[IN]VISIBLE ARCHITECTURE

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[I N] V I S I B L E

A R C H I T E C T U R E

ABSTRACT

Sound is time, a series of vibrations for an interval of time transmitted through a medium. The experience of sound relies heavily on the architectonic "container" of the medium, shaping reverberation, perceived loudness and clarity.

Digital technology and simulation allow us to "see" what was before invisible to the human eye. Can these technologies allow for a new aural design language that will enrich the design process of everyday spaces?

In the "age of information", the notion of time is contracting, approaching instantaneous. The essence of temporal experience has been lost, replaced with immediate hyper-real visual stimulus. Our perception of space is a synesthetic experience involving all our senses, yet we continue to design mainly for vision. There is a reciprocal relationship between sound and vision. Sound first directs one's gaze, and vision can then inform one how to listen. This phenomenon is an increasingly crucial subject to study as one rarely experiences silence in any aspect of modern life.

Is there a hidden dimension of architectural design that lies beyond the visual experience of space? One that could both enhance and complement the visual, the human dimension of Cartesian space, as a temporal sensual experience? How does spatial acoustics alter one's architectural experience and can it spatially change the politics of engagement?

INTRODUCTION

Sound and acoustics are essential in the phenomenal perception of space. However, the main focus of architectural “production” is traditionally on a visual two or three dimensional representation of space. Acoustics do not trump visual aesthetics, but without considering the perceived sound of a space the important “hidden dimension” affecting the temporal use, cultural propriety and spatial cognition is lost. Imagine the experience of a Gothic cathedral without the associated long reverberations, or an extremely busy, but silent city street. In the previous examples a certain experiential aspect that creates the associated “atmosphere” vanishes.

“How does it really sound, when we walk through it. When we speak, when we talk to each other – what will the sound be?”¹

Sound and light both “illuminate” space, bringing a temporal and sensible condition to otherwise static tectonics. However, sound, unlike light, can be individually produced, allowing a direct spatial reaction to the audible actions of one’s body.

When talking about the relationship between sound and space one must recall how music has both been created in response to architecture and influenced its acoustic design. One example is Bach’s Saint Matthew Passion, which was written for the Thomaskirche in Leipzig, Germany. Predating sound-art and elevator music another example, Muzak, was invented in 1934 by Major General George O. Squier. It was an early attempt at utilizing sound as a controlling device for space, creating an “atmospheric architecture” that could alter mood and behaviour.

Beyond the democratic distribution of sound within common acoustic design practice, different music styles require different reverberation times. Whereas a choir may sound beautiful in a cathedral, a musical style with a much faster tempo would sound convoluted. This principle also holds true

for any audible communication. In everyday life we experience a multitude of "acoustic territories", a term developed by Brandon LaBelle, each with their own acoustic characteristics; the street, the subway, the atrium, the office, the home. We experience spatial acoustics as often as we make sound, move, walk and talk. A large part of our social interactions revolve around audible communication, bringing issues of privacy and projection. These can be inhibited or enhanced by acoustic design. In his book *'Spaces Speak are You Listening?'*, Barry Blesser mentions the concept of the meta-instrument; architecture as the resonant body outside of a musical instrument. When this concept is applied to the sound in all spaces, architecture can be regarded as a social meta-instrument.

Blesser's excellent research, compiled information and fundamental concepts of "aural architecture" will be used as a foundation and a departure point for the ideas expressed in this thesis. Situated between aural architecture, soundscapes, the hidden dimension and traditional acoustics, this thesis explores the contribution of the sense of hearing to one's cognitive mapping and perception of space, thus leading to a synesthetic synthesis of aural and architectural design. The fundamental concept of sound is vibration, which is both heard and felt by multiple sensory organs. Materiality will also be explored, its effect on acoustics and relationship with the sense of touch.

Ultimately, we ask can the acoustics of a space influence not only one's perception, but also the interaction and use of space? How does architecture and its experience differ when sound is a primary motive in the design process?

ENDNOTES

1 Zumthor, Peter. *Atmospheres*. Basel: Birkhauser, 2006, p. 31

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I would like to thank my parents, Carolyn Brown and Hugh Dysart, for their endless support and help over my six years of study at Carleton University. I would also like to thank all my friends and thesis advisor, Roger Connah, for their support and guidance over the last eight months.

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(http://static.nai.nl/nai_101/upload/images/97_f_txt.jpg) altered by
authour

Nigel Tufnel: The numbers all go to eleven. Look, right across the board, eleven, eleven, eleven and...

Marty DiBergi: Oh, I see. And most amps go up to ten?

Nigel: Exactly.

Marty: Does that mean it's louder? Is it any louder?

Nigel: Well, it's one louder, isn't it? It's not ten. You see, most blokes, you know, will be playing at ten. You're on ten here, all the way up, all the way up, all the way up, you're on ten on your guitar. Where can you go from there? Where?

Marty: I don't know.

Nigel: Nowhere. Exactly. What we do is, if we need that extra push over the cliff, you know what we do?

Marty: Put it up to eleven.

Nigel: Eleven. Exactly. One louder.

Marty: Why don't you just make ten louder and make ten be the top number and make that a little louder?

Nigel: [pause] These go to eleven.¹

This Is Spinal Tap (1984) American "mockumentary" featuring a fictional British heavy metal band "Spinal Tap"

In some sense [spaces] are human because they are human inventions. But it is one of the paradoxes of an animal endowed with intelligence, foresight, and language, that it can become its own animal trainer: it can invent conditions for itself that it cannot handle because it was not evolved to handle them. The aural architecture of our modern spaces trains those of us who occupy or inhabit them.²

Robin Fox (1997) Robin Fox is an Anglo-American anthropologist.

A BRIEF HISTORY

SOUNDS IN SPACE

01

The human experience of sound has evolved with technological innovation throughout history, specifically alongside architectural development. As primitive building practices evolved from huts built of organic materials, to acoustically reflective stone structures, the relationship between the experience of sound and space was dramatically altered and the notion of acoustics born (roughly around the beginning of the Bronze Age, 3300 BC). Humans existing before this period, without the experience of enclosed reflective spaces, would not have understood the currently common concepts of reverberation or echo.³ As permanent dwellings became more common the aural experience of space shifted from a primarily exterior non-reflective sonic environment (one reflective surface, the ground), to an interior reflective environment, providing an acoustic barrier and reverberation from hard surfaces (four or more reflective surfaces: floor, walls, ceiling). It was not until the Greek and Roman civilizations that the philosophical and scientific study of sound began, as cities and civic gathering spaces were primarily permanent stone (reverberant) constructions. As early humans did not understand reverberation, Greek and Roman architects had no knowledge of current electroacoustic amplification, utilizing only "natural" reverberation and resonance. However, in the 21st century, with highly advanced acoustic modeling

This statement does not suppose that early humans would not have heard echoes. Rather, the acoustics of caves held a certain mysticism that was often connected with mythology and religious ceremonies. It is impossible to tell how humans of that age actually understood acoustics, but without crucial scientific discoveries they would have perceived sound much differently than we do today.

The Hausa people recognize only two senses: seeing and experiencing (Ritchie, 1991). In this culture, the vision sense is only a means for navigating the environment, and the experiencing sense encompasses intuition, emotion, smell, touch, taste and hearing. The anthropologist Anthony Seeger (1981), in addressing cultural meaning of sensation, commented "just as time and space are not perceived by the vast majority of human societies as a regular continuum and grid, so the [sensorium] is rarely thought of in strictly biological terms... The five senses are given different emphasis and different meanings in different societies. A certain sense may be privileged as a sensory mode."

The Hausa people are a large ethnic group located in West Africa, primarily located in Nigeria.

programs and a substantial knowledge of the properties of sound, we seemingly ignore the acoustics of spaces not intended for musical reproduction. In order to comprehend how and why we have lost interest in the acoustics of everyday spaces and currently favour an ocularcentric view of space, one must examine the origin of the classification of the five senses.

Already in classical Greek thought, certainty was based on vision and visibility. 'The eyes are more exact than the ears,' wrote Heraclitus in one of his fragments (Fragment 101a). Plato regarded vision as humanity's greatest gift (Timaeus, 47b), and he insisted that ethical universals must be accessible to 'the mind's eye'. Aristotle, likewise, considered sight as the most noble of the senses 'because it approximates the intellect most closely by virtue of the relative immateriality of its knowing'.⁴

Pythagoras, the philosophical founder of the "science of sound"

Pythagoras founded the basic philosophy of the "science of sound" nearly 2500 years ago⁵, though Aristotle is credited with the first western classification of the commonly accepted five senses; sight, hearing, touch, taste and smell. However, the majority of philosophical studies of the senses, especially within architectural discourse over the years, have favoured vision. From Brunelleschi's invention of perspective to Le Corbusier's seminal, *Vers une Architecture*⁶, architectural design historically relies heavily on an ocularcentric approach to, and representation of, space. This may

be partially due to the relatively primitive nature of visual reproduction as compared to the technological complexity required for recording of sound.

Though historically a fair amount of architectural theory has focused on the sense of sight, the hierarchical model of the senses was not always as biased towards vision as it is in the 21st century.

The hierarchy [of the senses] was not the same [as in the twentieth century] because the eye, which rules today, found itself in third place, behind hearing and touch, and far after them. The eye that organizes, classifies and orders was not the favoured organ of a time that preferred hearing. (Robert Mandrou) ⁷

The preference of hearing over vision was primarily due to the common practice of aural communication. This relationship inverted when printed text and literacy became ubiquitous⁸. Prior to the invention of the printing press (before 1400's), large areas for aural communication were essential to civic life. In Vitruvius Polio's '*De Architectura*', the first known western architectural treaty, he outlines the importance of musical education of the architect and describes, in the fifth of ten books, the use of resonating vessels as natural amplification for civic gathering spaces such as amphitheaters.

The human eye, regarded as humanity's greatest gift.

Vitruvius Polio

Diaphragm Resonators: are generally light panels, perforated or not, mounted on a peripheral framework that is fixed to a wall, creating a hermetic space between the panel and wall. Subjected to an acoustic wave, the panel shakes under the spring effect of the air contained in the resonating space, transforming some of the acoustic energy into kinetic energy.⁷

An example of a Greek vessel that acted as a diaphragmatic resonator in ancient amphitheatres.

In the field of architecture, the use of resonators goes back to antiquity. The oldest Helmholtz-type resonators, called *echeas*, were used in Greek and Roman theatres. These resonators were described by Vitruvius... these *echeas*, or brass vases, were tuned to the fourth, fifth, and octave. Two types were used simultaneously.⁹

These vessels would have been tuned to specific frequencies corresponding to common musical scales of the time, exploiting the use of resonance as amplification. Placed strategically near the stage and throughout the seating area, these vessels would have amplified the direct sounds of the actors as well as the reflected and delayed sound reaching the audience. These would have produced an overall amplification as well as what we commonly call artificial reverberation.¹⁰ Further, there are examples of niches and chambers utilizing the principles of resonance as natural amplification, which have been integrated into ritual spaces dating as far back as 3500 B.C.

Paul Devereux and Robert G. Jahn (1996) studied six Bronze Age structures in Great Britain, dating from around 3500 B.C. Chambers of varying geometries and configurations were thought to have been used as sites for ritual, burial and other ceremonies. Regardless of the builder's intent, all six configurations manifested sustained, discernible acoustic resonances in the vicinity of 110 Hz, well within the vocal range of a male adult.

Devereux and Jahn (1996) suggested that such spaces would have enhanced male chanting in ritual ceremonies.¹¹

No documentation has been found that suggests these interior spaces were intentionally designed with specific acoustic properties to enhance ritual vocalization. Regardless of intention, the spatial resonances would have created natural amplification, increasing the loudness of the chanting.

Sundials and hourglasses were superseded by clocks that chimed the hours, using a synchronized hammer to strike a bell, and that thereby replaced a small visual arena with a much larger acoustic arena. For more than a century after chiming clocks were invented, they did not have faces or hands, which would have required literacy, proximity and illumination. (Daniel J. Boorstin, 1983)¹²

Example of an ancient sundial with an additional compass.

In this case the sonic event supersedes visual recognition. The sonic event alone can carry significance, or be utilized to direct one's gaze to gather further visual information. These "soundmarks" are the aural equivalent of landmarks. Their advantage lies in the fact that in an urban environment the area covered by a sound is much larger than a visible area, and is relatively independent of both direction and focused attention of the listener.

Wallace Clement Sabine

Wallace Clement Sabine (1922) commented while designing the Boston Symphony Hall, cultures that gathered in enclosed spaces for music developed musical forms dominated by melody and harmony, and cultures that gathered in open spaces for music developed musical forms dominated by percussive sounds with strong rhythms.³

$$T = \frac{V}{A} \cdot 0.161 \text{ s/m}$$

Sabine's formula:

T= reverberation time,

V= room volume,

A= total absorption area

In 1895 Wallace Clement Sabine, an American physicist, was credited with the transformation of acoustics "from philosophy to science and engineering,"¹³ for his acoustic remodeling of the Harvard Fogg Lecture Hall. Sabine's most notable achievement was the acoustic engineering of the infamous Boston Symphony Hall in 1900. Although Hermann von Helmholtz and Lord Rayleigh both published seminal books on the study of acoustics (respectively, '*On the Sensations of Tone*' and '*The Theory of Sound*')¹⁴, it was not until twenty two years after Sabine's death (1931) that the first treatise on architectural acoustics was written by Hope Bagenal and Alex Wood¹⁵.

Currently in the 21st century, advances in electro acoustic amplification and digital manipulation of sound allow acoustic engineers to replicate acoustic space virtually anywhere¹⁶. Traditional notions of architectural acoustics remain relevant, as they ultimately influence amplification systems, but the flexibility and high fidelity of these systems allow architects and engineers to create acoustic spaces otherwise impossible with utilizing natural resonance and reverberation alone. To a large degree, the visual and spatial impact of a building can be designed irrespective of the "hidden" acoustic characteristics of space. This has altered the traditional spatial and social politics of engagement of humans in space, from a direct to a virtual relationship.

According to Lefebvre, architecture and the emerging discipline of urban planning had succumbed to an emphasis on opticality, relying upon notions of the "visible" and "readable"... As a consequence, visions of the urban future were complicit with a mode of production that overwhelmed and overshadowed what Lefebvre termed the "tactile" and the "experiential". As Lefebvre argued, opticality essentially supports an understanding of space as inherently "abstract" thereby alienating the more organic intensities of everyday life from the sites of their occurrence.

ENDNOTES

1 (Blesser and Salter, *Spaces speak are you listening?*, 4)

2 (Augoyard and Torgue, *Sonic Experience*, 102)

3 (Blesser and Salter, *Spaces speak are you listening?*, 144)

4 (LaBelle, *Acoustic Territories*, 224)

1 (<http://www.imdb.com/title/tt0088258/quotes>)

2 Blesser, Barry, and Linda-Ruth Salter. *Spaces Speak, are you listening?: experiencing aural architecture*. Cambridge: The MIT Press, 2007, p. 347

3 Ibid., 75 - "Early humans, when exposed to echoes (sound reflections) in a cave, would have felt they were hearing the sounds or even voices of spirits from a world beyond the cave wall." (Waller, 2001)

4 Pallasmaa, Juhani. *The Eyes of the Skin: architecture and the senses*. Chichester: John Wiley & Sons Ltd, 2005, p. 15

5 Blesser and Salter, *op cit.*, 296 - "Frederik Vinton Hunt (1978) noted that Pythagoras (570-497 B.C.) the founder of the science of sound, music, and vibrating strings..."

6 "Architecture is the view of an object in space from the eyes of man. It creates a spectacle where it takes an onlooker and puts him in front of the *paysage*: the architectural landscape. (Le Corbusier, 1947)

7 Pallasmaa, *op cit.*, 25 - (Jay 1994, p 34-5)

8 Ibid., 24 - "The shift from oral to written speech was essentially a shift from sound to visual space, and that 'print replaced the lingering hearing dominance in the world of thought and expression with the sight-dominance which had its beginning in writing' (quoted from Walter J Ong, *Orality & Literacy - The Technologizing of the World*, Routledge (London and New York), 1991, p.117, p.121

9 Ibid., 104

10 Augoyard, Jean-Francois, and Henry Torgue. *Sonic Experience: a guide to everyday sounds*. Translated by Andra McCartney and David Paquette. Montreal: McGill-Queen's University Press, 2008, p. 104 - "The vases placed beside the stage, close to the actors... were used for amplification at the source... The vases placed near the audience, produced a Haas effect... artificial reverberation."

11 Blesser and Salter, *op cit.*, 76 + 59 - Saint Werburgh in Chester, England rebuilt in 13-14th century. "The shrine's six recesses, where kneeling pilgrims would insert their heads while pleading their petitions, serve both as amplifiers and as filters, giving the petitioners' voices dramatic and emotional emphasis with only modest vocal effort." As described by Lubman (2004) 59

12 Ibid., 29

13 Ibid., 79

14 Hermann von Helmholtz published 'On the Sensations of Tone' in 1862, which was an accumulation of his lifelong study of hearing, acoustics and human perception of music. Lord Rayleigh published 'The Theory of Sound' in 1877, which describes the fundamentals of acoustic science, some of which is currently used in algorithms to compute acoustics. However, neither publication outlines architectural acoustics specifically. This information was derived from chapter 1 of Charles M. Salter's *Acoustics*.

15 Hope Bagenal and Alexander Wood. *Planning for Good Acoustics*. London: Methuen, 1931

16 Blesser and Salter, *op cit.*, 166 - "In the world of virtual spatiality, acoustic space and sound location are no longer based on the laws of physics; acoustic objects can change their size and location instantly. Acoustic space and sound location have become as dynamic as the sequence of notes in the composition."

02

(<http://wink.nixone.com/wp-content/uploads/2008/10/img2491.jpg>)
altered by authour

I used to write,

I used to write letters I used to sign my
name

I used to sleep at night

Before the flashing lights settled deep in
my brain

But by the time we met

By the time we met the times had already
changed

So I never wrote a letter

I never took my true heart I never wrote
it down

So when the lights cut out

I was left standing in the wilderness
downtown

Now our lives are changing fast

Now our lives are changing fast

Hope that something pure can last

Hope that something pure can last

*(Arcade Fire, The Suburbs, We Used To
Wait, 2010)*

"Sensory skills are acquired, rather than
innate; they are based on personal utility
and lifestyle."¹

"On the one hand, just as light sources are
required to illuminate visual architecture,
so sound sources (sonic events) are
required to "illuminate" aural architecture
in order to make it aurally perceptible."

*(Barry Blesser, 2007)*²

THE HIDDEN DIMENSION

PROXEMICS AND THE POLITICS OF ENGAGEMENT

02

The title of this chapter comes from the social anthropologist Edward T. Hall's influential 1966 book '*The Hidden Dimension*'. This is where Hall first demonstrated the social interaction of people at different established, but invisible, socio-cultural distances. Hall believed that virtually all human existence, specifically social interaction, is associated with the experience of space³. He established four social spheres that estimate the comfortable and socially acceptable distance to engage in intimate, personal, social and public interaction. The following is a brief summary of Hall's social spheres, which may be altered, "with differences in personality and environmental factors. For example, a high noise level or low illumination will ordinarily bring people closer together."⁴

Ray Charles never used a cane for navigating space.¹

Edward T. Hall

A diagram depicting the relative distances of E.T. Hall's social spheres.

Intimate Distance

"At an intimate distance, the presence of the other person is unmistakable and may at times be overwhelming because of the greatly stepped-up sensory inputs. Sight (often distorted), olfaction, heat from the other person's body, sound, smell and feel of the breath all combine to signal unmistakable involvement with another body."

Close Phase (0-6 in)

Sharp vision is blurred and vocalization plays a very minor part in communication.

Far Phase (6-18 in)

Vision remains distorted but vocalization at a very low level is used. Crowded areas force strangers into this social distance, who strip the intimacy from the situation by remaining as immobile as possible.

Personal Distance

"It might be thought of as a small protective sphere," the personal bubble.

Close Phase (1.5 - 2.5 feet)

Vision is no longer distorted, but three-dimensionality is pronounced. Touching the other is possible.

Far Phase (2.5 - 4 feet)

Sharp vision covers an area the size of one eye. The voice level is moderate. Touching with outstretched arms is possible.

Social Distance

(Close: 4-7 feet, Far: 7-12 feet)

The spatial "limit of domination." The voice level is normal, heard at a distance of up to twenty feet.

Public Distance

"Well outside the circle of involvement."

Close Phase (12 -25 feet)

"An alert subject can take evasive or defensive action if threatened." The voice is loud and grammatical or syntactic shifts in language may occur.

Far Phase (25 + feet)

"Thirty feet is the distance that is automatically set around important public figures."

John F. Kennedy

In the 21st century there are new factors influencing social interaction that were not present during the original social studies of E.T. Hall. Although the telephone had been invented, Hall did not examine its effect on social interaction. It wasn't until 1973 that the first consumer cell phone was released, which began the progression towards a "digital distance" present in the 21st century, internet and wireless communication. Through this new "digital distance", people can interact, in any place and at any time, as they would at a *"personal"* or *"social distance"*. However, the communication is limited to the senses of vision and hearing. Although technology such as live video chat (Skype) and smartphones allow for both visual and aural communication, we have noticed that visual communication, by means of text and images, is currently favoured. This is due in part to the associated costs and time. A short text message takes less time than a phone call and allows for the sender to simultaneously participate in other forms of social interaction. With the development and refinement of these technologies, social communication has been expedited and separated from physical human contact. Further, we have noticed a growing popularity of instant text messaging, a decline of phone calls and an increase in social planning through social media websites (Facebook). The interface between the user and these

Sample iPhone text message conversation

Live video chat, via high-speed internet connection

technologies is primarily visual, with a screen. This further demonstrates the current condition of the 21st century, of depthlessness, hyper-ocular centrality, the loss of temporality and physical proximity⁵. How did we get to this point?

The following chronological compendium of projects illustrates the progression of technological innovations that have shaped the way in which we currently perceive sound, acoustics, interact socially and design space.⁶

CHRONOLOGICAL VISUAL MAP TO THE HIDDEN DIMENSION

Prehistoric – 0

- Cave paintings, Prehistoric
- Bronze Age ritual chambers (natural resonance), 3500 B.C.
- Pythagoras, philosophical “science of sound”, 570-497 B.C.
- Mo-Ti, first mention of camera obscura, 400’s B.C.
- Aristotle, Classification of senses, 384-322 B.C.
- Euclid, Optics, 300 B.C.
- Vitruvius, De Architectura (Helmholtz-type resonance), ~ 27 B.C.

Cave painting, France, ~ 15000 B.C.

0 – 1799

- Filippo Brunelleschi, Invention of perspective, 1400’s
- Rene Descartes, La Geometrie, 1637
- Robert Boyle, sound waves require a transmission medium, Mid-17th century

2 point perspective drawing

1800 – 1900

- Joseph Sauveur, introduction of acoustics as term for science of sound, Early 18th century
- Sir Isaac Newton, attempts to determine speed of sound in air, 1735
- Pierre Simon, equation for calculating speed of sound, 1816
- Auburn State Prison “silent system”, 1821
- Charles Bullfinch, fabric to mitigate echoes, 1822
- John Scott Russell, isacoustic curve, 1839
- Joseph Henry, precedence effect, 1850
- Hermann von Helmholtz, psychoacoustics, *On the Sensations of Tone*, 1862

In 1821 Auburn State Prison instituted its “silent system”... Silence in this regard functioned as an absolute form of surveillance, control, and isolation, to confine the criminal body not only behind walls but also within an entirely restrained environment... From insanity one arrives in the padded cell, which is silence made complete by the removal of even the slightest reverberation-the padded cell is an acoustically dead space, where even the movements of one’s own body is void of echo.²

Boston Symphony Hall, crosssection

- Alexander Graham Bell, First telephone + microphone, 1870's

- Thomas Edison, Phonograph, 1877

First recorded sound

- Lord Rayleigh, *The Theory of Sound*, 1877

- Louis Le Prince, first film camera, 1888

- Max Planck, suggestion that light may be quantized, 1899

- Wallace Clement Sabine, Boston Symphony Hall, 1900

1901 - 1934

- Reginald Fessenden, first radio broadcast, AM, 1906

- Sabine, first acoustic tile, 1920

- Buckminster Fuller 4D tower, 1920's

Proposed communication technology integrated with affordable housing

- Le Corbusier, 'Vers Une Architecture', 1923

- Warner Brothers, first full-length movie with synchronized sound, 1926

- Erwin Panofsky, *Perspective as Symbolic Form*, 1927

- Paul Sabine, first sound level meter, 1930's

- Hythe Sound Mirrors, 1930's

Attempt to aurally connect England and France with large reflective discs

- Hope Bagenal and Alex Wood, first treaties on spatial acoustics, 1931

- Muzak, sound as emotional and spatial control, 1934

1935-1969

- First regular TV broadcasting, Berlin, 1935

- Les Paul and AMPEX, multi-track recording, 1940's

- Disney, *Fantasia*, 1940

First popular multichannel audio-visual display

- Zeiss, first "fixed" eye-level pentaprism 35mm SLR, 1949

Hythe sound mirror

- Karl Kryter, *The Effects of Noise on Man*, 1950's

- Constant's New Babylon, 1958

Proposal of spatial division with mood and ambience

- Iannis Xenakis, Philips Pavilion, 1958

Edgard Varese's installation of 350 loudspeakers

- Gaston Bachelard, *The Poetics of Space*, 1958

- LASER, 1960

- E.T. Hall, *The Hidden Dimension*, 1966

- Marvin Camra, sound/spatial boundaries experiment, 1968

Reproduction of "sound space" with only speakers

- Stanley Kubrick, *2001: A Space Odyssey*, 1968

- Stockhausen's concert in the Grotto in Lebanon, 1969

Exploiting the natural resonance and reverberation of a large cave

Constant's New Babylon

Philips Pavilion

1970 - 1989

- Osaka World fair 1970

German Pavilion, Xenakis 12 channel audio

- Leo Beranek, Boston Symphony hall acoustic simulation, 1970

- IRCAM, Pierre Boulez, 1970

Institute for Music Acoustic Research and Coordination

- Barry Blesser, Commercial digital audio signal-processing and artificial reverberation, 1970's

- Nolan Bushnell, first video game, Pong, 1972

- Motorola, First cell phone, 1973

- Louis Kahn, The National Assembly Building of Dhaka, 1974

- IBM, first consumer computer, 1975

- Piano + Rogers, George Pompidou Centre, 1977

- Hank Bull, Wiencouver, 1979

Pepsi Pavilion, Osaka World Fair 1970

Advertisement for first cell phone

First Sony Walkman

The legacies of electroacoustic music and sonic art since the 1950's still echo in contemporary practices that put to use sonic-spatial understanding. Forms of current sound practice often incorporate or presuppose sensitivity to architecture, and to questions of locational sound in general, leading to an overall recognition of sound's potent ability to act spatially. This has found additional application in the use of surround sound technology in cinema and home theater systems since the 1990's, making multichannel audio available for general use.⁵

Sound shower, Oslo

First iPod, Apple

Early technological communication project between Vienna and Vancouver

- Sony, Walkman, 1979
- Autodesk, AutoCAD, 1982
- Compact Disc, 1982
- Surround Sound for commercial movies, THX 1983

Response to stereo spatial deficiencies

- Jonty Harrison, BEAST sound diffusion, 1988

30 channel audio, virtual acoustics

1990 - 2000

- Kodak, first commercially available fully digital SLR, 1991

- Korenaga and Ando, 1993

General simulator for picking concert seats

- MP3, 1993
- Commercially available Internet, 1995
- Stuart Dempster, Cistern Chapel, 1995

Trombone recording in an empty 186 foot diameter water tank. 45 sec. reverberation

- Vito Acconci's Talking house, 1996

Exterior amplification of the interior of a suburban home

- Oslo Airport Sound Showers, 1998

Acoustic break from ambient noise. Utilizing sound focusing discs

- Peter Zumthor, Swiss Sound Box, 2000

2001- 2006

- Apple, iPod, 2001
- Daniel Libeskind, Jewish Museum, memory void, 2001

Reverberation of metal plates in a concrete void

- Blackberry smartphone 2002
- Sonic City Project, 2002-2004

Swedish experimental recordings of walks through Gothenburg

- Skype, 2003
- Peter Cook, Kunsthau Graz, media façade, 2003
- Henrik Wann Jensen, photon mapping, 2004
- Howard Stapleton, The Mosquito, 2005

High frequency audio repellent for loitering

- Positive soundscapes, 2006

British academic study of sound in public life

Kunsthau Graz

2007 – Present

- Apple, iPhone, 2007
- Autodesk, Revit as industry standard BIM, 2008
- Disney - Pixar, *Toy Story 3*, first movie with 7.1 surround sound, 2010
- Papa Sangre, 2011

iPhone game that utilizes only sound. Real-time binaural audio calculation.

- LG, Hyper façade, 2011
- Electric Fields + Polytectures, 2011

Multiple "musical" performances + a sound walk, exploring the relationship between sound and space

- Janet Cardiff: Forty-Part Motet, 2012

Sound sculpture, 40 channel audio recording and playback of a choir performance

- Sony's new personal 3d viewer, 2012

Personal 3D sound and video

First iPhone, Apple

Personal 3D viewer, Sony

As demonstrated in the above chronological mapping, technological innovation has become increasingly spatial and immersive. However, around the release of the Apple iPod a focus on personal audio and visual space emerged. This focus is pushed to the extreme with Sony's personal 3D viewer, which is a portable headset that provides surround sound and three-dimensional high-definition video, completely immersing an individual in a virtual audio-visual experience.

A generation that grew up with television, movies, computers, and video games has an elevated need for "eye candy", something to occupy vision while listening. Thus musical space has become only one of the many spaces in a total "audio-video" environment.⁷

First Gameboy, Nintendo 1989

From personal experience, I have found that when sight is omitted, as in a completely dark room or blindfolded, this desire for "eye candy" is not present, as there is nothing to "tease" or distract the eye. However, as soon as there is some form of visual imagery, our attention is drawn to the visual stimulation and attempts to create a connection to other sensory input. This elevated need for audio-visual stimulation may have been further emphasized by music videos and portable media players, in which visual imagery is always associated with sound. Justin Davidson, a classical music and architecture critic, argues that the Apple iPod, and similar MP3

players, have altered the spatial relationship between music, performance and listening.

Today, the environments that music occupies have gotten either very small or very large: the aural isolation of headphones or the anonymity of the stadium. Live, unamplified music still exists in cloistered precincts of the concert hall... But for much of the world, music has become either a solitary experience or a form of mass ritual. Yet the history of music is inseparable from the history of places where people gathered. (Justin Davidson, 2005)⁸

iPod advertisement

Though the iPod has recently altered the space of musical listening, Muzak was the first spatial manipulation of music. The Muzak Corporation was originally developed in 1934 by Major General George O. Squier as a form of "atmospheric architecture" to reduce the monotony of assembly line work.⁹ Since then it has taken a similar but inverted approach to music videos, of associating sound to visual imagery or space. However, the goal is to commercialize and increase the total aestheticization of social space.¹⁰ This integration of sound with space is deceptive. Rather than working harmoniously with architectural design to improve the sensual experience of space, it attempts to capitalize and aestheticize the invisible and hidden dimensions of architectural experience, masking acoustics and one's relationship with a space.

.....As Jonathan Sterne notes in his account of programmed music in the Mall of America, "music becomes a form of architecture. Rather than simply filling up an empty space, the music becomes part of the consistency of that space. The sound becomes a presence, and as that presence it becomes an essential part of the building's infrastructure." (Jonathan Sterne, *Sounds Like the Mall of America: Programmed Music and the Architectonics of Commercial Space*. *Ethnomusicology*, vol.41, no. 1 [winter 1997]: 23⁴

1889 Patent drawing for gramophone. The gramophone was developed by the Canadian, Emile Berliner. It used 5 inch discs. The phonograph, existing at the same time, utilized cylindrical "records."

The control room of a modern recording studio. Currently the majority of music is recorded digitally. Digital recording allows for greater flexibility, manipulation and processing of recorded and synthesized sounds than magnetic tape or vinyl recording techniques.

All of these studies, projects, and technologies contribute to the understanding of the "hidden dimension" of architectural experience. As an assemblage they have changed our perception of the possibilities of communication in space. For example, one can carry an orchestra in the pocket, or virtually attend a business meeting in a public park. The aforementioned technologies have also questioned the type and amount of space needed for social gathering, something historically performed by architecture. Although novel electroacoustic amplification techniques allow virtually any acoustic space to be reproduced in any building, the systems are prohibitively expensive and only utilized for important music venues. The majority of spaces we experience are not intended for musical reproduction and do not incorporate any kind of spatial amplification beyond a PA system. Further, even with the ability to recreate acoustics, room geometry and materials play an important part in the perception of sound in every space. The program, size and materiality of musical and audio-recording venues have been affected by electroacoustic technology. However, the majority of spaces in which we commonly aurally communicate have not been studied. In order to understand how geometry, materiality and basic acoustic principles can influence the design of non-musical space, one must examine the phenomenological experience and perception of space.

ENDNOTES

1 Blesser, Barry, and Linda-Ruth Salter. *Spaces Speak, are you listening?: experiencing aural architecture*. Cambridge: The MIT Press, 2007, p. 41

2 Ibid., 15

3 Hall, Edward. *The Hidden Dimension*. New York: Doubleday & Company, Inc., 1966, p. 171 - "Virtually everything that man is and does is associated with the experience of space. Man's sense of space is a synthesis of many sensory inputs: visual, auditory, kinesthetic, olfactory, and thermal."

4 Hall, *op cit.*, 110-117

5 As cited in Pallasmaa, Juhani. *The Eyes of the Skin: architecture and the senses*. Chichester: John Wiley & Sons Ltd, 2005, p. 30 - "The ocular bias has never been more apparent in the art of architecture than in the past 30 years, as a type of architecture, aimed at a striking and memorable visual image, has predominated... David Harvey relates 'the loss of temporality and the search for instantaneous impact' in contemporary expression to the loss of experiential depth. Fredric Jameson uses the notion of 'contrived depthlessness' to describe the contemporary cultural condition and 'its fixation with appearances, surfaces and instant impacts that have no sustaining power over time.'" (Harvey, *The condition of post-modernity*, 58)

6 The information used to create this timeline was derived from all books contained in the bibliography.

7 Blesser and Salter, *op cit.* 205

8 Ibid., 214

9 LaBelle, Brandon. *Acoustic Territories: sound culture and everyday life*. New York: Continuum, 2010, p. 172 - "With the development of Muzak (originally by Major General George O. Squier, a decorated veteran and then Chief Signal Officer of the United States Army), locating appropriate music within the workplace became a dynamic reality. Reorganized in 1934 as the Muzak Corporation, the company operated through the use of electrical cabling (later replaced by telephone wire), sending out programs of recorded classical compositions to workplaces."

10 Ibid., 186 - "The legacy of Muzak has instigated more contemporary approaches towards scripting space acoustically. Audio branding and sonification are currently active design strategies dramatically participating in the total aestheticization and crafting of contemporary social space."

1 Blesser and Salter, *Spaces speak are you listening?*, 39

2 LaBelle, *Acoustic Territories*, 68-71

3 LaBelle, *Acoustic Territories*, 166-7

4 LaBelle, *Acoustic Territories*, 147

(Holm, Lorens. Brunelleschi, Lacan, Le Corbusier: architecture, space and the construction of subjectivity. London: Routledge, 2010, p.95)+(http://www.paladium.net/00g/Brain01_public-domain-medical-brain-p.jpg)+(http://img1.etsystatic.com/il_fullxfull.281782441.jpg) altered by authour

I am the key to the lock in your house
That keeps your toys in the basement.
And if you get too far inside
You'll only see my reflection.
It's always best when the candle's out,
I am the pick in the ice.
Do not cry out or hit the alarm,
You know we're friends 'til we die
And either way you turn
I'll be there
Open up your skull
I'll be there
Climbing up the walls

(Radiohead, Ok Computer, Climbing Up the Walls, 1997)

"We shape our buildings, and afterward
our buildings shape us."

(Winston Churchill, 1943)

"Our skin is actually capable of
distinguishing a number of colours; we do
indeed see by our skin."

(Lauretta Vinciarelli, 1998)¹

"Auditory and tactile imagination
activated visual substrates. Similar cross-
modal reorganization has been found in
deaf individuals."

(Anne G. De Volder and colleagues, 2001)²

"My perception is [therefore] not a sum
of visual, tactile and audible givens: I
perceive in a total way with my whole
being: I grasp a unique structure of the
thing, a unique way of being, which speaks
to all my senses at once."

*(Maurice Merleau-Ponty, Sense and Non-
Sense, 1964)³*

PSYCHO [ACOUSTICS]

ACOUSTICS PHYSIOLOGY PERCEPTION

03

Herman von Helmholtz (1821-1894), a German physicist credited with the invention of modern psychoacoustics, categorized hearing into three stages: physical sound, sensory detection and transformation into a perception.⁴ In order to understand the last stage of hearing, perception, one must first examine the nature of acoustics, and the physiological human response to sound.

Herman von Helmholtz

We will thus go on to examine the physiology and interrelated influence of vision and hearing on spatial perception. The main focus will be on hearing and the perceptual synthesis of these senses to create cognitive strategies for interpreting space. We begin with a basic description of acoustics, as they pertain to "waves" and the experience of space.

CYMATICS: The study of visual sound and vibration. The above patterns are created with a fine sand placed on a diaphragm stretched over a speaker. As the frequency and waveform of the sound change, different patterns emerge in the sand. This was first recognized by Galileo, later studied by Chladni in 1787. Hans Jenny published *Cymatics: The Study of Wave Phenomena* in 1967, from which these images are taken.

Similarly, acousticians utilize speakers that create pure tones of a set frequency to measure the invisible sound forms present in a room. These are called room modes. They represent the peaks and troughs of reverberating sound within a space.

Drawing of room modes

ACOUSTICS

According to Barry Blesser, "sound is actually more complex than light for three simple reasons. First, light waves move instantaneously, whereas sound waves more relatively slowly. Second, the highest frequency of visible light is less than 2 times as great as the lowest, whereas the highest frequency of audible sound is 1000 times greater than the lowest. Third, relative to the size of object and surface variations, the wavelength of light waves covers an extremely narrow range, whereas the wavelength of sound waves covers a wide range... For these reasons it is easier to simulate, record, and analyze a visual space than an aural one."⁵

These three differences between light and sound waves are important to architectural acoustics and the perception of space. Sound and light both behave as a wave. They are both measured in Hertz (Hz), which is the frequency of wave oscillations per second, and by wavelength. Therefore, there are several similarities between the interaction of light and sound with space.

REFLECTION – sound + light

Both sound and light behave similarly to reflective materials, such as the equality of the angle of incidence and the angle of reflection. However, aurally reflective materials are not always reflective for light waves, and vice versa. The reflection of sound and light are both dependent on surface texture, density and porosity of a material. In general, smooth and hard surfaces best reflect sound and light, but light reflection is also dependent on surface colour, whereas sound is not affected by colour or illumination. For example, a smooth, soft and white material will reflect light but absorb sound.

Barry Blesser states that, "a sound reflecting surface is the aural equivalent of an opaque wall a spatial boundary, a **spatial reducer**."⁶

The common term for the collection of "late" sound reflections is reverberation. Reflected sound contributes to the perceived acoustic "brightness" or "liveliness" (many early sonic reflections) of a space. Likewise, reflected light contributes to the ambient brightness of a space. However, a space that is too reverberant degrades the intelligibility of conversation and spatial localization of sounds. Additionally, Barry Blesser suggests that both acoustically and visually non-reflective spaces are perceived as "dull" and uninviting⁷.

Diagrams displaying the angles of received sound reflections.
a= Shoebox
b= Fan
c= Reverse Fan

A reverse fan shaped auditorium reflects more sound waves back to the audience earlier than a shoebox or fan shape.

ABSORPTION – sound + light

Following Blesser's argument, "sound absorption is an aural **space expander**. Complete sound absorption would simulate a virtual window into an infinite, unbounded space, a space without the ability to respond to sonic illumination."⁸

Chart describing the sound insulative properties of varying thicknesses of wall assemblies.

Ambient sound and light are both affected by the presence of absorptive materials. Materials that provide sound absorption differ depending on the frequency range of the source sound, whereas light absorption is mainly dependent on surface colour and reflectivity. As outlined in Jean-Francois and Henry Torgue's '*Sonic Experience*', diaphragmatic absorbers (thin panels that vibrate in tune with a certain frequency) are best for attenuating low-frequencies, mid-range frequencies are best attenuated with Helmholtz-type resonators (volumes with openings that allow sound to be trapped), and high-frequencies are best absorbed by porous and fibrous materials.⁹

DIFFUSION – sound + light

According to Charles Salter's book '*Acoustics*', sound and light diffusion occurs when the reflected wave, "is fragmented into many reflections that have less intensity, which are scattered over a wide angle."¹⁰ Though sound and light diffusion are both influenced by geometry and surface texture, only light diffusion is sensitive to colour and transparency.

Example of a sound diffusion panel

RESONANCE – sound

Resonance is a spatial phenomenon specific to sound. Because light wavelengths are very short, they do not approach distances commonly found in buildings, as the longer wavelengths of sound do.

As outlined in '*Sonic Experience*', "the resonance effect refers to the vibration, in air or through solids, of a solid element. The production of resonance requires a relatively high acoustic level and a concordance between the exciting frequency and the object put into vibration."¹¹

Room resonance is perceptible when the wavelength of a sound is a fraction of the distance between two acoustically reflective walls. If a wavelength is the same as the distance between two walls the amplitude (loudness) will be increased at the location of the wave peak. This amplification gradually decreases as the

Example of standing wave patterns within a room. A key component to determining room modes.

Diagram displaying the focusing nature of curved geometry.

Diagram displaying the focusing nature of an ellipse, at the two foci.

wavelength becomes $1/2$, $1/3$, $1/4$ etc. of the distance between reflective surfaces. However, as the fractional proportion decreases, the amount of amplified peaks increases. The mapping of these peaks is referred to as "room modes". Small acoustically reflective spaces, such as shower stalls, exemplify room resonance. This contributes to the increased likelihood of someone to sing in the shower. The running water acoustically masks mistakes, while resonance amplifies the exterior perception of one's own voice.

GEOMETRY

Barry Blesser explains that, "large spaces have statistical uniformity over the entire frequency range, whereas smaller spaces have individual low-frequency resonances that dominate. The transition threshold between statistical uniformity and discrete resonances, called the "Schroeder frequency" (Schroeder, 1996), is simply much higher in a small space."¹²

Although surface materials contribute heavily to the reverberation of space, it is the geometry of space that influences a room's tonal character (signature filtering and amplification of certain frequencies) and direction that reflected sound will reach the ear. In general, larger spaces have longer reverberation times than small rooms. Another quality that affects the acoustic

signature of a space is the "mixing time", which is dependent upon the distances among all interior surfaces. This is the length of time for the reverberation of multiple sound sources to perceptually fuse. Rooms that resemble a square, in plan, will have a faster mixing time than those resembling a rectangle.¹³ Additionally, geometric irregularity in room surfaces decreases mixing time and increases sonic diffusion.

Selective location of geometric focal points can be used in architectural design to diffuse or focus sound. Curved room geometry heavily influences the sonic signature and the focusing of ambient sounds in a space. With a curved acoustically reflective surface, the sound source will be focused at a distance equal to the center of the curve's radius, and at an equal horizontal distance from the center plane of reflection. In an ellipse, sound is focused in the two foci points, whereas in a sphere or circle, sound is focused in the center. Blesser describes geometry's influence on sound through a common exhibit in science centres, "with two parabolic acoustic mirrors set 100 meters apart... A speaker at one focus easily communicates with a listener at the other. Two widely spaced areas are acoustically fused into a single area."¹⁴

Overview of the affects of geometry on sound.

PERCEPTION

"The spatial relation between two diverse sensory experiences is wholly one of meaning" which according to E.T. Hall's notion of proxemics, is culturally specific and learned.¹

Blesser suggests that the majority of our perception is subconscious, because it is controlled by our limbic system (the emotional brain). The limbic system is what provides links between memories, past experience and the present, a key component to perception.¹⁵ Although our common view of the senses fits within a categorical list, such rational distinctions do not exist in the synesthetic realm of perception. In his book *'The Eyes of the Skin'* Juhani Pallasmaa mentions the psychologist James J Gibson, who re-classifies the senses as synthetic systems.

"The psychologist James J Gibson... categorises the senses in five sensory systems: visual system, auditory system, the taste-smell system, the basic-orienting system, and the haptic system."¹⁶

James Jerome Gibson

Following Gibson's theory, the modern understanding of spatial perception begins with systems, which may consciously be biased toward one Aristotelian sense, but subconsciously synthesize information from all senses.¹⁷ Although the visual system is primarily informed by vision, the understanding of the visual data is derived from aural, tactile and olfactory experience. Similarly, the information received by the auditory system is primarily from hearing, but the sounds are interpreted with past visual, tactile and olfactory experience. These systems

are dynamic, subjective and abstracted representations of one's environment.¹⁸ One's internal representation of the external world is not mathematically accurate or perfectly consistent. However, these systems better describe the inherent connectivity between the five senses and one's perception of space.

THE EYE: VISUAL SYSTEM

To understand how the sense of hearing influences spatial perception, one must first examine vision. According to Harvey Carr, the author of *An Introduction to Space Perception*, "auditory localizations are known to be highly variable and plastic, and easily influenced by visual data."¹⁹ Further, due to the western fixation on vision throughout history, the current perception, treatment and language²⁰ of sound has been altered by the sense of sight. There are many possible causes for this fixation, one being the reasonably large amount of information the eyes send to the brain, in comparison to the ears. Edward T. Hall supports this argument in his book *The Hidden Dimension*.

Drawing from René Descartes (1596-1650) in *"meditations métaphysiques"*, illustrating the mind / body dualism.

"There is a general relationship between the evolutionary age of the receptor system and the amount and quality of information it conveys to the central nervous system. The tactile, or touch, systems are as old as life itself... Sight was the last and most specialized sense to be developed in man. Vision became more important and olfaction less essential when man's ancestors left the ground and took to the trees."²¹

2 point perspective drawing

Due to this perceived accuracy and refinement of sight, a large portion of architectural theory has been associated with the study of optics. The relationship most commonly drawn between the two is perspective. However, according to Hall, one's phenomenological sense of space is dynamic, not linear and static as the two most common forms of perspective, "single-point" or "two-point", supposing a single fixed viewpoint.²² The common notion of perspective must be broadened to include human physiology, movement and texture. The following is a brief summary of James J. Gibson's *Thirteen Varieties of Perspective as Abstracted from the Perception of the Visual World*,²³ in which he outlines several different types of perspective that are important for architectural design, visual reproduction and the understanding of spatial perception.

Illustration of perspectival fields of view.

Perspective of Position

1. Texture Perspective: increase in density with increased distance
2. Size Perspective: decrease in size with increased distance
3. Linear Perspective: vanishing point

Perspective of Parallax

4. Binocular Perspective: separation of eyes
5. Motion Perspective: closer objects seem to move faster

Perspective independent of position or motion

6. Aerial Perspective: haziness and changes in colour due to atmosphere
7. The Perspective of Blur: selective focus plane
8. Relative Upward location in the visual field: usually look down at close objects, up at far objects.
9. Shift of Texture or Linear Spacing: comparative shift in texture density due to distance
10. Shift in the Amount of Double Imagery: Object in focus close to viewer causes more double vision than on an object in the distance
11. Shift in the Rate of Motion: close objects move more laterally in relation to the viewer than far objects.

Perspective of Depth at a Contour

12. Completeness or Continuity of Outline: overlap, camouflage exploits this
13. Transitions Between Light and Shade: gradual transition = roundness, abrupt shift = edge

Texture perspective + Shift in Texture or Linear Spacing

Aerial Perspective + Overlap

Consider from both an aural and a visual perspective, two conceptual variants of a small space. The first variant replaces the solid walls with heavy but clear glass such that the visual scene is now open (unobstructed), while the auditory experience remains that of a box. A second variant replaces the walls with an acoustically transparent surface constructed with an open wire mesh and visually opaque cloth, so sound travels through it as if it were not present. The auditory scene is now open (unobstructed), even as the visual experience remains that of a box. Most listeners find that the feeling of encapsulation is weaker with surfaces that are acoustically transparent but visually opaque. Sound transparency removes the sense of solidity, as if you could leave the space at any time. No matter how constructed, an acoustically transparent wall feels insubstantial.²

All of these "varieties" contribute to spatial perception through the recognition of perspective clues, rather than the advantage of refined focused vision. They are mainly detected in non-foveal and peripheral vision. According to Richard Kearney, an Irish professor of philosophy, "there is medical evidence that peripheral vision has a higher priority in our perceptual and mental system."²⁴ This may be due to the fact that peripheral (non-foveal) vision covers a much larger area of our retina than foveal vision and that it lies in the preconscious realm. As previously mentioned by Blesser, it is the preconscious mental processes, such as those performed by the limbic system, that greatly influence perception. Because the majority of the "perspective varieties" depend mostly on peripheral vision, they are recognized subconsciously, thus having a greater influence on perception than conscious awareness. Further, movement is exaggerated in peripheral vision, a phenomenon which has been proven to influence the speed that people move through visually "busy" fields, such as city streets and crowded buildings.²⁵ Sparse visual fields provide fewer distractions and fewer points of reference to gauge movement and speed. Although vision is our most refined and "accurate" sense, it is unfocused peripheral vision that is most important in spatial perception. Foveal (high-acuity) vision is seemingly reserved for affirming the concordance between input from peripheral vision and the other

senses. According to the American psychologist David R. Perrot, the presence of foveal vision forced the evolution of the auditory system to perform much broader and more spatial localization, acting as “steering” aid for visual acquisition.²⁶

In conclusion, we can say it is peripheral vision that is most important to spatial perception, yet foveal vision forced the evolution of hearing to be much more “peripheral” than sight. Therefore, the importance of the auditory system in spatial perception is greater than at first glance.

THE EAR: AUDITORY SYSTEM

Blesser goes on to explain that the physiology of the ear acts as, “a spatial filter that changes the frequency content depending on direction.”²⁷ An important factor in the perceptual synthesis of hearing and sight is the similarity between the modes of visual and aural perspective, used in cognitive strategies for interpreting space. The following is a direct comparison between Gibson's aforementioned varieties of visual perspective and the invisible, but commonly perceived, varieties of “aural perspective”. The information for the aural perspective equivalents has been derived from Jean-Francois Augoyard and Henry Torgue's *'Sonic Experience'*, and Harvey Carr's *'An Introduction to Space Perception'*.²⁸

Medical diagram of the pinna (outer ear)

The 13 Varieties of Visual Perspective - Compared to the equivalent Aural Perspective (a.)

Aural Perspective of Position

1. Texture Perspective: increase in density with increased distance
 - a. **Decrease in tonal complexity with increased distance**
2. Size Perspective: decrease in size with increased distance
 - a. **Decrease in loudness with increased distance**
3. Linear Perspective: vanishing point
 - a. **Source origin point**

Aural Perspective of Parallax

4. Binocular Perspective: separation of eyes
 - a. **Binaural localization**
5. Motion Perspective: closer objects seem to move faster
 - a. **Doppler Effect: Increase or decrease in perceived pitch, in relation to relative speed of source**

Aural Perspective independent of position or motion

6. Aerial Perspective: haziness and changes in colour due to atmosphere
 - a. **Alteration to sound frequency based on environment temperature and air movement**
7. The Perspective of Blur: selective focus plane
 - a. **Synecdoche Effect: Selective hearing, tuning out of unwanted noise**
8. Relative Upward location in the visual field: usually look down at close objects, up at far objects.
 - a. **Commonly hear direct and close sounds laterally and from below, commonly hear ambient reflection and tonal character of a space from above.**
9. Shift of Texture or Linear Spacing: comparative shift in texture density due to distance
 - a. **Comparative shift in reverberation vs. direct sound loudness due to distance**
10. Shift in the Amount of Double Imagery: Object in focus close to viewer causes more double vision than on an object in the distance
 - a. **Ability to localize and separate close sound sources more easily than at a distance.**
11. Shift in the Rate of Motion: close objects move more laterally in relation to the viewer than far objects.
 - a. **Close sounds move more laterally in relation to the viewer than far sounds.**

Aural Perspective of Depth at a Contour

12. Completeness or Continuity of Outline: overlap, camouflage exploits this
 - a. **Mask Effect: A louder and more tonally complex sound will mask a quieter one**
13. Transitions Between Light and Shade: gradual transition = roundness, abrupt shift = edge
 - a. **Crossfade Effect: gradual transition = movement through one acoustically changing space, Cut Out Effect: Abrupt shift = threshold shift between acoustically different spaces**

This comparison demonstrates that the perspective principles involved in the visual perception of space have direct counterparts in aural spatial perception. Thus, one can imagine the use of aural perspective as an architectural design strategy not unlike traditional architectural "linear perspective". Although the perception of linear and other varieties of visual perspective are dynamic, dependant on one's location in space, one's presence does not affect the visual environment. However, architecture responds dynamically to aural perspectives and one's movement through space, providing a direct relationship between body and building.

"Sight isolates, whereas sound incorporates; vision is directional, whereas sound is omni-directional. The sense of sight implies exteriority, but sound creates an experience of interiority. I regard an object, but sound approaches me; the eye reaches, but the ear receives. Buildings do not react to our gaze, but they do return our sounds back to our ears."²⁹

Humans have the corporeal ability to "illuminate" space with sound, whereas vision requires a foreign light source. This impacts the perceived responsiveness and intimacy of human interaction with a building. Also, architectural acoustics have the potential to extend the spatial dimensions of the human voice, mainly through reverberation. Although we cannot directly sense spatial

There is a direct relationship between physical spatial properties, such as geometry and materials, and the resulting acoustic parameters, such as reverberation time... Second, there is the relationship between perceptual attributes, such as enveloping reverberance, and its physical parameters, such as measures of spatial diffusion... Finally, there is a relationship between auditory perceptual parameters, such as spectral balance, and human experience of those parameters, such as aural warmth and ambience. These bear directly on the bases of auditory art, emotion and affect, all of which derive their meaning from the specific culture. These cultural concepts are part of the phenomenology of aural space.³

Mapping of visible light frequencies to relative (+40 octaves) sound frequencies.

"One common signaling choice is vocalization, which has a more controllable and often wider geographic range than visual displays or chemical pheromones. It is not dependent on illumination and visibility. It is relatively immune to being blocked by physical obstacles. And it is biologically efficient to maintain. From this perspective, the auditory system would have adapted to receiving vocal broadcasts. Yet the human voice rarely extends above 6000 Hz, whereas an undamaged ear can hear frequencies above even 20,000 Hz. Clearly, the extra bandwidth can be used to detect, recognize, and localize other kinds of sounds. Hearing has been optimized for something beyond communications among conspecifics."³³

One reason that the human hearing range (20-20,000 Hz) is much greater than the range of conversational speech (250-6000 Hz) is for localization of non-conversational sounds, such as environmental noise and alterations in spectral frequency of sounds. Low-frequency sound travels easily around physical objects, whereas high-frequency sound is highly directional and easily blocked by objects. Therefore, the spectral sensitivity outside of conversational speech allows one to more easily perceive "acoustic shadows" and sounds from sources that are visually blocked. In his book *'Spaces Speak are You Listening?'* Blesser, the inventor of commercial digital reverberation software, proposes three acoustic perceptual dimensions, which influence the cognition of conversation and sound in space.

Diagram illustrating the relative frequency spectrum of conversational speech and musical instruments.

Dimension 1: Primary vs. Slave Sonic Events³⁴

In a large resonant space such as a concert hall, a violinist produces a primary sonic event (direct sound) and a slave sonic event (reverberation). But in a smaller resonant space, such as a bathroom where spatial resonances fuse with the direct sound, we aurally perceive only a primary event whose overtones are selectively amplified by the space.

Dimension 2: Localized vs. Diffused Sonic Events

The ability to localize a small sonic event, as opposed to the inability to accurately localize a loud, extremely reverberant sound, or multiple synchronous sounds.

Spatial acoustics can also change the apparent size of a musical source located at a single point in space. Acoustic scientists call the experience of aural size the “apparent source width”. The early sonic reflections, perhaps within the first 75 milliseconds, fuse with the direct sound rather than becoming distinct slave sonic events. But in fusing, they increase the perceived size of the primary sonic event.

Dimension 3: Fused vs. Decoupled Sonic Events

As a general principle, pitch, timbre, timing and directionality determine the degree to which sonic events will bind... a sonic event that results from fusion becomes a new sound, different from the sonic events that created it.

These dimensions provide clues to how architectural acoustics can be designed to enhance and control the intelligibility of vocal communication in space. An increase in early sonic reflections increases the perceived size of the sound source, whereas excessive reverberation inhibits aural localization and speech intelligibility.³⁵ Furthermore, the acoustic character of a space, reverberant or absorptive, influences the ambient “atmosphere” and the politics of engagement. Acoustics can support or inhibit social interaction within a space, creating an “inclusive” or “exclusive” aural architecture.

The bare marble floors and walls of an office lobby loudly announce the arrival of visitors by the resounding echoes of their footsteps... the aural architecture of the lobby thus determines whether entering is a public or private event.³⁶

ENDNOTES

- 1 Carr, Harvey. *An Introduction to Space Perception*. New York: Hafner Publishing Company, 1935, p. 26
- 2 Blesser, Barry, and Linda-Ruth Salter. *Spaces Speak, are you listening?: experiencing aural architecture*. Cambridge: The MIT Press, 2007, p. 20
- 3 Ibid., 216
- 4 Blesser and Salter. *op cit.*, 300
- 5 Blesser and Salter, *op cit.*, 215
- 6 Ibid., 56
- 7 Ibid., 61
- 8 Ibid., 56
- 9 Augoyard, Jean-Francois, and Henry Torgue. *Sonic Experience: a guide to everyday sounds*. Translated by Andra McCartney and David Paquette. Montreal: McGill-Queen's University Press, 2008, p. 113
- 10 Salter, Charles. *Acoustics: architecture engineering the environment*. San Francisco: William Stout Publishers, 1998, p.78
- 11 Augoyard and Torgue, *op cit.*, 99
- 12 Blesser and Salter, *op cit.*, 230
- 13 Ibid., 254
- 14 Ibid., 23
- 15 Ibid., 333 - "The emotional brain, which is sometimes labeled the limbic system, has no direct representation in brain consciousness, though it is a major, or perhaps the major, contributor to perception... The emotional brain also provides associations to those stored memories of historical experiences that are relevant to the current situation."
- 16 Pallasmaa, Juhani. *The Eyes of the Skin: architecture and the senses*. Chichester: John Wiley & Sons Ltd, 2005, p. 41
- 17 Hall, Edward. *The Hidden Dimension*. New York: Doubleday & Company, Inc., 1966, p. 62 - "The fact that man differentiates (without knowing that he does so) between the sense impressions that stimulate the retina and what he sees suggests that sensory data from other sources are used to correct the visual field."
- 18 Blesser and Salter, *op cit.*, 46 - "When sensing a spatial environment, an individual builds a cognitive map of space using a combination of sensory information and experiences accumulated over a lifetime. The cognitive map of space in our consciousness is subjective, distorted, and personalized – an active and synthetic creation – rather than a passive reaction to stimuli."
- 19 Carr, Harvey. *An Introduction to Space Perception*. New York: Hafner Publishing Company, 1935, p. 49
- 20 Reflection, refraction, diffusion, absorption, illumination etc. are all terms utilized in both the language of light and sound

21 Hall, *op cit.*, 40

22 Ibid., 108 - "Man's sense of space and distance is not static, that it has very little to do with the single-viewpoint linear perspective developed by the Renaissance artists and still taught in most schools of art and architecture. Instead, man senses distance as other animals do. His perception of space is dynamic because it is related to action - what can be done in a given space - rather than what is seen by passive viewing."

23 Ibid., 179 (Summary of Appendix)

24 Pallasmaa, *op cit.*, 13 (Quoted by Richard Kearney in *Modern Movements in European Philosophy*, Manchester University press, 1994, p.82)

25 Hall, *op cit.*, 68 - "Movement is exaggerated at the periphery of the eye. Straight edges and alternate black and white bands are particularly noticeable. This means that the closer the walls of any tunnel or hallway, the more apparent the movement. In the same way, trees or regularly spaced pillars will exaggerate the sense of movement... In restaurants, libraries, and public places, cutting down on movement in the peripheral field should reduce the sense of crowding somewhat, whereas maximizing peripheral stimulation should build up a sense of crowding."

26 Blesser and Salter, *op cit.*, 206, "Aural localization automatically determines where we should position our gaze, without which scanning would be required; it makes visual target acquisition more rapid and accurate (Pérrott, 1993)

348, "When the visual system of a species evolved a small high-acuity region, its auditory system came under adaptive pressure to evolve a wide-field localization ability to provide steering information to the visual system..."

27 Ibid., 188

28 Augoyard and Torgue, *op cit.*, Carr, *up cit.*

29 Pallasmaa, *op cit.*, 49

30 Blesser and Salter, *op cit.*, 21 - "We cannot see volume, but we can hear it... visually we can sense volume only by mentally multiplying the three dimensions of a space."

31 Blesser and Salter, *op cit.*, 195

32 Schell and Denham, *Environmental Pollution in Urban Environments and Human Biology*, 12 - "Stress is the primary mechanism by which noise produces non-auditory effects on physical and mental health. Exposure to a noise stressor provokes short-term physiological responses mediated by the autonomic nervous system and the endocrine system. The nervous system portion of the stress response involves numerous changes including altered blood pressure, heart rate, and respiration (Cohen 1977)."

33 Ibid., 336

34 Blesser and Salter, *op cit.*, 150-157

35 Ibid., 23

36 Ibid., 3

The Octophone - octophonic recording device - Evan Dysart, 2012

COMPARISON of AURAL and VISUAL SPATIAL LOCALIZATION

ACOUSTIC INVESTIGATIONS

04

Let us now test our theoretical research and findings on the perception of acoustics with first hand observations. In order to better understand how acoustics can influence one's spatial perception, a series of experiments was performed on a group of 25 individuals. Some test subjects had a prior knowledge of architectural design, while others did not, allowing for a comparison between the two groups. The reason for comparison is to observe whether average individuals who experience space, the end users, have similar abilities in "sensing" space as those of trained architects.

The objective of these experiments was to roughly determine both the sensitivity and acuteness of an average individual's sense of "*hearing space*" and the interconnectivity of the five classical senses. The metrics used in judging one's ability to hear space are based on Blesser's three acoustic perceptual dimensions (Primary vs. Slave, Localized vs. Diffused, Fused vs. Decoupled) and the aural equivalent of James Gibson's thirteen varieties of perspective. Specifically, "*hearing space*" refers to one's ability to distinguish spatial volume (based primarily on reverberation time), to detect the materiality of a given space (based primarily on the absorptive qualities of surfaces), and to identify the program (based on the previous two metrics in combination with active sound sources present in the space).

The evaluation of these “abilities” was achieved through the recording of multiple acoustic environments with an eight microphone array (octophonic recording device). These recordings are projected in a “semi-anechoic” listening chamber (octopod). There are two main classifications of test subjects, trained and untrained in architecture, who undergo a five-stage experiment lasting approximately fifteen minutes.

EXPERIMENTAL DEVICES

In 1991 two Japanese researchers at the Yamaha Corporation, Hiroaki Ide and Hidefumi Nagai, filed a patent (granted in 1993) for an “acoustic space reproduction method, sound recording device and sound recording medium.”¹ Their patent suggests that a minimum of an eight microphone array is required to accurately reproduce spatial results. Their findings suggest that omni-directional microphones capture a better aural image of the volumetric aspects of a space, whereas directional microphones are more appropriate for aural localization. They concluded that both techniques should be used simultaneously, with one directional and one omni-directional microphone corresponding to each loudspeaker.

There are two fundamental differences between their patent and the proposed octophonic recording device and listening chamber. First, their proposed microphone array is a static cluster of microphones around a single point, corresponding to a geometric axis to which the loudspeaker is aligned. Second, their playback device does not include a semi-anechoic environment; it is an open frame with precisely placed loudspeakers. The goal of the octophonic recording and projection system is to capture the sounds of one moving through

FIG. 1

FIG. 2

Patent drawings by Ide and Nagai
[<http://www.patentgenius.com/patent/5260920.html>]

space, not standing in a specific location, as one rarely stands at only one point in a building. It is the movement through a space that heavily influences one's spatial perception, yet spatially dynamic recording techniques are rarely used by acoustic engineers. This is the goal of this dynamic recording technique.

This is fundamentally a different style of recording than surround sound which incorporates a stereo center channel, a subwoofer, and several satellite speakers. The main difference is that the auditory spatial effects in movies are primarily created through digital manipulation and placement of stereo sounds within a virtual representation of the surround sound system. This is achieved with digital "automatable bus-destination routing software" (dynamic panning of audio between multiple speakers), such as the Steinberg company's *Nuendo* software. The octophonic recording technique involves four simultaneous stereo tracks, aiming to capture the natural movement of sounds between microphones, later perceived as sound movement between speakers. The end results may seem similar, but the techniques are completely different.

Octophonic Recording Device - Octophone:

This device consists of a wood frame support structure for eight small-diaphragm condenser microphones (Apex 185). The spacing of the microphones on the recording device corresponds directly to the location of the loudspeakers in the listening chamber. Each microphone is connected, with an XLR cable, to one preamp located on an eight channel sound card (Presonus FireProject Studio) that records the audio directly to a digital audio workstation program on a laptop (Logic 8 Express). Each microphone records mono audio to a separate channel, allowing full control over signal processing and later projection through loudspeakers.

The octophonic recording device is worn by an individual walking through a series of unique acoustic environments. The wood frame sits on the shoulders of the individual and also features an attachment for a laptop, freeing ones hands once recording has been begun. In addition to the wood frame, a backpack containing the soundcard and portable power source must be worn.

The octophonic recording device,
March 2012

Semi-Anechoic Listening Chamber - Octopod:

The listening chamber consists of 17 sonically insulated square boxes and 8 triangular speaker boxes. The form is created from the intersection of 3 octagonal prisms, creating 26 interior surfaces equidistant from a virtual centre point. The centre point corresponds to the location directly between the ears of the listener. This ensures that all speakers are equidistant, creating a balanced diffuse sound field.

Each microphone on the octophonic recording device corresponds to one loudspeaker in the same spatial location. This ensures that the projection of the recordings is as close to the original experience as possible. Additional microphones and speakers would increase the accuracy of the auditory spatial reproduction.

Exterior of the Octopod semi-anechoic listening chamber

The boxes are constructed from 12mm (1/2") Baltic birch plywood, ensuring maximum structural stability and density for the thickness and weight. The high-density plywood ensures that sufficient external noise is reflected from the outer surface of the chamber. Each box contains 6" of mineral wool sound insulation (Roxul Safe n' Sound) covered with felt cloth, which insulates the interior from residual external noise that travels through the plywood and absorbs most reflected sounds

created within the chamber. This effectively creates a space without an acoustic character or interior sound reflection, economically mimicking expensive anechoic chambers (hence, semi-anechoic). This allows for the sound from the loudspeakers to transparently recreate the acoustics of the recorded spaces.

The boxes are joined with pressure fit aluminum C-channels, allowing for easy disassembly, maximizing the portability of the chamber. The total exterior dimension of the chamber is nearly 4', with the interior being roughly 3.5'. This size allowed for the largest interior space with the least amount of material. The original design of the chamber was large enough to fully enclose a standing individual. However, issues of portability and budget limited the size.

One of the most common spatial recording techniques is binaural. It requires complex algorithms to process the audio signals and is only effective with the use of headphones. Without advanced signal processing binaural audio is perceived intra-cranially between one's ears, rather than as external sound. With binaural recording the natural spatial filtering performed by the structure of our ears is lost. Because the octophonic listening chamber utilizes speakers at a significant distance from the ear, "the pinna, whose nooks and

Interior of the Octopod
semi-anechoic listening chamber

crannies are actually a spatial filter that changes the frequency content depending on direction,"² provides a natural extra-cranial listening condition. Therefore, by creating sound sources outside of the ear, no significant post processing of the recordings is needed. The main objective of the octophonic playback technique is to allow for a listener's ears and existing cognitive and perceptual maps, which decode sounds into spatial information, to process the sound rather than a generally applied algorithm.

The combination of the octophonic recording device and the semi-anechoic listening chamber create the *"Octophonic Recording and Projection System."*

EXPERIMENT

The experiment performed on each test subject is comprised of five stages. In each stage a different space with a specific acoustic environment is played through the loudspeakers in the semi-anechoic chamber. The recorded spaces range from a suburban home, the Nepean IKEA parking garage and atrium, Carleton University Centre, Azrieli School of Architecture and Urbanism to the National Art Gallery of Canada. Each recording lasts approximately 40 seconds to two minutes. Within each recording there is a transition from a smaller or less reverberant space to a larger or more reverberant space. All of the recordings contain this threshold transition. The experiment is somewhat biased in this manner, as it supposes that the memory of test subjects between separate recordings would be less accurate than a relatively quick change of acoustics within one recording. The other reason for including acoustic thresholds in the testing was to aid in the development of the Invisible Architecture design language. Further, the materiality and general acoustics of each recorded space are markedly different, assuming that a greater contrast between acoustic environments would be perceived more easily.

Suburban home

Nepean IKEA (Ottawa)

National Art Gallery (Ottawa)

Following each stage (each of five recorded samples) of the experiment, the test subject is asked to fill out a questionnaire that describes their perception of the recorded space. The form asks general questions about the acoustics, size and the program of a space. Additionally, the form asks the subject to describe visual, tactile and material aspects of the space. These seemingly arbitrary questions are used to examine the presence, if any, of synesthetic relations between the sense of sound and one's other senses.

LISTENING CHAMBER QUESTIONNAIRE 01

P e r s o n a l I n f o r m a t i o n	ACADEMICS							
	Professor	☐	Graduate	☐	Student	☐	Other	☐
	ARCHITECTURAL EDUCATION							
	Yes	☐	No	☐				
	MUSICAL TRAINING							
	Experienced	☐	Casual	☐	Little	☐	None	☐
	SEX							
	Male	☐	Female	☐				
	AGE							
	18 - 24	☐	25-35	☐	36-59	☐	60+	☐
P e r c e p t i o n o f	SIZE/VOLUME	small room ----- open stadium				#1		
	PROGRAM	public ----- private				☐ ?		
	BRIGHTNESS	dark ----- light				☐ ?		
	TEMPERATURE	cold ----- warm				☐ ?		
	COLOUR	black grey white R O Y G B I V				☐ ?		
R e c o r d e d S p a c e s	SIZE/VOLUME	small room ----- open stadium				#2		
	PROGRAM	public ----- private				☐ ?		
	BRIGHTNESS	dark ----- light				☐ ?		
	TEMPERATURE	cold ----- warm				☐ ?		
	COLOUR	black grey white R O Y G B I V				☐ ?		
	MATERIALITY - list perceived materials							
	BUILDING TYPE + OTHER COMMENTS ON SPACE							

LEGEND		01 SOUND CLIP					02					03					04					05							
		SUBJECT	SIZE	PROG	BRI	TEMP	COL	SIZE	PROG	BRI	TEMP	COL	SIZE	PROG	BRI	TEMP	COL	SIZE	PROG	BRI	TEMP	COL	SIZE	PROG	BRI	TEMP	COL		
V A L U E S C A L E	10	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	9	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	8	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	7	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	6	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	5	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	4	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	3	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	2	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	1	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
C O L O U R / S H A D E	10	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	9	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	8	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	7	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	6	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	5	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	4	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	3	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	2	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	1	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
I F E M A L E	10	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	9	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	8	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	7	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	6	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	5	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	4	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	3	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	2	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	1	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
E D U C A T I O N A L	10	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	9	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	8	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	7	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	6	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	5	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	4	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	3	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	2	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	1	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
M U S I C I A N	10	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	9	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	8	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	7	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	6	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	5	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	4	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	3	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	2	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	1	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
A C T U A L V A L U E S	10	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	9	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	8	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	7	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	6	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	5	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	4	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	3	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	2	01	AGS	C	7	10	7	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY	10	5	GRAY
	 

FINDINGS + DEDUCTIONS

Admittedly, the test group of 25 subjects was quite small and mostly comprised of architecture students. Therefore, any conclusions deduced from these data are not significantly statistically relevant to the general population. However, in this experiment, the few test subjects without architectural education followed the same trends as architecture students. As earlier suggested by Blesser, the one test subject with acute claustrophobia did not feel claustrophobic in the listening chamber once the sound clips started. Generally, subjects described the aural experience as being "transported" to the actual recorded environment.

When creating the questionnaire I was expecting few people to associate brightness, temperature or colour with their experience. However, this was not the case. Most test subjects associated the aural experience with other sensual data (visual and tactile) that was not present. This suggests an interconnectivity of our sensual experience of space, affirming Pallasmaa's concepts discussed in *The Eyes of the Skin*. Additionally, this experiment demonstrates specific tendencies in spatial cognitive mapping. According to these findings, our aural perception of space seems to be based on universal acoustic archetypes, "acoustic territories." It seems that each one of these archetypal cognitive maps have a corresponding set of materials, temperature and brightness.

Sound clip 01: The National Art Gallery of Canada, The Great Hall

Average Perception: LARGE, PUBLIC, Dark-Light, COLD, GRAY (2 colours, 21 shades), no threshold

Generally, subjects interpreted the space accurately, though it was quite bright. There was a significant link to concrete, water and the underground, most likely due to the hard materials and long reverberation times of the space. Most people accurately did not observe any acoustic threshold (3 subjects did). From these observations, one can deduce that large highly reverberant spaces are perceived as cold, darker and colourless.

Sound clip 02: IKEA, Atrium to sound insulated parking garage, music present

Average Perception: LARGE, PUBLIC, Dark-Light, Warm-Cold, COLOUR (15 colours, 20 shades), threshold

Generally, the interpretation of the space was relatively random in terms of size, brightness and temperature. Most subjects perceived the space as colourful and public, as a bar exiting to an exterior parking lot. These observations suggest that music, rather than “illuminating” the room acoustics, masks accurate spatial perception and adds “colour” to the space. Most people accurately did observe an acoustic threshold (only 4 subjects did not). Further, the sound insulation in the parking garage led subjects to perceive the space as exterior (larger) than interior. This coincides with Blesser’s notion that sound absorption is a space expander.

Sound clip 03: A suburban home, hallway to living room to laundry room

Average Perception: SMALL, PRIVATE, Light-Dark, WARM, COLOUR (14 colours, 10 shades), no threshold

The suburban house was the most accurately perceived space. Most subjects noted a change in floor surfaces, specifically noting wood floors (rather than other hard flooring materials commonly present in homes). Most people inaccurately observed no acoustic threshold (only 7 subjects did). The space was generally perceived as warm, red and orange.

Sound clip 04: Carleton University, University Centre Atrium to tunnels

Average Perception: LARGE, PUBLIC, Lighter-Dark, Warm/Cold, COLOUR (7 colours, 18 shades),
½ threshold

Generally, subjects interpreted the space accurately, noting a distinct change in ceiling height. More than half of the subjects accurately observed an acoustic threshold (10 subjects did not). This inaccuracy is believed to be caused by a gradual transition of *acoustic areas, rather than an abrupt transition heard in the other recordings. From these observations, one can deduce that conversational "noise" does not have an adverse effect on spatial perception. Unlike music, ambient conversational speech seems to slightly increase one's ability to accurately perceive room acoustics.*

Sound clip 05: Carleton University, Architecture Building, Office to "street" to M.ARCH1 studios

Average Perception: Mid-Large, PUBLIC, Lighter-Dark, WARM, COLOUR (8 colours, 11 shades), no threshold

Generally, test subjects who spend the majority of their time in the architecture building were unable to accurately identify it. This suggests that we do not commonly "store" *specific acoustic information in our cognitive mapping of space. Rather, our aural spatial perception is mainly dependent on very general cognitive maps, archetypal notions of "acoustic territories" (the underground, exterior, small room etc.). The inability to recognize the acoustic environment may also be influenced by the presence of acoustic insulation in the space. This is because there are some aural clues that match the archetypal acoustics of a large space, but the associated reverberation time is decreased. In this case sound absorption seems to act as a spatial reducer, contradicting Blesser's theory. Additionally, most subjects did not observe the acoustic threshold present (only 6 subjects did), which may have been influenced by the presence of sound insulation.*

General Deductions

Large quiet reverberant space = cold and gray, mid brightness, public

Large non-reverberant space = warmer and lighter, less public

Presence of music = more colour, masking of acoustics, no apparent effect on brightness

Small non-reverberant space = warm, red and orange, mid-brightness, private

Perceived acoustics = based on archetypes

Perceived threshold = only when acoustics distinctly different, floor material has no effect on perceived spatial boundary, but wood flooring is perceived distinctly different than concrete flooring

Sound absorption = in a large space becomes somewhat confusing, a spatial reducer and increases privacy, in a small space sound absorption is a space expander (by absorbing the early sonic reflections and heavy resonances present in smaller rooms)

In conclusion, smaller spaces seemed to be aurally perceived as lighter and warmer than larger reverberant spaces. The presence of longer reverberation times seems to be associated with underground colourless darker spaces. Music, or Muzak, seems to mask spatial perception, but add colour. The noisiness of public spaces seemed to affect only the perceived program, not the size, brightness or colour. The addition of acoustic insulation seems to inversely affect the perceived size of a space, large becomes smaller, smaller becomes larger. The reduction in overall loudness of a space, with acoustic insulation, increases the perceived privacy of a space.

As general rules for music recording, floor surfaces should be reflective (preferably wood) and ceiling surfaces should be absorptive. The floor surface is the main contributor to the presence of early sonic reflections, whereas the ceiling has the greatest effect on the perceived spatial volume of a space. These techniques seem to be supported by my experimental findings. Test subjects were most sensitive to material changes in flooring, while large reverberant spaces were generally associated with high ceilings. The manipulation of floor material and ceiling height (or absorption) seem to be the most influential factors in the perception of recorded and physically experienced space.¹

ENDNOTES

1 This information is based off personal experience and research derived from recording music. Support for these claims and a detailed description of the design of recording rooms can be found here: [http://www.ethanwiner.com/acoustics.html#live or dead](http://www.ethanwiner.com/acoustics.html#live%20or%20dead)

1 <http://www.patentgenius.com/patent/5260920.html>

2 Barry Blesser and Linda-Ruth Salter, *Spaces Speak, Are You Listening? : Experiencing Aural Architecture*. Cambridge: MIT Press, 2007, p.188

Grueneisen, Peter. Soundspace: architecture for sound and vision. Basel: Birkhauser, 2003 p. 107, Royaltone Studios, altered by authour

"A room should not be fixed, sound not create a static mood, but should lend itself to change so that its occupants may play upon it as they would upon a piano."

(Buckminster Fuller, 1920's) ¹

*I was committed to life and then
commuted to the outskirts*

With all the love in the world

*Living for thirty minutes at a time
with a break in the middle for adverts*

*But it's a wonderful world within
these cinema walls*

*Where a shower of affection becomes
Niagara Falls*

*And you wish she could step down
from the screen to your seat in the
stalls*

*But if stars are only painted on the
ceiling above*

*Then who can you turn to and who do
you love*

I want to get out while I still can

I want to be like Harry Houdini

Now I'm the invisible man"

*(Elvis Costello, Punch the Clock, The
Invisible Man, 1983)*

*"We neither hear nor see the distance
between an auditory object and
ourselves. We merely hear the object
and interpret its spatial relation to
ourselves as a visible object."*

(Harvey Carr, 1935) ²

[IN]VISIBLE ARCHITECTURE

WHAT IS [IN]VISIBLE ARCHITECTURE?

Let us now extend our research and reading to an architectural application. Invisible architecture aims to unite the aural and visual design of space, through the

hidden dimension of experience. It is both invisible and visible. First, it is invisible in the sense that aural space is not visible, but the geometry and materials that create it are. The relationship between aural architecture and visual architecture is reciprocal. Second, it utilizes aural and visual "perspectives" hidden below the level of overt consciousness, which expand the physical understanding and design of space beyond linear perspective. Finally, it attempts to respond to the primacy of perception, of our initial corporeal response to space before the cognition of meaning, metaphor or a subject-object relationship. Invisible architecture is the design of the hidden dimension, of sensual experience, situated within the context of visual space.

That every visible is invisible, that perception is imperceptions, that consciousness has a "punctum caecum [blindness]," that to see is always to see more than one sees – this must not be understood in the sense of a contradiction ... One has to understand that it is the visibility itself that involves a non-visibility – In every measure that I see, I do not know what I see (a familiar person is not defined) which does not mean that there would be nothing there... The perceived world (like painting) is the ensemble of my body's routes and not a multitude of spatio-temporal individuals...³

05

In this case I am referring to the hidden dimension as a 4th invisible spatial dimension, not solely cultural and social space, but the subconscious visual and aural "perspectives" that contribute to spatial perception.

Maurice Merleau-Ponty

The sense of vision alone does not inherently contain conscious perception (recognition of meaning). To clarify, the French phenomenologist, Maurice Merleau-Ponty, suggests that what we consciously perceive is the cultural meaning of what we see, not the raw sensual data itself. It is the "blindness of consciousness."⁴ Therefore, what appears as consciously visible is actually not what is seen, but what is interpreted. The interpretation is invisible, as it is a mental process rather than a phenomenal experience. This is what he means by "perception" is "imperceptions," that the visible is invisible (this concept will be expanded later in the chapter with his idea of the "chiasm"). The same theory holds true for sonic experience. The sound's conveyed meaning, such as song structure, lyrics, information in conversation etc., is what is consciously perceived. The timbre, pitch and location of a sound are what allow us to perceive the sound as something recognizable. These are qualities of the sound itself that are subconsciously sensed, rather than the communicative message.

Invisible architecture attempts to diverge from the aesthetization of visual and aural space (sound walks, Muzak, etc. aesthetical complement and mask space rather than revealing integrated natural acoustics). Invisible architecture is to optical-centric architecture, what modern abstract art is to renaissance painting; the conveyance of an emotion or atmosphere without the use of established metaphors conveying specific meaning.

General George O. Squier, the founder of Muzak in the 1930's

BEYOND LINEAR PERSPECTIVE

According to Merleau-Ponty, "Renaissance perspective is a cultural fact, that perception itself is polymorphic and that if it becomes Euclidean, this is because it allows itself to be oriented by the system. Whence the question: how can one return from this perception fashioned by culture to the "brute" or "wild" perception?"⁵ Perception qua wild perception is of itself ignorance of itself, imperception, tends of itself to see itself as an act and to forget itself as latent intentionality, as being at⁶

One does not realize the act of perceiving, perception is involuntary, not a conscious activity. This is especially true for the sense of hearing, as one cannot voluntarily stop hearing as is possible with vision or touch. Possibly, the perception of acoustics and sound rather than the contained message, one that is subconscious, approaches "wild perception" as it is less constricted by cultural influence. The difference lies in hearing and listening. Listening implies a certain understanding that is dependent upon cultural influence, whereas hearing implies the experience of raw sensual data which does not require a culturally specific understanding. Though sonic effects such as the *Doppler effect*, or the *Cocktail effect* (selective hearing), are culturally termed, their perception does not change across cultures. An approaching noise will increase in pitch relative to its

speed, regardless of cultural influence. However, the association of this phenomenon with an experienced activity is culturally specific.

The same theory holds true for vision. Understanding spatial distance, through James J. Gibson's aforementioned thirteen varieties of perspective, mostly transcends cultural boundaries. This is because they rely on phenomena experienced by the sense of vision, many of them subconsciously in peripheral or non-foveal vision, rather than by attentive "seeing". Because these notions of space, and hearing rather than listening, are subconscious interpretations, they are potentially more resistant to cultural filtering. Though they can carry culturally significant messages, the main significance is primal reaction. The culturally learned filtering of our sense is what allows the transference of meaning, but is a secondary cognitive act of perception.

The Mix house, by KVL and EAR Studio. A theoretical house design that "goes beyond the modernist view of visual transparency" to "aural transparency". Utilizing audio recording equipment and a specifically designed skylight/acoustic mirror, the inhabitants can "mix" the interior and exterior sounds surrounding the house.

TOWARDS AN AURAL PERSPECTIVE

The sense of hearing allows for "surround" spatial localization (spherical), whereas vision is directionally restricted to attentive gaze (conical). Although the sounds within the horizontal plane are most useful for accurate localization, vertical and oblique sounds have a great influence on the perceived size and "atmosphere" of a space.

Let us further refine Gibson's 13 varieties of perspective into four categories of aural perspective, pertinent to the design of Invisible architecture.

Material Perspective:

The influence of a material on the reverberation of a space, amount of sound absorption and influence on spectral filtering. This influence on reverberation affects the perceived "intimacy" or "envelopment" of a room, independent of actual volume.

Stereo Perspective:

Because our ears are located on opposite sides of our head, hearing is more planar rather than directional. Though localization is least effective on the direct left or right side of the body, due to the lack of aural triangulation (monophonic vs. stereo), the imbalance is intensified. Thus, stereo perspective involves the manipulation of the *material perspective* to create acoustic environments that are experienced differently on opposite sides of the body.

Resonant Focal Perspective:

Resonant focal perspective involves the tuning of space towards certain frequencies (conversational) by the change in volume, wall distances and integrated resonators. It also incorporates the use of geometry to control the location of these increased resonances by wall distances and curvature.

Transitional perspective:

The use of markedly different acoustic areas. This involves the use of interstitial acoustics to prime one's ear for the change in acoustics between spaces, or markedly separate two acoustic areas. The transition may be an abrupt or a gradual one.

Diagram illustrating several different configurations of militarized aspects of fortifications

The adjacent diagram is an excerpt from '*Baffles and Bastions: The Universal Features of Fortifications*' by Lawrence H. Keeley, Marisa Fontana, and Russell Quick, published in the '*Journal of Archaeological Research*' in 2007. In this article they lay out a history of military fortifications, baffles and bastions, which mainly focus on thresholds. Although these examples were intended to restrict direct visual and physical contact, impeding invaders access, most form quite efficient sound blocking devices as well. With the incorporation of specific material and geometric choices, these entrances can become spaces that exemplify all of the abovementioned varieties of aural perspective.

CHIASM – [SUBJECT + OBJECT]

In the book, *'Brunelleschi, Lacan, Le Corbusier'*, published in 2010, Lorens Holm discusses the historical differences in the treatment of the subject and the object, in relation to the representation and construction of architectural space. He introduces Jacques Lacan's subject/object diagram to explain the different treatment of architectural perspective used by Filippo Brunelleschi and Le Corbusier.

"Lacan's doubled diagram is taken to mark the structure of a split, the split is not accidental but constitutive of subjectivity... With the invention of perspective by Brunelleschi, and the relationship that he establishes between perspective and architecture – in particular the new classical architecture which he develops out of the antique ruins – this simple default relationship between architecture and space changes irrevocably. Architecture may now be said to represent space. We call this – following Lacan – 'the mirror stage' in which architecture and space emerge together, and compare it to the emergence of the identity of the self."⁷

The main difference, understood here, between the linear perspective of Brunelleschi and that of Le Corbusier, is Le Corbusier's shift in the perceived location of the subject. With Le Corbusier, the subject sees and is simultaneously seen as an object.

Projection and Introjection + Chiasm

Figure 3.8a and b

The composite diagrams of Brunelleschi in his nave and Le Corbusier on the Acropolis (essentially Lacan's diagram of the visual field). Initially we put Le Corbusier in the other position (we viewed him in the snapshot), and allowed him to look back. But the subject is always both viewer and occupant. Le Corbusier is positioned in front of his own images, and in someone else's picture (the reader's, Klipstein's, another viewer's). For the subject (you, Le Corbusier, Brunelleschi), space functions as an image (in the eye of the beholder) and as someone else's picture in which the subject finds itself trapped. Hence: an idea of split space, which gives the lie to the illusion fostered by the Brunelleschi photograph, that the viewer's and the occupant's space are identical. And hence: a possible distinction between image and picture: An image is the subject's picture, a picture is the other's image.

Figure 2.2a and b

Brunelleschi went to Rome; Le Corbusier went to the Acropolis. Two spaces=two subjects. These spaces open onto two different images of subjectivity. The critical difference between them has to do with the visibility of the subject. This is a question of subjectivity, a subjective difference. The Allinari photograph of Brunelleschi's nave, San Lorenzo, Florence, c.1420, is reproduced in most textbooks on Renaissance architecture and was used by Wittkower to argue that the aesthetic value of architectural space is a 2D effect of the picture plane. This photo has become a signifier for a certain kind of space, and for a certain kind of art historical approach to space. The snapshot of Le Corbusier on the Acropolis, August 1911, is one of three from the Fondation Archives that Gresleri chose to publish, and now has iconic status in the origins of modern architecture.

This is a modified page from Holm's, Brunelleschi, Lacan, Le Corbusier, illustrating the different notions of space expressed by Brunelleschi, Le Corbusier, and Maurice Merleau-Ponty.

Lacan, "argues that nothing about 'geometral optics' requires vision (or light) and refers to Durer's woodcut of a perspective apparatus in which two seemingly blind men plot the outline of a lute upon a plane surface using string... Lacan is quite clear that this triangle [cone of geometric vision] only accounts for the *function of images*, which he defines as *simply the mapping of space* upon a 2D surface, and has nothing to do with light, let alone sight... Perspective is merely a matter of triangulation of space."⁸

The traditional notion of linear perspective has more to do with the geometry of optics than with the visual experience at all. It is an abstracted mathematical representation that supposes architectural experience as a viewpoint in Cartesian space, from which the majority of experience can be measured. However, as has been previously discussed, spatial perception has more to do with unconscious sensing related to aspects that are not easily quantifiable. Thus, for an architectural language that attempts to unite sensual experience with the design process, as Invisible architecture, traditional linear perspective and the Lacanian 'mirror stage' become less pertinent than the use of subconscious primal "varieties" of aural and visual perspective.

Maurice Merleau-Ponty's concept of "chiasm" provides the philosophical foundation to better understand the synthesis of sensual experience with design.

"Chiasm, instead of the *For the Other*: that means that there is not only a *me-other* rivalry, but a co-functioning. We function as one unique body."⁹

According to Merleau-Ponty, the chiasm is the space between bodies, which is a connective medium rather than a separation (chasm). It is the realm of phenomenal worldly experience, connecting the subject and the object and allowing for perception to take place.

The chiasm is not only a me other exchange (the messages he receives reach me, the messages I receive reach him), it is also an exchange between me and the world, between the phenomenal body and the "objective" body, between the perceiving and the perceived: what begins as a thing ends as consciousness of the thing, what begins as a "state of consciousness" ends as a thing.¹⁰

State of consciousness → object → consciousness of the thing

Phenomenal (chiasm) → objective → subjective

The difference between the "phenomenal body" and the "objective body" is the difference between the notion of an "individual" and a "user". In Cartesian or Euclidean space the viewer is a single geometric point¹¹, which is supported by linear perspective. It is a representation of space for an objective body, one that passively experiences space through vision alone. However, the

phenomenal body relates to space through the chiasm, primarily through a primal sensual understanding of being in the world and secondarily as a conscious member of a particular culture. In relation to this, architectural acoustics subconsciously alter one's phenomenal perception of the thing, at the level of the "state of consciousness". Thus, these influences are as close to "wild perception" as we can presently achieve, and are more corporeal, as they precede objective and subjective understanding.

"For Lacan, visual experience has to do with being seen: it is a precondition of vision that the subject is visible. The world, with the subject included, is shown to the subject. It is a precondition of vision because it is a precondition for subjecthood."¹²

The Lacanian diagram supposes conscious subjecthood, realizing oneself as a body that is simultaneously subject and object. Lacan's 'mirror stage' along with the recognition of the self, are located in the [objective → subjective] realm, as such realizations are cognitive processes that are subsequent to "wild perception." Therefore, a new diagram must be created in order to correctly display the relationship of subject and object within the space of the chiasm, one that exemplifies the realm in which Invisible architecture is designed.

Our modified Lacanian diagram illustrates the enveloping nature of the chiasm, displaying that both subject and object are within the same "space". Further, it shows that conscious perception is always mitigated by the overlap, learned cultural meaning, between the subject and object. This shows the location of the visible (raw sense) and the invisible (perceived sense). The foci of the chiasm's ellipse represent the location of the subject+object, suggesting that all messages sent from one point will always reach the other foci point.

SOUND OF CITIES - THE UBIQUITOUS IPOD

Following Blesser's argument, "as noisy machines and devices permeated society during the nineteenth century, the bucolic soundscape was replaced by an industrial one. Machines of this period produced noises at intensities well beyond that of hand tools... Public acoustic arenas shrank as noise overpowered this common resource... Sound became something that could be owned and controlled."¹³

The plan of Sir Ebenezer Howard.
Garden City - 1898

Cities that were created prior to the industrial revolution (c. 1800) and have retained their urban structure are generally much quieter than cities designed later. Once powered mechanical transportation overtook animal and pedestrian traffic, rail lines and larger urban streets significantly affected urban planning strategies (ex. Sir Ebenezer Howard's Garden City, Le Corbusier's Ville Radieuse). It is not that the materials of pre-industrial cities are more absorptive (they are often quite reverberant as sound attenuation was not an issue, though "pre-modernist" façade ornamentation contributes to sound diffusion), rather it is the fact they were not and still are not conducive to the automobile. Larger North American cities were often designed for efficient vehicle circulation. These cities are less favourable for pedestrian traffic as sidewalks are often located next to noisy traffic. This noise affects

the experience of the city, often causing stress (as mentioned in chapter 3), because there was often no significant design regard for the increased noise in urban areas beyond commercial zoning.

A design language that strengthens the benefits of the city, such as the increased density of people and cultures in an urban environment, through the suppression of unwanted noise and sensual corporeal design strategies, is especially relevant in a cosmopolitan environment. Such a design approach responds to raw experience rather than an interpreted metaphor, approaching a universal transcultural design language.

The first iPod

The ubiquitous use of iPods in urban environments, despite known risks associated with the masking of traffic and construction noise, is possibly because of the “ugly” acoustic environment of our cities. Due to the strong presence of the car in North American cities, reverberant exterior walls and narrow sidewalks all reflect these undesirable noises back to the individual. Because we are unable to shut off our sense of hearing, our only option for combatting noise is through “masking,” a function easily performed by an iPod and headphones. However, when one is listening to music through headphones they are effectively removing themselves from the present acoustic environment and surrounding social interaction. Maybe if the aural architecture of our urban environments was designed to suppress unwanted noise and increase audible social interaction, the constant need for the iPod would diminish.

ENDNOTES

1 As quoted in LaBelle, Brandon. *Acoustic Territories: sound culture and everyday life*. New York: Continuum, 2010 – (Buckminster Fuller. *Your Private sky*, 106)

2 Carr, Harvey. *An Introduction to Space Perception*. New York: Hafner Publishing Company, 1935, p. 93

3 Merleau-Ponty, Maurice. *The Visible and the Invisible*. Edited by Claude Lefort. Translated by Alphonso Lingis. Evanston: Northwestern University Press, 1968, p. 247

4 Merleau-Ponty, *op cit.*, 248

5 Ibid., 212

6 Ibid., 213

7 Holm, Lorens. *Brunelleschi, Lacan, Le Corbusier: architecture, space and the construction of subjectivity*. London: Routledge, 2010, p.13

8 Ibid., 137 -138

9 Merleau-Ponty, *op cit.*, 215

10 Ibid., 215

11 Holm, *Brunelleschi, op cit.*, 138 - The traditional notion of space from Brunelleschi's linear perspective and Euclidean geometry, "the Cartesian subject, which itself is a sort of geometral point" a single cone of vision

12 Ibid., 60

13 Blesser, Barry, and Linda-Ruth Salter. *Spaces Speak, are you listening?: experiencing aural architecture*. Cambridge: The MIT Press, 2007, p. 103

[IN]Visible Architecture - Evan Dysart, 2012

THE PRACTICE OF [IN]VISIBLE ARCHITECTURE

06

Modern digital technology increasingly divides and separates us physically. Though it may superficially connect us globally, it takes us out of the present physical moment into a virtual mental space that is almost always disconnected from one's surroundings. This technology is in place and is commonly used, that aspect of modern life cannot be changed or ignored. With time it will inevitably increase in sophistication and integration into our daily lives. The question is what impact does this have on our design of urban environments and individual works of architecture?

Most urban places for rest (such as plazas) are large, open, have hard surfaces and are mostly horizontally contained. Through this design approach, based mainly on durability, economics and visual aesthetics, they contain and reflect a lot of sound. In addition, they are intended for high pedestrian traffic public areas, inevitably resulting in significant ambient noise. If these spaces could be transformed to allow an aural pause, through using natural elements as sound absorbers and diffusers, as well as architectonic interventions, they could be converted into places that not only allow a physical rest, but also a mental and aural rest from the sonic stress of the city.

ACOUSTIC INFILL

Quiet homes for London, commissioned by the Greater London Authority in 2004. A report of city noise. "Drawing upon research done in the last 20 years, the study clearly indicates that domestic noise and "noisy neighbours" feature as one of the top two areas of complaint by the population. Material published in 2003 "suggested that neighbour noise annoyed 29% of the population sampled nationally, particularly in high density housing, in social and private rented housing, in deprived areas, and in more urban areas." [Janet Higgitt, Alan Whitfield, and Rick Groves, *Quiet Homes for London*, p.11]¹

It is evident that the treatment of sound in urban areas is significant to the pleasurable experience of the city and that our current approach to urban acoustics is insufficient. Whether in an apartment building or an urban plaza, the constant noise of the city is inescapable. As buildings increase in size and programmatic complexity, mega-structures, similar acoustic issues present in urban environments arise. For example, there has been a study, performed by Jeffrey Hopkins of Western university, on the acoustics of the West Edmonton Mall.² It reveals that the mall's defining description is "noisy", and that the interior ambient volume is louder than its busy parking lot. According to Hopkins, "a level of 55 dBA is considered the point where problems with normal speech interference commence... at 70 dBA the environment... demands amplified speech, shouting."³

Figure 2: Sound Level Mode by Time and Day, West Edmonton Mall
 SOURCE: Author survey, 1988. Cartography done by the University of Western Ontario Cartographic Section, Department of Geography.

Exerpt from Jeffrey Hopkins' study

As illustrated in the above diagram, the ambient volume of the mall is almost consistently above 55 dBA, usually above 70 dBA and reaches nearly 80 dBA on Saturday afternoon. This implies that the mall's acoustics are consistently unacceptable for audible social communication. Hopkins later mentions that such ambient volumes significantly reduce social interaction because of, "one's expectations that speech will be difficult."⁴ He also implies that elevated ambient noise levels significantly contribute to stress. Other than hearing loss, the only somewhat conclusive data regarding the adverse health effects of noise are related to physiological responses to mental stress.

Invisible architecture attempts to respond to this issue with the concept of "*acoustic infill*." Acoustic infill involves creating strategically placed areas within the urban environment that allow one to take shelter from stressful ambient noise. These spots of aural rest could be composed throughout the urban environment along popular circulation paths, as an architectonic equivalent of a musical "rest," creating a "score" for the city. Unlike traditional parks and plazas, sites of acoustic infill incorporate significant sound diffusion and absorption, providing an aural atmosphere of relaxation. We now have an idea of how Invisible Architecture can respond to an urban environment. Let us now reduce the scale of our observation by examining the "invisible" design process of a single building.

DESIGN PROCESS

The practice of Invisible Architecture would involve a five stage design process, aided by future BIAM (Building Information and Acoustic Modelling) software. The BIAM software, currently unavailable, is further explained in chapter 7. Although there are many acoustic modelling programs presently on the market, none easily integrates into a computer modelling program, hindering the current potential of Invisible Architecture.

STAGE 01: In the first stage, one lists initial design strategies based on aural, physical and geographic site analysis. The basic program and structuring concept is outlined in this stage.

STAGE 02: Stage two involves basic volumetric massing as a response to the site analysis. After massing is complete, initial aural analysis may be performed with acoustic modelling software. This analysis provides clues towards the proposed volume's inherent "room modes," revealing the loudest and quietest areas present within the space. The commonly used room mode diagrams (of acoustic engineers) focus on only a single frequency at a time. Although this is clear and accurate, it is mostly irrelevant to quickly analysing spaces for social conversation. A new form of "room mode" similar to the ones described in chapter 5 would be used.

FOUR AURAL PERSPECTIVES

Material Perspective: The influence of a material on the reverberation of a space, amount of sound absorption and influence on spectral filtering. This influence on reverberation affects the perceived "intimacy" or "envelopment" of a room, independent of actual volume.

Stereo Perspective: Because our ears are located on opposite sides of our head, hearing is more planar rather than directional. Though localization is least effective on the direct left or right side of the body, due to the lack of aural triangulation (monophonic vs. stereo), the imbalance is intensified. Thus, stereo perspective involves the manipulation of the *material perspective* to create acoustic environments that are experienced differently on opposite sides of the body.

Resonant Focal Perspective: Resonant focal perspective involves the tuning of space towards certain frequencies (conversational) by the change in volume, wall distances and integrated resonators. It also incorporates the use of geometry to control the location of these increased resonances by wall distances and curvature.

Transitional perspective: The use of markedly different acoustic areas. This involves the use of interstitial acoustics to prime one's ear for the change in acoustics between spaces, or markedly separate two acoustic areas. The transition may be an abrupt or a gradual one.

These diagrams would incorporate three dimensional representations of multiple room resonances. It would be similar to a three dimensional representation of the cymatic patterns observed by Chladni (referred to in chapter 2). These spatial diagrams would reveal the location of the loudest and quietest areas present in specific room geometry, for the entire frequency range of human conversation. One could then accurately judge the sonic implications of the visual manipulations performed on the design. At this stage one can begin to design with the four proposed aural perspectives

(Material perspective, Stereo perspective, Resonant Focal perspective, Transitional perspective).

STAGE 03: Stage three involves the creation and spatial mapping of social parameters. One begins to delineate the massing based on the desired acoustic atmosphere (public, private, reverberant, quiet etc.) and initial aural analysis. One should use Blesser's three dimensions of aural perception (Primary vs. Slave, Localized vs. Diffused,

Fused vs. Decoupled) and the four aural perspectives, as a guide for refining the social parameters. Then one begins to refine the initial volumetric massing in response to the social parametric mapping. Using aural perspectives along with traditional visual design, the architect should refine the design to a level that includes;

all materials, approximate wall thicknesses, location of visible structural elements, thresholds, openings and the overall intended "atmosphere."

STAGE 04: In this stage the design is subjected to further acoustic analysis. Decisions based on theoretical assumptions are now validated. If there are any discrepancies between the intended aural atmosphere and the simulated one, the design must undergo stage three again. At the end of this stage the design will have reached a refinement to the level of "presentation drawings."

STAGE 05: The design is now ready for "working" and "construction" drawings.

Let us now examine one possible architectural manifestation of Invisible Architecture. As BIAM software is currently unavailable, the following design project has been developed from the theory set forth in this thesis.

Dimension 1: Primary vs. Slave Sonic Events⁵

In a large resonant space such as a concert hall, a violinist produces a primary sonic event (direct sound) and a slave sonic event (reverberation). But in a smaller resonant space, such as a bathroom where spatial resonances fuse with the direct sound, we aurally perceive only a primary event whose overtones are selectively amplified by the space.

Dimension 2: Localized vs. Diffused Sonic Events

The ability to localize a small sonic event, as opposed to the inability to accurately localize a loud, extremely reverberant sound, or multiple synchronous sounds.

Spatial acoustics can also change the apparent size of a musical source located at a single point in space. Acoustic scientists call the experience of aural size the "apparent source width". The early sonic reflections, perhaps within the first 75 milliseconds, fuse with the direct sound rather than becoming distinct slave sonic events. But in fusing, they increase the perceived size of the primary sonic event.

Dimension 3: Fused vs. Decoupled Sonic Events

As a general principle, pitch, timbre, timing, and directionality determine the degree to which sonic events will bind... a sonic event that results from fusion becomes a new sound, different from the sonic events that created it.

PROJECT

The project is located in downtown Ottawa, Canada, near the intersection of Rideau, Wellington, Colonel By Drive and Sussex Drive. The main function of the project is to provide a link between Ottawa's future extended light rail transport system (LRT) and the current OC Transpo bus stop, located outside the Rideau Centre. According to <http://www.ottawalightrail.ca>, the project is set to commence in early 2013. The LRT extension includes the addition of thirteen new stops to the existing system, and a tunnel corridor running underneath downtown Ottawa. The project focuses on the proposed Rideau stop, the main hub and "heart" of the future LRT system, with a proposed theme of a gallery for contemporary Canadian art. The station is 150 meters long and will be located 29 meters below street level, so as not to disturb the foundation of the Rideau Canal system above. Currently, the proposed entrances are located on either side of the canal, one facing the National Arts Centre, the other facing the Rideau Centre. However, there is no proposed plan to link the existing OC Transpo system with the new LRT.

Over the duration of this thesis, the city has decided to move the Rideau LRT stop from its location underneath the canal, to the east of the Rideau Centre. This move has caused a great dispute in the city. The following design project incorporates a third exit to the original location of the Rideau station (beneath the canal), linking it to the OC Transpo bus stops along Rideau Street while gaining access to roughly 6000 more daily users. This decision allows the stop to access Confederation Square, the National Arts Centre, Elgin street and the Rideau Centre, providing an important landmark and servicing a large amount of travellers. Additionally, the proposed stop houses a permanent gallery for contemporary Canadian audio-visual art (a possible satellite venue for Ottawa's SAW gallery), a night club, three retail "shells" to be adapted by individual merchants and an underground connection to the Rideau Centre's undeveloped property. This program was chosen to exemplify Invisible Architecture, as the "underground", "open gallery", "bar" and "city street" are all archetypal "acoustic territories" that each require different acoustic design approaches and have specific existing cognitive maps. The two storey design lies almost entirely below grade, allowing maximum flexibility for future Rideau Centre expansions.

AERIAL ISOMETRIC View 2

In this location of Ottawa the city grid is approximately 30 degrees off from a North-South axis. The LRT tunnel corridor follows this grid offset. However, in this part of Ottawa the Rideau Canal and the Old Ottawa Train Station, the original main transportation lines of the city, are set approximately 60 degrees off from a North-South axis. The project incorporates both of these grids, echoing both the past and future of Ottawa's transportation system.

The connection corridor between the LRT station and the art gallery incorporates two escalators (in 3 divisions each), 2 staircases (9 sections each) and a horizontal "elevator" (similar to an enclosed ski gondola). Street musicians often gravitate towards subway stations, as many people pass by and the associated reflective acoustics enhance and spatially expand the aural presence of their performance. However, these spaces were not designed for musical performance, leaving little room for musicians. They consequently disrupt the circulation. The proposed corridor provides two "sound pods" allowing musicians to perform without disrupting efficient circulation.

The largest portion of the project is the gallery for contemporary Canadian audio-visual art. The gallery will display videos that can be choreographed with

sound. These videos will be projected onto moving textile screens, allowing a variety of temporary spatial divisions. The ceiling of the gallery space incorporates several sound focusing geometries. There are spherical, ellipsoidal and parabolic areas of the roof which focus sound precisely at the ear level of an average individual (1.4m). These geometries incorporate speakers, which are carefully placed to ensure that the sound emitted from them is focused at the focal point or foci (at ear level) of the geometry. Each projection screen has a designated listening area located beneath one of the ceiling geometries. The combination of the projection screens, speakers and ceiling geometry allows the open plan of the gallery to be subdivided into smaller acoustic areas.

The main attraction of the nightclub, entitled OKTO-LOUNGE, is its octophonic dance floor. With an enlarged version of the "Octopod," performing DJ's can control the spatial distribution and real-time 360 degree panning of their music. The night club also incorporates a kitchen, which also provides food for a restaurant located in the art gallery. The roof of the nightclub is 1.5 meters above grade, allowing southern light to penetrate the entry hall. On top of the roof there is a site of acoustic infill.

SW-NE Section

[IN]VISIBLE ARCHITECTURE

Composite drawing - Plan, Section, Detail

Main entrance from Rideau street

Entrance from Rideau Centre basement

Musician Pod - Along LRT connection corridor

Center of the Gallery for Contemporary Canadian Audio-Visual Art

New bus shelters along Rideau Street

Upper level walkway connecting "retail shells"

Entrance hall to the OKTO-LOUNGE

View from the stage of OKTO-LOUNGE

View of Gallery from the end of the LRT corridor

View towards the restaurant and seating area

On the upper level of the project (at the basement level of the Rideau Centre) there are three retail shells. These allow the stores of the mall to expand into this transportation hub, creating a novel retail atmosphere for Ottawa. These potential stores are connected by a walkway, which supports the tracks for the moveable projection screens below. This walkway also provides a basement level connection to the Rideau Centre's currently unused property (the proposed area for the expansion of the shopping mall).

Finally, the redesigned OC Transpo bus shelters incorporate light-wells that bring diffuse daylight into the art gallery and circulation corridor below. The shelters provide protection from traffic noise and a visual connection to the gallery below through the light-wells. This visual connection also allows users of the LRT, approaching the bus shelters from below, an early glimpse of the busses above.

Model image - Night time aerial view

Model image - View of the upper retail level (through the new proposed parking layout)

Model image - Entrance from the Rideau Centre basement level

Model image - Worm's eye view of gallery roof geometry

Model image - Entrance from the LRT corridor

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1 LaBelle, Brandon. *Acoustic Territories: sound culture and everyday life*. New York: Continuum, 2010, p. 53

2 Hopkins, Jeffrey. *Orchestrating and Indoor City: ambient noise inside a mega-mall*. Published in *Environment and Behaviour*, Vol. 26 No. 6. Sage Publications, 1994

3 Ibid., 798

4 Ibid., 802

5 Blesser, Barry, and Linda-Ruth Salter. *Spaces Speak, are you listening?: experiencing aural architecture*. Cambridge: The MIT Press, 2007, p. 150 - 157

CHRONOLOGICAL VISUAL MAP TO THE HIDDEN DIMENSION

?

POST SCRIPT

THE FUTURE OF [IN]VISIBLE ARCHITECTURE

Although chapter 6 outlined one possible physical conclusion of the ideas expressed in this thesis, the potential implications of Invisible Architecture are far more encompassing. Let us now extend the theory of Invisible Architecture to several different building typologies and imagine future technology that would facilitate the practice of Invisible Architecture. We begin with a description of the design of “everyday” space, and conclude with proposing novel software.

THE EVERYDAY

The main objective of Invisible Architecture is to incorporate acoustics in the design of “everyday” spaces outside of the musical realm, as spatial instruments for social conversation. Public space is where the largest number of citizens congregate, allowing for a high probability of social interactions and conversation. Consequently, the previous chapter and design project mainly focused on the Invisible Architecture of public space, and proposed an experiential improvement of the urban environment through acoustics. However, these public spaces are mostly transitory. The majority of people spend most of their time within the home and office. These are the true “everyday” spaces that are largely overlooked in terms of acoustics. We will now briefly examine the possible integration of Invisible Architecture in these truly “everyday” spaces.

OFFICE – professional gathering

From insanity one arrives in the padded cell, which is silence made complete by the removal of even the slightest reverberation-the padded cell is an acoustically dead space, where even the movements of one's own body is void of echo.¹

- This is similar to the dead acoustics of common office spaces

The concept of acoustic infill (mentioned in chapter 6) may be inverted when looking at the common open plan office building typology. Despite spatial efficiency, the *standard cubicle never gives a satisfactory level of acoustic separation that a traditional closed office does*. The common acoustic “design” approach to these buildings is to deaden the entire space, so different spatial configurations of office can achieve the exact same uniform acoustic properties. What this creates is a homogeneous aural landscape that is devoid of most sound reflections, comparable to the dead aural space of solitary confinement. The large issue with this technique is that it creates an aurally dead space, but does not sufficiently block out the unwanted noise, which is basically the worst possible aural architecture conceivable. Further, in an aurally dead space the directionality of sounds is emphasized, allowing ambient sounds to become separately distinguishable. In a reverberant space ambient sounds merge, creating a more constant “drone” that is easier to aurally tune out. Both extremes of an extremely reflective space and a dead acoustic space are equally unpleasant to be in *for an extended period of time*. Acoustic variation is desirable, and found in most public spaces. In general, public spaces benefit from acoustic reflections, while

individual private spaces benefit most from acoustic isolation. Therefore, if the social spaces of the office building were more sonically reflective, while the individual cubicles or working pods were to be more acoustically isolated, then the open spaces would be more acoustically pleasant for social gathering and offer a much different acoustic environment than the offices themselves. This would not only make the individual office spaces seem even more private, but would break up the uniformly dead sound of the office space, creating a multitude of aural landscapes within one static room.

URBAN vs. SUBURBAN dwelling – family gathering

A typical city apartment doesn't allow for any real acoustic break from the sounds of the city. Garbage collection, neighbour's arguing, pets, young children etc.; all of these noises are ever present in city living. This may be one contributing factor (of many) to why people move to the suburbs, to achieve a quieter environment. This is obviously not the only reason; it also has to do with not just sound pollution, but air pollution and safety etc. However, "peace and quiet" are important factors in choosing a house, sometimes outweighing convenience. One reason why this may be, according to Edward T. Hall (mentioned in chapter 3), is that our auditory system was evolved to that of a forest¹, one that wasn't reflective or particularly noisy all the time. If we could allow areas for aural rest at home, this may allow people to better cope in "noisy" environments. This can be achieved through acoustically separate spaces, not acoustically dead. For example, in an urban apartment there could be an open balcony that would allow the view to the city and street, providing that connection to the city that many urban dwellers enjoy. In addition, there could be a "sun room" that has been acoustically treated so that very little sound of the city would permeate the space, and possibly even the view of the city is shifted towards the sky. The sound insulation between units could also be greatly improved,

to minimize the constant aural presence of adjacent neighbours. Additionally (mentioned in chapter 3), Barry Blesser states that sound absorbing materials are an aural space expander. The use of sound absorptive material in small urban dwelling may not only reduce unwanted noise but increase the perceived size of the space.

RESTAURANT + COFFEE shop – food and social gathering

The presence of food always seems to gather people together. Some individuals prefer to do most of their thinking within these spaces (mostly coffee shops), as well as entertain clients and conduct business meetings. Almost all of the possible social interactions within restaurants involve vocal communication, yet so often the acoustics of these spaces are horrible. The spaces are often highly reverberant, creating an overall noisy and loud environment (although some people enjoy this). This “liveliness” of the space actually acts as an aural mask, where the directionality and intelligibility of each sound is obstructed. When sound insulation is used it often is located in areas that further impede the audibility of conversation (ear level within booth seating). This absorption of early reflections in conjunction with a generally noisy environment creates an aural architecture in which it is often quite difficult to communicate. Further, the visual ambience of expensive restaurants is often contrasted by “ugly” or noisy aural architecture. In these cases the lack of aural design strategies detrimentally affects the experience and enjoyment of these spaces.

If one were to design restaurants and coffee shops that retained their noisy or "lively" ambience, while additionally creating pockets of aurally separate space, the potential for intelligible vocal communication would be significantly increased. Each table or seating booth could incorporate sonic reflecting discs (with integrated lighting) and acoustic insulation (in the form of seating cushions) to retain the early sonic reflections needed for conversation, while simultaneously blocking the overall noisy characteristics of the space. If an individual preferred the traditional acoustic environment of the space, they could merely sit in an open area, rather than an isolated seating booth.

TECHNOLOGY

Invisible Architecture relies heavily on the use of modern technology, as is apparent through the numerous acoustic investigations, the use of acoustic and digital modelling software and the suggestion that technology has currently merged with visual and auditory experience. Paradoxically, it is the aid of digital technology in the 21st century that allows one to better incorporate the human sensual experience into architectural design. Due to budget, time and technological constraints, the integration process of acoustic simulations and architectural design is quite fragmented. However, with a greater knowledge of software design one could easily streamline the process.

BIM (Building Information Modelling) programs, such as Autodesk's Revit, are slowly becoming the industry standard for producing architectural drawings, eclipsing the historically 2D nature of AutoCAD. BIM allows for simultaneous 2D and 3D design of a building, while additionally integrating material and scheduling information into the digital file. The created digital models are parametric, facilitating design alterations. These files can also be linked to external databases containing any type of information desirable. The potential spatial and material information imbedded in these digital models is tremendous. The implications of

this technology on the design of Invisible Architecture can be equally tremendous. The software currently available, BIM (Revit) and acoustic simulation (EASE or ODEON), could be synthesized into one program that would bring the design of Invisible Architecture to the masses.

Let us use a fictitious name to represent the proposed software, BIAM (Building Information and Acoustic Modelling). As outlined in chapter 6, the design process would involve several stages. First, the user would three dimensionally “draw” the basic massing volumes of the project with generic materials. Once content with the initial design, one would add a set of “social parameters” involving public, private, transitory and social gathering areas to the massing model. These parameters would have multiple imbedded audio clips (containing potential conversations and ambient noises typically present in such spaces) that could later be used to test the acoustics of a space. These “social parameters” would also contain a list of suggested materials, contained in separate lists with headings such as absorptive, reflective and diffusion etc. In the next stage one would further develop the design by adding materials and specific wall assemblies. Each material and wall assembly would contain imbedded information regarding the acoustic absorption and

insulation properties. One could use the software up to this point without any real attention to the potential acoustics of the designed space. Once the massing, "social parameters", materials and wall assemblies are set one can test the acoustics of the proposed space. By running acoustic simulations, with varying degrees of accuracy (as can be done with visual rendering), the software would produce "room mode"² diagrams and other diagrams visually demonstrating the sonic reflections in the space. Additionally, one could utilize the aforementioned sound clips to listen to what the space may sound like. By making geometric, material and "social parameter" changes to the design one could compare the resultant impact on the sound of the space.

Once computer processing speed increases to a level that accurate acoustic simulation can be performed in real-time, the real advantage of BIAM software can be achieved. Imagine creating a digital building model (while wearing headphones or within an octophonic listening chamber) that gives instantaneous visual and audible feedback as you change the materiality, surface textures and angle of the walls. With these technological advances one could "aurally sculpt" the experience of space in a way never achieved without the aid of sophisticated technology. That is the ultimate goal of Invisible Architecture.

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1 LaBelle, Brandon. *Acoustic Territories: sound culture and everyday life*. New York: Continuum, 2010, p. 71

1 Hall, Edward. *The Hidden Dimension*. New York: Doubleday & Company, Inc., 1966, p. 40

2 The commonly used room mode diagrams focus on only a single frequency at a time. Although this is clear and accurate, it is mostly irrelevant to quickly analysing spaces for social conversation. A new form of "room mode" similar to the ones described in chapter 5 would be used. These diagrams would incorporate three dimensional representations of multiple room resonances. It would be similar to a three dimensional representation of the cymatic patterns observed by Chladni (referred to in chapter 2). These spatial diagrams would reveal the location of the loudest and quietest areas present in specific room geometry, for the entire frequency range of human conversation. One could then accurately judge the sonic implications of the visual manipulations performed on the design.

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Chapter 6

1. WEM graph: *Environment and Behavior*, Vol. 26 No. 6
2. Site Plan
3. Site Plan
4. Exploded axonometric
5. Section
6. Foldout – Composite drawing
7. 7-16: Digital renderings of project
8. 17-20: Photographs of project model

Chapter 7

1. Sketch by authour
2. Sketch by authour
3. Sketch by authour