HAPI

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Noise, Health, and Place

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Photo by Ann Forsyth

The HEALTH AND PLACE INITIATIVE (HAPI) investigates how to create healthier cities in the future, with a specific emphasis on China. Bringing together experts from the Harvard Graduate School of Design (HGSD) and the Harvard School of Public Health (HSPH), it creates a forum for understanding the multiple issues that face cities in light of rapid urbanization and an aging population worldwide.

Health and Places Initiative
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The Research Briefs series summarizes recent research on links between human health and places at the neighborhood or district scale and provides background for a number of other forthcoming products—a set of health assessment tools, planning and urban design guidelines, urban design prototypes, and neighborhood cases. While the Research Briefs draw out implications for practice, it is these other tools that really provide specific, real-world guidance for how to create healthy places.

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Big Ideas

- Evidence over the past several decades increasingly shows negative health effects from exposure to environmental noise, also known as noise pollution, especially with chronic exposure.
- Short-term impacts of environmental noise may include annoyance, cognitive impairments, and disturbed sleep.
- Long-term impacts of environmental noise may include secondary effects from sleep disturbance (e.g. possible mental health issues, increased risk of injury), ischemic heart disease (IHD) [lack of oxygen/reduced blood flow to the heart, also known as coronary artery disease], and an increased risk of heart attack. This is a particularly significant health correlation, as cardiovascular diseases are a leading cause of death worldwide.
- Decibels (dB) is the measurement of the physical quantity of noise (sound pressure), versus A-weighted decibels dBA or dB(A), which is a weighted measurement based on human sound perception.
- Research consistently shows noise has negative health effects once volumes reach around 55 dB during the night, and 70 dB during the day.
- At louder levels (greater than 85–100 dB), short-term exposure can lead to hearing impairment, tinnitus or deafness. Evidence suggests hearing loss is mostly caused through occupational exposure (e.g. manufacturing, agriculture) or specific events (e.g. concerts, festivals), not due to general environmental or community noise. The terms environmental noise, community noise, and noise pollution are used interchangeably in this brief.
- Children, the chronically ill, the elderly are populations vulnerable to environmental noise.
- Interventions policy-makers and planners might use include noise control ordinances, new road standards, land use planning, altering flight paths, or barriers beside highways.

What the Research Shows

Health Issues

Environmental noise affects the health and well-being of large numbers of people. Mostly, it just causes annoyance and some disruption. However, for those exposed to somewhat higher volumes, especially if chronically exposed over long periods of time (e.g. they have a residence in a flight path, or near a busy highway), noise can disrupt sleep, increase the risk of cardiovascular disease, and even increase the risk of heart attack.

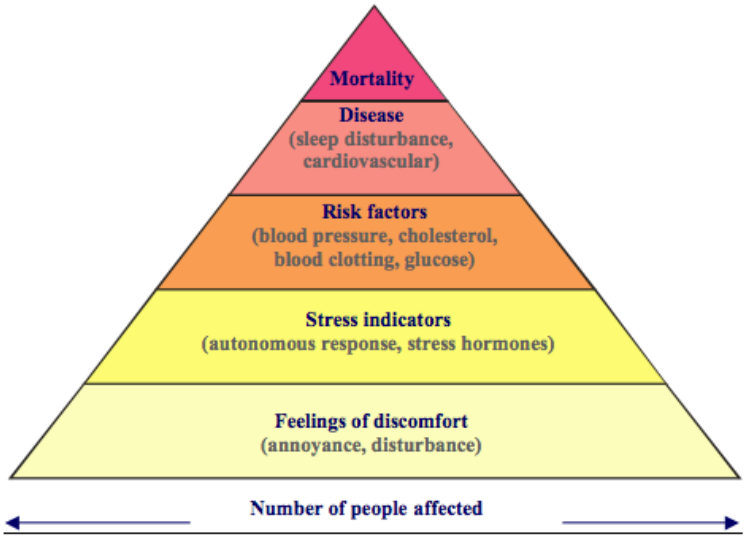
Table 1 below describes how noise levels and duration relate to health effects in specific environments. The specific environments reflect those in the literature cited for this table, mainly the WHO 1999 *Guidelines for Community Noise*.

Table 1.Environmental noise in specific environments and associated health effects.

Specific Environment	Health effect(s)	Noise level dB(A)	Duration Time [hours]
Outdoors[1]	Annoyance	55+	16
Noise outside bedrooms[2]	Sleep disturbance; Secondary effects: mental health impacts, increased risk of injury	45-60	8
Transportation noise: road traffic, aircraft noise[3]	Risks of IHD, other cardiovascular risk, children's cognition and memory	55-75	Long-term
Occupational noise[4]	Hypertension, IHD, increased risk of heart attack	80-100	Long-term
Events/festivals[5]	Hearing impairment	100+	4

1. Berglund et al. (WHO) 1999
2. Fritschi et al. 2011; Berglund et al. (WHO) 1999
3. Babisch 2006; Fritschi et al. eds. 2011, 45; van Kempen 2002, 314; Berglund et al. (WHO) 1999
4. van Kempen 2002, 314
5. Bergland et al. (WHO) 1999

Figure 1. Severity of noise health effects and the number of people affected.



Note: the framework for this diagram was based on Babisch (2002), however, the content was updated by the WHO (Fritschi et al. 2011), used with permission.

Place Issues

Environmental noise is a common health problem in urban areas, especially near busy roadways and airports.

Example: The World Health Organization's (2011) report *Burden of Disease from Environmental Noise* concludes, "Environmental noise, also known as noise pollution, is among the most frequent sources of complaint regarding environmental issues in Europe, especially in densely populated urban areas and residential areas near highways, railways and airports" (Fritschi et al. 2011, 99).

Example: The 2009 U.S. Census Housing Survey found that 22.7% of households surveyed were bothered by street or traffic noise in their neighborhood (U.S. Census 2011).

Traffic noise has been associated with anything from annoyance and sleep disturbance to increased risk of cardiovascular disease and impacting children's ability to learn in school (Babisch 2006; Fritschi et al. eds. 2011, 45; van Kempen 2002, 314; Berglund et al. (WHO) 1999.)

Vulnerable Groups

Vulnerable groups include children, the chronically ill, and older people.

Example: Fritschi, et al.'s World Health Organization Report (2011, 99) describes, "…the most vulnerable groups such as children, the chronically ill and the elderly."

Example: In a general review of 46 articles, Goines and Hagler (2007, 292) explain, "Although anyone might be adversely affected by noise pollution, groups that are particularly vulnerable included neonates, infants, children, those with mental or physical illnesses, and the elderly" [citations removed].

Example: In a systematic, qualitative review (2006–2011, 62 studies), van Kamp and Davies (2013) assessed how noise affects the health of vulnerable groups. They found that, "Available evidence shows that children are less vulnerable for annoyance than adults, but more vulnerable for cognitive effects of noise…Children seem to be less vulnerable for awakenings due to noise but more vulnerable for physiological effects during sleep and related motility… Evidence does not indicate that the elderly are more vulnerable to noise in terms of annoyance and sleep disturbance… But, possibly, the elderly are more vulnerable regarding cardiovascular effects, and this may be a combined effect of air pollution and noise" (van Kamp and Davies 2013, 158).

Example: Stansfeld et al. (2005) conducted a large (n=2844) cross-national (e.g. Netherlands, Spain, United Kingdom) study of aircraft and traffic noise and children's cognition. They found "that a chronic environmental stressor—aircraft noise—could impair cognitive development in children, specifically reading comprehension. Schools exposed to high levels of aircraft noise are not healthy educational environments" (Stansfeld et al. 2005, 1942).

China

China has occupational noise limits, but (as of 2000) these limits are high and it is unclear how well these are enforced.

Example: Zhi, Sheng and Levine (2000) investigated a total of 5197 worksites from different types of occupational environments (e.g. textile industry, production of construction materials) in 30 counties across China. They found, "The work sites with noise pollution (measured at the work station) above 90 dB(A) were 43% of the total. Those above 95 dB(A) were 23% of the total. The compliance rate for noise pollution was only 33%. (The standard issued by the Ministry of Public Health and the Ministry of Labor jointly is 85 dB(A) for newly established industrial premises and 90 dB(A) for older facilities.)" (Zhi et al. 2000, 845).

Road-rail traffic noise may be significantly bothersome to Chinese residents when noise levels exceed 63.5 dB.

Example: Di et al. (2012) surveyed 1536 local residents aged 15–75 of Dailan, China on the effect of traffic noise pollution (rail and road) on annoyance. They found "… when the L_{dn} [day-night equivalent noise level] >63.5 dB, the %HA [percent highly annoyed] due to the road-rail combined traffic noise was significantly higher than that due to the one dominant noise source with the same $L_{dn.}$ Thus, it is suggested that the planning permission buildings whose L_{dn} of road-rail combined traffic noise exceeds 63.5 – dB be reviewed more strictly" (Di et al. 2012, 189).

Things for Certain (or semi-Certain)

Environmental noise can disrupt the learning and memory of children.

Example: The World Health Organization's (2011) Burden of Disease from Environmental Noise report provides an overview of the literature on how environmental noise effects cognitive impairment in children (Fritschi et al. eds. 2011). They describe how, "It has been suspected for many years that children's learning and memory are negatively affected by noise. Over 20 studies have shown negative effects of noise on reading and memory in children: epidemiological studies report effects of chronic noise exposure and experimental studies report acute noise exposure. Tasks affected are those involving central processing and language, such as reading comprehension, memory and attention. Exposure during critical periods of learning at school could potentially impair development and have a lifelong effect on educational attainment" (Fritschi et al. eds. 2011, 45, citations removed).

Environmental noise disturbs sleep. When environmental noise is the cause of insomnia as determined by a medical professional, it is termed "environmental insomnia."

Example: In summary, the working group from the WHO 2009 *Night Noise Guidelines for Europe* describe the impact as follows, "Sleep is a biological necessity and disturbed sleep is associated with a number of health outcomes...There is sufficient evidence that night noise exposure causes self-reported sleep disturbance, increase in medicine use, increase in body movements and (environmental) insomnia. While noise-induced sleep disturbance is viewed as a health problem in itself (environmental insomnia), it also leads to further consequences for health and well-being. There is limited evidence that disturbed sleep causes fatigue, accidents and reduced performance. There is limited evidence that noise at night causes hormone level changes and clinical conditions such as cardiovascular illness, depression and other mental illness" (WHO 2009, 102-103). Note: "environmental insomnia" is a medical diagnosis, while "self-reported sleep disturbance" is basically the same, but reported in a survey.

See also Muzet (2007) and Pirrera et al. (2010).

Increasing evidence suggests a causal link between traffic and aircraft noise and cardiovascular disease. The studies below demonstrate the growing evidence from 2002 to 2011 on the topic.

Example: In a meta-analysis (n=43 articles included, 1970–1999) of the association between noise exposure (both occupational and environmental) and blood pressure and ischemic heart disease, van Kempen et al. (2002) found, "Air traffic noise exposure was positively associated with the consultation of a general practitioner or specialist, the use of cardiovascular medicines, and angina pectoris. In cross-sectional studies, road traffic noise exposure increases the risk of myocardial infarction [heart attack] and total ischemic heart disease. Although we can conclude that noise exposure can contribute to the prevalence of cardiovascular disease, the evidence for a relation between noise exposure and ischemic heart disease [lack of oxygen to the heart] is still inconclusive because of the limitations in exposure characterization, adjustment for important confounders, and the occurrence of publication bias" (van Kempen et al. 2002, 307).

Example: Babisch (2006) reviewed and synthesized 61 epidemiological studies on transportation noise (e.g. road and aircraft noise) and cardiovascular risk (e.g. mean blood pressure, hypertension, and ischemic heart disease, including myocardial infarction), as an update to his 2000 epidemiological review and synthesis. Both adults and children were included. The author found, "The evidence of an association between transportation noise and cardiovascular risk has increased since the previous review published in *Noise and Health* in the year 2000" (Babisch 2006, 1). Babisch also wrote the section on environmental noise and cardiovascular disease in Fritschi et al.'s (2011) (WHO) Burden of Disease from Environmental Noise and made similar conclusions.

Example: Stansfeld and Crombie (2011) reviewed 11 articles on cardiovascular effects of road traffic and aircraft noise in the United Kingdom. They found, "some evidence of an association among environmental noise exposure and hypertension in the UK studies" (Stansfeld and Crombie 2011, 229).

Things up in the Air

There is limited research on the effects of rail noise on cardiovascular risk.

Example: According to the World Health Organization (2011), "While there is evidence that road traffic noise increases the risk of ischemic heart disease, including myocardial infarction, there is less evidence for such an association with aircraft noise because of a lack of studies. However, there is increasing evidence that both road traffic noise and aircraft noise increase the risk of hypertension. Very few studies on the cardiovascular effects of other environmental noise sources, including rail traffic, are known" (Babisch 2011, 16).

More research is needed to better determine the range and severity of comorbidities (e.g. air pollution).

Example: The World Health Organization (2011) discusses how, "The health effects of noise in general refer to long-term chronic noise stress" (Fritschi 2011, 32). According to the WHO (2011), "The health impacts of the combined exposure to noise, air pollutants and chemicals are rarely considered in epidemiological studies. Combined exposures occur, for example, when people are exposed to road traffic where noise and air pollution co-exist" (Fritschi 2011,103).

Example: Huss et al. (2010) analyzed the Swiss National Cohort (n=4.6 million persons older than 30 years, followed from 2000–2005, 15,532 deaths from myocardial infarction). This included geocoded information on residence. Exposure to aircraft noise and air pollution was based on geospatial models and distance to major roads. Their results found, "Aircraft noise was associated with mortality from myocardial infarction, with a dose-response relationship for level and duration of exposure. The association does not appear to be explained by exposure to particulate matter air pollution, education, or socioeconomic status of the municipality" (Huss et al. 2010, 829).

Example: Gan et al. (2012) looked at traffic, air pollution, community noise, and the risk of coronary heart disease mortality (CHD) in a 5-year study in Vancouver, Canada (n=445,868). "Subjects in the highest noise decile had a 22%... increase in CHD mortality compared with person in the lowest decile. These findings suggest that there are independent effects of traffic-related noise and air pollution on CHD mortality" (Gan et al. 2012, 898).

It is uncertain at which point noise (type, duration, and volume) presents a significant risk for cardiovascular diseases. Also, more research is needed on the cardiovascular effects of long-term chronic noise exposure for children.

Example: Babisch (2011), a well-known noise researcher, gives an overview of the state of the evidence in noise research. He describes how, "The question at present is no longer whether noise causes cardiovascular effects, it is rather: what is the magnitude of the effect in terms of the exposure-response relationship (slope) and the onset or possible threshold (intercept) of the increase in risk" (Babisch 2011, 201).

The association between traffic noise and hypertension/high blood pressure needs more research (Babisch 2006).

The possible effect-modifying impacts of gender on cardiovascular reactions to noise needs more research.

Example: Babisch et al. (2005) investigated the relationship between road traffic noise and myocardial infarction (MI) in Berlin (n=1881 patients, n=2234 controls). It was found that "In the subsample of men who lived for at least 10 years at their present address, the odds ratio was 1.8 (1.0–3.2). Noise-exposed women were not at higher risk" (Babisch et al. 2005, 33). Odds ratios greater than one indicate that exposure is associated with a higher odds of a given outcome. However, the 95% confidence interval of 1.0–3.2 includes 1.0, which could mean no effect. All in all, this study found with reasonable confidence that men, but not women had a higher risk of MI, if they had lived for at least 10 years at their present address with road traffic noise.

Example: Davies and van Kamp (2012) reviewed the 2008–2011 literature on noise and cardiovascular disease. They describe how, "The association between noise and cardiovascular disease has been studied for several decades and the weight of the evidence clearly supports a causal link. Nevertheless, many questions remain, such as the magnitude and threshold level for adverse effects of noise, how noise and other cardio-toxic pollutants (such as particular matter) may interact in disease causation, identification of vulnerable populations, of exposure modifiers (i.e., location of bedrooms) and of other effect-modifiers (i.e., gender), and how epidemiologic methodology can be improved" (Davies and van Kamp 2012, 287).

Task-based performance may be more affected by intermittent noise levels than continuous noise (i.e. the decibel fluctuation causing more distraction, or potentially annoyance, than the decibel level itself).

Example: Szalma and Hancock's (2011) meta-analysis included 797 effect sizes derived from 242 studies. Effect sizes measure the strength of a phenomenon, such as how much intermittent noise can impact stress or performance versus continuous noises. They found that the evidence supported the "contention that change in the pattern of noise [intermittent noise] constitutes a crucial variable that moderates the relationship between noise and performance. Indeed, recent evidence indicates that unpredictable change in environmental input (including the task itself) may be one of the most significant sources of stress" (Szalma and Hancock 2011, 700). In other words, intermittent noises are more distracting, annoying, and stressful than other factors, such as volume of the nosie.

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Environmental noise has been associated with anything from annoyance and sleep disturbance to increased risk of cardiovascular disease and impacting children's ability to learn in school.

Photo by Ann Forsyth

Barriers are one way to block traffic noise from adjoining communities.

Implications

In these HAPI Research Briefs we aimed to find implications for planning and design at roughly the neighborhood level. These could include quantifiable standards, more qualitative but yet evidence-supported insights, and other good practices. Not every topic has a full complement of these implications.

Standards and Insights

Most of the health observational studies focus on room orientation, window opening, and building design as a strong modifier for noise exposure and health effects, as opposed to planning on a larger neighborhood level.

There are a number of guidelines for noise levels for different locations and activities with implications for building design (Babisch et al. 2014; Berglund et al. (WHO) 1999, xvi; WHO 2009, 110).

At the neighborhood level (and in other domains), noise management breaks down into two main categories: (a) reducing the noise at its source and (b) separating people from noise.

Ways to reduce noise at its source might include noise control ordinances (e.g. lower allowable engine noise levels, noise abatement programs, reducing speed limits, "quiet" road pavements). Examples of interventions to separate people from noise include land use planning, working with airports to alter flight paths, soundproofing buildings or placing barriers beside highways.

Example: Moudon (2009) reviewed 50 articles on what can be done to minimize community noise's effect on health and outlines strategies such as, "distancing people from noise sources or erecting noise barriers… Buildings can act as noise barriers if they form an uninterrupted street wall [which may include glazing] and if there are few driveways or side streets that allow noise to bend around facades. Soundproofing buildings helps to lower indoor exposure to urban noise, but it requires climate control machinery, which further raises outdoor noise levels" (Moudon 2009, 170).

Example: For Moudon, "Only approaches that reduce noise at the source will promise to abate noise exposure over the long run… Such regulation can aim to lower traffic speeds in noise-sensitive areas or develop temporal restrictions on noise-generating activities. It can also hasten the overdue adoption of 'quiet' road pavements made of noise-absorptive materials known to reduce traffic noise by at least 3-4 dB(A) " (Moudon, 2009, 170; citations removed).

Example: Dzhambov and Dimitrova's (2014) systematic review (5 included studies, international) investigated whether urban green spaces were effective as a psychological buffer for the negative health impact of noise pollution. "We found moderate evidence that the presence of vegetation can generally reduce the negative perception of noise" (Dzhambov and Dimitrova 2014, 157).

Example: The World Health Organization's *Guidelines for Community Noise* (Berglund et al. 1999, xviii) recommends that noise management:

1. Start monitoring human exposures to noise.
2. Have health control mitigation of noise emissions, and not just of noise source emissions. The following should be taken into consideration:
   - specific environments such as schools, playgrounds, homes, hospitals.
   - environments with multiple noise sources, or which may amplify the effects of noise.
   - sensitive time periods such as evenings, nights and holidays.
   - groups at high risk, such as children and the hearing impaired.
3. Consider the noise consequences when planning transport systems and land use.
4. Introduce surveillance systems for noise-related adverse health effects.
5. Assess the effectiveness of noise policies in reducing adverse health effects and exposure, and in improving supportive "soundscapes".
6. Adopt these Guidelines for Community Noise as intermediary targets for improving human health.
7. Adopt precautionary actions for a sustainable development of the acoustical environment.

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