two pollutants are regarded as the most serious in regard to human health (SenStadt, 2011). NO2 is a major source of indoor air pollution, can increase the risk of infections and emissions are not clearly dropping in urban areas, as opposed to other inorganic gases. PM10 is among the most serious burdens in urban area and is suspected to increase the risk of cardiovascular disease (Kühle, Klotzle, & Werdin, 2009; Lehmkuhl, 1999).

Only green spaces >0.5 ha with a suitable shape, unrestricted accessibility and without major environmental pollution are incorporated into the dataset to ensure executive quality.
seem below 2009 German prevalence rates, while participants with psychological symptoms are rather overrepresented (Robert Koch Institute, 2011).

Fig. 3 displays reported reasons for residential choice in both areas. It can be concluded that motivation for living in a high- or low-burden area hardly differed. As an exception, participants from high-burden blocks were more likely to choose their neighborhood for public transport connections ($\chi^2 (1) = 4.99, p = .04$) and less likely for proximity to natural or quiet environments ($\chi^2 (1) = 17.06$, $p = .001$).

2.3. Measures of the surveyed variables

The following section describes relevant measures from the survey which consisted of three parts: 1) background variables (personal and situational factors), 2) perception of ambient stressors and resources as individual-level predictors and appraisal of stressors, and 3) neighborhood-related health outcomes. Eight slightly different designs of the survey cover page enabled to allocate from which of the eight blocks submissions came. Participants were instructed to answer all neighborhood-related questions with respect to their proximate living environment in order to avoid the difficulties that have been associated with boundary-related neighborhood definitions (e.g., see Coulton, Kerbin, Chao, & Su, 2001). Proximate living environment was defined as the area of a maximum 2-min walk from participants' homes. The smallest unit of neighborhood is typically defined as an area of 5- or 10-min walk (Kearns & Parkinson, 2001). However, based on German average walking speed (Morgenroth, 2008) we chose 2 min in order to conform to the measurement levels of the GIS data. Preferred parsimonious scales published in English language were applied wherever available, and repeated translation procedures were used for optimized adaptation to German language. Verbal anchors of scales were chosen according to Rohrmann (1978) so as to ensure equidistance between scale points. Table 3 provides an overview on descriptive statistics and psychometric properties.

Table 1

<table>
<thead>
<tr>
<th>District</th>
<th>Mitte</th>
<th>Kreuzberg</th>
<th>Potsdamer Berg</th>
<th>Neus-KöllnTrep麟en</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burden level</td>
<td>high</td>
<td>low</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Response rate (%)</td>
<td>24.2</td>
<td>32</td>
<td>24.2</td>
<td>32</td>
</tr>
<tr>
<td>Urban structure%</td>
<td>10-14</td>
<td>14-18</td>
<td>10-14</td>
<td>14-18</td>
</tr>
<tr>
<td>Proportion of unemployed (%)</td>
<td>6-10</td>
<td>16-20</td>
<td>6-10</td>
<td>16-20</td>
</tr>
</tbody>
</table>

Note: Statistical information on urban structure, proportions of foreign/employed and social status is based on data from the Senate of Urban Development Berlin (SenStadt, 2011).

* 1: late-19th century block development with wings and rear buildings; 2: late-19th century block-edge development with major changes.

b Neighborhood social status evaluation (SenStadt, 2011).
Table 2: Sample characteristics and distribution of background variables in low-burden (n = 213) and high-burden (n = 215) blocks.

<table>
<thead>
<tr>
<th>Variable (measur. value)</th>
<th>Total sample</th>
<th>High-burden blocks</th>
<th>Low-burden blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female (%)</td>
<td>61</td>
<td>48</td>
<td>64</td>
</tr>
<tr>
<td>Mean age (years)</td>
<td>40</td>
<td>39</td>
<td>40</td>
</tr>
<tr>
<td>Education (%)</td>
<td>24</td>
<td>36</td>
<td>40</td>
</tr>
<tr>
<td>University admission (%)</td>
<td>74</td>
<td>78</td>
<td>67</td>
</tr>
<tr>
<td>Secondary school no degree</td>
<td>24</td>
<td>21</td>
<td>27</td>
</tr>
<tr>
<td>Employment status (%)</td>
<td>24</td>
<td>23</td>
<td>25</td>
</tr>
<tr>
<td>Full-time</td>
<td>71</td>
<td>75</td>
<td>67</td>
</tr>
<tr>
<td>Unemployed (%)</td>
<td>11</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Other status (%)</td>
<td>18</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>Non-German nationality (%)</td>
<td>7</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Marital status (%)</td>
<td>88</td>
<td>68</td>
<td>107</td>
</tr>
<tr>
<td>Single</td>
<td>17</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Separated/divorced/widowed</td>
<td>12</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Size of community where raised (%)</td>
<td>32</td>
<td>31</td>
<td>33</td>
</tr>
<tr>
<td>&lt;80000</td>
<td>53</td>
<td>44</td>
<td>62</td>
</tr>
<tr>
<td>80000-100000</td>
<td>15</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>100000-150000</td>
<td>15</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>150000-200000</td>
<td>15</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>&gt;200000</td>
<td>15</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Mean floor level (%)</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Length of residency (13)</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>&lt;1 year</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>1-5 years</td>
<td>41</td>
<td>31</td>
<td>51</td>
</tr>
<tr>
<td>5-15 years</td>
<td>45</td>
<td>35</td>
<td>55</td>
</tr>
<tr>
<td>&gt;15 years</td>
<td>43</td>
<td>33</td>
<td>53</td>
</tr>
<tr>
<td>Residential facility (%)</td>
<td>68</td>
<td>51</td>
<td>81</td>
</tr>
<tr>
<td>Windows facing street (%)</td>
<td>73</td>
<td>71</td>
<td>75</td>
</tr>
</tbody>
</table>

Note. Deviations are due to rounding total sample percentages.

2.3.2. Environmental perception and appraisal

In order to assess the perceived quality of all six environmental factors of main interest (i.e., provision with public green space, vegetation, traffic-related noise, air quality, behavior-related noise, and cleanliness) participants were asked to judge the quality of each of these factors in their proximate living environment on a five-point Likert-scale. Higher ratings corresponded to better environmental quality. Single item quality ratings were applied because, according to the theoretical background, we did not expect psychometric improvements from slightly differently worded items. As an example, the item for perceived air quality "How do you judge the air quality in your proximate living environment?" could be answered from 1 → very poor to 5 → very good. The perception of odor burden as an additional environmental quality aspect was not metrically assessed because of the multidimensional nature of odorous quality. Instead, participants were asked whether unpleasant odors were regularly present in their proximate living environments and, if yes, to describe the odor’s source.

Environmental stress appraisals were assessed only for the ambient stressors, as lack of resources was theoretically expected to impact health by different pathways than by stress appraisal. As suggested in the environmental annoyance literature (Langdon, 1992; Lazaro, 2001), four items per stressor were used to assess the nuances of emotional reactions to each stressor. Participants were requested to indicate, on 5-point scales, the degree each stressor in their proximate living environment impacted their well-being, annoyed them inside their dwelling, annoyed them outdoors, and how much they felt threatened in regard to health (with 1 → not at all impacted/unannoyed/threatened and 5 → very much impacted/unannoyed/threatened). Terminology of two environmental factors was changed here. That is, "air quality" was exchanged by "air pollution" and "cleanliness" was exchanged by "litter and dirt."

As displayed in Table 3, internal consistencies allowed for using a mean appraisal scale score from these four items for each stressor.

Table 3: Description of items and scales used in analyses.

<table>
<thead>
<tr>
<th>Scale title</th>
<th>No. of items</th>
<th>Scale points</th>
<th>n</th>
<th>M (SD)</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Rel. (alpha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental perception</td>
<td>Air pollution</td>
<td>1</td>
<td>5</td>
<td>427</td>
<td>2.35 (0.96)</td>
<td>0.42</td>
<td>0.49</td>
</tr>
<tr>
<td>Traffic noise</td>
<td>1</td>
<td>5</td>
<td>427</td>
<td>2.13 (0.77)</td>
<td>-0.06</td>
<td>-0.05</td>
<td></td>
</tr>
<tr>
<td>Cleanliness</td>
<td>1</td>
<td>5</td>
<td>427</td>
<td>2.00 (0.90)</td>
<td>-0.27</td>
<td>-0.40</td>
<td></td>
</tr>
<tr>
<td>Behavior-related noise</td>
<td>1</td>
<td>5</td>
<td>427</td>
<td>1.74 (0.96)</td>
<td>-0.40</td>
<td>-0.22</td>
<td></td>
</tr>
<tr>
<td>Public green space</td>
<td>1</td>
<td>5</td>
<td>427</td>
<td>1.30 (0.90)</td>
<td>-0.38</td>
<td>-0.19</td>
<td></td>
</tr>
<tr>
<td>Vegetation</td>
<td>1</td>
<td>5</td>
<td>427</td>
<td>1.52 (0.93)</td>
<td>-0.45</td>
<td>-0.20</td>
<td></td>
</tr>
<tr>
<td>Environmental appraisal</td>
<td>Air pollution</td>
<td>1</td>
<td>5</td>
<td>427</td>
<td>2.35 (0.96)</td>
<td>0.42</td>
<td>0.49</td>
</tr>
<tr>
<td>Traffic noise</td>
<td>1</td>
<td>5</td>
<td>427</td>
<td>2.13 (0.77)</td>
<td>-0.06</td>
<td>-0.05</td>
<td></td>
</tr>
<tr>
<td>Litter and dirt</td>
<td>4</td>
<td>5</td>
<td>427</td>
<td>2.85 (0.84)</td>
<td>0.18</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>Behavior-related noise</td>
<td>4</td>
<td>5</td>
<td>427</td>
<td>2.34 (0.89)</td>
<td>-0.44</td>
<td>-0.37</td>
<td></td>
</tr>
<tr>
<td>Odorism</td>
<td>4</td>
<td>5</td>
<td>427</td>
<td>2.96 (0.81)</td>
<td>-0.06</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>Life satisfaction</td>
<td>1</td>
<td>5</td>
<td>427</td>
<td>3.24 (0.73)</td>
<td>-0.43</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>General physical health</td>
<td>1</td>
<td>5</td>
<td>427</td>
<td>3.57 (0.86)</td>
<td>-0.22</td>
<td>-0.58</td>
<td></td>
</tr>
<tr>
<td>Health behaviors</td>
<td>1</td>
<td>5</td>
<td>427</td>
<td>6.91 (0.81)</td>
<td>0.47</td>
<td>-0.56</td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td>6</td>
<td>5</td>
<td>427</td>
<td>1.68 (0.81)</td>
<td>1.53</td>
<td>2.18</td>
<td></td>
</tr>
<tr>
<td>Anxiety</td>
<td>6</td>
<td>5</td>
<td>427</td>
<td>1.00 (0.94)</td>
<td>1.28</td>
<td>1.13</td>
<td></td>
</tr>
</tbody>
</table>

Note. High environmental perception scores correspond to negative evaluations; high environmental appraisal scores correspond to high stress appraisals. High values refer to good neighborhood-related health.

Inapplicable: health behavior is considered a formative measure due to the heterogeneity nature of the construct (cf. MacKinnon, Podsakoff, & Jarvis, 2005).
2.3.3. Outcome

Neighborhood satisfaction was assessed with a German adaptation (Freeseegger, 2004) of a four-item scale from Weidemann, Andersen, Butterfield, and O'Connell (1982). The items directly inquire into the degree of satisfaction with the living environment, e.g., “How satisfied are you with living here?” The scale was chosen because direct neighborhood satisfaction measures have proven more valid than indirect scales (Ambühl & Aragonés, 1999). As in the original version, items could be answered on four-point scales with item-dependent verbal anchors and high values indicating high satisfaction.

Life satisfaction was assessed with a scale developed by Diener, Emmons, Larsen, and Griffin (1985). It assesses how participants judge their own life as a whole. It consists of five items, such as “The conditions of my life are excellent,” that have to be answered on a five-point scale (1 = do not agree at all and 5 = very much agree). Similar to neighborhood satisfaction, overall judgments should be preferred over domain-specific evaluations, since individuals may place different values on certain domains (c.f. Diener et al., 1985). According to an expert panel discussion (Tösch-Wöhrer, Schupp, Wolper, Knahe, & Junghans, 2010), affective measures of subjective well-being are more sensitive to daily variations than cognitive evaluations. Therefore, a cognitive measure was preferred.

Health behavior was assessed using a revised version of an index from Feldman and Spero (2004). Participants were asked to indicate if they were a) currently smoking, b) consuming two or more units of alcoholic beverages on at least three days of the week, and c) carried out any vigorous physical activity like running, sports or dancing within the last two weeks. In accordance with the original authors, we created a composite index by counting each health-compromising response as one point (with c) reversed coded). Thus, index scores could be treated as a metric variable and would range from 0 (good health behavior) to 3 (poor health behavior).

General physical health was assessed with a single item from the German version of the SF-36 health survey (Bolliger & Bächler, 1998), asking as global one-item health ratings are good predictors of unspecific somatic symptoms such as pain, dizziness or problems with the respiratory system (e.g., Willenius, 2004) and of mortality (Biller & Benham, 1987). Participants were asked how they would describe their health status in general on a scale from poor (1) to excellent (5). In addition, we included a check-off list of eight physical symptoms that have been linked to chronic stress (i.e., chronic pain symptoms, gastrointestinal complaints, frequent infectious diseases, hypertension/coronary heart diseases, cancer, diabetes mellitus, rheumatism, and asthma). The design of this list was guided by the literature (e.g., Carstens, 2004; Deegell & Baeum, 2001; Wester et al., 2001).

Psychological symptoms were measured using two scales from the German adaptation (Frankle, 2000) of the Brief Symptom Inventory by Derogatis (1983). Namely depression and anxiety. These scales were chosen because they represent symptoms associated with different kinds of environmental stress and relate to common emotional stress reactions according to our literature review. The inventory lists various problems and discomforts and asks participants to indicate how intense they were disturbed within the last seven days – from “not at all” (1) to “very intense” (5).

2.4. Procedure

After posting announcement flyers through the study areas, 2000 questionnaires were equally distributed in each of the eight blocks in August 2003. Thus, 250 households in each block received a questionnaire. The survey could be completed in 25–30 min. An accompanying information letter invited residents from age 18 to participate in a study on the perception of environmental conditions in residential areas and on general well-being of Berlin residents. Letters did not indicate any reasons for selection of the site.
As an incentive for participation, addresses could fill out and return a lottery ticket within four weeks for a dinner voucher at a restaurant of their choice. In addition, they were provided a postage-paid envelope, were offered a report on results, and asked to name suggestions concerning the improvement of their neighborhood. That would be summarized and forwarded to local authorities.

2.5. Statistical analyses

All 428 returned surveys were included in comparisons between high- and low-burden areas since information on location of residence was available for each participant. In order to control for potential confounds due to background variables, the characteristics of participants from high-burden and low-burden areas displayed in Table 2 were compared using Pearson’s chi-square tests for dichotomous variables, logistic analyses for nominal variables with three categories, and analyses of variance (ANOVA) for metric variables. No significant differences in background variables were found, with a few exceptions. According to self-reports more residents from low-burden blocks have apartments with balconies, terraces, patios or shared gardens ($\chi^2(1) = 25.67, p = .00$) and apartments without windows facing the street ($\chi^2(1) = 4.33, p = .04$). Environmental perception and appraisal in high-burden versus low-burden blocks were compared using ANOVA. In order to test the assumption that residents from high-burden blocks would report poorer health than residents from low-burden blocks, logistic regressions were used for dichotomous and analyses of covariance (ANCOVA) for metric outcome indicators with age as a covariate to reduce error variance.

Age was integrated in all analyses since it is associated with poor health and neighborhood environment (Carp & Capr, 1982). Age effects are not of particular interest in the current study and are not reported unless necessary to clarify effect sizes. Since verbal anchors of each scale were equidistant, all parametric assumptions for ANOVA and ANCOVA were met except normality and homogeneity of variance in some cases. However, the F-statistic is quite robust to violations of both assumptions when group sizes are equal (cf. Field, 2008), as is the case with these groups.

Hierarchical regression analyses (cf. Cohen, Cohen, West, & Aiken, 2003) were applied to test whether outcomes can be predicted by stressors in a hierarchical condition. Results indicated that outcome indicators of environmental stress are better predicted than by a singular burden alone. Subjective perceptions of environmental stressors and resources were chosen as predictors. The complete sample was included in a multiple forced-entry regression performed with all environmental perception variables assessed for each of the outcome variables in order to reduce the amount of predictors for hypothesis testing, $p = .01$ was determined to be the minimally required strength of influence. Accordingly, a hierarchical regression was run with age entered in the first step, the predictors simultaneously in the second step, their interaction terms in the third step and higher-order interaction terms in the fourth step when necessary. The predictors were z-transformed to counterbalance different standard deviations and to reduce multicollinearity (Jonas & Siegler, 1999). Normality of errors and collinearity diagnosis indicated no violation of assumptions.

Throughout the following chapter, environmental perception indicators are presented reversed coded so that high values of perception and appraisal correspond to negative environmental evaluations.

3. Results

3.1. Descriptive results

Table 3 provides an overview of mean perceptions and appraisals. In regard to odor burdens which were not assessed in a metric way, 29% of the total sample ($n = 122$) indicated perceiving unpleasant odors regularly. Odors came from various sources for lasting causes, including neighboring industries (20%), traffic exhaust fumes (21%), litter and dog excrements (15%), and open waters or canals (10%). Correlations of perception items and appraisal scales with criteria and age are presented in Table 4 for clarity. Interrelations within perception items or appraisal scales are not displayed. Among perceptions, they ranged from $r = .16$ (lack of green space and behavior-related noise) to $r = .51$ (traffic noise pollution) and better perceived quality in one factor was correlated with better perceived quality in the other. Among appraisals, intercorrelations had constant directions ranging from $r = .17$ (air pollution and litter and dirt) to $r = .69$ (air pollution and traffic noise).

3.2. Comparisons of high-burden and low-burden neighborhood blocks

As shown in Table 5, the perceptions of air pollution, traffic noise and pollution with non-residential public green space differ significantly, with traffic noise differentiating most clearly. It was also confirmed that residents from high-burden blocks appraise air pollution and traffic noise more negatively. Beyond the objectively varied factors, residents from high-burden blocks reported living in somewhat dirtier environments ($F(1,424) = 4.21, p = .04$, partial $\eta^2 = .01$) and less vegetated areas ($t(425) = 13.63, p = .00$, partial $\eta^2 = .03$) neighborhood and perceived more incidences of odor burdens ($t(425) = 3.79, p = .00, \phi = .14$) and physical exercise ($t(425) = 2.15, p = .03, \phi = .12$). However, they did not appraise these non-validated environmental factors significantly more negatively.

Results on comparisons of health indicators in both areas are also displayed in Table 5. Contrary to the hypotheses, residents from high-burden neighborhoods did not report lower life satisfaction, poorer general physical health or more psychological symptoms. Neither did they suffer from one or more stress-related physical symptoms more often ($F(2,233) = 3.23, p = .04$). However, they indicated being significantly less satisfied with their neighborhood and behaviorally significantly less healthy. To break down the health behavior index, chi-square comparisons were significant in regard to nicotine consumption (43 vs. 29%: $\chi^2(4, n = 426) = 8.39, p = .00, \phi = .14$) and physical exercise (22% from high-burden vs. 20% from low-burden blocks had not carried out any vigorous physical activity in the preceding two weeks: $\chi^2(1, n = 426) = 7.15, p = .01, \phi = .13$). Alcohol consumption did not

Table 4

<table>
<thead>
<tr>
<th>Age</th>
<th>Environmental perception</th>
<th>Air pollution</th>
<th>Traffic noise</th>
<th>Traffic-related noise</th>
<th>Public green space</th>
<th>Vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Environment satisfaction</td>
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<tr>
<td></td>
<td>Life satisfaction</td>
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<td></td>
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<td></td>
<td>General Physical Health</td>
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<tr>
<td></td>
<td>Health behavior (HBE)</td>
<td></td>
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<tr>
<td></td>
<td>Depression (D)</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Anxiety (A)</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Table 5

<table>
<thead>
<tr>
<th>Environment satisfaction</th>
<th>Life satisfaction</th>
<th>General Physical Health</th>
<th>Health behavior (HBE)</th>
<th>Depression (D)</th>
<th>Anxiety (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment perception</td>
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<td></td>
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<tr>
<td>Air pollution</td>
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<tr>
<td>Traffic pollution</td>
<td></td>
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<tr>
<td>Traffic-related noise</td>
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<tr>
<td>Public green space</td>
<td></td>
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<tr>
<td>Vegetation</td>
<td></td>
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</tr>
</tbody>
</table>
Table 5

Results from ANOVA comparing environmental perceptions and appraisals among residents from high-burden blocks (HBB) versus low-burden blocks (LB) and from ANOVA comparing health outcomes. Likewise.

<table>
<thead>
<tr>
<th>Environmental perception</th>
<th>HBB mean</th>
<th>LB mean</th>
<th>t</th>
<th>df</th>
<th>p</th>
<th>partial df²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air quality</td>
<td>2.57</td>
<td>2.22</td>
<td>-2.5</td>
<td>66</td>
<td>0.02</td>
<td>0.04</td>
</tr>
<tr>
<td>Traffic noise</td>
<td>1.51</td>
<td>2.71</td>
<td>2.34</td>
<td>66</td>
<td>0.03</td>
<td>0.08</td>
</tr>
<tr>
<td>Green space</td>
<td>0.97</td>
<td>1.43</td>
<td>-2.9</td>
<td>66</td>
<td>0.01</td>
<td>0.09</td>
</tr>
<tr>
<td>Environmental appraisal</td>
<td>2.36</td>
<td>2.71</td>
<td>2.34</td>
<td>66</td>
<td>0.03</td>
<td>0.06</td>
</tr>
<tr>
<td>Air pollution</td>
<td>2.58</td>
<td>3.12</td>
<td>-1.5</td>
<td>66</td>
<td>0.16</td>
<td>0.01</td>
</tr>
<tr>
<td>Traffic noise</td>
<td>1.51</td>
<td>2.71</td>
<td>2.34</td>
<td>66</td>
<td>0.03</td>
<td>0.08</td>
</tr>
<tr>
<td>Green space</td>
<td>0.97</td>
<td>1.43</td>
<td>-2.9</td>
<td>66</td>
<td>0.01</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Note: High environmental perception and appraisal scores correspond to negative evaluations.
1 High values refer to good neighborhood-related health.
2 High values refer to poor health. Only estimates of interest are presented. Significance levels are two-tailed.

Table 5

<table>
<thead>
<tr>
<th>Health outcomes</th>
<th>HBB mean</th>
<th>LB mean</th>
<th>t</th>
<th>df</th>
<th>p</th>
<th>partial df²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neighborhood satisfaction</td>
<td>0.85</td>
<td>0.69</td>
<td>2.34</td>
<td>66</td>
<td>0.02</td>
<td>0.08</td>
</tr>
<tr>
<td>Life satisfaction</td>
<td>0.85</td>
<td>0.69</td>
<td>2.34</td>
<td>66</td>
<td>0.02</td>
<td>0.08</td>
</tr>
<tr>
<td>General physical health</td>
<td>0.85</td>
<td>0.69</td>
<td>2.34</td>
<td>66</td>
<td>0.02</td>
<td>0.08</td>
</tr>
<tr>
<td>Health behavior</td>
<td>0.85</td>
<td>0.69</td>
<td>2.34</td>
<td>66</td>
<td>0.02</td>
<td>0.08</td>
</tr>
<tr>
<td>Depression</td>
<td>0.85</td>
<td>0.69</td>
<td>2.34</td>
<td>66</td>
<td>0.02</td>
<td>0.08</td>
</tr>
<tr>
<td>Annoyance</td>
<td>0.85</td>
<td>0.69</td>
<td>2.34</td>
<td>66</td>
<td>0.02</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Note: High environmental perception and appraisal scores correspond to negative evaluations.
1 High values refer to good neighborhood-related health.
2 High values refer to poor health. Only estimates of interest are presented. Significance levels are two-tailed.

Table 5

4. Discussion

4.1. Multiple neighborhood burdens and neighborhood-related health outcomes

The aim of the present study was to analyze the relations between multiple neighborhood burdens and health indicators, incorporating both ambient stressors and lack of environmental resources. A spatial analysis combining environmental data with health outcomes revealed the following results: Neighborhood satisfaction was explained by perceived air pollution with good public space quality (β = 0.21, p = 0.03). Behavioral-related noise (β = 0.23, p = 0.03), air quality (β = 0.56, p = 0.00), and vegetation (β = 0.47, p = 0.01) also contributed significantly. Life satisfaction could only be explained by perceived air quality (β = -0.19, p = 0.04, R² = 0.06); n = 412), whereas poor health behavior was merely related to perceived traffic noise (β = 0.05, p = 0.03; R² = 0.04; n = 412). General self-reported health was explained by age (β = -0.47, p = 0.00; R² = 0.22; n = 412) and air quality (β = -0.22, p = 0.02; R² = 0.04); n = 412). Likewise, air quality was the only environmental factor related to depression (β = 0.13, p = 0.01; R² = 0.04; n = 412) and anxiety (β = 0.11, p = 0.03, R² = 0.03; n = 412). In order to explore the effects of sociodemographic variables, separate regression analyses were performed for gender, education, and employment status subgroups. It is beyond the scope of this article to report them in detail. In short, regarding neighborhood satisfaction, the strength of the relationship did not significantly vary across groups, while traffic noise remained non-significant in all analyses. Air quality remained the strongest predictor of life satisfaction and general self-reported health and anxiety. In addition, cleanliness was positively related to depression and anxiety in women and the low-educated group. Finally, while environmental perception was unrelated to health behavior in unemployed participants, health behavior of employed participants and the other status group could be predicted from traffic noise and air quality. In summary, neighborhood satisfaction as a measure of neighborhood-related health could be predicted from additionally co-occurring environmental burdens, whereas air quality plays a crucial role in predicting more general self-rated health. It is interesting to mention that among the four air pollution appraisal forms, the degree of annoyance at home correlated higher with the relevant health outcomes (i.e., neighborhood satisfaction, life satisfaction, self-rated health, depression, anxiety) than impaired well-being, annoyance outdoor or subjective health threats.

4.2. Environmental perceptions and appraisals of varied environmental burdens

As hypothesized, variations in traffic noise, air pollution and provision with green space among inner-city neighborhood blocks in available environmental datasets are reflected in residents' perceived levels of these factors. Residents distinguished traffic noise burdens most strongly, but they were also able to distinguish varied levels of traffic-related air pollution and provision with near-residential public green space. Thus, this study validates results of spatial analyses of environmental stressors and resources as a valuable tool for research in environmental psychology and similar disciplines.

Moreover, these data suggest that multiple burdens from different sources co-occur spatially and temporally. This was already found for factors usually available in environmental datasets such as noise from different sources, air pollution, lack of green
space and climatic conditions (e.g., Pearce, Richardson, Mitchell, & Shortt, 2010). In addition, according to our data, residential areas with a high level of such burdens may also be affected by further stressors (in this case, litter and dirt and a high frequency of odor burdens) and by a lack of environmental resources for recreation other than public green spaces such as urban vegetation, which may worsen the impact of the stressed situation.

We also confirmed that varied levels of traffic noise and air pollution are reflected in residents’ stress appraisals. That is, residents from high-burden blocks perceived more impaired, anxious, or threatened by traffic noise and air pollution compared to residents from low-burden blocks and may therefore be unable to habituate to these ambient stressors. In accordance with the World Health Organization that specifies annoyance of environmental burdens as an adverse health effect (Bergholm, Lindvall, & Schwela, 1999), these residential areas might pose a disadvantage to their residents’ health.

4.1.2. Varied environmental burdens and self-reported health behavior

As hypothesized, residents from high-burden blocks reported to engage in poorer health behavior with the exception of unemployed residents. After controlling for the potentially confounding effects of age, gender, and degree of education, participants from high-burden blocks reported consuming more nicotine, exercising less and consuming marginally more alcohol. In the literature, spatial patterns of health behavior in urban areas have mostly been attributed to differences in neighborhood social status, scales, large-scale variations in health education, or density of substance providers (D'Alessio & Stokols, 2000; Lauer, 2006; Taylor et al., 1987). However, in our study, these explanations can be ruled out. As shown in Table 1, the comparison of high-burden and low-burden blocks is not systematically biased by differences in neighborhood social status. Moreover, differences in neighborhood education or substance providers are unlikely due to the close spatial proximities of the compared blocks. Our results contradict a study from Seppey and Feldman (2001) who did not find any relationship between perceived neighborhood stressors and health behavior. As these authors did not consider objective burden levels, we can be almost sure that differences in health behavior in our data may be attributable to physical environmental conditions rather than cognitive factors. The higher incidence of smoking in high-burden blocks coincides with an experimental study that found smoking behavior to increase with higher levels of noise (Cherek, 1985). Moreover, in the regression analysis of the relationship between the perceived intensity of multiple factors and health behavior (traffic noise and – when unemployed participants were excluded – air pollution) were significant predictors. Taking into account our theoretical framework, this finding may point to a strategy of residents from high-burden blocks to cope with environmental stress. Moreover, the lower extent of physical activity found here may be due to a lack of environmental affordances (cf. Gibson, 1977) not only in terms of street conditions but also in terms of a lack of public green spaces and vegetation, which were shown to stimulate physical activity (Sullivan et al., 2004).

4.1.3. Prediction of neighborhood satisfaction

The expected difference in neighborhood satisfaction between residents of both burden level areas was confirmed; however, the effect was small. Our results indicate that neighborhood satisfaction can be better predicted from perceived levels of multiple, independently co-occurring environmental stressors and resources than from the objective variation of fewer burdens. In regression analysis, perceived levels of air quality, provision with public green space, behavior-related noise, and cleanliness explained 34% of the variance, with additive and comparably strong contributions. The effect size is remarkable, as other factors generally assumed to have stronger effects on neighborhood satisfaction (e.g., Sleep, perceived economic value or perceived safety; Framoscura, 2002; Hur & Morrow-Jones, 2008; Kjell & Finkelstein, 1991) were not included. With respect to the theoretical framework, the result may indicate that the difference in neighborhood satisfaction between high-burden and low-burden blocks is due to the perceived differences in air quality and provision with green space rather than traffic noise. According to Innes and Evans (1996), the additive effects indicate that these five environmental burdens demand different coping resources or strategies. To our knowledge, no studies have yet been published that is sure this finding also applies to earlier research approaches that exploited neighborhood satisfaction using additive stress scores (e.g., Handal, Blakely, & Morrissey, 1991). The benefit of our approach is that it enables to clarify which factors to tackle in interventions for sustainable urban development.

4.1.4. Environmental factors and general health indicators

Regression analyses indicated that perceived air quality was the only environmental factor related to life satisfaction, general self-rated health, depression, and anxiety in the total sample. This replicates earlier findings on a relationship between air pollution and impaired mental health (cf. Evans, 2003). As the annoyance-at-home item correlated strongest with these outcomes it can be assumed that subjectively affected participants felt they could not escape from poor air quality even in their own dwelling. A lack of perceived control over environmental stressors enhances their detrimental health effects (Bryant, Maude, Moles, & Cray, 2007), which could explain the relation between perceived low air quality and mental health. However, contrary to our prediction, life satisfaction and poor health symptoms were not related to objective burden levels. Thus, the relation between air quality and mental health might be more strongly influenced by other variables than by objective levels of NO2 and PM10. Further research is needed to clarify this aspect.

To summarize, our results suggest the following: Residents from inner-city neighborhoods with high levels of traffic noise, air pollution and little green space might be at greater health risk in comparison to lower-burden neighborhoods due to enhanced stress appraisals and differences in health behaviors. Moreover, neighborhood satisfaction can be additively predicted from perceived levels of multiple burdens. Finally, perceived air pollution plays a crucial role in predicting general health.

4.2. Limitations

Concluding that neighborhoods with the physical conditions studied here (i.e., traffic noise levels above 65 dB(A), high levels of NO2, and PM10, no provision with sufficient public green spaces within a 500 m radius) do not pose a risk to their residents’ general health would be premature due to some limitations of the present study. The response rate of 21% is quite low, albeit on average in comparison with other recent residential surveys without individual financial or similar compensations (e.g., Kearney, 2006; Leslie & Cotin, 2008; Sputtoe & Feldman, 2001). A sample bias arising from higher non-response of more affected residents is unlikely due to the well-balanced responses from high- and low-burden blocks. However, judging from degrees of education and foreigner, our sample under-represents lower social status groups that can be expected to be generally more vulnerable to suffer from poor mental or physical health. The lack of variance in social status
limited the statistical power to detect adverse health effects in residents of low social status.

Another limitation is the environmental data used in this study. While noise pollution data is available on a 5 m raster level, air pollution and public green space are only available on higher-level averages, which did not allow for establishing metric relationships between objective and subjective burden levels and more precise burden estimations for each participant.

Finally, causal inferences are impossible due to the cross-sectional design. No data on causality was derived from the study. For example, the finding that residents from high-burden blocks engage in poorer health behavior can alternately be explained by self-selection processes due to differences in health consciousness: Highly health-conscious people who are physically more active and who consume less nicotine and alcohol might also be more concerned about health risks arising from environmental pollution. Therefore, they may choose residential areas with lower perceived burden intensities.

4.3. Conclusion

Our study is the very first to investigate both multiple stressors and lack of environmental resources and their interplay on an individual, as well as on a neighborhood street block level. Our approach has proven worthwhile for multiple reasons. Unique partitions of variance in neighborhood satisfaction could be explained by multiple burdens. Moreover, according to participants' reports, multiple burdens (namely air and odorous pollution, traffic noise, lack of green space and urban vegetation, and litter) co-occur spatially and temporarily in neighborhood street blocks. Hence, our findings highlight the importance of an integrative multiple-burden framework, such as the one we propose in Section 3.1, in future research. Studies on hot spots of environmental vulnerability, urban health risk and environmental justice should also take into consideration less-examined factors such as littering behaviors, odor burdens, behavior-related role in noise and lack of urban vegetation. Data on the spatial dispersion of such factors are not available for many cities, including Berlin. If city administrations implement environmental burden datasets and integrated them with health reports and social development monitoring, it would be a fruitful addition and could be used to better evaluate health-relevant neighborhood qualities. Furthermore, the finding that neighborhood satisfaction can be predicted from multiple stressors and resources implies urban development projects, which improve several factors simultaneously, should be prioritized. For example, small patches of green (e.g., road side or vertical vegetation) are effective and inexpensive ways to enhance the amount of urban vegetation and to ameliorate air quality at the same time (Koswirat et al., 2011).

The finding that residents in neighborhoods with high levels of traffic and little provision with public green spaces behave less healthy can be applied in sustainable urban development in both health promotion strategies and urban planning. Billboard health campaigns, informative household flyers, or special health promotion programs should be targeted specifically in such high-burden areas. In addition, the results stress the importance of providing residents with sufficient public green spaces within a 500-meter radius to their homes. If public green space cannot be added in areas that lack them, it should be compensated by other measures to involve residents in regular physical exercise. This might be achieved by providing more gyms, sport halls or sport programs, and by supporting sport units. In addition, urban greenfields and voids can function like parks if specific design aspects are considered (Hofmann, 2011).

Our results may be generalized to other cities to some degree, as the city of Berlin does not have extreme levels of the burdens studied here (cf. European Environment Agency, 2008). Our study design is based on environmental data that are classified according to EU standards (cf. Dertouzos, 2011) and are available in most European cities. Moreover, we used predominantly standardized scales for data collection. Thus, comparative studies in different urban areas are possible and may allow new insights.

Finally, comparing the effect sizes of outcomes predicted from objective environmental data versus subjective perceptions highlights the importance of taking into account subjective neighborhood evaluations from city residents, in addition to objective evaluations based on environmental data. This is also important since urban designers, architects, and municipal policy makers cannot anticipate residents' subjective evaluations (Broms, 2012a, 2012b; Hardt & Bohnet, 2008). Residential surveys can be used to identify priorities in concrete steps for improving social urban development projects or urban design projects on smaller or larger scales. Combining both approaches (that is, enhancing the diversity of environmental data and integrating subjective perspectives of users) might be the most promising approach in defining priorities for intervention programs within urban areas in order to ensure healthy living environments for all city residents.

Acknowledgments

This research was funded by Deutsche Forschungsgemeinschaft (DFG). In addition, we especially thank Jim Welzl and Thomas Schneider from the European Environment Agency, 2008. Our study design is based on environmental data that are classified according to EU standards (cf. Dertouzos, 2011) and are available in most European cities. Moreover, we used predominantly standardized scales for data collection. Thus, comparative studies in different urban areas are possible and may allow new insights.

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References

Running head: RESIDENTIAL EXPOSURE TO MULTIPLE STRESSORS

Residential exposure to multiple stressors and cortisol level: New insights from a Berlin neighborhood study

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Abstract

**Background:** Although multiple environmental stressors may often occur simultaneously in urban residential areas, most research has examined single stressor exposure. Moreover, few studies have assessed endocrine markers, which may play a crucial role in the health risk of environmental stress. This study investigates the relation between residential exposure to a high versus low level of ambient stressors and health in two inner-city neighborhoods, with a focus on hair cortisol level as an objective health indicator.

**Methods:** Stressor level was determined by a spatial analysis of environmental data in a Geographic Information System. Potential mechanisms between stressor exposure and health were explored by quantitative and qualitative interview data.

**Results:** While residents from the high-burden area perceived stress from multiple burdens and were less satisfied with their neighborhood than residents from the low-burden area, their cortisol levels did not differ. However, subjective stress appraisal of air pollution was related to cortisol in the high-burden area. Moreover, duration of tenure and cortisol were unexpectedly related only in the low-burden area. Qualitative analysis pointed to an emerging conflict arising from the early stages of gentrification in this area.

**Conclusions:** We discuss implications for environmental stress research, as well as public communication and urban governance.

**Keywords:** stress; health; neighborhood satisfaction; traffic noise; air pollution; gentrification

**Abbreviations:** Geographic Information System (GIS)
1. Introduction

Chronic diseases such as depression, cardiovascular diseases, and cancer have become major causes of morbidity and mortality in developed countries (World Health Organization, 2008, 2009). Stress is assumed to be an important co-factor in the onset or course of these diseases (e.g., Dougall & Baum, 2001) and arises from multiple aspects associated with modern lifestyle. Some of these sources may be ambient stressors such as noise, odor, or air pollution (Campbell, 1983). The potential of physical environmental factors to elicit distress and impair subjective well-being is well established. However, the effect of long-term exposure to multiple co-occurring stressors, especially with respect to objective stress indicators, is unknown. Self-reported stress and health assessments are prone to bias and do not always correspond to objective health indicators (e.g., Ambrasat, Schupp & Wagner, 2011; Ising & Kruppa, 2004). Therefore, the present study aims to answer this question from a psychological stress perspective by using an objective marker of chronic stress.

1.1 Theoretical perspectives on environmental stress

According to the cognitive-transactional stress perspective (e.g. Bell, Green, Fisher, & Baum, 2001; Lazarus, 1991; Lazarus & Folkman, 1984), environmental stimuli can cause stress when they are perceived and negatively appraised. In the environmental stress literature, stress appraisal is investigated using various terms (e.g., nuisance, discomfort, anger, concern; e.g., Koelega, 1987; Lima, 2004), and often using “annoyance” as an umbrella term. Acute stress manifests in altered cognitive, emotional-physiological, and behavioral states in order to cope with the stressor. Coping reactions are adaptive efforts aimed at changing the situation (e.g., problem solving, self-protection) or at adapting psychologically (e.g., wishful thinking, regulation of emotions, e.g. expression of emotions) and are likely to be sustained when they are capable of mitigating the stress reaction (Homburg & Stolberg, 2004; Ojala, 2012). However, as ambient stressors do not necessarily
elicit action (Campbell, 1983), permanently exposed individuals may cognitively habituate to them, resulting in a diminishing of appraisal of stressors over time. Habituation is presumed to be less likely with higher degrees of stimulus salience and stress appraisal, and with exposure to multiple ambient stressors as opposed to just one (Cooper, Boyko, & Codinhoto, 2009; Glass & Singer, 1972; Lepore & Evans, 1996; Miller & Kraus, 1996; Priemus, 1986). If individuals cannot habituate or successfully cope with stressors, a stress reaction may be automatically triggered from the environmental cue (Lazarus, 1991) and potentially be intensified due to the costs associated with coping efforts (Cohen, Evans, Stokols, & Krantz, 1986; Craik & Zube, 1976). In this case, acute stress may become chronic and manifest in impaired well-being such as mental fatigue, social withdrawal, enhanced aggression, or impaired mood. In addition, more severe health effects may occur over time, which are best explained from a neurophysiological perspective.

In neurophysiological terms, endocrine pathways are assumed to play a key mediating role in the hazardous effects of chronic stress (McEwen & Seeman, 1999). Acute stress is accompanied by an enhanced activation of two interrelated systems, the sympathetic-adrenal medullary system (SAM) and the hypothalamic-pituitary-adrenocortical axis (HPA). In the short run, enhanced activity of these and other systems have adaptive functions and manifest in increased levels of catecholamines and cortisol, amongst other agents (e.g., Romero & Butler, 2007; Sapolsky, Krey, & McEwen, 1986). However, with frequent or permanent stress, these systems cannot return to normal levels or fail to catabolize the stress hormones. If this state accumulates over an extended period of time allostatic overload arises, which bears a severe risk of damage to brain cells and tissues (see Juster, McEwen, & Lupien, 2010, for a review). In particular, enhanced cortisol levels resulting from chronic HPA-hyperactivity are associated with a variety of pathophysiological changes and stress-related disorders such as enhanced susceptibility to infectious diseases, major depression, diabetes, impaired memory
functions, hypertension, and cardiovascular disease (e.g., Chrousos, 2009; Fries, Hesse, Hellhammer, & Hellhammer, 2005; Heim, Ehlert & Hellhammer, 2000; Kudielka & Kirschbaum, 2005). The probability that chronic stress results in impaired well-being and health may increase with other health risk factors such as low socioeconomic status, poor health behavior, a lack of social support and specific personality traits (Baum, Reverson, & Singer, 2001; Carlson, 2004; Marsland et al., 2001; McEwen, 2000; Romero & Butler, 2007).

1.2 Empirical findings on ambient stressors and health

Acoustic noise from different sources, unpleasant odors, litter, climatic conditions, spatial or social density, and other ambient stressors were shown to cause annoyance and to impair mood, cognitive performance and social behavior, and to impact neighborhood satisfaction (for reviews, see Berglund & Lindvall, 1995; Cooper et al., 2009; Evans, 2001; Evans & Cohen, 1987; Glass & Singer, 1972; Ouis, 2011; Rotton, & Frey, 1984; Steinheider & Winneke, 1993; R. B. Taylor, 1982; S. M. Taylor, 1982). Regarding general health outcomes, most studies focused on the long-term exposure to traffic noise and air pollution. Traffic noise may interfere with sleep quality (Öhrström, Skånberg, Svensson, & Gidlöf-Gunnarsson, 2006), but there is little evidence of an impact on mental health disorders (cf. Clark & Stansfeld, 2007; Evans, 2001). With respect to physical health, the literature is inconclusive (Babisch, 2006; Babisch & Ising, 2000; Berglund, Lindvall, & Schwela, 1999; Bluhm, Berglind, Nordling, & Rosenlund, 2007; Ising & Braun, 2000; de Kluizenaar, Gansevoort, Miedema, & de Jong, 2007; Krupa, Ising, & Babisch, 1999; Tafalla & Evans, 1997; van Kempen et al., 2002; Willich, Wegscheider, Stallmann, & Keil, 2006). Some of these publications report a slightly increased risk of hypertension, ischaemic heart disease, or myocardial infarction in individuals with chronic exposure to daytime noise of >60 dB(A) or >65 dB(A) and even lower nighttime levels. However, significance levels were rarely reached, and results were partly limited to specific age groups, smokers, low socioeconomic
status groups, or housing conditions such as bedroom orientation to the street and non-soundproof windows. Moreover, only a small number of these publications assessed catecholamines and cortisol levels, and their findings were inconsistent. In an extensive study on aviation noise in six European countries, Selander et al. (2009) found enhanced levels of morning saliva cortisol levels in women but not in men, whereas the extent of reported annoyance was unrelated to cortisol.

Air pollution was shown to be associated with diverse indicators of mental health (life satisfaction, general well-being, depression, anxiety, psychiatric emergencies, etc.), especially when subjective pollution levels and interaction with stressful life events were assessed (Chattopadhyay, Som, & Biswas, 1993; Evans, Jacobs, Dooley, & Catalano, 1987; Honold, Beyer, Lakes, & van der Meer, 2012; Jacobs, Evans, Catalano, & Dooley, 1984; Rotton & Frey, 1984; Steinheider, 1999; Strahilevitz, Strahilevitz, & Miller, 1979; Zeidner & Shechter, 1988). Severe levels of air pollution were recently linked with somatic diseases and changes in the central nervous system (e.g., Brook et al., 2009; Calderón-Garcidueñas et al., 2008; Choi et al., 2007; Chuang, Yan, & Cheng, 2010; Currie, Neidell, & Schmieder, 2009; Harrabi, Rondeau, Dartigues, Tessier, & Filleul, 2006). However, the latter studies may indicate direct toxic effects rather than stress effects, and we are not aware of recent publications on neurophysiological correlates, while older studies on air and odorous pollution are ambiguous (Bullinger, 1989; Chattopadhyay, Som, & Mukhopadhyay, 1995; see also Steinheider & Winneke, 1993). Thus, the causal relation between air pollution and mental health is poorly understood.

Regarding the cognitive-transactional stress theory, the literature on chronic exposure to ambient stressors and health might be more conclusive if long-term coping strategies or habituation were assessed. However, to our knowledge no validated instrument for the assessment of coping with ambient stressors is available, and researchers who operationalized
coping as a global trait often failed to confirm the relevance of coping in this field of research (e.g., Asmus & Bell, 1999; Cavalini, Koeter-Kemmerling, & Pulles, 1991; Steinheider & Winneke, 1993). Thus, individuals may cope with environmental pollution differently than with other stressors (Homburg & Stolberg, 2004). With regard to the question of whether habituation to single ambient stressors can occur, the literature is sparse and ambiguous (e.g., Evans, Jacobs, & Frager, 1982; Griefahn & Robens, 2010; Öhrström, Björkman, & Rylander, 1988; Weinstein, 1982). Moreover, subjective habituation to ambient stressors is not necessarily reflected in neurophysiological parameters (Kuroiwa, Suzuki, Sasazawa, Kawada, & Tamura, 2002) and is less likely to occur with multiple stressors (Bullinger, 1989) and when nearby green spaces are lacking (Gidlöf-Gunnarsson & Öhrström, 2007). Therefore, a lack of green spaces may be an additional environmental burden of health along with ambient stressors (e.g., Maas, van Dillen, Verheij, & Groenewegen, 2009; Mitchell & Popham, 2007; Richardson & Mitchell, 2010; Takano, Nakamura, & Watanabe, 2002). In addition, this may also apply to streetscape vegetation (van Dillen, de Vries, Groenewegen, & Spreeuwenberg, 2012).

1.3 Questions of interest

Few studies on exposure to ambient stressors and health outcomes have addressed HPA hyperactivity, and most have focused on single stressor exposure while, especially in inner-city areas, multiple environmental burdens may co-occur and potentially interact (Cooper et al., 2009; Lepore & Evans, 1996; Martimportugués-Goyenechea & Gómez-Jacinto, 2005; Pearce, Richardson, Mitchell, & Shortt, 2010). Therefore, we aimed to investigate the relation between long-term exposure to multiple co-occurring ambient stressors (in an area that additionally lacks green space) and the objective indication of chronic stress, as evidenced by measurements of cortisol. In addition, we report neighborhood satisfaction, life satisfaction, and perceived general health as subjective health outcomes for comparative purposes. Our
study was conducted within a subsample of a previous neighborhood survey (Honold et al., 2012). Based on the assumption that habituation to multiple burdens is unlikely, we hypothesized that residents from an area with multiple burdens report higher stress appraisals and have a higher cortisol level than residents from an area with a low level of physical environmental burdens. According to the concept of accumulated allostatic overload, we also hypothesized that duration of residence covaries with cortisol level in the high-burden area, but not in the low-burden area. Finally, by qualitative interviews we aimed to investigate potential mechanisms between stressor exposure and cortisol.

2. Method

2.1 Study area

Two inner-city living areas of Berlin with a walking distance of about 700m from each other were chosen as study sites (see figure 1). They differed with regard to traffic noise (>65 vs. ≤50 dB(A)), air pollution (heavily vs. minimally burdened with NO2 and PM10), and provision of near-residential public green space (>6m2 vs. <0.1m2 per resident within 500m). These burden levels were determined by a spatial analysis using data from a Digital Environmental Atlas (Senatsverwaltung für Stadtentwicklung, 2011a) in a Geographic Information System (GIS) (see Honold et al., 2012, for an extended description). An unpublished analysis of environmental quality ratings from the previous survey suggested that behavior-related noise, unpleasant odors, and litter and dirt were also significantly higher in the high-burden area, and the provision of streetscape vegetation was significantly lower. According to the Berlin rent index (Senatsverwaltung für Stadtentwicklung, 2011b), which classifies living areas as basic, middle or upscale on a micro-scale, both sites are basic residential areas. Social monitoring data (Senatsverwaltung für Stadtentwicklung, 2011c) imply that part of the high-burden area was of lower socioeconomic status due to a higher percentage of foreign and unemployed residents.
2.2 Sample

In the preceding survey 75 participants from the selected areas provided personal contact data for recruitment. Compensation consisted of 20 Euros and a study report. Thirteen addresses declined to participate or met exclusion criteria (i.e., relocation, dyed hair, hair length <2cm, use of glucocorticoid medication) and 30 were not available. Thus, the sample comprised \( N = 32 \) participants from 24 to 58 years of age and 59% females. As shown in table 1, 17 participants lived in the high-burden and 15 in the low-burden area. All participants were tenants with regular termination conditions with the exception of one apartment owner. Mean living spaces per residential unit and per resident represent Berlin average values of 70.4 m² and 38.7 m², respectively (Senatsverwaltung für Stadtentwicklung, 2011a). The percentage of foreigners and unemployed conformed to the city average, while individuals with lower degrees of education were under-represented (Amt für Statistik Berlin-Brandenburg, 2011). Finally, mean duration of tenure was lower than reported in an earlier study from Berlin (Babisch, Fromme, Beyer, & Ising, 2001).

2.3 Measures

In addition to previously collected demographic information, data was obtained by an online survey, qualitative interviews based on semi-structured guidelines, and by hair samples for cortisol extraction. These measures are described in more detail below.

*Online-survey*

Subjective health ratings were assessed in the beginning of the survey to avoid emotional priming bias on satisfaction measures. Neighborhood satisfaction was measured with a direct scale that assessed the degree of satisfaction through response to four items such as “How satisfied are you with living here?”. This scale was originally developed for the assessment of
housing satisfaction (Weidemann, Anderson, Butterfield, & O'Donnell, 1982). It was later translated into German and adapted to the assessment of neighborhood satisfaction (Feuersenger, 2004). Items have item-dependent verbal anchors on four points, with high values consistently indicating a high degree of satisfaction. The scale was chosen because global, direct ratings were shown to be valid measures of satisfaction (see Amérigo, 2002). For the same reasons, a direct scale of life satisfaction with five items (Diener, Emmons, Larsen, & Griffin, 1985) was applied. It assesses a respondent’s cognitive evaluation of the conditions of his live on a five-point scale, with high values indicating a high degree of agreement to statements such as “If I could live my life over, I would change almost nothing”. A single widely-used item “How would you describe your health status in general?” from the German SF-36 health survey (Bullinger & Kirchberger, 1998) assessed perceived general health. The item is substantially related to physical health complaints and mortality (Idler & Benyamini, 1997; Wallenius, 2004).

Perception and appraisal of all ambient stressors of interest were obtained (traffic noise, air pollution, behavior-related noise, unpleasant odors, and litter and dirt). Participants were instructed to relate all questions on environmental evaluation to their proximate living environment, which was defined as the area within a 2min-walk from their home. Based on the estimated walking speed (Morgenroth, 2008), this unit was chosen to represent the data units of the GIS analysis. Perceived environmental quality was measured with a single item per stressor (e.g., “How strong is traffic noise in your proximate living environment?”). Item-dependent answer scales had five points, with high values indicating good environmental quality. As an exception, due to the multidimensionality of odor burdens, we assessed the perception of odors by asking whether unpleasant odors were regularly present. In addition to the ambient stressors, perceived provision with green space and streetscape vegetation were obtained in the same way for control purposes regarding the multiplicity of burdens.
Appraisal of each stressor was measured by four items with a five-point answer scale in order to cover different emotional stress reactions (i.e., impaired well-being, annoyance at home, annoyance outdoors, and perceived health risk; see also Langdon, 1987; Lazarus, 1990). High values indicated a high degree of perceived stress. As the reliability was high (see table 2), a mean appraisal score was calculated per stressor.

– Insert table 2 about here –

In order to control for other, neighborhood-independent sources of chronic stress, a widely-used German scale (Trier Inventory of Chronic Stress; Schulz, Schlotz, & Becker, 2004) was applied. The scale is based on a transactional stress concept and asks participants how often they have experienced 12 different stressful situations related to work overload, social overload, excessive work demands, lack of social recognition, and chronic concern within the last three months from never (1) to very often (5). Participants’ raw scores were transformed into T-scores in accordance with age group norms available in the manual. Finally, participants provided information on household composition, net income, apartment size, current smoking, and relocation intentions as additional control variables.

Interview guidelines.

Guidelines contained information on the background and aim of the study and on data handling. Qualitative interviews began with a general question on environmental quality (“What are your main thoughts when you think of the environmental conditions in your immediate surroundings?”). A list of catchwords ensured that any ambient stressor and other critical issue participants mentioned was scrutinized in more detail, e.g., by examining in what situations participants were annoyed, disturbed or felt threatened, and how participants reacted to and/or coped with them. Finally, questions on social aspects (e.g., “Do you know other residents in this neighborhood?”; “How do people in the public space behave?”) and a general question (“Is there anything else relevant to your well-being here in this neighborhood
that we have not talked about yet?”) ensured that all potentially relevant issues would be covered.

Hair cortisol analysis.

Psychophysiological methods depicting the response of the autonomic nervous system and endocrine stress markers from blood, urine or saliva assess momentary activation rather than chronic stress levels (Sauvé, Koren, Walsh, Tokmakejian, & van Uum, 2007; Stern, Ray, & Quigley, 2001). Therefore, the recently developed method of cortisol extraction from hair (Davenport, Tiefenbacher, Lutz, Novak & Meyer, 2006) was used to assess long-term HPA activity (see also Dettenborn, Tietze, Bruckner, & Kirschbaum, 2010; Fourie & Bernstein 2011; Gow, Thomson, Rieder, van Uum, & Koren, 2010; Kalra, Einarson, Karaskov, Van, & Koren, 2007; Kirschbaum, Tietze, Skoluda & Dettenborn, 2009; Sauvé, Koren, Walsh, Tokmakejian, & van Uum, 2007). Two tied strands of hair were cut from the posterior vertex region as close to the scalp as possible. The samples were marked with an anonymous code and sent to a laboratory for analysis. For a technical protocol of the method, see Kirschbaum et al. (2009). Samples were analyzed in three 2cm-segments. Cortisol measures become less reliable with the age of the hair (Kirschbaum et al., 2009; Sauvé et al., 2007), and data from the second and third segments was missing for three and eight participants, respectively. Therefore, only the first segment was used for analysis, which captures approximately the last two months before the interview. Cortisol values refer to pictogram cortisol per milligram hair (pg/mg).

2.4 Procedure

The ethics commission of the Institute of Psychology approved the study protocol. Interviews were conducted in August and September 2010 at participants’ homes, approximately one year after the survey, and few days after participants answered the online survey. The visits began with the obtainment of informed consent and an update of
demographic data. The unabridged audio from each interview was recorded. Finally, hair samples were collected and participants were compensated. The first author and three trained student assistants transcribed the audio files verbatim, including breaks and non-semantic verbal expressions. The first author double-checked transcripts and conducted the analysis.

2.5 Data analyses

The significance level was set to $\alpha = .10$ for the following reasons: Results in the environmental stress literature are equivocal and effect sizes are small. The methods we chose were extensive and did not allow analyzing a larger sample size. Moreover, this research was of an explorative nature and implemented an innovative design aimed at stimulating continued research. Therefore, we considered a potential beta error more critical than an alpha error.

After plausibility checks, the relation between potential control variables and cortisol was examined using correlation analysis for ordinal and cardinal variables, as well as ANOVA for nominal variables. The distribution of nominal, ordinal and cardinal background variables between both study areas was examined with Pearson’s chi-square tests, log-linear analyses and ANOVA. In order to test whether participants from the two areas differed in environmental evaluations and outcomes, we conducted AN(C)OVA with age as covariate in predicting outcomes (e.g., Aguilera, 2011; Carp & Carp, 1982). Age did not differ significantly between the high-burden and the low-burden block, indicating independence of the burden level as the factor of interest. The assumption of normality within the two study sites was partly violated. However, as the sample sizes were nearly equal, a considerable bias of the $F$-statistic was unlikely (cf. Field, 2009). The hypothesis, that a positive relation between duration of residence and cortisol level would be present in the high-burden area, was tested separately for both areas through the use of hierarchical regression analyses. Age was entered in the first step and tenure in the second, as they were expected to covary. No
assumptions were violated. In general, no data is missing unless otherwise stated. Values of environmental perception are displayed as inversely coded in the tables. Thus, high values of environmental perception and appraisal indicate negative environmental evaluation.

We applied qualitative content analysis according to Mayring (2003; see also Atteslander, 2008; Lamnek, 2010) in order to analyze the interview transcripts. Categories and subcategories were deductively defined and inductively complemented after reading the transcripts. Categories referred to the evaluation of potential stressors (e.g., constraint, disturbance, belief, attribution), reactions to stressors (e.g., optimism, neglect, worry, adjustment, activity), and general neighborhood evaluation (e.g., dissatisfaction, indifference, affiliation, future planning). Relevant sections from all interviews were coded and subsequently, single cases analyses were conducted. The main findings from single case analyses were documented in a categorical system for comparison and combination with quantitative data for further exploration.

3. Results

3.1 Descriptive statistics

Regarding the relation between metric control variables and cortisol (see table 3), descriptive analyses revealed no significant correlation with perceived stress, but a significant correlation with age and tenure. The correlation between tenure and age was $r = .58$ ($p = .00$). Furthermore, cortisol was unrelated to household net income ($\tau = -.11, p = .46$). With respect to the nominal background variables displayed in table 1, cortisol was not significantly related to gender ($T(30) = -.08, p = .93$), education level ($F(2, 31) = 2.32, p = .12$), professional status ($F(2, 31) = 2.11, p = .14$), or social living conditions ($F(2, 31) = 0.18, p = .84$).

However, Germans ($M = 27.31, SD = 13.61$) had a higher cortisol level than non-Germans ($M = 20.34, SD = 5.38$), $T(15.69) = 1.96, p = .07$. Moreover, the three divorced or separated participants had a higher cortisol level ($M = 42.91, SD = 21.20$) than single ($M = 24.42, SD = $
11.29) or married participants ($M = 24.42$, $SD = 9.30$), $F(2, 31) = 3.18$, $p = .06$. Among environmental evaluations, only the correlation between appraised air pollution and cortisol was significant ($p = .09$). Appraised air pollution and cortisol correlated significantly in the subgroup from the high-burden area ($r = .59$, $p = .01$), but not in the low-burden area ($r = .12$, $p = .68$). Subjective outcomes were unrelated to cortisol level. For example, the correlation between neighborhood satisfaction and cortisol was the strongest among them ($r = .19$, $p = .30$).

– Insert table 3 about here –

3.2 Environmental perception, appraisal, and cortisol in the high-burden versus low-burden area

As shown in table 1, most background variables did not differ significantly between both areas – with few exceptions: More residents from the high-burden area were unemployed ($\chi^2 (1) = 5.23$, $p = .02$, $\Phi = .40$) and intended to move ($\chi^2 (1) = 6.13$, $p = .01$, $\Phi = .45$). The ones who considered relocation reported reasons related to environmental quality and ranged from 1-8 years of tenure.

The results of the comparisons of quantitative environmental evaluations and outcomes between both areas are displayed in table 4. All metrically assessed environmental evaluations differed in the expected direction, with participants from the high-burden area evaluating environmental conditions more negatively. Moreover, participants from the high-burden area were far less satisfied with their neighborhood. Single case analyses revealed that almost all residents from the high-burden area perceived stress from several burdens – with the exception of four participants who pointed to only one stressor, and whose apartments had access to the backside of the building. Most residents from the low-burden area did not mention any physical nuisance and valued quietness and proximity to nature. Some of them indicated strong attachment to their neighborhood due to the environmental quality.
In addition to the physical environment, evaluations of the social environment differed strikingly between both sites. Most residents from the high-burden area did not mention social contact between neighbors or perceived their neighborhood as anonymous. Conversely, almost all residents from the low-burden area referred to a positive, pleasant “atmosphere” in their neighborhood. They pointed to informal contact and the friendly behavior of pedestrians in the public space, as well as common backyard uses, street festivals, initiatives, and public meeting points. Some appreciated the high diversity in age and professional background, and several participants indicated that the social climate was at least as important to their well-being as the physical conditions.

– Insert table 4 about here –

However, as displayed in table 4, mean cortisol level did not differ between the two areas. Additional two-way AN(C)OVA conducted post hoc excluded bias caused by an interaction between cortisol and either gender, smoking, or apartment and bedroom orientation (street vs. backyard).

3.3 Duration of residence and cortisol in both areas

Tenure and cortisol correlated significantly in the low-burden area ($r = .71, p = .00$), but not in the high-burden area ($r = .08, p = .77$). This unexpected finding was confirmed by regression analyses (see table 5). In the low-burden area, 51% of variance in cortisol was explained by equal weights of age and tenure, while both variables were unrelated to cortisol in the high-burden area. Exploratory post hoc analyses showed that tenure remained a significant predictor of cortisol in the low-burden when age, marital status, and nationality were controlled. Qualitative content analysis identified one critical issue in the low-burden area, which was mentioned by all longer-term (> 4 years) and some shorter-term residents. This was described as change brought on by an influx of “young people”, accompanied by apartment renewals and developments, and a “tenser atmosphere”. Specifically, some named
an initiative of “established” residents who protested against this change. Others expressed annoyance from an aggressive protest group claiming to represent all residents’ opinion. Two longer-term residents also regretted the relocation of acquaintances due to rent increases, and some were concerned about the future of this trend or about the willingness of new arrivals to integrate into the neighborhood community. In the high-burden area, a few participants also mentioned the influx of young students and the opening of a new café, but described both as a positive change to the neighborhood.

– Insert table 5 about here –

3.4 Additional results from qualitative content analysis

As air pollution correlated highest with cortisol levels among all environmental evaluations, qualitative interviews were explored for potential mechanisms. Participants, presumably from the high-burden area, perceived dust inside their apartments (esp. on windows or window ledges) or inferred the presence of pollution from a high amount of traffic. A few mentioned irritation of eyes and throat when being outdoors or noticed dirt on their body afterward. Moreover, several participants stressed the fact that they constantly inhaled, or were surrounded by, pollutants. Some claimed to know about the health risks from traffic-emitted pollutants, or considered the entire city’s air unhealthy. At the same time, most expressed that they did not feel affected, and few referred to their robust health. In general, both female and male participants with different educational backgrounds made similar statements.

– Insert table 6 about here –

Regarding coping, the following reactions were identified among the 22 participants who perceived stress from at least one factor: Expression of emotions (e.g., anger, fear, disgust, cynicism), downward comparison/extenuation (e.g., comparison with mega-cities), active measures of self-protection (e.g., changing use of rooms, earplugs, modification on the
building, use of green spaces for recreation), and passive acceptance/resignation. The number of codes that were assigned to each ambient stressor is shown in table 6. Because several kinds of coping were coded in many participants, we were unable to classify persons by dominant styles. Furthermore, eleven participants indicated habituation to one or several stressors (e.g., no perception of noise or annoyance from litter anymore). Six of these made contradictory statements, for example by reporting being woken by noise or becoming agitated by litter at the same time. Subjective and objective outcome values of these eleven participants were predominantly in the average range for their neighborhood (i.e., $M +/- 1SD$), with few exceptions equally below or above. In general, emotion-oriented styles dominated, while active coping attempts, such as measures of self-protection and behaviors targeted at the source of the stress, were rare especially in relation to air pollution and behavior-related noise.

4. Discussion

4.1 Main findings

The aim of the present study was to examine the relation between long-term exposure to multiple co-occurring ambient stressors and hair cortisol level as an objective indicator of chronic stress, and to investigate potential underlying mechanisms. Comparative analyses of hair cortisol, survey data, and qualitative interviews were conducted among residents from a high-burden and a low-burden neighborhood area. They revealed the following main findings, which are discussed in the following paragraph: Residents from the high-burden area appraised multiple burdens as more stressful and were less satisfied with their neighborhood than residents from the low-burden area. However, they did not differ in cortisol level. Moreover, tenure and cortisol were only related in the low-burden area, while the appraisal of air pollution and cortisol were only related in the high-burden area.

As hypothesized, survey data revealed that residents from the high-burden area appraised all ambient stressors significantly more negatively. Moreover, they were considerably less
satisfied with their neighborhood, and more residents considered moving due to the environmental quality. Qualitative interviews revealed stress from multiple burdens in most residents from the high-burden area. Moreover, they suggested that the remarkable difference in neighborhood satisfaction was partly a result of the physical environmental quality, and partly due to social conditions. Residents from the low-burden area pointed to neighboring behaviors suggestive of a higher sense of community or neighborhood social capital (e.g., Lochner et al., 1999; McCulloch, 2003; Pretty, 1990; Townley, Kloos, & Wright, 2009). This variation may not only stem from differences in socioeconomic conditions, but also the varied burden level, as physical environmental quality may impact social capital (e.g., Leyden, 2003; Skjaeveland & Gärling, 1997; Wood & Giles-Corti, 2008).

Despite higher stress appraisals neither hair cortisol level nor perceived general health differed between the two sites. Therefore, our hypothesis of chronic HPA-hyperactivity as a result of long-term exposure to multiple stressors was not confirmed. To our knowledge, this is the first study to investigate the relation between multiple environmental stressor exposure and hair cortisol. The advantage of the method we applied is that, unlike the existing literature, it assesses long-term HPA activity rather than acute neurophysiological activation. As discussed in section 1.2, earlier publications on the neurophysiological correlates of exposure to single ambient stressors were inconclusive. Cortisol reactions to noise were predominantly reported in experimental settings (e.g., Burow, Day, & Campeau, 2005; Gilbert, Meliska, & Plath, 1997; Tafalla & Evans, 1997; Waye, Clow, Edwards, Hucklebridge, & Rylander, 2003) and in field research with an indicator of morning cortisol (e.g., Selander et al., 2009). Therefore, noise and other stressors may not affect absolute levels on the long term. However, habituation is not a likely explanation for the lack of difference in cortisol levels. As discussed above, environmental appraisals and neighborhood satisfaction differed considerably. Moreover, statements of habituation were partly ambiguous and were
not reflected in better health outcomes. The hypothesized increase in HPA-activity as a result of multiple burdens would be masked if other kinds of stressors were enhanced in the other area. The relation between tenure and cortisol points to this direction.

Contrary to our hypothesis, duration of residence was unrelated to cortisol levels in the high-burden area. The relatively short tenure in this area may have been insufficient to detect allostatic load from environmental burdens, as was shown, for example, by Mair, Cutchin, and Kristen Peek (2011) in residents of an underprivileged neighborhood with 30 years of tenure. However, a large amount of variance in cortisol was explained by age and tenure in the low burden area. According to the neurophysiological stress perspective (e.g., Chrousos, 2009; McEwen & Seeman, 1999; Juster et al., 2010), this finding suggests accumulated stress with higher age and longer duration of residence in the low-burden area. Qualitative interviews revealed an initial process of gentrification, accompanied by a perceived neighborhood conflict. As predominantly long-term residents mentioned this aspect in the context of questions concerning their personal well-being in their neighborhood, this aspect may provide an explanation. In general, several parts of Berlin have experienced an appreciation of values and displacement since the reunification in 1990, and there are ongoing conflicts, initiatives, and debates on gentrification issues in the media and in the public space (Ahlfeldt, 2011; Levine, 2004; Papen, 2012; White & Gutting, 1998). This circumstance may have contributed to the sensitivity of our interviewees toward this topic. Some participants were concerned with a decline in social diversity or a loss of social ties and sense of community. So far, the literature regarding the effects of gentrification on social networks is equivocal (cf. Atkinson, 2000). In our case, some persons anticipated an adverse effect. As discussed above, the social capital seemed rather high in this neighborhood, which was shown to be a resource for mental and physical health (e.g., Adams, 1992; Kahana, Lovegreen, Kahana, & Kahana, 2003; Kawachi, Kennedy, & Glass, 1999; Ziersch, Baum, MacDougall, &
Putland, 2005). The conservation of resources (COR) theory (Hobfoll, 1988, 1989, 1998) points to the importance of shared resources in human communities. Moreover, it assumes that a stress reaction most probably arises when a loss of resources is expected, or has occurred. Besides material objects, resources can be immaterial social conditions or health itself. Thus, an expected or perceived loss of neighborhood social capital may have occurred, which is more likely in longer-term residents who generally perceive more social ties in urban neighborhoods (Adams, 1992).

COR-theory may also help to explain the relation between appraisal of air pollution and cortisol, which was highly significant in the high-burden area. Male and female participants inferred that the air quality was poor or even unhealthy from perception of traffic and coarse particles, which may have been influenced by recent public debates on fine dust particles. In addition, some perceived that air pollution was present from sensory irritation or odorous pollution, as was already found in earlier studies (e.g., Carp & Carp, 1982; Cermak & Bollen, 1982; Evans et al., 1982; Steinheider & Winneke, 1993). Some participants felt affected inside their apartments. The special impact of a lack of protection from environmental burdens within the dwelling to endocrine stress reactions has been shown before for traffic noise (Babisch et al., 2001). A lack of control is assumed to determine or exacerbate the effects of stressors on health (see Wallston, 2001, for a review). Our participants might have considered self-protection from air pollution impossible, as indicated by the absence of active coping styles, and since active coping is rare when situations are hard to control (e.g. Knoll et al., 2005). Moreover, qualitative and quantitative data suggested that air pollution was more often appraised as a health risk than traffic noise, odor burdens, litter, and behavior-related noise. Thus, air pollution may evoke more health concerns than other stressors (Walsh-Daneshmandi & MacLachlan, 2000) and therefore, cause higher HPA activity by an expected loss of resources. Alternatively, trait anxiety may impact air quality evaluations (Navarro,
Simpson-Housley, & de Man, 1987; Zeidner & Shechter, 1988) and cortisol levels (Takai et al., 2004; van Uum et al., 2008). However, the significant relation between cortisol and appraisal only in the area with high amounts of air pollution suggests that this finding was not (merely) caused by intrapersonal, but also by environmental conditions. This is an important finding in light of the still poorly understood relation between air pollution and mental health (e.g., Chattopadhyay et al., 1993; Honold et al., 2012; Steinheider, 1999) and suggests the importance of health risk beliefs.

4.2 Limitations

Before conclusions are drawn, a few limitations of this work should be noted. The environmental data we applied did not allow for exact estimations of individual burden levels especially within participants’ apartments, which might allow a more precise estimation of the endocrine effects of noise (Babisch et al., 2001; Ising & Braun, 2000). Moreover, our data are cross-sectional and do not show causal relations, and the methods utilized demanded a small sample size. Therefore, we could not analyze vulnerable subgroups such as individuals with higher age, medical conditions, low socioeconomic status or a history of negative life events (e.g., Evans, Jacobs, Dooley, & Catalano, 1987; Miller, 1996; Pickett & Pearl, 2001). Finally, cortisol analysis from hair is a new method that requires further exploration. Norm values are not available yet, which would have helped in interpreting the results. Moreover, it is unknown under which conditions chronic stress results in HPA-hypoactivity instead of hyperactivity, the latter of which is prevalent in patients with chronic pain and fatigue (e.g., Fries et al., 2005; Heim et al., 2000; Kudielka & Kirschbaum, 2005). Cortisol may be the most important endocrine mediator in the harmful effects of chronic environmental stress (e.g., Babisch, 2003; Bigert, Bluhm, & Theorell, 2005), but it is one of several interconnected agents. Thus, our design may be applied with the more extensive allostatic load index (e.g., Gruenewald et al., 2012; Juster et al., 2010; Mair et al., 2011) in future research.
4.3 Conclusion and implications

Despite its limitations, our innovative mixed-methods approach yielded fruitful new insights for continuative research on the health effects of both, the physical and social urban environment. The potential of combining environmental data with subjective evaluations and neurophysiological measures to form a better understanding of how environmental burdens and mental health are related is evidenced by the air pollution results presented here. Furthermore, while Atkinson, Wulff, Reynolds, & Spinney (2011) investigated gentrification from the perspective of the already displaced, we are not aware of any publication that addresses the perception and cognition of residents from a neighborhood at an early stage of this process. Due to the small sample size and the fact that the study sites were not systematically selected for gentrification research, the relation between tenure and cortisol in this neighborhood could be caused by unaccounted third variable influences. Therefore, this result is to be interpreted with caution. However, by all means, the interview results indicate the need for psychological research in this topic – especially in the light of the impact of gentrification in many contexts (e.g., Atkinson, 2000; Atkinson et al., 2011; Biro, 2007). Moreover, the potential effects of environmental burdens and environmental resources on social aspects of neighborhoods should be elaborated further. Finally, as discussed in other fields of stress research (e.g., Cohen, 1991; Neufeld, 1990; Schwarzer & Schwarzer, 1996), theoretical work should expand our understanding of the concept of coping. Based on the finding that reactions to different or the same ambient stressors varied intraindividually, and that sometimes no coping styles were identified, more research on the validity of psychometric instruments (e.g., Homburg & Stolberg, 2004; Ojala, 2012) in research on ambient stressors is required. For example, Moser (1994) hypothesizes an absence of coping attempts under high and low stressor levels. Moreover, coping should be investigated as a
changing process over a period of time to learn about its transactional character (cf. Lazarus, 1990).

In addition to research directions, we suggest practical implications. The findings on air pollution suggest that the public should be informed in a more differentiated way about the health risks of fine dust particles on the one hand, and visible, coarse pollutants on the other. For example, Schwartz (2006) discusses examples of risk exaggerations in mass media communication, misinterpretations of scientific publications, and the consequences of publication bias, which might all contribute to public misperception of air pollution. Moreover, public communication should focus on solutions and specific situations rather than on the problem (Hazard, 1996) and be context-specific, as the perception of air pollution underlies socio-cultural influences (e.g., Bickerstaff, 2004; Bickerstaff & Walker, 2001) and is impacted by information on potential effects (Ruback, Pandey & Begum, 1997). Doing so may reduce concern and thus, stress reactions to the perception of air pollution. However, it will not replace the urge to improve emissions from a psychological perspective, as the public may not follow advice of risks from air pollution (Semenza et al., 2008), and because even expert knowledge may not significantly impact behavior (Morris & Smart, 2012). Finally, our participants’ perceptions of gentrification stress the need for regulative measures by public authorities on several levels, such as city and district administrations, as well as neighborhood development agencies. This refers not only to a moderation of the rate of influx of new habitants, but also to regulation of sale of real estate and rising rents. Opportunities for informal contact between longer-term and new residents through neighborhood activities (e.g., a market, gastronomic services, social projects) might help to sustain or enhance neighborhood networks as a potential health resource.
References


*Health and Place, 5*, 259–270.


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Figure caption

Figure 1. Map of the two study sites. Interviews were conducted in the encircled areas. Study area one is referred to as the low-burden area having a low level of traffic noise and air pollution, and being provided with sufficient near-residential public green space. Study area two is referred to as the high-burden area with a high level of traffic noise and air pollution, and no provision of sufficient near-residential public green space. Shaded blocks signify late-19th century block development structure. The degree of air pollution is indicated with curves along the streets and with no indication of air pollution being equivalent to minimal air pollution. Data source: Berlin Senate Department for Urban Development (Senatsverwaltung für Stadtentwicklung, 2011).
### Table 1

**Sample Characteristics.**

<table>
<thead>
<tr>
<th>Variable [missing]</th>
<th>Total sample</th>
<th>High-burden area</th>
<th>Low-burden area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>32</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Female gender</td>
<td>19 (59%)</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>German nationality</td>
<td>27 (84%)</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Age&lt;sup&gt;a&lt;/sup&gt;</td>
<td>36.00 (10.16)</td>
<td>36.59 (10.92)</td>
<td>35.33 (9.57)</td>
</tr>
<tr>
<td>Years of tenure&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.97 (3.43)</td>
<td>3.35 (2.98)</td>
<td>4.67 (3.87)</td>
</tr>
<tr>
<td>Living space per unit&lt;sup&gt;a&lt;/sup&gt; (m$^2$)</td>
<td>72.03 (24.34)</td>
<td>73.94 (29.28)</td>
<td>69.87 (17.95)</td>
</tr>
<tr>
<td>Living space per resident&lt;sup&gt;a&lt;/sup&gt; (m$^2$)</td>
<td>42.73 (15.93)</td>
<td>43.24 (15.92)</td>
<td>42.16 (16.48)</td>
</tr>
<tr>
<td>Perceived stress&lt;sup&gt;a&lt;/sup&gt;</td>
<td>53.72 (8.75)</td>
<td>51.50 (9.12)</td>
<td>56.46 (7.74)</td>
</tr>
<tr>
<td>Smoking</td>
<td>12</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary school degree</td>
<td>6 (19%)</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>University entrance qualification</td>
<td>6 (19%)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Academic degree</td>
<td>20 (63%)</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Professional status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employed</td>
<td>20 (63%)</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Students/retired/homemakers</td>
<td>7 (22%)</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Unemployed</td>
<td>5 (16%)</td>
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<td>0</td>
</tr>
<tr>
<td>Household net income [2]</td>
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<tr>
<td>&lt; 1000€</td>
<td>11 (34%)</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>1000-1999€</td>
<td>10 (31%)</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>≥ 2000€</td>
<td>9 (28%)</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Marital status</td>
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<td></td>
</tr>
<tr>
<td>Unmarried</td>
<td>25 (78%)</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Married</td>
<td>4 (13%)</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Divorced/separated</td>
<td>3 (9%)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Social living condition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alone</td>
<td>12 (38%)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>With partner and/or children</td>
<td>12 (38%)</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Apartment share</td>
<td>8 (25%)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Intention of relocation [1]</td>
<td>6 (19%)</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>
Note. Deviations are due to rounding total sample percentages.

*a* Indicated are mean values with standard deviations in parentheses.
Table 2

Description of Measures Used in Analyses.

<table>
<thead>
<tr>
<th>Scale title</th>
<th>No. of items</th>
<th>Scale points</th>
<th>N</th>
<th>M (SD)</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Rel. (alpha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived stress</td>
<td>12</td>
<td>5</td>
<td>32</td>
<td>3.43 (1.64)</td>
<td>0.90</td>
<td>0.52</td>
<td>.92</td>
</tr>
<tr>
<td>Environmental perception</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air quality</td>
<td>1</td>
<td>5</td>
<td>32</td>
<td>1.31 (1.06)</td>
<td>-1.37</td>
<td>1.62</td>
<td></td>
</tr>
<tr>
<td>Traffic noise</td>
<td>1</td>
<td>5</td>
<td>32</td>
<td>1.91 (1.15)</td>
<td>0.08</td>
<td>-0.83</td>
<td></td>
</tr>
<tr>
<td>Cleanliness</td>
<td>1</td>
<td>5</td>
<td>32</td>
<td>2.09 (0.83)</td>
<td>0.19</td>
<td>-0.29</td>
<td></td>
</tr>
<tr>
<td>Behavior-related noise</td>
<td>1</td>
<td>5</td>
<td>32</td>
<td>1.69 (1.06)</td>
<td>-0.51</td>
<td>-0.24</td>
<td></td>
</tr>
<tr>
<td>Public green space</td>
<td>1</td>
<td>5</td>
<td>32</td>
<td>0.66 (0.70)</td>
<td>-0.60</td>
<td>-0.71</td>
<td></td>
</tr>
<tr>
<td>Vegetation</td>
<td>1</td>
<td>5</td>
<td>32</td>
<td>1.16 (0.92)</td>
<td>-0.73</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Environmental appraisal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air pollution</td>
<td>4</td>
<td>5</td>
<td>32</td>
<td>2.04 (0.80)</td>
<td>0.21</td>
<td>-1.41</td>
<td>.84</td>
</tr>
<tr>
<td>Traffic noise</td>
<td>4</td>
<td>5</td>
<td>32</td>
<td>2.36 (0.99)</td>
<td>0.36</td>
<td>-0.04</td>
<td>.93</td>
</tr>
<tr>
<td>Litter and dirt</td>
<td>4</td>
<td>5</td>
<td>32</td>
<td>2.02 (0.74)</td>
<td>0.15</td>
<td>-0.92</td>
<td>.78</td>
</tr>
<tr>
<td>Behaviour-related noise</td>
<td>4</td>
<td>5</td>
<td>32</td>
<td>1.90 (0.92)</td>
<td>0.96</td>
<td>-0.33</td>
<td>.93</td>
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<tr>
<td>Unpleasant odors</td>
<td>4</td>
<td>5</td>
<td>32</td>
<td>1.80 (0.76)</td>
<td>0.65</td>
<td>-0.33</td>
<td>.80</td>
</tr>
<tr>
<td>Health outcomes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neighborhood satisfaction</td>
<td>4</td>
<td>4</td>
<td>32</td>
<td>3.13 (0.58)</td>
<td>-0.66</td>
<td>-0.35</td>
<td>.85</td>
</tr>
<tr>
<td>Life satisfaction</td>
<td>5</td>
<td>5</td>
<td>32</td>
<td>3.55 (0.54)</td>
<td>-1.37</td>
<td>1.62</td>
<td>.76</td>
</tr>
<tr>
<td>Perceived general health</td>
<td>1</td>
<td>5</td>
<td>32</td>
<td>3.65 (0.88)</td>
<td>0.35</td>
<td>-0.57</td>
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<tr>
<td>Cortisol</td>
<td></td>
<td></td>
<td>32</td>
<td>26.22 (12.87)</td>
<td>1.09</td>
<td>0.68</td>
<td></td>
</tr>
</tbody>
</table>

Note. High environmental perception means indicate negative evaluations; high environmental appraisal means indicate high stress appraisals.

a high values correspond to good well-being. b high value corresponds to poor well-being.
Table 3  

*Correlations of Metric Control Variables, Environmental Perception Items, and Appraisal Scales with Outcomes: Neighborhood Satisfaction (NS), Life Satisfaction (LS), Perceived General Health (GH), and Cortisol Level (C).*

<table>
<thead>
<tr>
<th>Control variables</th>
<th>NS</th>
<th>LS</th>
<th>GH</th>
<th>C</th>
</tr>
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<tbody>
<tr>
<td>Age</td>
<td>-.29</td>
<td>-.24</td>
<td>-.23</td>
<td>.34*</td>
</tr>
<tr>
<td>Tenure</td>
<td>-.02</td>
<td>-.11</td>
<td>-.22</td>
<td>.44*</td>
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<tr>
<td>Perceived stress</td>
<td>.27</td>
<td>-.17</td>
<td>-.15</td>
<td>-.17</td>
</tr>
<tr>
<td>Living space per unit (m²)</td>
<td>.02</td>
<td>.02</td>
<td>-.03</td>
<td>-.01</td>
</tr>
<tr>
<td>Living space per resident (m²)</td>
<td>.01</td>
<td>-.13</td>
<td>-.08</td>
<td>.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental perception</th>
<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Air quality</td>
<td>-.70**</td>
<td>-.26</td>
<td>-.30</td>
<td>.11</td>
</tr>
<tr>
<td>Traffic noise</td>
<td>-.65**</td>
<td>-.27</td>
<td>-.14</td>
<td>.01</td>
</tr>
<tr>
<td>Cleanliness</td>
<td>-.64**</td>
<td>-.22</td>
<td>-.14</td>
<td>.08</td>
</tr>
<tr>
<td>Behavior-related noise</td>
<td>-.60**</td>
<td>-.20</td>
<td>-.27</td>
<td>.06</td>
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</table>

<table>
<thead>
<tr>
<th>Environmental appraisal</th>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Air pollution</td>
<td>-.47**</td>
<td>-.21</td>
<td>.00</td>
<td>.31*</td>
</tr>
<tr>
<td>Traffic noise</td>
<td>-.53**</td>
<td>-.19</td>
<td>-.11</td>
<td>.20</td>
</tr>
<tr>
<td>Litter and dirt</td>
<td>-.60**</td>
<td>-.22</td>
<td>-.02</td>
<td>.07</td>
</tr>
<tr>
<td>Behavior-related noise</td>
<td>-.46**</td>
<td>.01</td>
<td>-.10</td>
<td>.09</td>
</tr>
<tr>
<td>Unpleasant odors</td>
<td>-.64**</td>
<td>-.06</td>
<td>.05</td>
<td>.11</td>
</tr>
</tbody>
</table>

*Note.* High environmental perception means indicate negative evaluations; high environmental appraisal means indicate high stress appraisals.

*a* high values correspond to good well-being. *b* high value corresponds to poor well-being.

* p < .10; * p < .05; ** p < .01.
Table 4

Results From ANOVA Comparing Environmental Evaluations Among Participants From the
High-burden Area Versus the Low-burden Are, and From ANCOVA comparing Outcomes Likewise.

<table>
<thead>
<tr>
<th></th>
<th>High-burden area</th>
<th>Low-burden area</th>
<th>F</th>
<th>df</th>
<th>p</th>
<th>partial $\eta^2$</th>
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<td><strong>Environmental perception</strong></td>
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<tr>
<td>Traffic noise</td>
<td>2.59</td>
<td>1.13</td>
<td>21.22</td>
<td>1, 32</td>
<td>.00</td>
<td>.41</td>
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<tr>
<td>Air quality</td>
<td>1.94</td>
<td>0.60</td>
<td>20.94</td>
<td>1, 32</td>
<td>.00</td>
<td>.41</td>
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<tr>
<td>Provision with green space</td>
<td>0.88</td>
<td>0.40</td>
<td>4.16</td>
<td>1, 32</td>
<td>.05</td>
<td>.12</td>
</tr>
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<td>Cleanliness</td>
<td>2.59</td>
<td>1.53</td>
<td>16.78</td>
<td>1, 32</td>
<td>.00</td>
<td>.36</td>
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<tr>
<td>Behavior-related noise</td>
<td>2.29</td>
<td>1.00</td>
<td>18.60</td>
<td>1, 32</td>
<td>.00</td>
<td>.38</td>
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<tr>
<td>General vegetation</td>
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<td>0.67</td>
<td>10.44</td>
<td>1, 32</td>
<td>.01</td>
<td>.26</td>
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<td><strong>Environmental appraisal</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic noise</td>
<td>2.90</td>
<td>1.75</td>
<td>15.82</td>
<td>1, 32</td>
<td>.00</td>
<td>.35</td>
</tr>
<tr>
<td>Air pollution</td>
<td>2.43</td>
<td>1.60</td>
<td>11.30</td>
<td>1, 32</td>
<td>.00</td>
<td>.27</td>
</tr>
<tr>
<td>Cleanliness</td>
<td>2.35</td>
<td>1.65</td>
<td>8.86</td>
<td>1, 32</td>
<td>.01</td>
<td>.23</td>
</tr>
<tr>
<td>Behavior-related noise</td>
<td>2.25</td>
<td>1.50</td>
<td>6.25</td>
<td>1, 32</td>
<td>.02</td>
<td>.17</td>
</tr>
<tr>
<td>Unpleasant odors</td>
<td>2.15</td>
<td>1.40</td>
<td>10.08</td>
<td>1, 32</td>
<td>.00</td>
<td>.25</td>
</tr>
<tr>
<td><strong>Outcomes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neighborhood satisfaction $^a$</td>
<td>2.78</td>
<td>3.52</td>
<td>22.50</td>
<td>1, 32</td>
<td>.00</td>
<td>.43</td>
</tr>
<tr>
<td>Life satisfaction $^a$</td>
<td>3.42</td>
<td>3.69</td>
<td>1.85</td>
<td>1, 32</td>
<td>.18</td>
<td>.06</td>
</tr>
<tr>
<td>Perceived general health $^a$</td>
<td>3.59</td>
<td>3.71</td>
<td>1.96</td>
<td>1, 32</td>
<td>.58</td>
<td>.01</td>
</tr>
<tr>
<td>Cortisol $^b$</td>
<td>26.14</td>
<td>26.30</td>
<td>0.25</td>
<td>1, 32</td>
<td>.97</td>
<td>.00</td>
</tr>
</tbody>
</table>

*Note.* High environmental perception means indicate negative evaluations; high environmental appraisal means indicate high stress appraisals.

$^a$ high values correspond to good well-being. $^b$ high value corresponds to poor well-being.

Significance levels are two-tailed.
Table 5

Hierarchical Regression Analyses Predicting Cortisol Levels from Tenure in the High-burden Area And in the Low-burden Area.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>High-burden area</th>
<th>Low-burden area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>β</td>
</tr>
<tr>
<td>Step 1: Age</td>
<td>0.21</td>
<td>0.19</td>
</tr>
<tr>
<td>Step 2: Tenure</td>
<td>-0.15</td>
<td>-0.04</td>
</tr>
<tr>
<td>Total R²</td>
<td>.04</td>
<td></td>
</tr>
<tr>
<td>Corrected R²</td>
<td>-.10</td>
<td></td>
</tr>
</tbody>
</table>

Note. * p < .05.
Table 6

*Codes of Reactions to Ambient Stressors (Coping styles, Habituation) in Qualitative Content Analysis: Expression of Emotions (A); Downward Comparison/Minimization (B); Active Measures (C); Passive Acceptance/Resignation (D); Subjective Habituation (E); Ambiguous Subjective Habituation (F).*

<table>
<thead>
<tr>
<th>Ambient Stressor</th>
<th>Reaction (number of codes)</th>
<th>Combination of styles&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Traffic noise</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Behavior-related noise</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Air pollution</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Litter/dirt</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Unpleasant odors</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Total counts</td>
<td>32</td>
<td>4</td>
</tr>
</tbody>
</table>

<sup>a</sup> Indicates how often two or more reactions to one specific stressor were coded in single cases analyses.
Title: Healthy urban design: Beyond public parks

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Abstract

Despite promising findings from experimental research, few studies have addressed the potential long-term health benefits of urban nature. The article examines cross-sectional relations between two kinds of urban nature (neighborhood vegetation visible from home, use of public green spaces) and three health outcomes (life satisfaction, perceived general health, hair cortisol levels) in a sample from Berlin. Views from home on a high amount of diverse vegetation, as well as regular use of two nearby green spaces were related to lower cortisol levels. We conclude that multiple kinds of nature beyond parks such as green ways and diverse streetscape vegetation should be addressed in urban design. This may enhance the recreational value of urban neighborhoods and encourage city residents to engage in restorative activities and sustainable modes of commuting.

Key words: vegetation; green way; hair cortisol; health; neighborhood; urban planning
1. Introduction

Designers and visionaries depict future cities as conglomerates of sustainably built and managed structures and diverse ecosystems, home to an abundance of species, and a healthy human population (e.g., Farr, 2008; Feireiss & Feireiss, 2009; Klanten & Feireiss, 2011). Global challenges such as climate and demographic change, environmental pollution and related health risks evidence the necessity to implement such visions in practice. The envisaged transformation of highly sealed “concrete jungles” into “urban green jungles” can only be achieved through a long-lasting process of small steps and requires multi-disciplinary research to set priorities amidst conflicting power interests in cities. In recent psychological research, evidence of the immediate health benefits of nature experiences has increased. However, the majority of these studies is of experimental nature with low external validity (Gaber & Gaber, 2004) and gives little information on the long-term effects of permanent or frequent contact with nature. Hence the present paper examines the relation between different kinds of urban nature in the public space and health. By urban nature, we refer to different kinds of coherent green spaces (e.g., parks, small-scale green spaces) and diverse kinds of planted or spontaneously grown vegetation in the streetscape (i.e., mainly nature of the third kind; see Kowarik, 2005). Accordant to the World Health Organization (1946), we conceptualize health as a state of complete physical, mental and social well-being and thus include life satisfaction as the most common measure of subjective well-being (Amérigo, 2002; New Economics Foundation, 2012). Theoretically, health benefits from nature may arise from different pathways, as described in the following section.

1.1 Theoretical perspectives on the psychological benefits of urban nature

processes such as perception, cognition, emotion, and communication. The effort of these processes depends partly on the physical properties of the environmental surrounding. Natural environments are assumed to consist of an optimal degree and configuration of information due to a high level of coherence and legibility, and moderate complexity and mystery (see Kaplan & Kaplan, 1989, for a discussion of these terms). Contrary to downtown areas which may overstrain attention capacity due to an overload of information (see Bell, Greene, Fisher, & Baum, 2001), urban nature spaces may allow for attention restoration because they are compatible with behavioral intentions, create a sense of being away from everyday routine tasks and permit the experience of spatial extent and a “whole other world” (Kaplan, 1995, p. 173). They may further evoke fascination by aesthetically pleasing attributes (e.g., leaves in the wind, sunsets) that enable reflection and encourage explorative behavior (Herzog, Black, Kimberlee, Fountaine, & Knotts, 1997; Kaplan & Kaplan, 2011). Besides proximate nature experiences, a window view on nature may provide a “micro-restorative experience [due to] something compelling or fascinating to look at” (Kaplan & Kaplan, 2005, p. 280).

Stress reduction theory (Ulrich, 1983; Ulrich, Simon, Fiorito, Miles, & Zelson, 1991) constitutes unconsciously triggered affective rather than cognitive responses as the core element of humans’ immediate reaction to nature. This tendency is assumed to be evolutionary determined and specifically evident in Savannah-like surroundings, as early humans’ well-being depended on open landscapes with prospect for food supply and water, as well as trees and other vegetation for resources and refuge from wildlife (Appleton, 1975; Orians & Heerwagen, 1992). The perception of such cues may elicit aesthetic responses (e.g., perceived beauty or pleasantness) and alter neurophysiological activation towards an optimal level if the positive affective state is not modified by negative cognitive appraisal of these
stimuli (e.g., if evaluated as harmful; Ulrich, 1983). Finally, these processes are assumed to elicit action impulses and result in adaptive behaviors or better functioning.

Whether attention restoration and stress reduction are coinciding, interacting or mutually determining processes is not clearly resolved (Hartig, Böök, Garvill, Olsson, & Gärling, 1996; Hartig, Evans, Jamner, Davis, & Garling, 2003; Kaplan, 1995; Ulrich et al., 1991). From a long-term perspective, it is of special importance to consider the consequences of a lack of nature experiences. Sullivan (2005) argues that city residents may permanently suffer from stress due to their unfit habitat (i.e., dissimilarity to Savannah-like landscapes). Chronic stress involves permanent over-activation of neuroendocrine and cardiovascular systems, a critical state called allostatic overload (McEwen, 2000; McEwen & Seeman, 1999). The hypothalamic-pituitary-axis (HPA), which regulates cortisol and other corticosteroids, is presumed to be an important mediator in the health risks resulting from allostatic load. Elevated cortisol levels over an extended period of time have an immunosuppressive effect and may thus be a cofactor in various syndromes such as autoimmune and inflammatory diseases, metabolic syndrome, anxiety, depression, and impaired memory (for reviews see Gold & Chrousos, 2002; Kaltsas & Chrousos, 2007; Miller, Chen, & Zhou, 2007; Raison & Miller, 2003). HPA over-activation may be exacerbated by other health risk factors such as higher age and low socioeconomic status (e.g., Allen, Bentler, & Gutek, 1985; Otte et al., 2005; Pickett & Pearl, 2001; Wills & Fegan, 2001).

In addition to restoration, both attention restoration theory and stress reduction theory presume action impulses as a consequence of nature experiences (i.e., exploration; adaptive behaviors). According to the theory of affordances (Gibson 1979; Heft, 2010) environments entail functional significance and stimulate specific behaviors. If natural surroundings stimulate moderate or vigorous physical activity and social networking (cf. de Vries, 2010)
more than other urban surroundings, the physiological and psychological effects associated with these behaviors may bring about distal health benefits in addition to the above discussed proximal outcomes (cf. Ward Thompson & Aspinall, 2011; see also Brand & Schlicht, 2007; DiPietro, Seeman, Merrill, & Berkman, 1996; Phillips, Kiernan, & King, 2001; Seeman, 1996; Uchino, Cacioppo, & Kiecolt-Glaser, 1996).

To summarize, city residents’ health may improve with more frequent visual exposure to nature and with more time they spend in a natural environment. In the following section we review the literature on these two areas of interest, each with experimental studies on short-term benefits and field investigations with a longer-term perspective.

1.2 Empirical evidence of the benefits of nature

According to experimental research, visual exposure to natural as opposed to non-natural scenes improves mood and reduces perceived stress, neurophysiological activation, and potentially mental fatigue even in non-stressed individuals and across different cultural contexts (Berto, 2005; Chang, Hammitt, Chen, Machnik, & Su, 2008; de Kort, Meijnders, Sponselee, & IJsselsteijn, 2006; Honeyman, 1992; Laumann, Gärling, & Stormark, 2003; Parsons, Tassinary, Ulrich, Hebl, & Grossman-Alexander, 1998; Ulrich et al., 1991). Beyond natural landscapes, perception of ivy facades, meadow roofs, hedges, foliage and flowers may bring about cognitive, emotional and physiological benefits (Haviland-Jones, Rosario, Wilson, & McGuire, 2005; Kaplan, 1983; Nakamura & Fujii, 1992, as cited in Velarde, Fry, & Tveit, 2007; White & Gatersleben, 2011). Preference research suggests that vegetation should be diverse, in a healthy state, and maintained rather than wildly grown (Hofmann, Westermann, Kowarik, & van der Meer, 2012; Schroeder, 1982). Moreover, for trees a spreading and broad shape is generally preferred, while the importance of a dense crown is less clear (Lohr & Pearson-Mims, 2006; Summit & Sommer, 1999). Few cross-sectional field
studies compared window views on highly vegetated versus non-vegetated settings and found accordant relations with recovery rates in stationary patients (Ulrich, 1984), stress at the workplace (Aries, Veitch, & Newsham, 2010; Leather, Pyrgas, Beale, & Lawrence, 1998; Shin, 2007), familial aggression, and neighborhood satisfaction (Hur, Nasar, & Chun, 2010; Kaplan, 2001; Kuo & Sullivan, 2001a). The literature on views on water or sky is less conclusive (e.g., Kaplan & Kaplan, 2011; Ulrich et al., 1991; van den Berg, Koole, & van der Wulp, 2003).

Regarding use of public green spaces, the majority of studies compared the immediate effects of activities in green spaces versus non-vegetated outdoor or indoor environments. In accordance with attention restoration and stress reduction theory, studies have shown improvements in cognitive performance and mood (e.g., Hartig, Mang, & Evans, 1991; Roe & Aspinall, 2011) and decreases in cortisol levels (Park, Tsunetsugu, Kasetani, Kagawa, & Miyazaki, 2010; van den Berg & Custers, 2011). However, the effects may be moderated by a number of situational conditions such as degree of urbanity, being in a group or alone and perceived safety (Johansson, Hartig, & Staats, 2011; Staats & Hartig, 2004), and level of maintenance (Martens, Gutscher, & Bauer, 2011). Moreover, open grasslands may allow for better benefits than forests (Fenton, 1985) and diverse vegetation may be more important than the size of the space or the presence of avifauna (Fuller, Irvine, Devine-Wright, Warren, & Gaston, 2007). Following survey and census data analyses, city residents may benefit from near-residential public parks with respect to perceived mental and general health (Maas et al., 2009; Maas, Verheij, Groenewegen, de Vries, & Spreeuwenberg, 2006; Mitchell & Popham, 2007), cardiovascular and respiratory disease in men (Richardson & Mitchell, 2010), and longevity in the elderly (Takano, Nakamura, & Watanabe, 2002), regardless socioeconomic status. More frequent use seems a likely mediator, as use of green spaces is negatively related
to perceived stress and declines considerably from 0m to 1000m distance (Grahn &
Stigsdotter, 2003; Nielsen & Hansen, 2007). However, Nielsen and Hansen could not explain
the relation between distance to green spaces and perceived stress and obesity by the number
of visits. Maas et al. (2009) presumed sense of community rather than actual use as the
explaining link. Moreover, there is little evidence on whether green spaces stimulate physical
exercise and social contact, which could provide additional health benefits (Annerstedt et al.,
2012; Barton & Pretty, 2010; de Vries, 2010; Hansmann, Hug, & Seeland, 2007; Pretty,
Peacock, Sellens, & Griffin, 2005). Beyond parks, streetscape vegetation is related to
enhanced use of outdoor space, social activities, reduced aggression and crime (Kuo &
Sullivan, 2001b; Sullivan, Kuo, & Depooter, 2004) and may predict self-reported physical
and mental health in addition to public parks (van Dillen, de Vries, Groenewegen, &
Spreeuwenberg, 2011).

To summarize, potential immediate psychological and physiological benefits from visual
access to and use of urban nature are evident. However, few studies have addressed the
relationship between frequent exposure to urban nature and subjective health. Moreover, we
are not aware of a study on the long-term physiological correlates of exposure to different
kinds of urban nature. As subjective health indicators do not necessarily correspond to
objective indicators and may underestimate physical diseases (e.g., Ambrasat, Schupp, &
Wagner, 2011; Gibson, 1991; Johnston, Propper, & Shields, 2007; Murberg, Bru, Svebak,
Aarsland, & Dickstein, 1996), both measures should be combined.

1.3 Overview of the present study and hypotheses

The present article aims to answer these unsolved questions with quantitative and
qualitative analyses of a sample from two inner-city neighborhoods in Berlin. By this, we
answer Ward Thompson’s (2010) call for in-depth inquiries of specific places and people’s
experiences in research on the health effects of nature. We hypothesize that both vegetation quantity (i.e., the amount of vegetation) and diversity (i.e., different kinds of vegetation such as trees, bushes, shrub, etc.) visible from home, and the frequency of use of public green spaces are related to subjective health and cortisol level as an objective indicator of health. The underlying theoretical framework and measures applied are depicted in figure 1.

2. Method

2.1 Study site

The present study was conducted in two inner-city neighborhood areas in Berlin, Germany. They are situated in two districts (Alt-Treptow, Neukölln) about 1km walking distance of each other and are of similar urban structure. That is, late 19th century block developments composed of attached units of a front house, two side wings and a rear building with an enclosed backyard, with few changes caused by World War II. According to environmental data provided by the Berlin Senate Department for Urban Development (Senatsverwaltung für Stadtentwicklung, 2012), the two sites differ in provision of public green space (more than 6m² vs. less than 0.1m² per resident within 500m). As depicted in figure 2, one site is adjacent to a park of about 14 ha size (Görlitzer Park) and several smaller public green spaces (“area 1”), while the other area is about 1500-1700m off the closest park entrance (“area 2”). Both are situated by a canal (Landwehrkanal) that provides a connection to other parts of the city with a highly vegetated pedestrian path. Another park of about 88ha size (Treptower Park) that extends to an urban forest eastwards is situated in a similar distance from both areas (1000-1500m).

2.2 Sample

The reported study was part of a follow-up of a neighborhood survey on environmental burdens conducted one year before (Honold, Beyer, Lakes, & van der Meer, 2012). In the
chosen areas, 75 residents could be contacted for recruitment. Exclusion criteria were removal, hair length of less than two centimeters, dyed hair, use of glucocorticoid drugs, and absence from the neighborhood of more than 3 weeks within the preceding four months. Addressees received financial compensation and feedback on the results as incentives.

Thirteen declined participation or met exclusion criteria and 30 were unavailable, so that the sample consists of $N = 32$ residents ($n = 15$ from the area adjacent to the park and $n = 17$ from the other area). They ranged from 24 to 58 years in age ($M = 36.00, SD = 10.16$) and from 1 to 14 years in tenure. With $n = 5$ participants of non-German nationality and $n = 5$ unemployed (16%), the sample represents the Berlin foreigner and unemployment rates in 2010 of 14% each; however, well-educated are overrepresented (Amt für Statistik Berlin-Brandenburg, 2011; Senatsverwaltung für Wirtschaft, Technologie und Forschung, 2012). Further sample characteristics are displayed in table 1.

2.3 Design

Independent variables are view of vegetation from home (quantity and diversity of vegetation) assessed by photographic ratings (metric variables), and frequency of use of public green spaces assessed by coding of qualitative interviews (non-metric variables). Dependent variables are life satisfaction and general health assessed by an online survey, and HPA activity obtained through hair cortisol analysis. Interviews were conducted at participants’ homes.

2.4 Measures

Demographic information was available from the prior survey. Data were collected with four methods: 1) An online survey, 2) a semi-structured interview, 3) photographs, and 4) hair samples for cortisol extraction. Relevant measures are described in the following section.
Online-survey. The survey assessed subjective outcomes variables and perceived chronic stress as a control variable. It was designed with commercial web-based software according to the literature on internet research (e.g., Batinic, Reips, & Bosnjak, 2002).

Life satisfaction was assessed with a direct, 5-item scale developed by Diener, Emmons, Larsen, and Griffin (1985). It reflects cognitive evaluations of one’s life conditions on a Likert scale from 1 (do not agree at all) to 5 (very much agree), e.g. “In most ways my life is close to my ideal”. It was chosen because direct evaluations are parsimonious and valid assessments of satisfaction (Amério, 2002). General health was assessed by asking participants how they would describe their health status in general on a scale from 1 (poor) to 5 (excellent). The item is derived from the German version of the SF-36 health survey (Bullinger & Kirchberger, 1998) and was shown to enable prediction of mortality (Idler & Benyamini, 1997) and unspecific somatic symptoms (Wallenius, 2004).

A screening scale from a widely-used German inventory of chronic stress (Schulz, Schlotz, & Becker, 2004) assessed how often participants experienced 12 different situations within the last three months from 1 (never) to 5 (very often). The situations represent work overload, social overload, excessive work demands, lack of social recognition, and chronic concern.

Semi-structured interviews. Interview guidelines ensured standardized information concerning the purpose, procedure and data handling and consisted of catchwords in order to cover all questions of interest. Following introductory questions on interviewees’ general neighborhood perception and evaluation, participants were asked which green spaces they ever used from their neighborhood, close districts, the entire urban area, and the hinterland. They were asked to estimate how often they visited these spaces during the preceding spring
and summer months, and were interviewed about their perception and evaluation of these spaces, and the purposes and circumstances of visits.

*Photographs.* The interviewer or the participants themselves digitally photographed all window views in each room of the participants’ apartments. Pictures were taken from an eye level in approximately three meters distance with focus and illumination adjusted to the outdoor area. In total, 96 pictures were taken (2-7 pictures per participant) and coded by three raters (the first author and two students) in regard to vegetation quantity and diversity as predictors, as well as structural diversity and range of view as control variables. Concerning quantity, raters estimated the percentage of greenery, sky and built area in each view, with a required sum of 100%. The strategy facilitated estimation, as values could be calibrated against each other. Only steps of 5% were allowed to avoid bias at the extremes of the scale. Vegetation diversity was assessed by a sum of the following kinds of outdoor vegetation (coded by 1 if visible): Conifer species; bushes/shrub/flowers; vertically growing vegetation; balcony or terrace plants; lawn/grass strips; broadleaf trees. As broadleafs were the dominate type of vegetation in the pictures, raters differentiated between one species (coded by 1) and two or more clearly different species (coded by 2). Clearly different species refers to the visual appearance and has no botanical meaning. All raters were psychologists in order to rate diversity from a lay perspective. Thus, the sum could range from 0 to 7. Structural diversity refers to multiplicity in façade designs (shapes, colors etc.), building shapes, vanishing points, and angles and was assessed by a Likert item from 1 (*not diverse at all*) to 7 (*extremely diverse*). Range of view was evaluated on an ordinal scale with four levels: 1) Few meters (view completely obviated by trees or parts of buildings), 2) distance to buildings on the opposite side of the street or the building unit (which was comparable in all cases due to the uniform layout at the sites), 3) up to few hundred meters (e.g., prospect into a street, gap
between buildings), and 4) very wide range of view (upper-floor apartments overseeing other buildings).

_Hair samples._ Cortisol extraction from human hair is the only method currently available to assess long-term HPA activity with only one measure (Davenport, Tiefenbacher, Lutz, Novak, & Meyer, 2006; Kalra, Einarson, Karaskov, van Uum, & Koren, 2007; Kirschbaum, Tietze, Skoluda, & Dettenborn, 2009; Raul, Cirimele, Ludes, & Kintz, 2004) and was therefore chosen as objective health indicator. Two tied bundles of hair (about 3mm diameter each) were cut from the hair line at the central back head (lower parietal bone) and marked with an anonymous code. Cortisol was extracted in 2-cm-segments in an independent laboratory, approximately representing the last two months before the interview (1st segment), respectively the period of two to four (2nd segment) and four to six months (3rd segment). Hair cortisol analyses become less reliable with higher age of hair and may represent HPA activity very well only for the preceding 1-2 months (Sauvé, Koren, Walsh, Tokmakejian, & van Uum, 2007) or 3 months (Kirschbaum et al., 2009). Intra-individually, segment 1 and 2 levels did not differ significantly \((T = -1.84, p = .08, N = 29)\). All first segments could be analyzed \((N = 32)\), while the second segment was missing for three persons. Therefore, only the first segment was used for analysis. Cortisol levels are indicated in pictogram cortisol per milligram hair (pg/mg). A technical protocol of the cortisol analysis is described in Davenport et al. (2006).

2.5 Procedure

The protocol of the present study was approved by the ethics commission of the psychological department. Data were collected in August and September 2010. Participants answered the online survey a few days prior to the interviewers’ visit. After obtaining informed consent, the interviewer checked demographic information for necessary updates.
The qualitative interview was audio recorded, and photographs and hair samples were obtained at the end. Interview audio files were transcribed verbatim for analysis.

2.6 Data processing and analyses

Ratings of all photographed window views were aggregated to one value for each of the four variables (vegetation quantity and diversity, structural diversity, range of view) per participant. This procedure was exploratory and chosen to obtain an “overall picture” for each participant. Regarding vegetation quantity, the mean percentage of greenery over all views was calculated from three raters’ scores. An ANOVA with rater as three-level factor was not significant \(F(2, 95) = 0.12, p = .89\), indicating high inter-rater agreement. Thus, the three raters’ codings were aggregated so the raters’ mean vegetation quantity estimation served as a participant’s vegetation quantity score. For vegetation diversity, a sum of all kinds of vegetation registered in any view was computed. It could range from 0 to 7 and was treated as a metric composite index. As an example, an apartment with two views, one containing different broadleaf tree species (+2) and bushes (+1) and the other containing bushes and vertical vegetation (+1) would result in a vegetation diversity score of 4. In total, 5 of 32 ratings (16%) were non-conform between the raters and were discussed and resolved to determine the final score. Regarding structural diversity, the procedure was the same as for vegetation quantity. The average rating over all views was computed per rater. An ANOVA with rater as three-level factor was not significant \(F(2, 95) = 1.43, p = .37\). Thus, the raters’ mean structural diversity score was used for further analyses. Finally, participants’ maximum range of view was compared between the raters. They absolutely agreed on 20 cases (63%), and in 9 cases (28%) values from two raters agreed and served as final score. The remaining three non-conform ratings were resolved after discussion. Examples of views from residents’ homes and their individual ratings are depicted in figure 3. Hierarchical regression analyses
were applied to test the relation between vegetation quantity and diversity and health outcomes. Age was entered as a control variable in the first step, vegetation quantity and diversity as main predictors in the second step, and their z-transformed interaction term in the third step. No model assumptions were violated.

Interview transcripts were analyzed with qualitative content analysis (Mayring, 2003; Lamnek, 2010). Categories and subcategories were theoretically derived (see Atteslander, 2008) and inductively complemented after reading the transcripts. They referred to cognition of green spaces (e.g., knowledge, distance), their contents (e.g., meadow, water), to affective experiences and aesthetic judgments, and to the four empirically determined clusters of activity in green spaces, that is, active recreation, passive recreation, social activities, and extrinsically motivated activities (Hofmann, 2011). After extraction of relevant material from the transcripts, single case analyses were conducted and compared. In addition to content analyses, three raters (the first author and two students) classified frequencies of visits to specific green spaces by the following numerical categories: More than 3 times a week; 2-3 times a week; once a week; more than 2 times a month; more than or equal to once a month; less than once a month. These categories were inductively defined and conform to the literature (e.g., Grahn & Stigsdotter, 2003). In order to quantify total use frequency, general estimations were classified if available. However, many participants had difficulties in explicitly estimating how often they used green spaces in total, while they could better quantify how often they visited specific places. Most preferred using one specific space most often and others less regularly, reported regular routes crossing several spaces, or would at times replace their favorite, most visited green space with an alternative. Therefore, the code of the most frequently visited space served as an indicator of total use frequency when general estimations were missing. Absolute agreement was obtained in 53% and two of three raters
agreed in 21% of all ratings (n = 128). For the remaining 26%, values were determined by
discussion between the three raters. In order to test whether regular use of green spaces was
related to outcomes, codes were transformed into a dichotomous variable with at least once a
week vs. less than weekly. The adequacy of the exploratory chosen cut-off was confirmed by
visual data inspection. Since assumptions for ANCOVA were violated, the relation was tested
using Mann-Whitney-U-Tests. Effect sizes $r = Z/N^{0.5}$ were calculated according to

3. Results

3.1 General descriptive statistics

The correlations of metric control variables with health outcomes are displayed in table 3. The correlation of age and cortisol was marginally significant ($p = .05$). Regarding the
relations of categorical control variables and outcomes, simple ANOVA with the six variables
displayed in table 1 as a two-, respectively three-level factor revealed no significant relations
except a marginally significant relation between marital status and cortisol levels, $F(2, 29) =
3.18, p = .06, \eta^2 = .18$.

3.2 Green view

All photographs contained views on backyards or streetscapes without open waters or
parks. Participants’ vegetation quantity ranged from 7% to 87% and vegetation diversity from
1 to 6. The two predictors did not correlate ($r = .01, p = .95$), and none of the four view
variables correlated significantly with outcomes (see table 3). Hierarchical regressions
revealed no significant relationship with subjective health outcomes. However, 32% of the
variance in cortisol levels was explained by age and an interaction effect of vegetation
quantity and diversity (see table 4). That is, controlling for age effects, participants’ cortisol
levels were lowest when their view was of high vegetation quantity and diversity at the same
time. Repeated analyses with separate gender groups suggest that the interaction effect was similar for female ($\beta = -.38, p = .16, n = 19$) and male ($\beta = -.40, p = .35, n = 13$) participants.

The method of aggregating scores from different views of vegetation from a home was exploratory and chosen to represent the entire surrounding environment. Alternatively one single green view anywhere in the apartment could be sufficient for positive health effects. Therefore, regressions were repeated with the maximum score of vegetation quantity and diversity among the views. None of them revealed significant findings.

3.3 Use of green spaces and health

Most participants used an urban green space at least once a week (72%), while only few travelled to the hinterland for recreational purposes at least once a month (22%). The most frequently visited green space was the canal with its highly vegetated trail. The correlations of frequency of visits to green spaces and health outcomes are displayed in table 3. Mann-Whitney $U$-tests were applied to compare potential effects of regular use (i.e., once a week or more) with less regular use. They revealed no significant differences in regard to total use frequency (i.e., general estimations or the frequency of the most often visited urban green space), use of Treptower Park, other urban green spaces, and the hinterland. However, participants who used the trail along the canal at least once a week had lower cortisol levels, $U = 49.50, z = -2.62, p = .01, r = -.46$, and were more satisfied with their life, $U = 66.00, z = -1.99, p = .04, r = -.35$, while not differing significantly in regard to perceived general health, $U = 75.00, z = -1.62, p = .12$. According to qualitative content analysis most participants evaluated the canal trail as a positive, restorative environment and used it predominantly for promenading, running, and for daily routes by foot or bicycle. Moreover, participants who used Görlitzer Park at least once a week had significantly lower cortisol levels than the ones with less regular use, $U = 50.50, z = -1.98, p = .05, r = -.35$, but did not differ in regard to life
satisfaction, $U = 89.50, z = -0.29, p = .78$, and perceived general health, $U = 77.00, z = -0.76, p = .52$. Even frequent users perceived this park as unkempt, overcrowded, and noisy, while appreciating a high cultural diversity, its “hustle and bustle”, services, festivals, and infrastructure for children’s use. The park served as a passage or as a meeting point to residents from both areas; however, no participant indicated opportunities for new social contact or communication with strangers. Residents from area 1 used the adjacent Görlitzer Park significantly more often than residents from area 2, $U = 74.00, z = -2.33, p = .02, r = -.41$. However, they differed neither significantly in total use frequency, $U = 91.50, z = -1.40, p = .17$, nor trips to the hinterland, $U = 116.00, z = -0.60, p = .58$.

3.4 Further results from qualitative analysis

Besides the canal, a number of participants from both areas and genders described other highly vegetated streets and paths rather than parks. Some of them incorporated parks in their routes to pass through, rather than describing the parks as a destination. Green ways were used for active and passive restoration in leisure time. In addition, many participants chose green ways for daily commutes even if they were detours, regardless their age, gender, residential area, and socioeconomic status. Contrary, traffic-loaded and non-picturesque connections to appreciated parks deterred female participants from using these parks at times. In addition, highly-valued parks were rarely used when they were off daily routes, which was of special importance among professionals and parents.

4. Discussion

4.1 Relations between urban nature and health

The present paper examined the relations between two kinds of urban nature (green view from home, use of public green spaces) and subjective and objective health indicators in a sample of inner-city Berlin residents. In the next section, we discuss the following main
results from analyses of photographs, interview data, and hair samples: A green view consisting of a high amount and a high diversity of vegetation, as well as frequent use of nearby green spaces were related to lower cortisol levels as an indicator of objective health. Moreover, green ways were identified as an important kind of urban green space.

*View from home and health.* Unlike hypothesized, vegetation quantity and quality were not significant main predictors of health. However, a substantial amount of variance in cortisol levels was explained by their interaction. That is, a view on a high amount of diverse kinds of vegetation was related to lower cortisol levels. To our knowledge, this is the first neighborhood study to replicate laboratory findings on the effect of visual access to nature on reduced physiological stress levels (e.g., Chang et al., 2008; de Kort et al., 2006; Parsons et al., 1998). Furthermore, it suggests that cortisol may mediate the potential protective effects of a green view against health risks arising from occupational stress (Aries et al., 2010; Leather et al., 1998) and the relation between green view and duration of recovery from illness (Ulrich, 1984). While these investigations compared extreme conditions (e.g., natural scenes vs. built environment), our finding provides additional insights. As vegetation quantity was not a significant predictor, views obviated by a tree may not provide physiological restoration. This finding conforms to Kaplan and Kaplan (2005) and Ulrich (1983) who presume natural environments with moderate to high levels of complexity and focality (i.e., scenes with a focal point or an area attracting observer’s attention) and visual depth or openness are more likely to elicit positive responses than monotonous landscapes. These aspects may provide an additional aesthetic value and signal escape options (Bell, 2010), but may not bring about any health effects per se, as range of view and structural diversity were not related to cortisol levels in our study. Finally, as life satisfaction and general health are
multi-determined (e.g., Baum, Revenson, & Singer, 2001; Diener, 2009), a higher statistical
tower may be required to detect potential environmental effects.

*Green spaces and health.* Participants who used the vegetated pedestrian trail along the
canal at least once a week had lower cortisol levels and were more satisfied with their life
than less frequent users. Qualitative analysis suggested physiological and psychological
restoration from use, as suggested by experimental research (e.g., Park et al., 2010; Roe &
Aspinall, 2011; van den Berg & Custers, 2011). Moreover, frequent users of Görlitzer Park
had significantly lower cortisol levels. Users appreciated this park as a place for cultural and
social experiences, rather than nature experiences. While a visit to green spaces may elicit
better restoration with higher cognitive engagement with nature (e.g., focus on the aesthetic
aspects of nature; Duvall, 2011), we can only speculate whether this finding was due to nature
effects despite the low degree of perceived beauty and naturalness. Alternatively, cultural and
social leisure-time experiences might reduce physiological stress levels by satisfying needs
that are associated with park visits but not necessarily related to nature (e.g., escape from
everyday routine, experience of freedom; Chiesura, 2004). Finally, because use of this park
was predominantly associated with social motives, the lower cortisol of frequent users may be
due to high social support as a third variable influence (Seeman, 1996; Uchino et al., 1996).
As we are not aware of another study on the relation of frequent use of outdoor settings and
HPA activity, consecutive research is required to answer such questions.

Unlike expected, the indicator for total frequency of use of green spaces was not related to
subjective and objective health. Most participants had frequent contact with urban nature, as
the ones with less than weekly visits to public green spaces used private outdoor facilities
instead or travelled often. Moreover, participants had difficulties in retrospectively estimating
how often they used green spaces in general, which questions the validity of retrospective and
unspecific questionnaire items on use of green spaces in cross-sectional research (e.g., Grahn & Stigsdotter, 2003; Nielsen & Hanson, 2007).

*Green ways.* Vegetated trails and connections to public green spaces played a crucial role in the present study in the light of the above-discussed relation with HPA activity. Moreover, participants from area 1 that the Senate Department for Urban Development considered better provided with green spaces (Senatsverwaltung für Stadtentwicklung, 2012) did not differ from participants from area 2 in total use frequency, which may be due to the proximity of the canal as the most frequently used green space in total. Generally, different green ways were perceived and used as restorative leisure-time destinations. A lack of pleasant connections impeded use of attractive parks, which other studies have already found to be true for the elderly (Sugiyama, Thompson, & Alves, 2009; Takano et al., 2003). This may be generalizable to diverse groups of city residents, as motivation to visit a park may emerge from a desire to escape urban environmental stressors (Hartig, 1993). Moreover, participants chose green routes for healthy and sustainable modes of daily mobility (i.e., cycling, walking, or skating; see also Terzano & Morckel, 2011) rather than the shortest ways. Our findings complement other research on the relation between green ways and neighborhood attachment (Halpenny, 2010), and biodiversity conservation (cf. Miller, 2005; Samways, 2007), as well as a finding on the elevation of anger and aggression during a walk in a non-vegetated urban environment (Hartig et al., 2003).

4.2 Limitations

The study yielded new important findings of high external validity, which were only possible by choosing extensive measures of views of vegetation from home, use of green spaces and cortisol levels. However, our approach entails limitations that should be considered in further research. Because some of the measures were too effortful to allow
analyzing a larger sample, the statistical power and the opportunity for subgroup analyses were limited. Moreover, green view and use of green spaces were operationalized in an exploratory way due to a lack of applicable research and validated instruments. Longitudinal assessments of frequency, duration, purposes and activities of use of green spaces may provide more precise predictors of city residents’ health. Furthermore, extraction of cortisol in human hair is a novel marker of chronic stress. Hair cortisol levels did not correlate with subjective stress, which was shown before for hair cortisol (van Uum et al., 2008) and short-term changes in salivary cortisol (Kirschbaum, Kudielka, Gaab, Schommer, & Hellhammer, 1999). This may be attributable to the fact that subjective health indicators reflect feelings about a current state (Gibson, 1991), while assessments of emotional states do not necessarily correlate with physiological measures (cf. Schmidt-Atzert, 1996). More research is needed in order to clarify the validity of both indicators of chronic stress. Finally, our results on the relations between urban nature and health are cross-sectional and need to be replicated in longitudinal field research for causal interpretations.

4.3 Conclusion

Despite its limitations, our mixed-methods approach has proven worthwhile in the light of the above discussed findings. The findings on a significant relation between urban nature and cortisol level may be generalizable, as the affective-physiological reaction to nature is assumed to be universal (Ulrich, 1983) and was shown in samples from different countries and continents (e.g., Chang et al., 2008; de Kort et al., 2006; Park et al., 2010; Parsons et al., 1998). Green ways might be at least as important in other cities as in Berlin, since the amount of public green spaces in Berlin is above European average (European Environment Agency, 2009).
The results have implications for urban design. They point to the potential of a high amount of diverse vegetation (e.g., different species of trees, bushes, flowers) in residential streets and backyards. For example, diverse vegetation around tree pits, roadsides, and walls might help regulate HPA activity and thus, protect residents from the health risks of allostatic load (McEwen, 2000; McEwen & Seeman, 1999). This may be achieved by municipal programs, by supporting spontaneous vegetation, or by neighborhood initiatives. The latter could educate and encourage residents for active participation in gardening activities, which might keep the costs of maintenance low and increase residents’ acceptance and upkeep (e.g., Hartig, Kaiser, & Bowler, 2001). Moreover, gardening may help to increase individuals’ networks and bring additional health benefits (e.g., van den Berg & Custers, 2011). On a larger scale, authorities should provide city residents with networks of green ways in addition to parks. Walkways along rivers and canals are but one example. A former railway track transformed to a pedestrian path and vegetated connections to green spaces also played a significant role in the present study. Thus, the comprehensive planning principle “city of short distances” applied in many European cities may be supplemented by the concept of a “city of green distances” for the design of sustainable and livable future urban areas.
References


Figure captions

Figure 1. Conceptual Framework of the Present Study and Methods of Indicators.

Figure 2. Map of study area. Interviews Were Conducted in One Area Considered Provided With Public Green Space (1) and in Another Area Considered Unprovided (2) (Senatsverwaltung für Stadtentwicklung, 2012).

Figure 3. Examples of Views From Participants’ Homes. The three raters scored the pictures as the following: 1) Vegetation Quantity = 0/0/0 [%], Vegetation Diversity = 1/1/1 [of 7]; Range of View = 2/2/2 [of 4], Structural Diversity = 1/1/2 [of 7]; 2) Vegetation Quantity = 70/70/70, Vegetation Diversity = 1/1/1; Range of View = 2/2/1, Structural Diversity = 1/1/1; 3) Vegetation Quantity = 55/50/55, Vegetation Diversity = 4/4/4; Range of View = 3/3/3, Structural Diversity = 2/2/3.
Figures
Table 1

*Sample Characteristics (N = 32) and Descriptive Relations With Outcome Variables.*

<table>
<thead>
<tr>
<th>Variable (missing)</th>
<th>n</th>
<th>Life satisfaction M (SD)</th>
<th>General health M (SD)</th>
<th>Cortisol levels M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>13 (41%)</td>
<td>3.40 (0.68)</td>
<td>3.69 (0.63)</td>
<td>26.45 (16.35)</td>
</tr>
<tr>
<td>Female</td>
<td>19 (59%)</td>
<td>3.65 (0.42)</td>
<td>3.61 (0.61)</td>
<td>26.06 (10.35)</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary school degree</td>
<td>6 (19%)</td>
<td>3.53 (0.59)</td>
<td>3.60 (0.55)</td>
<td>25.57 (9.44)</td>
</tr>
<tr>
<td>University entrance qualification</td>
<td>6 (19%)</td>
<td>3.63 (0.27)</td>
<td>3.83 (0.75)</td>
<td>35.88 (17.24)</td>
</tr>
<tr>
<td>Academic degree</td>
<td>20 (63%)</td>
<td>3.53 (0.61)</td>
<td>3.60 (0.60)</td>
<td>23.51 (11.46)</td>
</tr>
<tr>
<td>Professional status</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Employed</td>
<td>20 (63%)</td>
<td>3.54 (0.60)</td>
<td>3.53 (0.51)</td>
<td>28.54 (13.68)</td>
</tr>
<tr>
<td>Students/retired/homemakers</td>
<td>7 (22%)</td>
<td>3.69 (0.30)</td>
<td>4.00 (0.58)</td>
<td>17.69 (4.60)</td>
</tr>
<tr>
<td>Unemployed</td>
<td>5 (16%)</td>
<td>3.40 (0.63)</td>
<td>3.60 (0.89)</td>
<td>28.87 (14.20)</td>
</tr>
<tr>
<td>Household net income (2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1000€</td>
<td>11 (34%)</td>
<td>3.42 (0.68)</td>
<td>3.82 (0.60)</td>
<td>26.69 (12.38)</td>
</tr>
<tr>
<td>1000-1999€</td>
<td>10 (31%)</td>
<td>3.66 (0.53)</td>
<td>3.50 (0.71)</td>
<td>28.34 (17.35)</td>
</tr>
<tr>
<td>≥ 2000€</td>
<td>9 (28%)</td>
<td>3.64 (0.42)</td>
<td>3.50 (0.42)</td>
<td>23.54 (9.02)</td>
</tr>
<tr>
<td>Marital status</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Unmarried</td>
<td>25 (78%)</td>
<td>3.53 (0.55)</td>
<td>3.71 (0.55)</td>
<td>24.42 (11.29)</td>
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<tr>
<td>Married</td>
<td>4 (13%)</td>
<td>3.90 (0.12)</td>
<td>3.75 (0.96)</td>
<td>24.92 (9.30)</td>
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<tr>
<td>Divorced/separated</td>
<td>3 (9%)</td>
<td>3.27 (0.76)</td>
<td>3.00 (0.00)</td>
<td>42.91 (21.20)</td>
</tr>
<tr>
<td>Social living condition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alone</td>
<td>12 (38%)</td>
<td>3.45 (0.63)</td>
<td>3.50 (0.52)</td>
<td>24.81 (12.95)</td>
</tr>
<tr>
<td>With partner and/or children</td>
<td>12 (38%)</td>
<td>3.70 (0.43)</td>
<td>3.73 (0.65)</td>
<td>27.97 (15.05)</td>
</tr>
<tr>
<td>Apartment share</td>
<td>8 (25%)</td>
<td>3.48 (0.57)</td>
<td>3.75 (0.71)</td>
<td>25.71 (10.28)</td>
</tr>
</tbody>
</table>

*Note.* Deviations are due to rounding total sample percentages.
Table 2

*Psychometric Properties of the Metric Study Variables.*

<table>
<thead>
<tr>
<th>Scale title</th>
<th>No. of items</th>
<th>Scale points</th>
<th>N</th>
<th>M (SD)</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>α</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived chronic stress</td>
<td>12</td>
<td>5</td>
<td>32</td>
<td>3.43 (1.64)</td>
<td>.90</td>
<td>.52</td>
<td>.92</td>
</tr>
<tr>
<td>View ratings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation quantity</td>
<td></td>
<td></td>
<td>32</td>
<td>43.71 (20.57)</td>
<td>.11</td>
<td>-.51</td>
<td></td>
</tr>
<tr>
<td>Vegetation diversity</td>
<td></td>
<td></td>
<td>32</td>
<td>3.63 (1.24)</td>
<td>.02</td>
<td>.31</td>
<td></td>
</tr>
<tr>
<td>Structural diversity</td>
<td>1</td>
<td>7</td>
<td>32</td>
<td>1.70 (0.97)</td>
<td>2.41</td>
<td>4.56</td>
<td></td>
</tr>
<tr>
<td>Outcomes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Life satisfaction(^a)</td>
<td>5</td>
<td>5</td>
<td>32</td>
<td>3.55 (.54)</td>
<td>-1.37</td>
<td>1.62</td>
<td>.76</td>
</tr>
<tr>
<td>General health(^b)</td>
<td>1</td>
<td>5</td>
<td>32</td>
<td>3.65 (.61)</td>
<td>.35</td>
<td>-.57</td>
<td></td>
</tr>
<tr>
<td>Cortisol(^b)</td>
<td></td>
<td></td>
<td>32</td>
<td>26.22 (12.87)</td>
<td>1.09</td>
<td>.68</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* High environmental perception means correspond to positive evaluations.

\(^a\)high values refer to positive outcomes. \(^b\)high values refer to negative outcomes.
Table 3

*Correlation Coefficients of Metric Control Variables and Predictors with Criteria*

<table>
<thead>
<tr>
<th></th>
<th>Life satisfaction&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Perceived general health&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Cortisol levels&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-.24</td>
<td>-.23</td>
<td>.34</td>
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<tr>
<td>Perceived chronic stress&lt;sup&gt;*&lt;/sup&gt;</td>
<td>-.17</td>
<td>-.15</td>
<td>-.17</td>
</tr>
<tr>
<td>Photographic ratings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation quantity</td>
<td>-.13</td>
<td>.09</td>
<td>.00</td>
</tr>
<tr>
<td>Vegetation diversity</td>
<td>.00</td>
<td>-.08</td>
<td>-.18</td>
</tr>
<tr>
<td>Structural diversity</td>
<td>.09</td>
<td>-.08</td>
<td>-.08</td>
</tr>
<tr>
<td>Range of view&lt;sup&gt;**&lt;/sup&gt;</td>
<td>.08</td>
<td>.02</td>
<td>.03</td>
</tr>
<tr>
<td>Use of green spaces&lt;sup&gt;**&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total use frequency&lt;sup&gt;**&lt;/sup&gt;</td>
<td>-.12</td>
<td>.22</td>
<td>-.14</td>
</tr>
<tr>
<td>Görlitzer Park&lt;sup&gt;**&lt;/sup&gt;</td>
<td>.11</td>
<td>.27</td>
<td>-.24</td>
</tr>
<tr>
<td>Treptower Park&lt;sup&gt;**&lt;/sup&gt;</td>
<td>-.20</td>
<td>-.06</td>
<td>.09</td>
</tr>
<tr>
<td>Canal&lt;sup&gt;**&lt;/sup&gt;</td>
<td>.13</td>
<td>.23</td>
<td>-.37&lt;sup&gt;**&lt;/sup&gt;</td>
</tr>
<tr>
<td>All other urban parks&lt;sup&gt;**&lt;/sup&gt;</td>
<td>-.07</td>
<td>.30</td>
<td>.04</td>
</tr>
<tr>
<td>Hinterland&lt;sup&gt;**&lt;/sup&gt;</td>
<td>.13</td>
<td>.32</td>
<td>.01</td>
</tr>
</tbody>
</table>

*Note.* High environmental perceptions correspond to positive evaluations.

<sup>*</sup>represents T-scores aligned with age norms.  <sup>**</sup>Correlation coefficients for ordinal variables represent Kendall’s τ; all other coefficients represent Pearson’s r.

<sup>a</sup>high values refer to positive outcomes.  <sup>b</sup>high values refer to negative outcomes.

<sup>**p < .01</sup>
Table 4

Hierarchical Regression Analysis Predicting Cortisol Levels from Green View Variables.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>B</th>
<th>β</th>
<th>ΔR²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>.41</td>
<td>.35*</td>
<td>.12*</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 2</td>
<td></td>
<td></td>
<td>.09</td>
</tr>
<tr>
<td>Vegetation quantitya</td>
<td>-0.08</td>
<td>-.13</td>
<td></td>
</tr>
<tr>
<td>Vegetation diversityb</td>
<td>-3.06</td>
<td>-.30</td>
<td></td>
</tr>
<tr>
<td>Step 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity x diversity</td>
<td>-6.19</td>
<td>-.41*</td>
<td>.11*</td>
</tr>
</tbody>
</table>

Note. Total $R^2 = .32^*, N = 32$. a Vegetation quantity refers to the mean proportion of vegetation in all views of an apartment and was rated from 0% to 100%. b Vegetation diversity is the sum of different kinds of vegetation visible from the apartment and could range from 0 (no vegetation) to 7 (i.e., diverse broadleaf trees, conifers, bushes/shrub, vertically growing vegetation, balcony or terrace plants, lawn/grass strips).

*p < .05.
SELBSTÄNDIGKEITSERKLÄRUNG


Berlin, den 04.09.2012

_______________________________
Jasmin Honold