



Studies of Combination Effects of Sound on Biology and Cognition- Interdisciplinarity in Action

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ABSTRACT

The Sound Environment Center at Lund University has since 2005 hosted interdisciplinary research on sound environment issues promoting exchange of ideas between researchers through research projects, interdisciplinary symposiums and publications. The center aims at developing a holistic view to a field that is scientifically fragmented and scattered. Ranging from acoustics, noise abatement and soundscape understanding, to issues of epidemiological mapping of health, biological effects, hearing and voice disorders, music and cognition the center covers a multitude of facets of sound and noise.

The work of the center is connecting to both national and international research networks and partners. Going from research to practice and change, in joint collaborations between acoustics, logopedics and cognitive science the center is exploring how memory, cognition and reception are affected by sound and noise. Current major projects focuses on health and cardiovascular issues and noise, acoustics, voice production, speech intelligibility and understanding, as well as eye-tracking studies of cognitive aspects of noise and sound exposure.

The preliminary outcome of interdisciplinary design has been positive and fruitful leading to deepened network collaborations and continuously new research projects.

Keywords: Soundscape, Health, Cognition I-INCE Classification of Subjects Number(s): 61, 63,2

1. INTRODUCTION – A PRELIMINARY NOTE ON RETHINKING SOUNDSCAPE

Soundscape approach is currently moving focus of environmental acoustics to a more human centered paradigm, as is being manifested in the recently finished COST-Soundscape project (Cost td804). This shift is positive but notably problematic because, although people in many ways have similar perception of sound and noise, there are also apparent differences between individuals as the human mind is of ever changing and non-solid character, as sensitive to cultural inheritance as to moods and spurs of the moment.

It has been stated in the memorandum of understanding of the COST Soundscape project that sound shouldn't be treated as waste. The sound environment can be seen as a resource – although not necessarily noise as such. Through conscious management of soundscapes a valuable resource becomes possible for well being and enjoyment of people in urban - as well as rural - environments. What is needed is a constant *rethinking* of sound environment with awareness of possibilities and dangers, and of how soundscape connects to our inner beings and can affect emotional and physical status. This rethinking is however complicated as people are different, being extroverts, introverts, young and old and have cultural and subcultural differences.

If people can't bear to be aware of the sounds of the environment, it might be as difficult to hear ourselves and the inner qualities of life, noise becoming a part of an impoverishment of life.

In zen, the sound of the bell evokes both sound and silence and bring them back to life...

2. BACKGROUND

The complexity of exposure to sound in today's life and urban environment calls for interdisciplinary approaches that encompasses technical, medical, psychological and cultural disciplines to get an understanding of effects of sound on a multitude of levels. Especially since the receiving part, the subject, being neither stable or constant, is changing individually with daily status

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and emotive states in response to the distribution of sounds in cityscape and architecture.

The scientific treatment of sound and sound environment has until recently usually been specialized in a multitude of disciplines and approaches with highly specialized discourses. Acoustics, audiology, environmental medicine, environment & sustainability studies, psychology, neurophysiology, musicology, cognition, phonetics... The list touches upon difficult dividing lines that academic research has trouble dealing with, such as those between humanities and natural sciences. There are also differences between underlying economical and political interests and scientific understanding and analysis on the other.

On top of this the huge subject is awaiting, of dealing with noise and the health aspects of noise exposure, and how to develop strategies for action. Noise is becoming an internationally high priority area, as a steep escalation of noise exposure is predicted for the EU and the rest of the world in the coming decades by the World Health Organization WHO.

3 METHODS - A SOUND ENVIRONMENT CENTER

As a response to this complexity of sound environment issues, Lund university in Sweden has inaugurated an interdisciplinary academic center for research, The Sound Environment Center. Today this has been up and running since 2006. Basic functions of the center have annually been financed by the university, while larger research projects has benefited from funding from external foundations and donators. The center has got an interdisciplinary board appointed by the vice chancellor in consultation with the involved faculties.

3.1 Research activities – larger project

The Center provides an scientific framework to initiate research on different aspects of noise problems simultaneously. The research is its core activity, and a number of research projects has received substantial external funding. Some main fields can be identified, such as a) biological effects of acoustics on voice performance and voice health, b) effects of acoustics and noise on cognition and learning, c) cardiovascular health and noise exposure, d) the role of sound in multisensory perception and stress recovery. Interdisciplinary collaborative designs acts as a prerequisite for all projects.

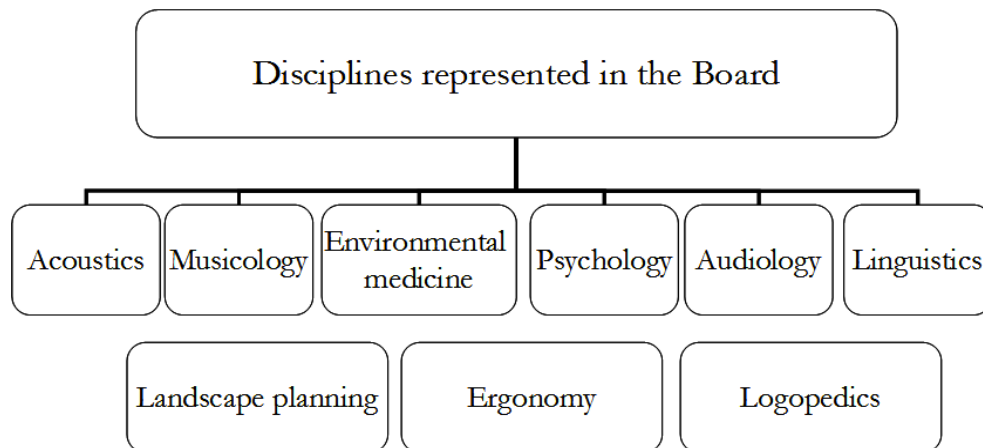


Figure 1 - Disciplines represented in the board of The Sound Environment Center, Lund University in Sweden 2014

3.1.1 Speaker's Comfort, Acoustics and Voice health

The project "Speaker's comfort" (funded by AFA) was led by ass.prof. Jonas Brunskog at Technical University of Denmark, DTU. It's dealing with teacher's voices in different acoustic conditions in regard to health aspects and room acoustics (Brunskog, Rydell, Åhlander, García, & Lövgren, 2011). The project has produced two dissertations; one in logopedics at Lund

university, "Voice use in teaching environments, Speaker's comfort" by Viveka Lyberg Åhlander, (2011) (Åhlander, 2011), and one by David Pelegrín García, "The role of classroom acoustics on vocal intensity regulation and speaker's comfort" (García, 2011). The core research group under the leadership of Jonas Brunskog have currently started a new and fully financed project investigating the early development of voice problems by using high speed camera techniques.

3.1.2 Health Hazards of Noise Exposure: Cardiovascular Disease

The traffic flow in urban areas are growing fast. In the largest cities of Sweden it's estimated that there has been an escalation of traffic noise exposure (above 55dB A) by fifty percent between 2000 and 2006 (Bluhm & Eriksson, 2011, p. 215). As is well known today, studies from a growing number of research units the world over, have confirmed connections between exposure to traffic noise and cardiovascular health risks. Recent interdisciplinary studies done in Lund (Bodin et al., 2009) under supervision of prof. Maria Albin in cooperation with The Sound Environment Center, confirms that evidences are growing stronger today.

A survey published 2009 combined epidemiological GIS-data on peoples dwellings, self-reported prevalence of hypertension and traffic noise exposure. The study, conducted on large group of over 24,000 inhabitants, showed significant effects in many age groups. Most pronouncedly 40–59 year olds exposed to 60-64dB had about 27 percent higher risk compared to control groups (Odds Ratio 1.27) with risk rising rapidly with higher noise levels > 64dB (Odds Ratio 1.91) (Bodin et al., 2009).

An important fact that surfaces in the data, is that hypertension noise exposure effect doesn't seem to fade when exposure lessens or stops (i.e. when people move to a quieter dwelling), but stays as a permanent chronic health condition. Similar long-term effects of vascular changes have been studied in animal experiments (Babisch, 2011, p. 202). If this means that once being heavily exposed people can't move away from the health effects of traffic noise, this might be an area in urgent need of further research.

The research group is now collecting combined data from medical consumption, noise and airborne particle exposure in an expanded study that will be published later this year.

3.1.3 Particles and Noise - Combination Effects of Noise and Airborne Particles

"Health effects from combined exposure to particles and noise" is another large joint project conducted in collaboration between environmental medicine, acoustics and aerosol technology investigating exposures in chamber experiments. Epidemiologic studies have shown that noise and diesel exhaust are important environmental risk factors for cardiocvascular disease and premature death. The main goal of the study is to determine effects on the cardiovascular system from simultaneous exposure.

Effects were studied on lower and higher respiratory systems (spirometry and nasal wash), heart (ECG measuring pulse and including variability of heart frequency as markers of autonomous dysfunction, blood pressure and markers of inflammation carried in the blood stream and stress hormones). To this were added evaluations of self-reported symptoms and cognitive performance (Xu et al., 2013).

3.2. Pilot Projects

3.2.1 Urban Green Environments and Well Being

The urban environment is complex consisting of much more than street crossings and concrete buildings. The importance of variations in the cityscape in the form of patches of greenery and parks cannot be stressed enough. Experience from a large number of surveys shows that the concrete must be balanced to be experienced as pleasant.

An interdisciplinary research project, executed on behalf of Sound Environmental Center in Lund at The Swedish Agricultural University, SLU, conducted a study comparing GIS-data of sound exposure to a survey of how people relate their wellbeing to a number of green environmental qualities (Skarback 2012). Qualities found were "Serenity", places where nature sounds could be heard, well kept in terms of physical care and with absence of disturbing people. Other qualities were "Wild" and "Lush" with variety of plants and living creatures, "Spaciousness" and "Culture" with included examples historical remains. Complementing cross sectional studies (Skarback, Bjork, Grahn, Stoltz, & Brundell-Freij, 2012) showed that physical activity, general health and

neighborhood satisfaction were associated with a presence of the three perceived green qualities: 1) historical remains (culture), 2) silence such that sounds of nature can be heard (serene) and 3) richness in animal and plant species (lush) (Annerstedt et al. 2011).

Many of these findings point at transparency of sound/noise, i.e. an auditive perspective is experienced as positive. A sonic perspective of far and near, that allows different sound sources at different levels and distances to be heard, and no single closeup source dominating the sound field. Though being a limited study, the results adds evidence-based knowledge with relevance to urban development projects and city planning (Skarback:2012).

A rehabilitation garden was planned as recreational grounds where patients with burnout symptoms were to be given opportunities for recovery in green settings. It was made by making use of eight different environmental qualities, amongst them the sound environment. In reality the premises were not far placed from a large and busy highway that emitted substantial noise clearly heard in the gardens (Grahn & Stigsdotter, 2003; 2010). Nevertheless patients repeatedly reported experiencing the garden as a peaceful place. This has led to the hypothesis that noise disturbance can be modified by other factors in the environment, a conclusion that can be important when developing strategies for noise problems in certain situations. *Research Question: Can experiences of annoyance by traffic noise be balanced by pleasant and well constructed outdoor environment?*

3.2.2 Stress Recovery in Multisensory Perception of Virtual Reality Environment

Looking further at questions of stress recovery another project is investigating the impact of different soundscapes by making use of laboratory experiments in digital virtual reality simulated environments. "The aim is to compare any differences in stress recovery reactions depending on different sound exposure in a virtual nature environment. The different sounds would hypothetically represent "positive nature experience" (twittering birds) and "negative nature experience" (rain). This may potentially provide insights into seasonal/weather-related differences in the health reactions to nature, an area previously unexplored in the literature. Even if the sounds prove not to represent any value-based reactions (positive or negative), the study would provide clues to whether different sounds in nature evoke different biological reactions in humans" (Annerstedt et al., 2011).

3.2.3 Effects of Dysfunctional Acoustics and Teachers Dysphonic Voices on Children's Learning

Research directions into fields of cognition, sound and hearing impairment are covered in a number of pilot projects. In collaboration with audiology and phoniatry Jonas Brännström looks at how the comprehension of school children is affected by noise. The complexities of today's activities in schools needs to be matched by contemporary acoustic research. Are children's cognitive capacities affected by teachers with dysphonic voices? In this project the concept of "noise" is stretched to include bad acoustic conditions and investigated by phoniatrics and audiology dealing with cross interdisciplinary fields including psychology, cognitive science speech pathology etc.

3.2.4 Sound Environments of Leisure and Hearing Impaired Youth - a Cultural Study

Another project, this time in collaboration with ethnology and cultural science, is looking at "noise" from the same broader viewpoints, studying "sound environments of leisure" from the perspectives of hearing impaired youth and cultural implications of this. The main question of the project is how leisure time activities and emotional status of hearing impaired young people are affected by their handicap.

3.2.5 Effects of Sound and Noise on Eye Movement and Cognitive Measures

Questions of how normal hearing young people are affected by noise, music, speech or silence has been investigated in a number of projects done in the ultra modern laboratory environment at HUMlab at Lund university, making use of eye tracking equipment, galvanic skin response measurement and other advanced research technologies. The effects on cognitive facilities were investigated in a joint project involving cognitive science, audiology, musicology, linguistics and acoustics. Data were being analyzed from eye tracking and GSR as reactions on stress and cognition collected in experiments with people reading texts while being exposed to various sound sources (Johansson:2009).

3.2.6 Campus Acoustics, Learning & Academic performance

Moving from theory to practise the center is currently preparing a large inventory of the acoustic properties of lecture halls at the university, bearing in mind the effect of acoustics on the cognitive performance of students. Factors with implications not only on the hearing impaired or students with reading and writing difficulties, but also on normal hearing students. A large number of halls are to be investigated in terms of reverberation time, speech intelligibility and measurements connecting to the research results from the Speaker's Comfort project. The measurements will be done by staff from the Technical Acoustics dep. at LTH.

4 OTHER ACTIVITIES

The Center arranges a number of interdisciplinary symposiums providing platforms for exchange of information and contact within the university as well as the outside world. The symposiums have incorporated the sound environment research community on national and inter nordic levels. As these activities are widening, so are contacts with the international research community.

The symposiums are woven around current sound environment specific topics with headlines such as *Sound & Health*, *Hearing Impairment*, *Sound Design*, *Seductive Sounds*, *Sound, Silence & Recreation*, *Sound, Mind & Emotion*, *Sounds in History*, *Wind Power Noise* and similar. Many of the symposiums results in printed publications. To this day a few, but a growing number, are available in english; "Man, Mind & Emotion" (Juslin et al., 2009), "Sounds in History" (Lund, Rindel, Hagström, & Brunskog, 2008), "Man & Sound Environment 2010", "Speaker's Comfort" (Brunskog et al., 2011) and the recent report from the "Care for Sound" symposium on health care. The center keeps a quarterly newsletter in swedish.

5 FINAL REMARKS

Although the conduct of the center lays within the humanities, environmental health aspects and acoustics have hitherto by necessity been given domination in projects and arrangements. The ambition has still been to bring together humanistic and natural science in this complex platform. One problem is that "sound studies" or equivalent names, such as "sonic culture" or "auditive culture" used in the cultural science field, provides a vague research area, still striving to get a solid foothold, not really being clear about how to relate to acoustics and environmental studies, tending to create a vacuum between the two research fields.

Effects of noise exposure are seldom only biological or psychological but often simultaneously affecting sensorial, biological, physiological, psychological and cultural levels, as they often touch upon culturally inherited habits and behaviours. It is therefore important to keep a wide perspective with open passages between different disciplines and schools of thought.

The interdisciplinary approach has however proven to provide a fruitful scientific platform and environment for soundscape studies. The academic framework of the Sound Environment Center offers opportunities both to design and apply for funding of joint research projects.

The response to the work of the center has been overwhelmingly positive to this day. The Center was awarded The Swedish Acoustic Society's Large Sound Prize 2008 for "the innovative mobilization of power the center constitutes with an aim to coordinate and initiate interdisciplinary sound environmental projects with the human being in focus."

The preliminary outcome of the interdisciplinary design provides a creative research environment being both positive and fruitful, leading to deepened network collaborations and continuously new research projects.

REFERENCES

1. Annerstedt, M., Jönsson, P., Wallergård, M., Johansson, G., Karlson, B., Grahn, P., et al. (2010). Physiology & Behavior. *Physiology & Behavior*, 118, 1–11. doi:10.1016/j.physbeh.2013.05.023
2. Bodin, T., Albin, M., Ardo, J., Stroh, E., Östergren, P.-O., & Björk, J. (2009). Road traffic noise and hypertension: results from a cross-sectional public health survey in southern Sweden. *Environmental Health*, 8(1), 38. doi:10.1186/1476-069X-8-38
3. Babisch, W. (2011). Cardiovascular effects of noise. *Noise and Health*, 13(52), 201.

- doi:10.4103/1463-1741.80148
4. Bluhm, G., & Eriksson, C. (2011). Cardiovascular effects of environmental noise: Research in Sweden. *Noise and Health*, 13(52), 212. doi:10.4103/1463-1741.80152
 5. Bodin, T., Albin, M., Ardo, J., Stroh, E., Östergren, P.-O., & Björk, J. (2009). Road traffic noise and hypertension: results from a cross-sectional public health survey in southern Sweden. *Environmental Health*, 8(1), 38. doi:10.1186/1476-069X-8-38
 6. Brunskog, J., Rydell, R., Åhlander, V. L., García, D. P., & Lövgren, A. (2011). *Speakers Comfort*. Lund, Sweden: Sound Environment Center at Lund university, Sweden.
 7. García, D. P. (2011). The role of classroom acoustics on vocal intensity regulation and speakers' comfort. www.hearingthewords.com
 8. García, D. P., Brunskog, J et. al. (2009). Development of an auditory virtual environment to measure the speakers comfort and increase of voice levels in lecture halls
 9. Grahn, P., & Stigsdotter, U. A. (2003). Landscape planning and stress. *Urban Forestry & Urban Greening*, 2(1), 1–18. doi:10.1078/1618-8667-00019
 10. Grahn, P., & Stigsdotter, U. K. (2010). The relation between perceived sensory dimensions of urban green space and stress restoration. *Landscape and Urban Planning*, 94(3-4), 264–275. doi:10.1016/j.landurbplan.2009.10.012
 11. Xu, Y., Barregard, L., Nielsen, J., Gudmundsson, A., Wierzbicka, A., Axmon, A., et al. (2013). Effects of diesel exposure on lung function and inflammation biomarkers from airway and peripheral blood of healthy volunteers in a chamber study. *Particle and Fibre Toxicology*, 10(1), 60–60. doi:10.1186/1743-8977-10-60
 12. Juslin, P., Rosenhall, U., Nielzén, S., Olsson, O., Källstrand, J. & N. S., Sikstrom, S. & S. G., et al. (2009). *Sound, Mind & Emotion* (No. 8). (F. Mossberg, Ed.). Lund.
 13. Karlsson, H. (2006). *Lyssnande Lund - förstudie om ett tvärvetenskapligt ljudmiljöcentrum vid Lunds universitet*. Retrieved from <http://www.ljudcentrum.lu.se>
 14. Lund, C. S., Rindel, J. H., Hagström, C., & Brunskog, J. (2008). *Sounds of History* (No. 6). (F. Mossberg, Ed.).
 15. Skarback, E., Bjork, J., Grahn, P., Stoltz, J., & Brundell-Freij, K. (2012). *Malmöbors upplevelse av fem utemiljökaraktärer. SLU, LTJ Rapport 2012-10* (p. 1–27).
 16. Åhlander, V. L. (2011, May 14). *Voice use in teaching environments*. lup.lub.lu.se
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