



Report no. 6 from

Sound Environment Centre
at
Lund University

Sounds of History



Lund University
2008

Publisher: Sound Environment Centre, Lund University

Text © Editorial, Frans Mossberg; individual chapters, the contributors, 2008

This book is licensed under an Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. This license allows users to download and share the article for non-commercial purposes, so long as the article is reproduced in the whole without changes, and the original authorship is acknowledged. (See full terms and conditions here: <https://creativecommons.org/licences/by-nc-nd/4.0/>)

e-ISBN 978-91-89415-26-3

DOI <https://doi.org/10.37852/oblu.139>

ISSN 1653-9354

Publications from the Sound Environment Centre at Lund University Report no. 6

Cover art by Jens Holger Rindel; Computer model of Roman Theatre

Printed in Sweden by Media-Tryck, Lund University, Lund 2008

(Citation, e.g.: Mossberg, F. (Ed.) (2008). Sounds of history. (Ljudmiljöcentrum skriftserie; Vol. 6). Sound Environment Center at Lund university. DOI: <https://doi.org/10.37852/oblu.139>)

Information about the Sound Environment Centre, Lund University, can be found here: <https://www.lmc.lu.se/>

**Publications from
Listening Lund - Sound Environment Centre
at Lund University**

Report no. 6

Sounds of History

Edited by Frans Mossberg

Texts from an interdisciplinary symposium held 27 october 2007
arranged by The Sound Environment Centre at Lund university,
Sweden.

Lund 2008

Cover illustration:
Jens Holger Rindel; Computer model of Roman Theatre

ISSN 1653-9354

Editor: Frans Mossberg
Lund 2008

Contents

Frans Mossberg <i>Sounds of History - Preface</i>	6
Cajsa S. Lund <i>Prehistoric Soundscapes in Scandinavia</i>	12
Jens Holger Rindel <i>Roman Theatres and their Acoustics</i>	30
Charlotte Hagström <i>Sounds Now and Then</i> (English translation: Jessica Enevold)	43
Jonas Brunskog <i>Building Acoustics in Old Houses</i>	53

Sounds of History - Preface

Frans Mossberg

Throughout history, the life of man and other creatures has been accompanied by sounds. But what were really the sounds of history? Even if we never can hear history as such, we have to acknowledge the sounds of myriad of days, moments and creatures, sounds soft and loud, distant and near, and admit that they are a part of a totality constituting our perception of history. A reasonable question to pose today then is: what have the sound environments of man been like, and how have they changed over time? Historically, how have sounds been experienced and interpreted? This is of course too big a subject to cover in a few pages. This volume from The Sound Environment Centre at Lund University will present some examples of contemporary research on sound environments in history, ranging from the soundscapes of prehistoric times to the sounds of disturbing neighbours in old houses today.

In the essay "On the history of silence", the Swedish writer and historian Peter Englund describes how the soundscape has changed through different times and how sounds that today are experienced as background sounds, for example the sounds of wind, rain or bird song, once were filled with meaning and messages that were meticulously read and interpreted. As the agricultural areas of man gradually were enlarged, their acoustic properties reached farther and farther geographically; the common spaces came to be extended and more people thus ended up sharing soundscapes, soundscapes that remained unchanged for a long time. Single sounds could travel long distances as they were reasonably few and far between and did not drown each other out. "The acoustic horizon was defined by different landmarks of sound, sound marks, amongst which

the barking of the dogs of the farm was only one of many, and the ringing of the church bells without a doubt the most important one”.¹

The towns offered different soundscapes and a wanderer walking through a town could experience how the sounds changed with the different seasons and the weather, as well as between different blocks and parts of the town, which all had their own “acoustic signature”. Englund provides some vivid pictures: “the shoemaker’s tapping, the beating of the cooper, the saw of the carpenter, the ringing sound of the silversmith and so on.” [...] “One passes the animal market with its mixtures of neighing, mooing, grunting and bleating; there, the passage to the alley of the knife grinder opens up and out shoots cascades of hissing, squeaks and scraping; and there, the air is filled with the rhythmic swishing and thumping of the potter’s wheel.” Here, his observations resemble the poetry of the Swedish poet and songwriter Carl Michael Bellman (1740-1795).²

Even if urban environments always have been noisy—from a historical perspective—they have largely, as Peter Englund writes, been noisy in a human scale. In general, the walls of noise and sound have not been impenetrable but have provided a certain transparency that has let weaker sounds and messages slip through. However, industrialism and urbanisation brought forth a development in which those walls of sound and noise became more solid; both sounds and silence came to be revaluated as recreation and labour became geographically separated in different parts of the cities.

The earliest prehistoric soundscape of man, as well as his earliest sound tools, is a subject that has been the main research topic for the musicologist and archaeologist Cajsa S. Lund, who, for many years, had tried to propose answers to the question of what the sounds of musical

1 Englund, Peter. *Tystnadens historia och andra essäer*, Stockholm, 2003:20 (my translation),

2 ff.

prehistory might have been like. When did man pass the magic border that separated sounds from other experiences and impressions and made him deliberately use sounds as tools and communication? When did this deliberately produced sound become so skillfully made, that it was provided with patterns and regularities in rhythm and pitch that it resembled what we today regard as music?

Musicologists have for a long time been interested in the earliest stages of the prehistory of music and many researchers have built their own theories and discourses on the subject. Much has been written on the development of music from the grunts of the earliest caveman to the complex orchestration of a symphony, but Cajsa S. Lund starts from a different point, from archaeological discoveries of items that have or might have been used as sound tools by prehistoric man. Close examinations of items provide material which may be used in figuring out how they might have been used sonically in past times. The research of Cajsa S. Lund constitutes a large part of the unique field of *music archaeology* in which systematisation and inventory of finds from archaeological sites help us get an idea and understanding both of the prehistoric soundscapes and the earliest music of man.

In the preparatory study, *Listening Lund*³, Henrik Karlsson reminds us that the past seldom was as quiet as we might imagine. Seneca, the younger, who lived approximately between 4 B.C. and 65 A.D. together with other citizens in the tight cities of the classical antiquity and the middle ages, as well as in Rome 2000 years ago, were irritated by the same type of disturbances as people are today: business, transports, trade, and neighbours. Seneca writes: *If silence is as necessary as it seems for someone who want seclusion to read and study, then I'm really in trouble. Here I am surrounded on all sides by a variety of noises. I live right over a*

³ Karlsson, Henrik, Lyssnande Lund, en förstudie om ett tvärvetenskapligt ljudmiljöcentrum vid Lunds Universitet, Lund 2004:14.

*public bath. Just imagine the whole range of voices which can irritate my ears. When the more muscular types are exercising and swinging about lead weights in their hands, and when they are straining themselves, or at least pretending to strain, I hear groans. And when they hold their breath for a while and then let it out, I hear hissing and very hoarse gasps. [...] I could wear myself out just listening to the variety of shouts among people selling drinks, sausages, and pastries; each restaurant or snack bar has its own huckster with a recognizable jingle.⁴ Some words from the Latin poet known as Martial comment on the lack of peace in the city: *There is no place in the city where a poor man may have a quiet moment for thought....* He cannot avoid to note that noise disturbances large are a question of class, and that money buys silence, then as well as now, when he says. *...you Sparsus, know nothing of these things, nor can you ever know, you who enjoy the luxury of a mansion, you whose home looks down on the hilltops, you who own a country estate right here in Rome.*⁵*

Today, Greek and Roman theatres are famous all over the world for their acoustics. What is less known is how their construction has been differentiated for particular purposes and conditions. This is an area of research that has been thoroughly explored by the Danish acoustician, Professor Jens Holger Rindel. In the large international and interdisciplinary research project ERATO, supported by the European Commission, Professor Rindel has, together with a group of researchers from Italy, France, Switzerland, Turkey and Jordan, investigated the acoustic properties of Roman theatres and other ancient sites, for example, the mosques of Istanbul.

⁴ Seneca the younger, Letter 56.1.2 cited in Jo-Ann Shelton: *As the Romans Did. A Source book in Roman Social History*, Oxford University Press, New York 1988:313.

⁵ Martial, Epigrams 12.57.1-14, 18-21, 24-28 cited in Jo-Ann Shelton: *As the Romans Did. A Source book in Roman Social History*, Oxford University Press, New York 1988:70.

Through data modelling and 3D virtual environments of the sites as they appear today compared to how they have appeared in past times, with support of all imaginable historical data, Rindel has been able to calculate how the sources of sound and acoustics have interacted. In the project, recreations of the music of the time have been made that are being played on reconstructions of ancient musical instruments. These have, in turn, been acoustically measured with the help of ODEON, a software developed under the leadership of Professor Rindel, to help find out how the music really must have sounded in its time and place.

Auditory sensations and impressions might not be the most common of subjects in ethnological or humanistic research. One obvious reason is that it is not given to easy quantification and measuring. Another reason is that sensations from a single sense, such as hearing, most often come as a “package”—a totality of several impressions. Statements and utterances concerning sound also very often seem to appear in contexts where something else is the prime topic. Therefore, it is often difficult to search for such information in literary and scientific databases.

At the Folk Life Archive at Lund University, a survey was conducted of a group of informants experiences of sounds in their life. Charlotte Hagström writes about the results of this survey that among other things reported that memories of sounds appeared as both highly individual and personal and that almost all of the informants had vivid memories of certain sounds in their life history. When a close reading of the stories is performed, differences and similarities appear that tell a lot about how sounds are experienced and how these can constitute significant markers of history. For example, some older people still remember the sounds of British bombers crossing the Swedish borders and Scania on their way to Germany bringing devastation to their victims. Hagström means that this unique material, available at The Folk Life Archives in Lund, offers a rich foundation for further research and analysis, once digitalised and structured.

Acoustician Jonas Brunskog closes this volume with his exploration of how building materials and construction techniques affected how people were disturbed by each other in buildings from the period 1880 – 1950 in Swedish and Scandinavian cities.

Taking the subject of disturbance seriously he explores how sound is transmitted both by way of air waves and through construction materials. He then provides a valuable overview of the historical development of building technology and sound insulation.

Lund august 2008

Prehistoric Soundscapes in Scandinavia

Cajsa S. Lund

Archaeological discoveries have shown that prehistoric man supplemented natural sounds with his own artificially made ones. Any kind of object used to produce the latter category of sounds can be described as a 'sound tool'. This term will thus encompass both the prototypes of what are commonly called musical instruments as well as the sound tools unknown to us or obsolete in modern society. This terminology implies that even the word 'music' acquires a wider connotation than normally in everyday speech. (See figure 1.)

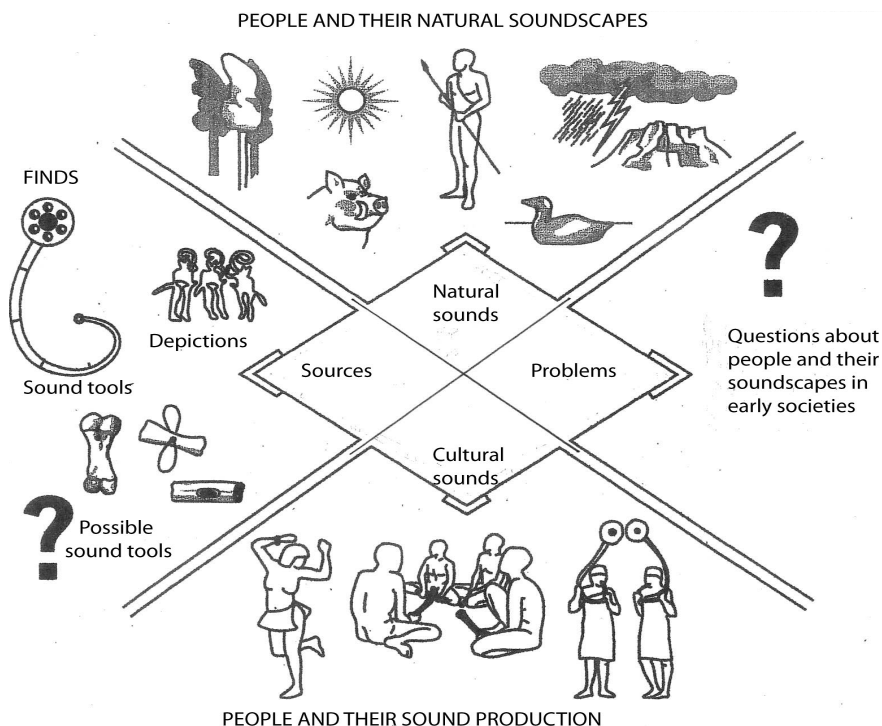


Figure 1. The fields of research in Music archaeology.
Drawing: Cajsa S. Lund.

Music archaeology is an overall term used for research trying to answer questions about mankind's intentionally produced non-verbal soundscapes from early times using archaeological finds as the primary source of evidence. Who produced these sounds, for whom were they intended, which sounds, when, why, how, how far? What did it really sound like?

This paper will focus on Scandinavia's prehistory, a period of about 12,000 years or some 360 generations! The so-called Viking Age (ca. 800-1050 AD) is the last period of prehistoric Scandinavia. The boundary between prehistoric times and the medieval period is naturally flexible. Standard archaeological practice places it at 1050 AD for South Scandinavia up to and including the counties of middle Sweden. In the more northern parts of Scandinavia, the transition is taken to have occurred much later.

Is it possible to determine anything?

Sources

Obviously, we can never provide satisfactory answers to such questions as mentioned above. Our knowledge of man's intentionally produced sounds in prehistory is primarily based on archaeological finds of sound tools, intact or in fragmented form.

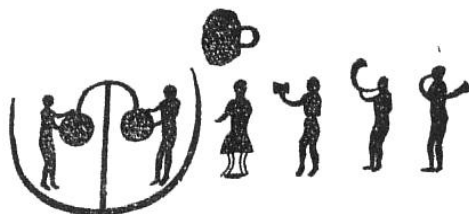


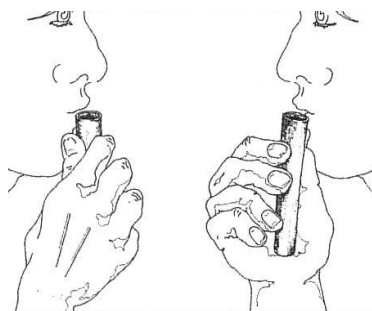
Figure 2. Rock engraving of "musicians" from Kivik, Sweden. Early Bronze Age. Drawing: Ulla Sjösvärd.

Another source, though relatively limited concerning Scandinavia, consists of preserved contemporary iconographic material, such as images of musical instruments and of entire musical situations, for example dancing scenes. Figure 2. There are also sporadic mentions of singing, playing and other sound production in early written sources

related to ancient Scandinavia. If used with care and a critical eye, the written sources and the archaeological finds can complement each other in a useful manner. However, our main source consists of the material traces of the sounds.

Hitherto, music archaeologists have documented roughly one thousand sound tools – proven and possible – dating from Scandinavian prehistory. These objects are divided into five groups according to their probability for having been used for sound production, primarily or secondarily. Group 1 means objects, which clearly are sound tools, such as bells and lyres. Others are possible sound tools on a diminishing scale. Group 5 includes objects with the lowest degree of probability. What about the tube of bone with bevelled ends? Is this a whistle or something completely different? (See figure 3.)

The majority of the sound tools/possible sound tools, which were excavated thus far, are so-called rattle instruments. Wind instruments are also in evidence, as are stringed instruments and drums (that is, membranophones). However, the two last-mentioned groups are rare in Scandinavia so far.



*Figure 3. Bone tubes used as end-blown whistles (cf. bottle blowing).
Drawing: Lars Bolander.*

Compared to the amount of other types of archaeological finds in Scandinavia, the preserved sound tools are few in number. This could mean that tool-based sound production and music-like activities mattered little to our oldest ancestors. Instead, the voice may have been the dominant means by which the people of that time created their extra lingual or language-enhancing music, in the shape of lullabies, dirges, heroic lays/epic poems, suggestive magical rigmarole, epic tales on repeating tonal formulae, calls from the summer pastures, inciting war-cries, etc.

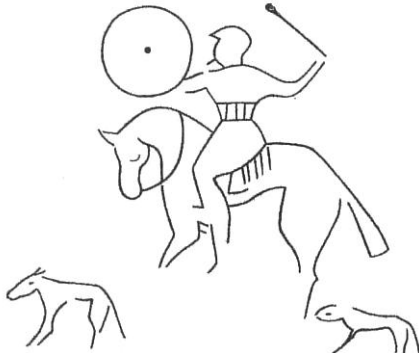


Figure 4. Motive on the Möjbro runestone, Sweden. Late Iron Age. Is the rider 'playing' his shield as a percussion instrument? Drawing: Swedish Museum of National Antiquities.

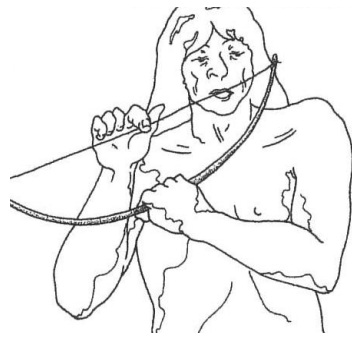


Figure 5. Mouth bow in function. Drawing: Lars Bolander.

Coming excavations will no doubt result in new finds of sound tools. On the other hand, sound tools do not have to be specifically constructed for the purposes making sound. A metal shield makes a percussion instrument, and a bow makes not only a hunting and combat weapon, or a drill-bow, but also a stringed instrument (figures 4-5). However, it is likely that the majority of the purpose-built sound tools of prehistory are permanently lost, because they were presumably made from plant matter and other easily perishable materials. This would include e.g. flutes and pipes made of willow, reed, straw, plant stalks and nutshells, what I call 'green music'.

The natural soundscape

The total result of an interdisciplinary archaeological excavation project is quite often a rather detailed picture of the investigated society in question – its social, economic and religious structure. To this knowledge can be added an acoustic dimension, that is, we can gain some idea of the soundscape of this society as well, including natural as well as cultural sounds, sounds produced by man himself.

Climatologist's knowledge of the weather conditions provides clues to how the elements may have behaved and sounded in the form of rain, storm, thunder and so forth. Botanists', zoologists', osteologists'

and geologists' interpretations of man's treatment of nature, as well as of more concrete find material of animal bones and pollen grains, offer descriptions of the plant and animal life. All these data can give us altogether a fair idea of the natural soundscape.

People and their sound production

The preserved work-related tools give clues to man's unintentional sounds, that is, sounds that ineluctably accompanied his activities. Such sounds were generated by the friction of scrapers against animal hides, by flint knapping, by the shooting of arrows, the blows of axes, the blacksmith working the iron, the sound of scythes cutting down grass and corn, and so on.

Which sounds did man deliberately produce in prehistory, and when did he do it, how and why? Hypotheses of a high degree of probability can be formed, for example that unintentional sounds sometimes were consciously used and possibly reinforced and structured. Thus the thud of axes and picks may have been made to sound in patterns, which regulated a work rhythm. Such work sounds may well have been further reinforced by measured calls and songs which facilitated the coordination of collective labours such as rowing or the prying loose of heavy stones, trees, etc.

Rock-carvings in Scandinavia can be numbered in the thousands. The earliest are from the Stone Age but most of them were made in the Bronze Age. Researchers seem to agree that rock-carvings are connected with the religious observance of that time. Carving and hewing on stone slabs and stone blocks are processes rich in sound. One may wonder whether those who made the carvings attributed any intrinsic value of a magical/ritual nature to these sounds.

A probable hypothesis, based on ethnographic and ethnological parallels, is that hunting in prehistory was facilitated by specially produced sounds, that is, hunters lured their prey within shooting and catching distance by imitating their sounds with the help of sound tools. Comparative material of interest in this context can be found within Scandinavia itself, in the form of archaic hunting practices such as the imitating of seal, otter and sea birds. These, as well as all kinds of popular hunting practices, are interesting to music archaeology, partly because they stimulate analogies

with hunting in prehistory and partly because they may actually constitute continuous traditions with roots far back in the hunter Stone Age.

The listening man

We know that *Homo sapiens* has changed very little as a species in any case during the last 40, 000 years. Those changes, which have been ascertainable in man's living patterns, clearly arose more from changes in his environment than from changes in man himself. From this we can also hazard the guess that certain features of man's relation to his sound environments have remained quite unchanged throughout the millennia.

The supply of sounds in the environment, as well as the meanings we attribute to various acoustic events, help determine how we hear: some sounds are considered important, others not. It is reasonable to assume that prehistoric man, as modern man, alternated between active listening and passive hearing. Certain sounds in certain situations, such as cries of anguish, or the calls of prey, predators and other potential threats, would naturally have alerted them to be vigilant, while corresponding or other sounds in different situations would only have existed as a background carpet of sound deep into their consciousness. We usually only notice such sound carpets if they cease, as in the sudden, threatening silence before a storm.

The manufacturing of flint tools is a resounding process. Subjectively speaking, flint has a superb sound, which Stone-Age man can be presumed to have exploited for various purposes. We know that modern flint knappers usually judge the quality of their raw material by listening to its sound. The same working method must have been employed by flint knappers in prehistoric times. This can be compared to blacksmiths, who throughout time have distinguished between hardened and non-hardened iron by the sound of the material. Potters as well are known to listen to the sound of their products in order to judge their quality.

As already mentioned, there are also written accounts that are of interest to music archaeology in Scandinavia, for instance passages in the oldest Nordic poetry and sagas, and a number of non-Scandinavian (including Arabic) contemporary texts. All these sources are relevant for Scandinavia's late Iron Age despite the fact that the Nordic texts were not written down until the Middle Ages. A problem is that we cannot with any

certainly distinguish between metaphor and concrete ‘musical’ information in these stories. Nevertheless, the written sources provide us with some valuable information about extra-musical acoustic environments and how these were listened to, perceived and used, as illustrated by the following two examples from Scandinavian epic poetry. The first verse is about men who decide to urge their horses on, so that the women inside their houses at home can hear the running coursers in the distance:

*”Nu hetsar vi hästen så att kvinnorna inuti husen
långväga kan lyssna till springarens lopp mot gården.”*
(Heimskringla: History of the Norse Kings, ca. 1225 AD)

The following verse tells us about a ship in a rough sea, where the storm causes mighty whining waves and roaring, crashing sounds around the stem.

*”Stormen med stora hugg mejslar kring skeppets stäv
väldigt vinande, sjudande vågor.
Iskall andedräkt ur ondskefull jättemun
brusar runtom bogen med allt förgörande brak”.*
(Egils Saga, ca. 1220-40 AD)

The epic English poem ‘Beowulf’ – which probably originated in the 8th century at a princely court in Western Europe – was written down in the 10th century. This poem mixes epic Germanic poetry with elements of Irish stories, Anglo-Saxon folklore, and Scandinavian history. ‘Beowulf’s’ grand opening lines give us a significant insight of the acoustic environment of a great hall: the din of level echoing high in the hall, the sound of harps, the clear song of the poet who sang how the world came to be.

“...hela dygnet/ högljudd gamman/ och harposlag
klangfull skaldesång/ den kunnige kväder
om ätters upphov/ i urtidsdagar.”
(Swedish translation, Björn Collinder)

In the “Beowulf” poem, attention is given not only to acoustic images that consist of singing or the playing of instruments; it also describes, for instance, how the broadswords were swung so that their whining could be heard a great distance.

An Arabic traveller, Ibrahim ibn Ahmad at-Tartuski, who visited Scandinavian territory in the 900s, wrote that he found local singing to be ‘...more bestial than the howling of dogs.’ And the German priest and historian, Adam von Bremen, wrote in the 11th century, basing his accounts on available sources, that the songs in the pagan temple at Uppsala’...are many and disgraceful, and thus it is best to say nothing of them.”

The Roman historian and author, Tacitus, wrote in his work ‘Germania’ (98 AD) about the Germanic peoples’ manipulation of their voices in war activities (let us assume here that Tacitus also refers to people in Scandinavia although this is not proven): *“Hären med sin sång eftersträvar särskilt en hård klang och taktfast brölande. Därför håller de sköldarna framför ansiktet för att ljudet – när det kastas tillbaka – skall bli fylligare och kraftigare.”* (Swedish translation: Bertil Cavalin) ‘They chiefly study a tone fierce and harsh, with a broken and unequal murmur, and therefore apply their shields to their mouths, whence the voice may by rebounding swell with greater fulness and force.’ (English translation, Thomas Gordon)

Such potential functions of non-musical acoustic events as quoted above – which in many cases overlap or are outright replaced by more “musical” events – are obviously timeless, and thus always of immediate interest, even though they are seldom analysed and commented upon.

Sound tools

When this paper was read, it was supplemented with demonstrations and discussions of prehistoric sound tools in the form of replicas and reconstructions of the original finds. References were also made to similar medieval finds and to popular as well as present-day sound tools. This is a short summary of the sound tools that were demonstrated.

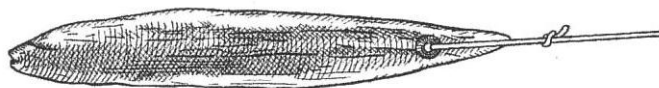
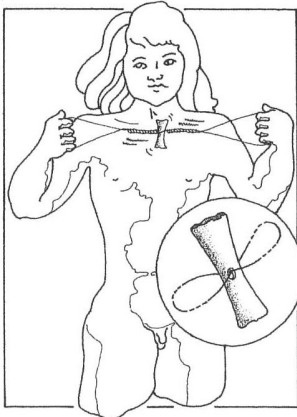


Figure 6. Bull-roarer made of bone (length ca. 11 cm), from Kongemosen, Denmark. Early Stone Age. Drawing: Jörgen Kraglund.

Bull-roarers and buzzers

are two related, globally distributed types of sound tools. They are made to sound by being swung round in the air with a string. A bone artefact found at Kongemosen in Denmark, dated to the hunter-gatherer Stone Age (ca. 6500 BC), has been interpreted as the hitherto known oldest sound tool of Scandinavia (figure 6). Among early peoples the world over bull-roarers are used chiefly as magical implements, for instance in initiation rites. In popular European contexts they were used for attracting bats and you can still find people who can tell us about this tradition. In modern societies bull-roarers are usually encountered as toys.



Buzzers, such as buzz-disks and buzz-bones, have been common since early times and are found in many parts of the world. Several buzz-bones, made from a pig's metapodial and with one or two holes bored through the centre, dating from the Viking Age and medieval times, have been found in Scandinavia (figure 7).

*Figure 7. Buzz-bone in function.
Drawing: Lars Bolander.*

Indeed, buzz-bones still exist today as toys. However, the most common type of buzzer is the button on a sewing thread. According to both ethnological records and early written sources buzz-bones once had, in addition to their function as toys, a certain role in popular belief. For example, there are stories told in Scandinavia that the sound of buzz-bones was used to frighten away small trolls.

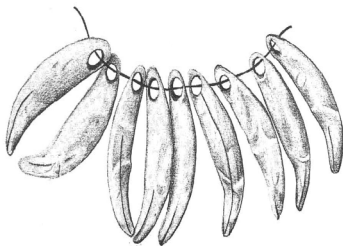


Figure 8a. Type model of a rattle adornment made from animal teeth. Drawing: Jörgen Kraglund.

Rattles

Stone-Age objects that can be interpreted with certainty as rattles have yet to be found in Scandinavia. However, it is probable that our prehistoric ancestors like many traditional non-European peoples used their body adornments (made of shells, nutshells, teeth, bits of bone, clay, etc...) not only as decoration and/or status-symbols but also for the sake of their sound. (Figure 8a-b.) The sounds might have had a double function: as auditive support to dance, and to increase the potential magical effect of the same dance. Several peoples, both formerly and today, have believed – and still believe – that the sound of such rattles would frighten away evil spirits.

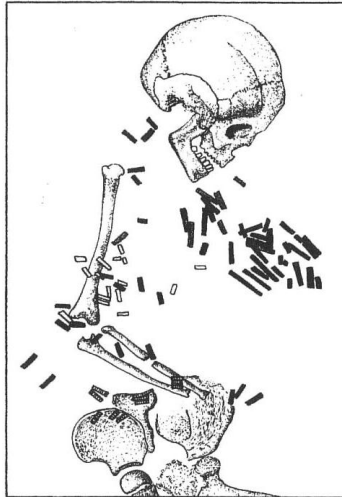
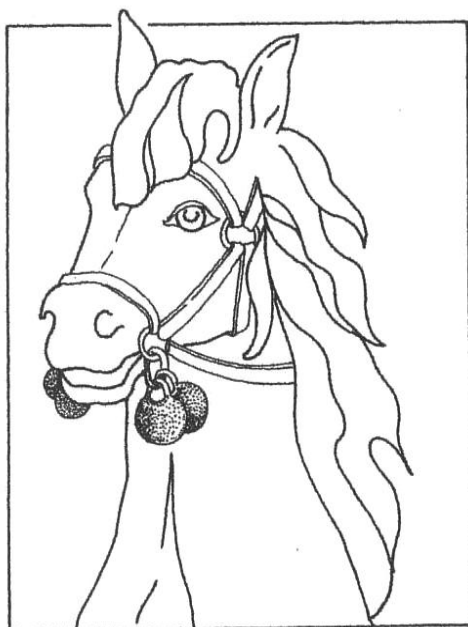


Figure 8b. Rattle adornment of bone tubes in an inhumation on Gotland, Sweden. Late Stone Age. Drawing: Gunborg O. Janzon.

A large number of finds of so-called strung and sliding rattles exist from second millennium BC Scandinavia. In the Bronze Age smaller bronze plates were fixed on larger bronze objects, such as knives, ornaments, bridles, bronze lurs and other objects (see figure 9).

An odd variant of Scandinavian iron rattle is what we, using its Norwegian name, call a *rangle* (plural, *rangler*). Basically, it consists of a number of iron rings threaded onto a larger loop or ring (approximately 20 cm. in diameter), which in turn is attached to a movable socketed handle or, alternatively, a hook. About 250 *rangler* have been found thus far, mostly in Norway and date from the Viking Age. Evidence suggests that they were fitted to the ends of the traces of horse-drawn vehicles (figure 10a-b).



*Figure 9. Bronze rattles found on Gotland, Sweden (late Bronze Age) on a bridle.
Drawing: Lars Bolander.*

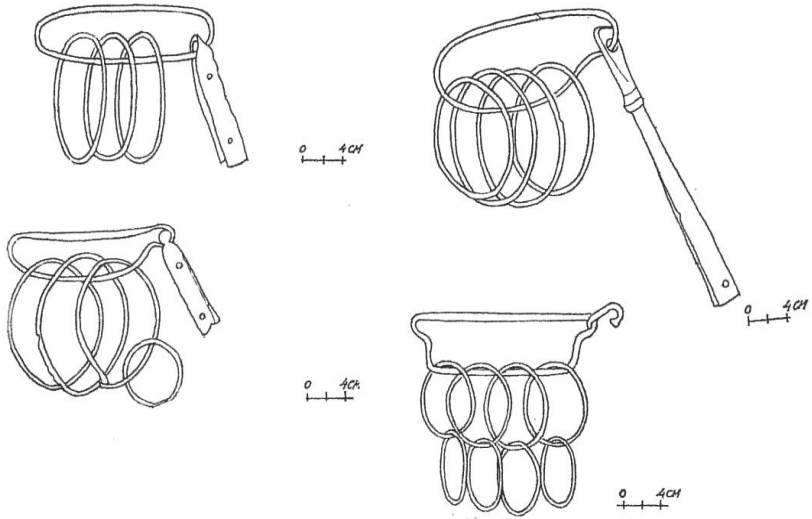


Figure 10a. Different types of the Norwegian rangler (iron rattles).
 Drawing: Magnus Bauer-Nielsen.

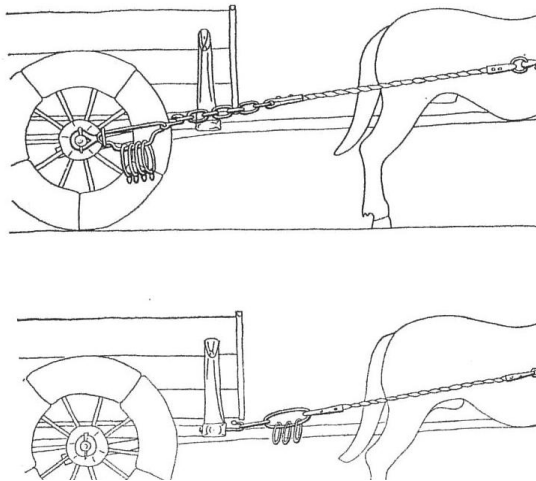


Figure 10b. Norwegian rangler used as end-mountings on wagon traces. Drawing Jörgen Kraglund.

The find circumstances indicate that the rangler were reserved for the most distinguished persons in society. Perhaps they were resounding symbols of spiritual and secular power. The rattling symbols of rank - bells - found in Scythian kings' graves are interesting comparative material. As sound tools the *rangler* may have had both apotropeic, practical (e.g. signals) and sound entertaining functions simultaneously. Similar iron rattles as the *rangler* are used on farmers' horse-and-wagon equipages in China even today, however – as far as I know - the sounds from these have only an entertainment function.

Pellet bells are common late Iron-Age finds. It is reasonable to assume that the jingling of the iron pellet bells, which the Vikings sometimes attached in rows to the horse equipment, also had similar combined functions as the *rangler*.

Interesting information in this context is a note by the Danish priest and historian, Saxo Grammaticus (died in the early 1200s), that the fertility rites of the pagan era in Uppsala were accompanied by *crepitacula*, which means jingling, ringing objects. It is a matter of discussion which sound tools he refers to – bells, pellet bells, *rangler*, chains, and/or other jingling metal objects.

In the Viking-Age marketplace Birka in Sweden, deceased children were buried with small bronze pellet bells. These may have served both as acoustic toys and as magical protection against evil forces. The latter function is well known in Scandinavian folk traditions even right up into modern times. The hitherto earliest known child rattle in Scandinavia is made of clay and dates from the Danish early Iron Age (see figure 11).

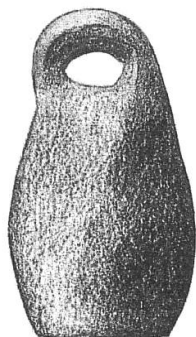


Figure 11. Clay rattle (8 cm high), containing a clay pellet. Vendsyssel, Denmark. Early Iron Age. Drawing: Jörgen Kraglund.

Percussion stones

It is obvious that prehistoric man struck all sorts of objects and materials for the sake of their sound: logs, sticks, nutshells, vessels of wood and of clay, skulls and other bone objects, metal shields, stones, etc. Folk tradition in Scandinavia offers much information on both stone slabs and stone blocks having been used as percussion instruments because of their metallic sound. They have a number of so-called cup marks (a non-figurative rock-carving motif) and according to both legend and ethnological records these stones once had a certain role in popular belief.

Their traditional names are usually onomatopoeic; here are some Swedish examples: *Ballersteneren* (the county of Västergötland), *Sangelstainen* (the island of Gotland), and *Klongestenen* (the island of Öland). These, and other 'singing stones' in Scandinavia, were certainly also performed upon in prehistoric times.

Reed instruments

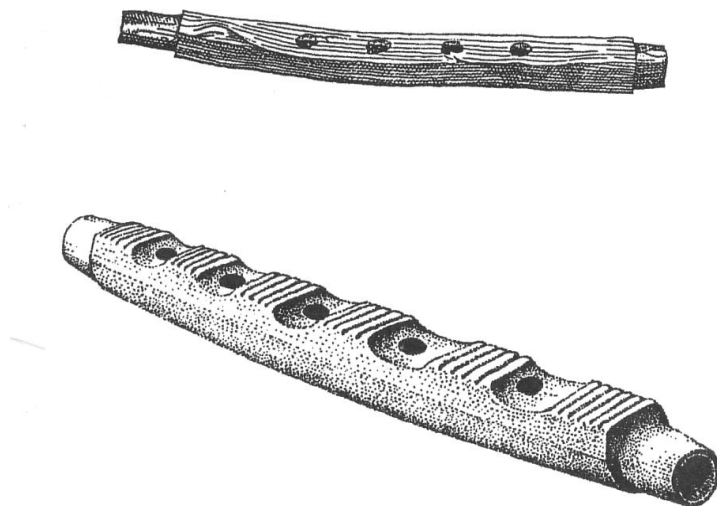


Figure 12. Chanters of elder wood for hornpipes, or bagpipes? Late Viking Age/early Medieval Ages. The chanters were found in Lund, Sweden (above, length 19,7 cm) and on Falster, Denmark (below, length 18,4 cm). Drawings: Musikmuseet, Stockholm (above) and the Viking Ship Museum, Roskilde (below). The Falster pipe was fragmented; the drawing is a proposed reconstruction.

Two wooden chanters for reed instruments have been found in Scandinavia, one on the island of Falster in Denmark (five finger holes), the other in the town of Lund in Sweden (four finger holes). Figure 12. They are dated to ca. 1050 AD or somewhat later, that is late Viking Age/early Medieval period. Without doubt these chanters were parts of hornpipes and/or bagpipes. Both are carved from local elder wood. Their ends are cut so that they can be joined with now-missing parts: being hornpipes, for example, they would have had a bell made of cow horn at the lower end, and a capsule made of wood or cow horn at the blowing end to protect the delicate reed fitted with the chanter.

The hornpipe reed is sounded by air blown directly from the mouth into the capsule while the bagpipe reed is sounded by air coming from a bag. A similar Viking-Age wooden chanter has been found in York, England, in excavations of the Scandinavian settlement there.

The bagpipe was known in the Mediterranean area as early as Roman times. When and how was the bagpipe and/or hornpipe introduced into Scandinavia? Did the Vikings learn about these instruments on their journeys to foreign countries or was it traders from the East who introduced the instruments to them during their visits to Scandinavia? Was it the Scandinavians who brought the instruments with them to the West or was it the other way round – Western merchants who brought them to us? Or did they come to Scandinavia as well as Western Europe from Slavic peoples tribes living by the shores of the Baltic Sea?

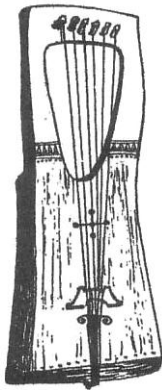
A reasonable assumption is that bagpipes/hornpipes were used for dance music in various feasts and ceremonies in the villages and at the marketplaces; and they also might have been manufactured and played by shepherds to entertain themselves as well as their herds or simply trying to kill time.

The lyre

Until the end of the Viking period, the six-stringed lyre seems to have been the most widespread type of stringed instrument in the North-West of Europe. The remains of some twenty lyres (the oldest dated back to ca. 450 AD) have been discovered at archaeological excavations so far. The Iron-Age finds in Scandinavia, all excavated in Sweden, are made up of three bridges: two were found on the island of Gotland (made of amber and bronze respectively) and one was found in Birka (made of elk horn). Figure 13.

The lyre was played by warriors, chieftains or other distinguished personages as well as poets and singers. Besides being used for accompanying verse and epic tales, the lyre might have been used for dance music as well.

The lyre as a plucked instrument died out in the Nordic countries during the 13th century. However, it continued to be played with a bow all the way into the 1800s. The bow presumably began to be used some time in the 11th century. Where, when and how this came to be, we do not know. It may have been a parallel development, occurring in different parts of the world at the same time.



As yet there is no concrete evidence that harps were used in prehistoric Scandinavia. It is likely that the term 'har', used so often in written sources, was the collective denomination of the times for stringed instruments. In any case, only fragments of lyres, not harps, have been recovered in Scandinavia so far.

Figure 13. Outline of a plucked Viking-Age lyre (length ca. 60 cm). Drawing: Styrbjörn Bergelt.



Figure 14a. Block-and-duct bone flute (length 14,4 cm) from Birka, Sweden. The Viking Age (ca. 8-900 AD.) Photo: Cajsa S. Lund.

Whistles and flutes

Prehistoric bone whistles (no finger holes) have been found in Scandinavia. However, they are few in numbers. For sure, our ancestors made whistles also of bark, nutshells, shells, etc, so-called 'green instruments'. Whistles were probably used in magic rites as well as in various practical activities (such as signalling, hunting calls) or also just for pleasure. The hitherto oldest known bone flute with finger holes found in Scandinavia comes from Viking-Age Birka in Sweden. It is 14,4 cm long with two finger holes and is dated to ca. 800-900 AD. This flute can be classified as a block-and-duct flute. See figure 14a. The Birka flute may have belonged to a shepherd who played for his flock, or a trader who made music to lure customers to his stall. Cf. figure 14b including the picture caption.

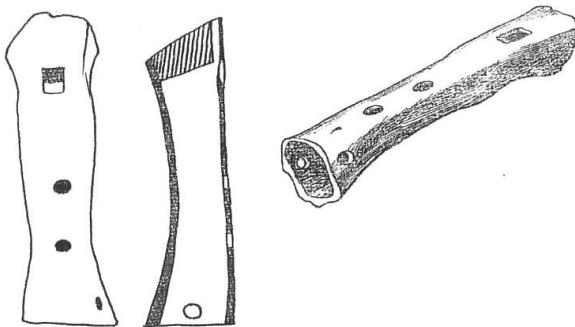


Figure 14b. Traditional block-and-duct bone flute (length ca. 15 cm). Such bone flutes were used as late as the mid-20th century by wandering merchants in Moravia, the Czech Republic. Drawing: The Ethnographic Institute, Moravian Museum, Brno.

Perhaps it might also have been intended to frighten off wolves by means of trilling high-pitched sounds – we know that latter-day shepherds in Sweden have used bone flutes for similar purposes. And/or this flute may also have been used by someone wanting to entertain himself and others with an upbeat melody!

References

- Lund, Cajsa S. 1981, The archaeomusicology of Scandinavia (pp.246-265) in *World Archaeology* 3/1981
- Lund, Cajsa S. 1985, Bone flutes in Västergötland, Sweden – Finds and Traditions (pp.9-25) in *Acta Musicologica* Vol. LVII: Fasc.I
- Lund, Cajsa S. 1991, Fornnordiska klanger/The Sounds of Prehistoric Scandinavia. CD including a booklet. Stockholm 1991: Musica Sveciae, MSCD101
- Lund, Cajsa S. 1994, Forntiden (s.21-38) in *Musiken i Sverige*, Vol. I (Huvudred. Leif Jonsson)
- Lund, Cajsa S.1997, Strövtåg i den fornnordiska terrängen (s.33-50) in *Musik i Norden* (Huvudred. Greger Andersson)
- Lund, Cajsa S. 2002. Vikingatida ljudlandskap (s.18-23) in *Tidskrift för Tidig Musik* 4/2002

Roman Theatres and their Acoustics

Jens Holger Rindel

*Odeon A/S, c/o Ørsted-DTU, Bldg. 352, Technical University of Denmark,
DK-2800 Kgs. Lyngby, Denmark*

Abstract

The ancient Greek and Roman theatres are famous for the excellent acoustics. However, it is not generally well known that different kinds of theatres were built, for different purposes and with different acoustical conditions. In the ERATO project the acoustics of the open air theatres has been studied and compare to that of the smaller, originally roofed theatres, also called odea (from Greek: *Odeion*, a hall for song and declamation with music). The method has been to make computer models of the spaces, first as they exist today, and then to complete the computer models in accordance with archaeological information, to make virtual reconstructions of the spaces. The acoustical simulations have given a lot of interesting information about the acoustical qualities, mainly in the Roman theatres. It is found that the Roman open-air theatres had very high clarity of sound, but the sound strength was quite low. In contrast, the odea had reverberation time like a concert hall, relatively low clarity, and high sound strength. Thus, the acoustical properties reflect the original different purposes of the buildings, the theatre intended mainly for plays (speech) and the odeon mainly for song and music. The virtual reconstruction, including some auralisation examples with reconstructed music played on reconstructed musical instruments, has been made with the ODEON room acoustic modelling program. This makes it possible for the first time to listen to these historical buildings as they sounded in the past.

Introduction

The main objectives of this research are identification, virtual restoration and revival of the acoustical heritage in a few, selected examples of the theatre and the roofed odeum in a 3D virtual environment. The virtual restitution integrates the visual and acoustical simulations, and is based on the most recent results of research in archaeology, theatre history, clothing, theatre performance and early music. The project was undertaken with support from the European Commission under the headline: Preserving and use of cultural heritage. The short title of the project is ERATO and it involved seven partners from Denmark, Italy, France, Switzerland, Turkey, and Jordan. More information is available from the project website [1].

The selected theatres and odea

Five spaces have been selected for virtual reconstruction in the ERATO project: Three theatres, see Fig. 1, and two odea, see Fig. 4. Acoustical measurements were made in the best preserved theatres in Aspendos and Jerash. In Jerash there are two well preserved theatres, and the larger one (the South theatre) was chosen for the project. The smaller Jerash North theatre may have been an odeon. In the theatre of Syracuse and the two odea the state of preservation was not sufficient to make acoustical measurements meaningful.

The odeon in Aosta was selected because this is the only known example where some of the outer walls still exist in full height. The odeon in Aphrodisias was selected because there was very good and detailed information available from the archaeological excavations, and many of the interior details like statues and marble floor in the orchestra still exist. In Aphrodisias there is also a well preserved large theatre. The reconstructions of the odea are inspired by - but not identical to - the reconstructions suggested by Izenour [2].

In order to get reliable results all the simulations were carried out with three source positions and 15 receiver positions. This means 45 data sets for each parameter in each of the eight frequency bands. The only exception is the Aphrodisias odeon in its present state where only six receiver positions were used because of the small size of the present theatre.

Acoustical results in open-air theatres

The open-air theatres have been used for popular theatre plays and music with an audience representing all social classes. These theatres had a substantially higher background noise from the surroundings and the weather (rain, wind, etc.) making the acoustics somehow poorer compared to the acoustics in the odea.

The open-air theatres studied in this project have suffered less degradation through time than the odea. The original materials of these open-air theatres have mainly been hard stone and a few wooden structures.

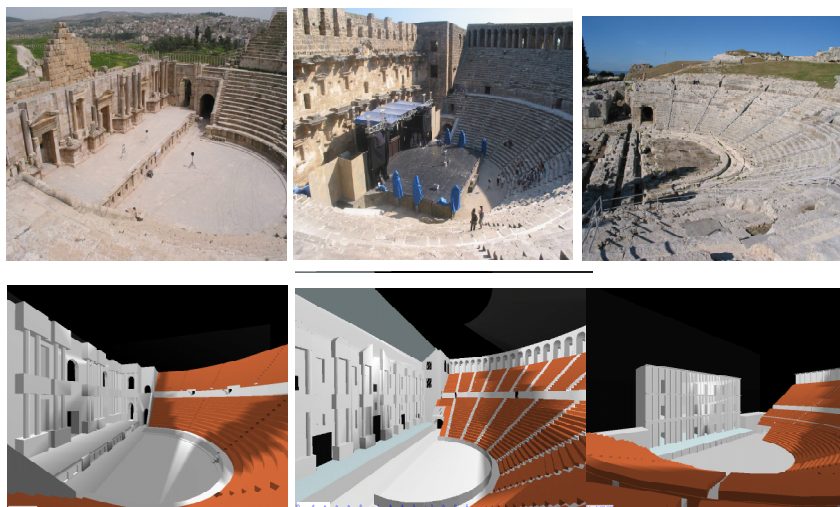


Figure 1. Above: Photos from the three selected theatres. Below: View from computer models, reconstructed for the Roman period. Left: Jerash South theatre, Middle: Aspendos, Right: Syracuse.

The theatres in Aspendos, Jerash and Syracuse

These three theatres differ in shape and size as well as in cavea slope. In the Roman time, the Aspendos and Syracuse theatres had a colonnade behind the last rows of the cavea, and there are good reasons to assume

that was also the case in the Jerash South theatre, although the traces have disappeared. The Aspendos theatre had a Velum (sunscreen over the audience area) made of wool like the sails for ships. The acoustical parameters for the three theatres in their different configurations are shown in Table 1 together with the cavea diameter to indicate the size of each theatre.

	T30 (s)		G (dB)		C80 (dB)		STI		Cavea Diameter (m)
	Empty	Full	Empty	Full		Full	Empty	Full	
Aspendos Roman	1,95	1,59	-2,34	-4,36	1,17	4,08	0,53	0,61	95,5
Aspendos Present	1,89	1,53	-4,37	-6,09	2,68	6,53	0,60	0,70	95,5
Aspendos Present (Stage)	1,77	1,43	-4,49	-6,05	4,42	8,27	0,63	0,71	95,5
Jerash Roman	1,54	1,06	-0,72	-3,05	3,46	6,88	0,62	0,70	87,8
Jerash Present	1,21	0,86	-1,18	-3,29	5,98	9,85	0,67	0,75	87,8
Syracuse Roman	1,81	1,67	-6,69	-8,24	4,07	8,25	0,62	0,70	138,6
Syracuse Present	1,25	0,97	-10,60	-11,61	12,88	18,12	0,88	0,93	138,6

Table 1. Calculated parameters in different configurations of the theatres. The parameter values are averaged over all source-receiver positions and over the 500-1000 Hz octave bands

Table 1 shows that the difference in reverberation time between empty and full theatre is generally about 0.3 – 0.4 s. The reverberation time when full seems to be more adequate in the roman reconstructions than in the present state models.

The overall strength is the highest in Jerash and lowest in Syracuse, partly due to the different slopes and their great difference in cavea diameter.

The clarity is exceptionally high in all the theatres despite the levels of reverberation, and this is due to the lack of roof that make the field more like free field than a diffuse field. As a consequence of this, the STI values are also remarkably high in theory if we neglect the background noise from outside the theatres.

From Table 1 it is seen that in Jerash theatre the reconstruction of mainly the frons scaenea results in an increase of the reverberation time of around 0.3 s. It is also seen that the Syracuse theatre in the Roman era had around 0.6 s longer reverberation time than in the present stage. This is mainly due to the frons scaenae but also the colonnade provided some reverberation.

In Fig. 2 is shown the frequency dependency of the calculated reverberation times in the Aspendos theatre in different configurations. It is seen that in the present state, the modern stage provides a decrease of reverberation time at mid-frequencies, and in the case of the Roman reconstruction (with added velum and stage canopy) there is only minor difference in reverberation.

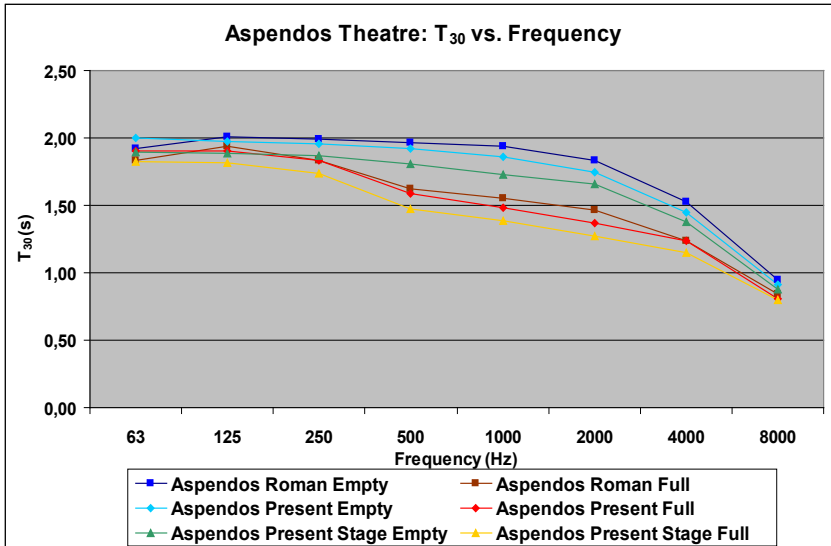


Figure 2. Calculated reverberation time T_{30} as a function of frequency in different configurations of Aspendos Theatre. The values are averaged over all source-receiver positions.

In Fig. 3 is shown the strength G as a function of the distance from source to receiver in the Aspendos theatre. In general the strength is reduced by 2 – 3 dB when the theatre is occupied by an audience. In all cases the strength decreases with the distance, and the attenuation per distance doubling DL_2 is around 4.5 dB in the full reconstructed version, and around 6.0 dB in the present condition of the theatre. For the other reconstructed theatres the results are similar.

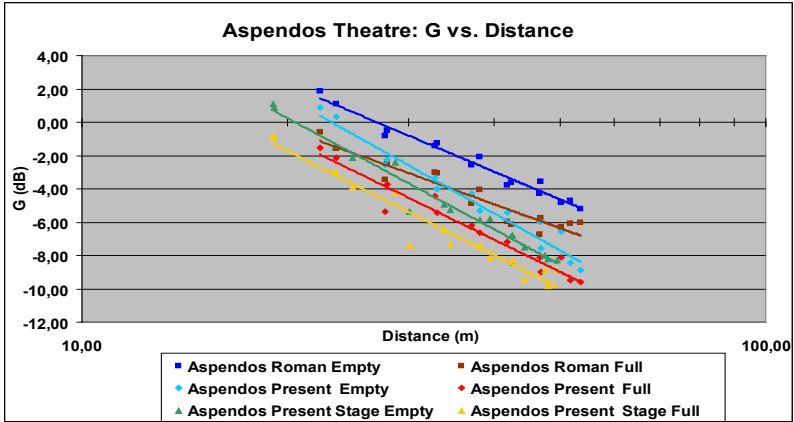


Figure 3. Calculated strength G in different configurations of Aspendos theatre. The values are for one source position and averaged over the 500-1000 Hz octave bands.

Acoustical results in odea

The two odea that have been analysed are depicted in Fig. 4. This type of theatres has the property of being closed rooms with wooden roof structures used for more intimate music and theatre plays and often only for an exclusive audience. They have been made of hard materials as stone or marble and they are assumed to have had open windows to the outside for lightning and ventilation.



Figure 4. Above: Photos from the two selected odea. Below: View from computer models, reconstructed for the Roman period. Left: Aosta, Right: Aphrodisias.

The open windows and the audience seated in the cavea have provided the main acoustical absorption in these buildings. These rooms have thus been over-reverberant from an acoustical point of view if we compare them to today standards.

The odea in Aosta and Aphrodisias

The Aosta and Aphrodisias odea differ mainly in their volume and in their shape. The outer walls of the Aosta odeon follow a rectangular shape whereas in the Aphrodisias odeon the shape is semicircular following the seating area. The Aosta odeon in Roman time had almost double the volume of the Aphrodisias odeon as reconstructed, due to the difference in ground floor area and ceiling height. Results of the acoustical computer simulations are shown in Table 2 and Fig. 5.

	T30 (s)		G (dB)		C80 (dB)		STI		Cavea Diameter (m)
	Empty	Full	Empty	Full	Empty	Full	Empty	Full	
Aspendos Roman	1,95	1,59	-2,34	-4,36	1,17	4,08	0,53	0,61	95,5
Apendos Present	1,89	1,53	-4,37	-6,09	2,68	6,53	0,60	0,70	95,5
Aspendos Present (Stage)	1,77	1,43	-4,49	-6,05	4,42	8,27	0,63	0,71	95,5
Jerash Roman	1,54	1,06	-0,72	-3,05	3,46	6,88	0,62	0,70	87,8
Jerash Present	1,21	0,86	-1,18	-3,29	5,98	9,85	0,67	0,75	87,8
Syracuse Roman	1,81	1,67	-6,69	-8,24	4,07	8,25	0,62	0,70	138,6
Syracuse Present	1,25	0,97	-10,60	-11,61	12,88	18,12	0,88	0,93	138,6

Table 1. Calculated parameters in different configurations of each odea. The parameter values are averaged over all source-receiver positions and over the 500-1000 Hz octave bands.

By comparing the reverberation times of the two odea in Roman time it is seen that Aosta Odeon has a longer reverberation time, mainly caused because of the greater volume. The ruins of the Aphrodisias odeon in the present have too little surfaces to provide a reverberant field for satisfactory acoustics as it is seen from the table. Aosta odeon has not been reconstructed in its present state since there is only one wall standing.

In the reconstructed models of the Roman era, both odea are over-reverberant when they are empty. The Aphrodisias odeon has a reverberation time when full, which is comparable to the optimum for modern concert halls of similar volume. The Aosta odeon seems to have been over-reverberant even when full. The strength G of both odea is seen to have optimum values both when empty and full. The clarity C_{80} of Aosta odeon is too low mainly because of its high reverberation whereas Aphrodisias has an adequate clarity. The STI values show that the Aphrodisias odeon is satisfactory for speech when full whereas the Aosta odeon is just bearable. It has to be mentioned that the background noise level of the audience is not known and has probably caused lower speech intelligibility.

Overall, the calculation results of the reconstructed model of Aphrodisias odeon have shown an excellent acoustic ambience comparable to modern halls. It is a hall that has been optimal for music but also good enough for theatre plays and chorus. The Aosta odeon is less adequate for spoken performances but still acceptable for music.

From figure 5, showing reverberation time T_{30} as a function of frequency, it is seen that T_{30} decreases with increasing frequency in all the odea in the Roman configuration. For the odea fully occupied it is seen that T_{30} decreases most notably at low and mid frequencies, which is due to the absorption from the people. For the 4000 - 8000 Hz frequency bands there is not a big difference between empty and occupied state, and this is due to the air absorption at high frequencies.

Reconstructed music and auralisation

The music

As part of the ERATO project four different musical instruments were reconstructed; aulos, kithare, tympanon, and scabellum. Examples of musical pieces were composed in accordance with musical style of the period around the first century AD. Some pieces included solo song and chorus, see Figure 6. The newly developed multi-channel auralisation technique was used [3]. This implies that four microphones were used for the anechoic recordings in order to capture some of the directional characteristics in the recording. This technique makes it possible to give the sources acoustical width and depth when applied in the auralisation. In addition it is possible to capture and reproduce acoustically the movements of the performers, which all together makes the auralisation very realistic.



Figure 6. From the anechoic recording of music with reconstructed musical instruments. In the first row is seen from left to right; tympanon, scabellum, aulos, and kithare.

The Plays

In the case of the odea the simulations show that these highly reflective rooms (marble surfaces), have similar acoustical properties to modern concert halls when the windows are closed, even though the only absorption is provided by the audience. The roof has shown to give more satisfying results when using a coffered ceiling than a plane surface.

Anechoic sound recordings of a group of 10 actors from Yildiz Technical University, Istanbul were made in June 2005. The two Greek dramas Antigone and Agammenon as well as the sound of an audience crowd in different moods were played. These performances were recorded with a four microphone setup and filmed with a video camera to capture the movements.

The anechoic sound recordings of the plays and the previously recorded music pieces were auralised in the ODEON software using the following procedure: First the sound source position in the virtual room is placed on the stage, and the source is split into four parts (front, left, back, right) corresponding to the four microphone directions used for the recordings. Then each signal is fed to each part and its contribution to the room is calculated separately. Finally a listener position is chosen in the sitting area and all the calculated contributions are added together at this position. The sound of the performance in the simulated room can be listened to over headphones and the movement of the actors during their performance can be heard, particularly when the receiver is near the stage.

The Crowd Sounds

For the auralisation of the audience crowd a different approach was used. The procedure was the following: Ten people in an anechoic room were told to perform as an audience in different moods: clapping, supporters, opponents, cry, laugh, surprise, idle talk. Each of the moods was recorded separately and the signals were auralised in a computer model of the theatre.

A random distribution of 20 sources in the audience area was generated. The anechoic sound signal for a selected emotional reaction of the crowd was fed to each of the sources. The contribution of each source to the sound heard at a chosen receiver was calculated. All the sounds from each of the sources were then mixed together and attenuated and delayed randomly to create a greater sense of mixture.

In order to create the impression of a bigger audience and get more diversity, the different crowd signals were edited in the AUDITION software. Using a multi-track set-up, the different crowd reactions were displaced in time and filtered and finally mixed with the play or music. It was hereby possible to fit the reactions of the crowd to the actions of the actor in the different parts of the play as well as the music.

The total number of final sound files with music/play and crowd for the integration was 61. In the integration process the auralised sounds of the crowd and actors were used to synchronise the visual actions of the virtual humans.



Figure 7. View from a performance in the virtual reconstruction of the Odeon in Aphrodisias

Conclusion

The acoustic simulations of the reconstructed spaces show a clear difference between the theatres and the odea. In the theatres the reverberation times are surprisingly long, even with a full audience it is around 1.6 s in the theatres with a colonnade. In Jerash without a colonnade reverberation time is significantly shorter, and this raises the question if it is possible that also the Jerash South theatre had originally a colonnade? It is likely that the building material has been removed and reused in later times, e.g. for building the Byzantine churches in the fourth century. The reverberation in the Roman theatres can be explained from the big frons scaenae in closed connection with the auditorium and the surrounding colonnade. This allows high order sound reflections even without a ceiling.

In the odea the reverberation time depends strongly on the ceiling height and the size of the windows, which contribute some sound absorption to the spaces. In general there is no firm information available about the ceiling height, and in the case of the Aphrodisias odeon a moderate height of around 15 m has been assumed, leading to a quite moderate reverberation time of around 1.6 s with audience. However, in the case of Aosta the ceiling height is 21 m, which is defined by the walls that are still standing, and this leads to a considerably longer reverberation time of around 3.5 s with audience. While the shorter value in Aphrodisias odeon is similar to the reverberation time in a modern concert hall, the longer value in Aosta odeon is more similar to that of a modern church.

The acoustics of the reconstructed open-air theatres can be characterised by a very high clarity and a rather low strength of sound. The sound strength decreases with distance, and more so if there is no colonnade. The acoustics of the reconstructed odea are quite different with a rather low clarity and a high strength of sound. The sound strength does not decrease much with distance in the odea. The results of the acoustic simulations in the reconstructed theatres and odea confirm the assumption, that they were dedicated for different purposes. The theatres with very high clarity of sound were excellent for plays (speech), whereas the odea with a higher sound strength and more reverberant sound were excellent for song and music from instruments like the lyre or kithare. Some short examples of different typical performances can be experienced in the virtual reconstruction and auralised sound examples can be heard at the ERATO website [1].

Acknowledgements

The ERATO project (Contract Number ICA3-CT-2002-10031), is financed by the European Commission under the Fifth Framework INCO – MED Program. The visual reconstructions were made by the project partners from EPFL, Lausanne and MiraLab, University of Geneva. The archaeological and architectural research was made by the project partners from The Hashemite University, Jordan and Yildiz Technical University, Istanbul, Turkey. The reconstruction of music and plays was created by the Music department of Yildiz Technical University, Istanbul, Turkey. Acoustic measurements and sound recordings were made in collaboration with colleagues from the University of Ferrara, Italy. Evaluation and subjective testing of results were made by AEDIFICE, Lyon, France.

References

- [1] ERATO homepage: <http://server.oersted.dtu.dk/www/oldat/erato>
- [2] G.C. Izenour: *Roofed Theatres of Classical Antiquity*. Yale University Press, New Haven and London (1992)
- [3] F. Otondo, J.H. Rindel, 'A new method for the radiation representation of musical instruments in auralizations', *Acta Acustica/Acustica* (2005) Vol. 91, pp. 902-906.

Sounds, Now and Then

Charlotte Hagström

Department of European Ethnology and Folklife Archives, Lund University



Silence is about to be broken. Bellringer at Akebäck church, Gotland, 1957. Photographer unknown. (The Folklife Archives, B 35627)

I remember from the Skälderviken of my childhood that the freight trains could be heard, first, as they hooted at the grade crossing, and then, as they rustled over the Rönne Creek bridge. In the spring of 2005 a tunnel was opened under the railroad down to the beach and the hooting came to an end. Once I read an anecdote about a steam whistle in Baku that had been hooting without interruption for 30 years. One night it failed to hoot and went silent and the entire town woke up. A good story that seems to be true – there are always sounds that one does not notice until they stop. This does not apply to the noise of dogs barking, which never can be shut out. They are utterly annoying (M 25154).

Asking questions about sounds

Just before Christmas 2005, The Folklife Archives sent out yet another open ended questionnaire to the network of informants associated with the Archive. It was the 219th list to be sent out since it all started in 1932, and the topic this time was *Sounds and Noises*.¹ Under a number of thematic headings – Everyday Sounds, Old sounds, Feelings and Sounds, Conscious and Unconscious Sounds, Noise, Silence, Sounds and Hearing – a number of questions were listed that the informants could use to inspire their meditations and reflections on the subject.

The layout of the list did not differ from other lists that had been sent out previous years, but the perspective was slightly different. The questionnaire topic is usually picked to fit one of the projects currently undertaken at either the archive or the Department of Ethnology, of which The Folklife Archives are a section, and the answers become part of the gathering of data for the project as the same time as they are recorded for the archive to be used for continued and future research. This time there was no project. The idea was born from a lunchroom discussion around senses and feelings.

We had observed that material on the senses was to a large extent lacking, or rather: sensory impressions and experiences as such have seldom been the starting point of ethnological research. Certainly, there are stories about smell, taste, hearing and so on, but usually they are not the focal point of the interview or record. Finding stories about sounds is possible but not entirely easy, since, from the point of view of the chronicler and registrar, they are about something else. A story about a train-journey from the beginning of the last century may for example contain memories of how it sounded and smelled. However, these observations are seldom mentioned in the data-base description of the material, which consequently makes such information un-searchable.

The lunchroom discussion led to the decision to design a number of lists around the senses where the informants would be asked to reflect on their experiences, memories and opinions about sound, smell, taste, sight and touch. The first sense chosen was hearing. A reason for this was that the tendency has been to prioritize visual interpretations - within ethnological

¹ All of The Folklife Archives' questionnaires are available at: <http://etnhum.etn.lu.se/arkiv/> Click "documentation".

research not the least - and sight has thus been heralded as the "most significant" sense (Hylland Eriksen 2000:50). We wanted to challenge this assumption by starting off with another sense.

Another reason was quite simply that sounds and noises appeared increasingly interesting the more we broached the topic. Rather quickly, we, the lunchroom attendants, realized that we had distinct sound memories depending on how old we were, where we had grown up and what we took an interest in. We found that we liked and disliked different types of sound and that sound was more or less important to us. If we, six-seven people sharing a work space, had such divergent notions and experiences and that many different stories of sounds, just imagine the stories that our 130 informant might yield, reflecting on their memories of sound! The work designing LUF 219 *Sounds and Noises* commenced.

Those who regularly fill out the archive's questionnaires are called informants and today this group consists of 130 people. Anybody can become an informant; the only requirement is that s/he should participate fairly regularly by answering the questions that are sent out between two and four times per year. The subjects vary quite a lot; for example, in the past few years the informants have been sent questionnaires LUF 207 *Food and restaurant habits*, LUF 214 *Biomedicine and health-care priorities* and LUF 218 *Trees*. All informants do not answer all questionnaires and their responses differ in length. On average, an answer is between two and five pages long and each list generates approximately 70 to 95 answers.

The informant group is not homogenous; it consists of people of various backgrounds and life styles: young and old men and women from the city as well as the rural areas. They include hairdressers, clergymen, machine-operators, farmers, journalists and post-office clerks. As a group the informants are not representative of the Swedish population. The average age is quite high; there are more women than men and very few have an immigrant background. The answers are not suited for quantitative study, but that is not the point either. Questionnaire answers are qualitative data that with advantage can be combined with other material and methods (Hagström & Marander-Eklund 2005). The 78 answers that were received from questionnaire LUF 219 *Sounds and Noises* are consequently not suitable to use as one's single source of data on how people in Sweden remember and reflect on sounds. On the other hand, they yield

considerably more detailed knowledge of how a number of people reflect and remember than, for example, statistical surveys and inquiries do (cf. Bolstad Skjelbred 2005). What is lost in breadth is thus gained in depth.

Telling stories about sounds

By close-reading the answers and juxtaposing them, interesting similarities and differences appear that become departure points for further questions, problems and analyses (cf. Sjöholm 1999), for instance, how the respondents relate to silence and background noise. Two people in their forties, a man and a woman, are of completely contrary opinions. The woman writes:

Silence is after all very agreeable – yet, I think, people are afraid of it. Afraid of what it needs to be filled with. I am often irritated about the TV having to be on when we are supposed to socialize. There is resistance to turning it off – fear (M 25138).

The man, on the other hand, thinks that:

This thing with sounds is important to me. Most of the time I have the radio or the TV turned on (M 25117).

Another point of entry is the profession of the storytellers. The sounds at their workplace are often so natural a part of their weekday that they, after a while, “fade away”. First when they no longer are part of their everyday life, or when they are encouraged to talk about them, they reappear. The following excerpts are from three people who in their daily work are surrounded by very different sounds:

Other phases of my life...the pneumatic dispatch and the teleprinter when I worked at a local newspaper. The dispatch made a sucking, slurping sound; the ting-a-ling of the teleprinter was always a bit professionally exciting – did something happen?! The ticking of the fax machine is also something I remember – it is still used where I work, but not as often. Now what comes through is the sound of the printer as it automatically changes paper tray – or whatever the heck it does. It makes sounds anyway (M 25087).

The sound level at work is completely different from the one at home. Since I work as a butcher, one of the sounds I hear most comes from the saw that cuts the pig halves in smaller pieces, but also the sounds from workmates and the sounds they make as they go about their work (M 25117).

My weekdays mostly include motor sounds, not from car engines but from electric motors. I milk the cows in the morning, then, there is the vacuum pump rumbling and the animals that rattle their chains (M 25112).



What is to some a beautiful sound is to others a disturbing noise. The driver of this Ford Galaxie from the 1960's, parked at Ed railway station, would probably describe the sound of the car engine in positive terms. Photographer: Tina Skovsted, 1995. (The Folklife Archives, B 34088)

The sound experiences vary with the age of the storyteller. One reason for this is that they move in different environments at different ages, and certain sounds no longer are parts of their everyday life as it enters a new phase. The shouting and hollering in the schoolyard and the scraping of chairs and the rustling of paper in the class room are sounds that people

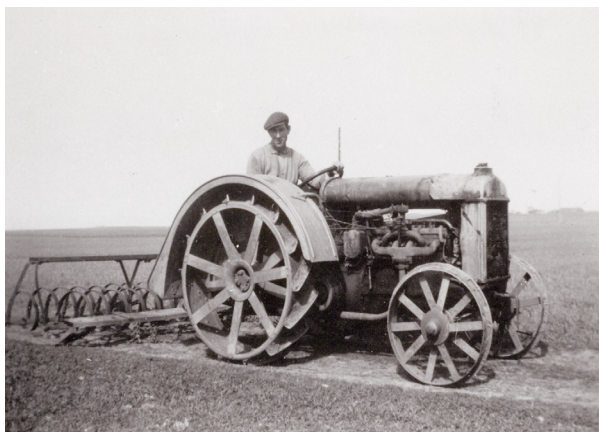
associate with childhood and youth, with the exception of those who work within the educational system. But there are also sounds tied to a certain time period that no longer can be heard such as the sound of the bomber planes that flew over Sweden during the war. Several of the informants, who then were young, mention this sound in particular, for example, this man who at the time lived in Skåne:

A very special sound memory that I have preserved in my head [sic] is the grinding roar of thousands of heavy bomber planes that many nights in the final stage of the world war traversed the sky above us. They were British and American planes from bases in England that flew by way of Skåne to bomb Hamburg and Berlin. The roar lasted up to an hour before midnight, as it did when the planes returned a few hours later after misery and death in Germany. The entire family used to step out on the balcony, gaze up into the dark space and feel the wings of world history flapping (M 25083).

As I mentioned earlier, people who want to become informants do not need to fulfill any specific criteria. Nevertheless, it is assumed that they enjoy writing and are interested in sharing their memories and experiences. Many of those who answered the sound questionnaire obviously found reminiscing about old sounds entertaining, and the material thus contains a lot of vivid and colorful accounts. Among these is the following excerpt, written by a woman born in the 1930s:

When I was a child, there was a bread deliverer who used a horse and carriage. He rang a bell and then the housewives came out of the houses to buy bread. I also recall that sometimes the water was to be turned off for our street and then a man was walking around blowing a horn. And one remembers of course when the air-raid drill siren sounded. As I recall the siren sounded once a month, it is never heard these days. It was also nice to hear the steam engines. In Österlen they can still be heard in the summer. In the 50s when I was newly married I lived on Trollebergsvägen. A fish dealer on bicycle came to the house. He opened the street doors and yelled, in quick succession, Herring, cod and plaice and smoked herring! (M 25146).

To others, things seemed much more difficult. A man born in the 1920s writes in his very short reply (half a page): *I grew up in the country – there were no sounds* (M 25154).



The industrial revolution changed the rural soundscape. The text on this photograph, from Skegrie in Skåne, informs us it is "Rickard on his first tractor". Photographer unknown. (The Folklife Archives, B 31319)

Most likely there were as many sounds where he grew up as where other people of the same age and background grew up and wrote about in their answers. But people remember differently and notice different things and that becomes very obvious in the answers to this questionnaire. Several people emphasize the significance of the various senses and point out that they have either a few or many sound memories. For example, if they have few memories of sound it often depends on their having more memories of smell instead. The same event or environment can be remembered differently by different people depending on which sense they experience to be the most important one or the one they use the most.

As I think more closely on sounds it is mostly music that pops up in my memory: my strongest impressions of sound are musical and they are both positive and negative impressions. These are sounds that I notice; if I walk down the street I seldom notice any sounds: they are there as a part of life and they cannot be shut out apart from paying very little attention to them. Perhaps that is why I hear sirens long before anybody else does (M 25154).

Using sounds

Sounds and questions about *soundscapes* have not had a prominent place within Ethnology, but a change seems to be taking place. In Uppsala, Karin Eriksson has begun working on her dissertation on the ethnology of sound (Eriksson 2007). Several researchers have also become increasingly interested in various senses, among them hearing, in studies of a number of phenomena and settings. Tom O'Dell who has studied spa cultures, for instance, discusses the importance of smells and sounds in connection with spas and how they are used to enhance experiences. Sounds and music are used to create and bring out the atmosphere in a room, for example, the massage room where the treatment is accompanied by relaxing music (O'Dell 2006:226). Maybe the dominance of the visual that Hylland Eriksson (2000) observed is being broken.

But people's experiences of sounds, and sounds as cultural expressions, are of course not only of concern for ethnologists². They are of relevance to all those who do research within the humanities, and the material that was collected with questionnaire LUF 219 *Sounds and Noises* may thus be used in many ways and for varying purposes. The material has not yet been processed but is registered, and since the Folklife Archives are open to the public it is entirely possible for all who are interested to take part of it already.

Our aim is to compile the material in a way that makes it easier for interested researchers to make use of the material. Such compilations have been made, in various forms, of previous questionnaire answers; these can consist of excerpts from the answers that have been listed thematically or based on a few criteria selected beforehand (see e.g. Hagström 2005). Another option is to go one step further and not only supply a compilation of the descriptions and stories about different sounds but also include the sounds themselves. It could possibly be done by first close-reading the answers and then selecting a number of sounds according to certain criteria such as "childhood sounds", "favorite sounds", "unpleasant sounds" and/or sounds that are associated with "safety" or "worry". A number of these sounds are then recorded, which may require some work since some of

2 E.g. Bennett discusses in *Culture and Everyday Life* (2005:131ff) how cultural studies researchers have studied "music and urban soundscapes" and the use of iPods and walkmans and background music at airports, gyms, shopping malls etc. See also Strömberg 2006.

them are very unusual today. This sound-bank is then made accessible on the internet to researchers and teachers at Lund University, who can make use of it in research as well as teaching and presentations. There are many potential areas of use:

- as resource in web-based material (an article about the state of alert during the war may include a clickable link to the sound of a bomber plane)
- for teaching (a lecture on city planning may include letting the students listen to positive and negative city sounds)
- as components of a museum exhibition (instead of merely constructing a visual environment, the visitors are also offered sound experiences typical for the time and setting presented)

The answers to questionnaire LUF 219 *Sounds and Noises* make up a unique and exciting material. It can be used in a number of ways and is a source of deeper knowledge on how people experience and relate to sounds – sounds that surround us today as well as sounds that no longer are heard very often. Sounds are significant, sounds create meaning. As one of the informants so graphically described it:

It happens that, when I step into a room, a church or another bigger hall, that the sound of my footsteps, the scraping of an object that is moved or the banging of a door that suddenly is slammed shut make me recall an incident that is connected to a room with similar acoustic properties, but which otherwise has no similarity to the room where I am. It is as if one happened to enter a search term that makes the brain's hard drive download texts and images that one did not know existed. (M 25083).

(English translation: Jessica Enevold)

Source material and Literature

The Folklife Archives, Lund University

LUF 207 *Mat och restaurangvanor*

LUF 214 *Biomedicin och prioriteringar i vården*

LUF 218 *Träd*

LUF 219 *Ljud och oljud*

Svar på frågelistan [answers to questionnaire] LUF 219

Ljud och oljud: M 25076 – M 25154

Literature

Bennett, Andy, 2005: *Culture and Everyday Life*. London: Sage.

Bolstad Skjelbred, Ann Helene, 2005: "Pizza i Norge". In: Hagström & Marander-Eklund (eds.): *Frågelistan som källa och metod*. Lund: Studentlitteratur.

Eriksson, Karin, 2007: "Ljudets etnologi". In: *Kulturella Perspektiv*. No. 4.

Hagström, Charlotte, 2005: "Om ordet är mitt. Meddelarnas tankar om skrivandet". In: *Upptecknaren. Nytt från Folklivsarkivet*. No 2.

Hagström, Charlotte & Lena Marander-Eklund (eds.), 2005: *Frågelistan som källa och metod*. Lund: Studentlitteratur.

Hylland Eriksen, Thomas, 2000: *Små platser, stora frågor. En introduktion till socialantropologi*. Nora: Nya Doxa.

O'Dell, Tom, 2006: "Magic, Health and the Meditation of the Body's Geography". In: Falkheimer & Jansson (eds): *Geographies of Communication. The Spatial Turn in Media Studies*. Göteborg; Nordicom.

Sjöholm, Carina, 1999: "Biobiljetter, filmstjärnealbum och frågelistor". In: Bergquist & Svensson (ed): *Metod och minne*. Lund: Studentlitteratur.

Strömberg, Mikael, 2006: "Ljud och manipulation" In: *Förföriska ljud. Skrifter från Lyssnande Lund Ljudmiljöcentrum vid Lunds universitet*. Report no 2.

Sound Insulation in Old Buildings

Jonas Brunskog
DTU

Introduction

A large part of the existing buildings in Swedish and Scandinavian cities are from the period before sharp building regulations, approximately the period 1880-1950. How will this influence how neighbours are disturbing each other? This text discusses how the multi family buildings in this period was designed and constructed, and the sound insulation in these buildings. Some example of constructions used in Sweden and Denmark, found in the literature, will be discussed. Some advises concerning improvement of the sound insulation in these constructions will also be given. A general introduction to sound insulation will first be given.

Sound insulation

The sound insulation of a building structure or element is the capacity to reduce the sound when it is transmitted through the structure. The building structure or element is typically a wall or a floor of a building. The sound insulation can be of two kinds: airborne or structureborne. The latter case is here impact sound insulation due to e.g. footsteps.

The transmission loss R (or the sound reduction index) is a measure of the airborne sound insulation of a partition (wall, floor, window etc.). The transmission loss for a partition between two rooms can be determined from the difference between the average sound pressure levels in the two rooms, with a correction for the sound absorption in the receiver room, see figure 1.

$$R = L_1 - L_2 + 10 \log \frac{S}{A_2} \text{ (dB)}$$

The absorption area of the receiving room A_2 is determined from the volume V_2 and the measured reverberation time T_2 . Note that a high value of the transmission loss is positive – not much sound is transmitted. Also note that transmission loss is a measure of attributes of the wall, not on the disturbing sound.

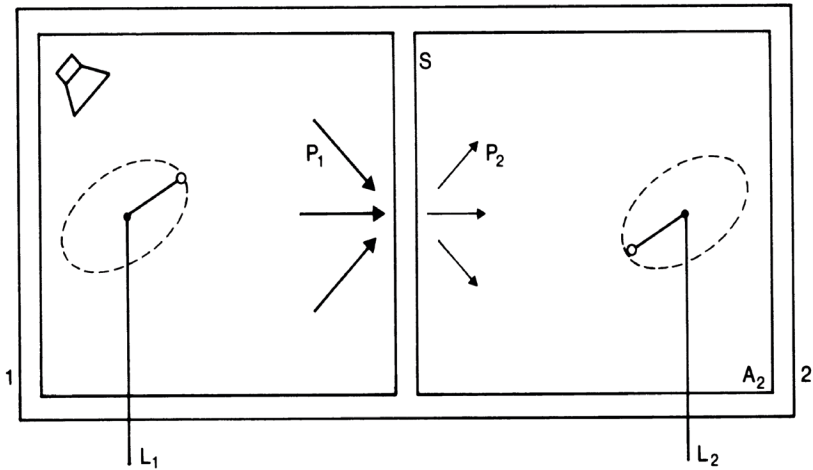


Figure 1 The sound transmission through a partition with area S . P_1 and P_2 are the incident and transmitted sound powers, L_1 and L_2 are the spatially averaged sound pressure levels in room 1 and 2, respectively. From Jens Holger Rindel, "Sound insulation in buildings", Note no4214, AT, Electrical Engineering, DTU, 2007.

The mass law expresses the airborne sound insulation of a plate in dependency of its mass per unit area. A very large uniform/homogenous plate of mass m per unit area is examined, as the resonant normal modes are disregarded. The plate is excited by a plane sound wave at normal incidence so all parts of the plate will move in phase and the bending stiffness can be disregarded. Under these idealized conditions the

transmission loss is dependent only on the mass m and the frequency f . The mass law is characterised by a 6 dB increase every time m or f is doubled.

The traditional constructions considered here are mainly made of timber. The situation is then more complicated than for the simple mass law case. At low frequency is there a mass law dependency, but for higher frequency the dependency is rather as two walls in series. The situation is even more complicated due the mechanical coupling due to the timber joists.

$$L_n = L_2 + 10 \log \frac{A_2}{A_0} \text{ (dB)}, A_0 = 10 \text{ m}^2$$

The impact sound pressure level L_n is a measurement for the sound transmission in a room when the floor in another room is influenced by a standardized tapping machine, see figure 2 and 3, where L_2 is the mean sound pressure level in dB re 20 μPa in the receiving room. A_2 is the equivalent sound absorption area of the receiving room, and $A_0 = 10 \text{ m}^2$ is a standardized area. Note here that a high value of the impact sound pressure level is negative – a large fraction of the sound power is transmitted.

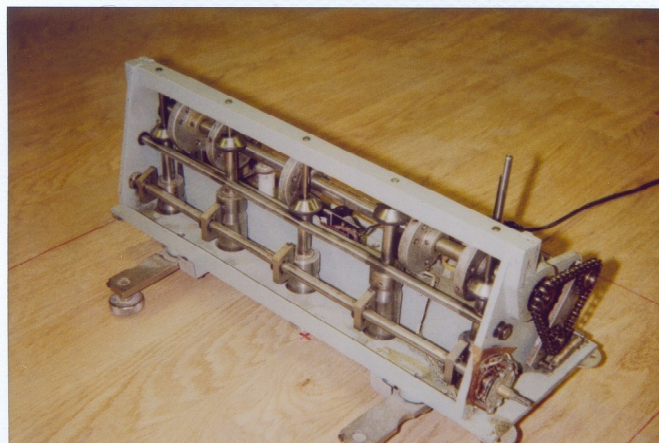


Figure 2 The tapping machine. Photo: Jonas Brunskog.

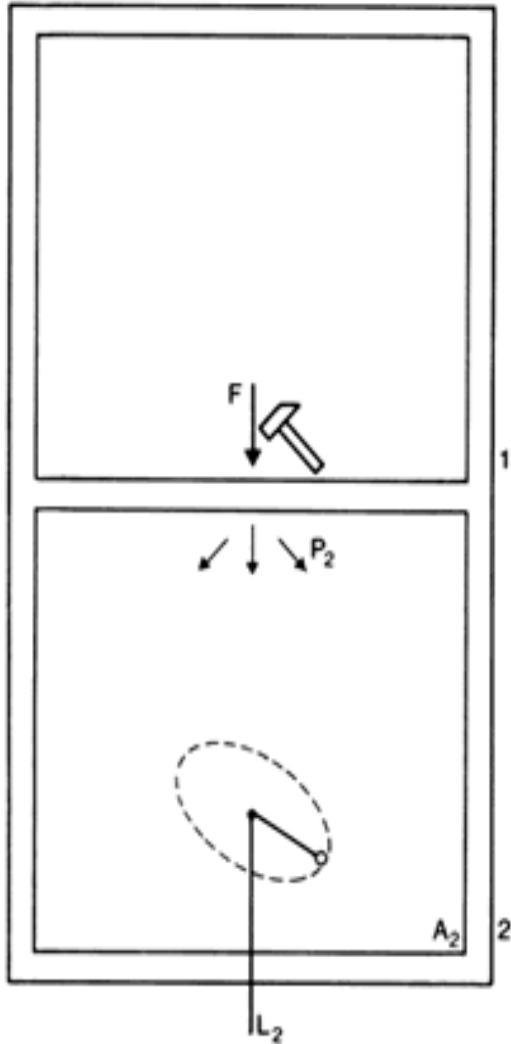


Figure 3 Principle of measuring the impact sound pressure level L_2 in the receiving room with an impact force F applied to the floor in the source room. P_2 is the sound power radiated to the receiving room that has the absorption area A_2 . From Jens Holger Rindel, "Sound insulation in buildings", Note no4214, AT, Electrical Engineering, DTU, 2007.

Impact sound is the major problem for timber based floor structures. For these types of floors, footsteps represent the primary source of disturbances. At low frequencies, the sound level is determined primarily by the person's body weight, foot weight, and number of steps per second. At high frequencies, the type of footwear is relevant, at least for hard surfaces. An important difference between the sound of footsteps and other sources of noise is that, even at low frequencies, footsteps produce a high degree of noise disturbance. As described above, the impact noise is measured with the standard tapping machine. Although the machine provides no genuine simulation of real footsteps, the test results obtained yield valuable information concerning the dynamic behaviour of the floor. The low frequency content of the excitation signal is problematic for the wooden joist floors – they have major resonances in the low frequency region, both the so called fundamental (mass-spring-mass) resonance with opposite phase of the two surfaces, and also structural resonances in the plates.

There is a national building regulation for sound insulation and noise control in Sweden today. It is based on a sound classification system. This system is based on two standards, SS 25267 and SS 25268, the former for dwellings and the latter for other buildings (schools, offices, etc). The sound classification system comprising four sound classes, A, B, C, and D. Class C is intended to be the minimum requirement in the national building codes. Classes A and B are recommended when the objective is a good sound climate, while Class D may be acceptable in certain rebuilding projects, and is the sound insulation of often found in the buildings from around the year 1900.

Overview of the historical development of building technology and sound insulation

In Scandinavia, all really old buildings are built with the load bearing floor structure in wood. These structures were naturally manufactured on site. In the cities the buildings were multi family and multi storey buildings. The material of the load bearing construction in the walls were masonry (brick or stone) or timber. The material choice was mainly depending on geographical and economical facts – e.g., in the south of Sweden masonry

is more common than timber, due to the lack of local timber. The wooden floor structure differs to some degree depending on the wall material: in the masonry houses the wood frames were often of larger dimensions. From about 1880 sawed timber was used [1]. The cavity between the timber joists was typically partly filled with saw dust or sand, sometimes on a so called blind floor.

Concrete floor started to be used in stone houses first in the 1930's. When the concrete floors started to appear, these gave a better fire resistance, better strength and also better sound insulation. At almost the same time building regulation started to appear in the Scandinavian countries, which were most easily fulfilled with the concrete floor, so the traditional way of building multi storey buildings disappeared [i].

For the walls, the traditional way of building with wood was to use solid timber, in the late period (about 1910 to the end of the 1930's) sawed timber of smaller dimensions. The wooden frame wall with sheets of boards or panel and a cavity in between is a modern phenomenon [i].

From measurements on these constructions, one can generally conclude that the masonry walls are without sound insulation problems (due to heavy weight and the mass law). The solid timber walls have generally low airborne sound insulation. The most problematic is however the impact sound insulation of the timber floors. The airborne sound insulation is generally accepted. A common rule of thumb is that if the impact sound is under control, then also the air borne sound insulation is under control. This rule was tested and confirmed by Bodlund [i]. When renovating these buildings these facts must be taken into consideration, as discussed more below.

The development in Denmark has been very similar to the Swedish one. One difference is that the variation in the construction design is smaller in Denmark; the typical floor structure consists of timber joist with a blind floor in the cavity. A layer of clay was used on the blind floor in order to improve fire resistance and sound insulation. In figure 4 an example of such a floor is shown. After about 100 years the clay is dry and the blind floor has partly collapsed. Not much of the fire resistance and sound insulation improvement then remains.



Figure 4 A Danish renovation project, before and after. Photo: Jens Holger Rindel.

Improvement of the constructions and modern timber constructions

As discussed above, the old timber based floor structures cause problems when renovating the buildings. Thus, the timber floors were still of interest even if they were no longer used in new built houses. In case of an extensive renovation the building regulations have to be fulfilled (in some periods there has been separate building regulations for these cases); it was then necessary to find ways to improve the sound insulation of these structures. An important reference is again Bodlund [i]. The improvement of the floor can be on top of the timber joist or below them, or a combination of both. The best result is often found if the improvement can be done below the joists, and the practical problems with e.g. doors are then also avoided. However, the improvement is done in another apartment than the one being the source, which might be a problem.

Due to the new function based building regulations in the 1990's, including the fire regulation was it once again possible to build multi story houses in wood and timber. There was then a lack in knowledge of how to build these houses. The sources to rebuild this knowledge came partly from North America, where timber frame is the dominating system used in multi-residential constructions. However, the knowledge from the renovation projects of the old timber houses were used, e.g. Bodlund [i]. From these improvements it is possible to learn how to build a proper new wooden joist floor structure. The Nordic Wood program [2] was financed by the Nordic Industrial Fund and industry in Sweden, Denmark, Finland and Norway, and was ongoing in the later half of the 1990's. In the first phase 6 different building sites (2 in Sweden, 2 in Finland and one each in Norway and Denmark) were built with timber frame multi storey, in collaboration between researches and industry. The two projects in Sweden were Orgelbänken in Linköping and Wälludden in Växjö [3]. Most of these buildings turned out to be successful in term of sound insulation, but to a high cost. However, they showed that it was possible to build with timber frame structures on site today with a high sound insulation as a result. The result of the project is described in [iii] and [4].

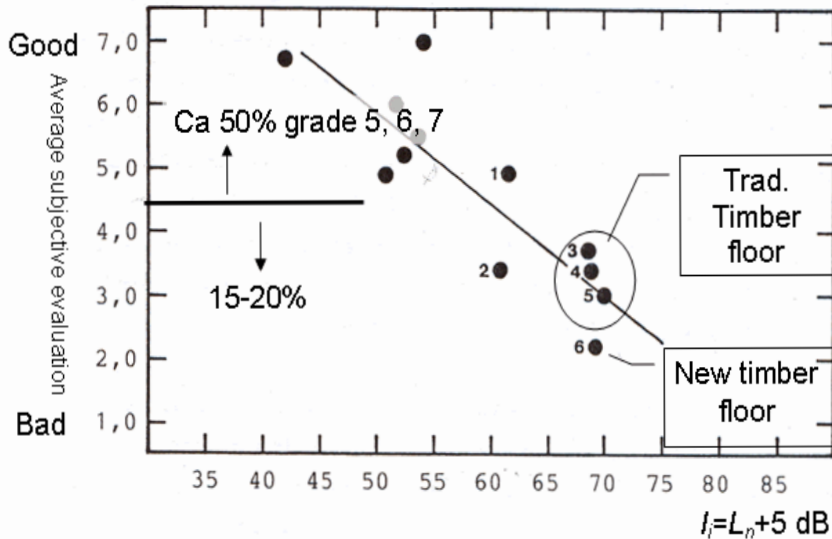


Figure 5 Subjective evaluation vs. impact noise level for floor structures. From [i].

Annoyance

Is one really disturbed by the poor sound insulation in the traditional timber based floors? This question was examined by Bodlund [i] using a questioner. Some of the results are shown in figure 5.

It is clearly seen the generally the traditional timber floor structures studied are considered too annoying: the floors 3-5 have an average grade of about 3-3.5 (grades from 1 to 7). So, yes, one is generally disturbed by the sound insulation of these buildings, and it is the poor impact noise insulation that is the problem. The sound of neighbours walking, moving furnishes or children playing is heard clearly, which is considered disturbing. It should be noted that this is a problem with the building – not with the neighbours – a fact of the habitants and others often forgets.

Conclusions

- The impact noise insulation in old buildings is often too poor.
- This impact noise insulation of typical timber floors can be improved. It is best to improve from below.
- The knowledge of how to improve old timber floors has been used to design new timber based floors.

- i Bodlund, K, Ljudisolering i ombyggnadsprojekt med träbjälklag, BFR Report R54:1987, Byggeforskningsrådet, 1987
- ii Thörnqvist, T and Thelandersson, S. (editors), 'Flervånings trähus', Nordic Wood, ISBN 91 85 576 369, 1997
- iii Hammer, P. Sound insulation in a multi-storey wooden house, Wälluden and Orgelbänken. TVBA 3084 A-B, Engineering Acoustics, LTH, Lund University, Box 118, SE-221 00 Lund, Sweden, 1996
- iv S. Hveem, A. Homb, K. Hagberg and J.H. Rindel: Low-frequency Footfall Noise in Multi-storey Timber Frame Buildings. NKB Nordic Committee on building Regulations, Report 1996:12 E, Helsinki, Finland 1996.



Sounds of history

What are the sounds of history? How has the soundscape changed throughout history? Every age has its own soundscapes. In an interdisciplinary symposium at *Sound Environment Centre* at Lund University in 2008, researchers from different disciplines gave their views on historic soundscapes and the sounds of yesterday. From archeological findings of prehistoric sound tools, acoustics in Roman Theatres, sound insulation in old buildings to old people's memories of sounds of yesteryear, this collection of texts gives samples of recent research on historic soundscapes.

Cajsa S. Lund * Jens Holger Rindel
Charlotte Hagström * Jonas Brunskog

Listening Lund - Sound Environment Centre at Lund University

Box 117, 221 00 Lund
Telefon 046-222 09 46.
www.ljudcentrum.lu.se