Composing with Sculptural Sound Phenomena in Computer Music

Dissertation

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Words fail to express the thanks I owe wife, Verena Lercher.

Note on Translation

This document is the English translation of my dissertation "Komponieren mit Skulpturalen Klangphänomenen in der Computermusik". Though having published frequently in English over the last 10 years, after some deliberation I had decided within the framework of my doctoral studies to write the original work in German first. One reason for this was that as a composer, I aimed for a certain sound in a style of speech that in the context of artistic research would connect the fields of music, sound art, philosophy, sociology, musicology and engineering sciences, with my efforts leading to success in my native language. Additionally, many of the newly introduced terms, for example from the field of sculpture theory or theory of space are not one hundred percent handled equally by authors in both languages and I had to keep this investigative process out of the actual work. Alone the different use of the terms sculpture and plastic in English and German occasioned long discussions. The first version of the translation was scheduled for early 2017, but had to be postponed again and again due to my composition and concert activities, as well as the following appointment as Edgard Varèse guest professor at the TU Berlin for the winter semester 17/18. In the present translation by Christian Liberty Marshall and myself, it was very important to find both a sound and a flow in the English language close to the original work, in addition to the detailed and exact matching of the terms of various disciplines and their own research results. I must thank the Artistic Doctoral School at the University of Music and Performing Arts Graz for having supported this lengthy translation process.

(Gerriet K. Sharma, May 2018)

Abstract

This thesis includes a practical and theoretical investigation into electroacoustic space-sound phenomena, *plastic sound objects* [González-Arroyo, 2012], previously little researched. Over the last 60 years these have increasingly appeared in certain sound projection techniques in the field of computer music. A special loudspeaker system developed by the Institute of Electronic Music and Acoustics (IEM) at the University of Music and Performing Arts Graz, the icosahedral loudspeaker[1](IKO), has been used and further developed for this purpose. The focus of all of the artistic research endeavors is the question of "Shared Perceptual Space" (SPS), the space in acousmatic music [Chion, 2009, 144] within which the perceptions of composers, scientists and audience intersect in respect of three-dimensional sound objects. The research aims to use artistic actions in order to demarcate this space or to trigger its formation. To do so it repeatedly implements a three-phase process: within the context of a series of progressively evolving electroacoustic compositions, the plastic qualities of these sound phenomena are explored. Parallel to the compositional process, an attempt will be made to find the language to establish generalizable descriptions of the objects produced. Research into existing terminologies and their application was employed to this end. Further to this, these terms were reviewed in an attempt to classify the researcher's own compositional process. Additionally, engineering sciences were used to simulate and explain the artistically produced spatial sound phenomenon in psychoacoustic terms with listening experiments, measurements and virtual modeling.

The resultantly interlocked descriptions and also collisions of perceptions gradually informed the ensuing compositional process and led to an expanded understanding and a different practice of artistic work with these phenomena.

[1] Throughout the thesis, gender-specific terms may be used in order to ease the text flow. Whenever a gender-specific term is used, it should be understood as referring to both genders, unless explicitly stated.

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To find something, a lot of people - and maybe most people - first need to know that it is there.

(Georg Christoph Lichtenberg)

I'm blind and music is my little Antigone who will help me see the unbelievable.

(Jean Luc Godard)

One can't see acoustically what happens in the space until you illuminate it, by putting sounds in it.

(Max Neuhaus)

If I as a composer work with loudspeaker systems, which can produce to this day unheard sound-space phenomena, how can I know that the audience will perceive them? Am I the only one at the end of a compositional process who perceives this technically mediated offering of a world? Am I only researching myself over the course of my work? Would we then all be alone in the medially generated sound space, or is there perhaps an intersubjective space of perception for this music?

(Gerriet K. Sharma)

CHAPTER I

Conditions - Methods and Practices

1. Introduction

1.1. Artistic Research

Much debate has surrounded the concept of artistic research in recent years [Borgdorff, 2012; Brandstätter, 2013; Badura et al., 2015]. After careful consideration of the positions held in thematically relevant literature and numerous discussions at Graz's University of Music and Performing Arts Doctoral School, as well as attending international symposiums and conferences, I believe it to be important that this work does not preclude a final definition of artistic research. Rather, on the following pages, I present my research methods as cognition-driven, contextually informed, process-reflexive, and communicative. My artistic activity, which is the driving force behind this research, focuses on the medially connected human being, or rather his perception and the influence and alteration of his perception by acoustic media. The artistic proposal is to create a different sensory description of a world at the moment of the encounter in and with the space-sound composition. Said differently: My content is concerned with the reference to and the refinement of perceptual possibilities by means of electro-acoustic space-sound composition. My artistic research methods prove this possible through provocation from experiences at the boundary of terminology. In other words, I repeatedly find myself exploring my own areas of experience, as well as neighboring fields proving themselves as strange and difficult to relate to, and must lay these paths bare. As the research topic suggests, it is about space, the awareness of space through art and in art. I therefore take part in a search for a different - auditory - spatial aesthetic.

1.2. Personal Background and Compositional Practice in the Field of Research

One key aspect of my work as a composer is the long-term focus on spatialization [Harley, 1994, 179-180; Zvonar, 2004; Ojala, 2009, 357ff; Roads, 2015, 240], the arrangement and composition of electroacoustic sounds in loudspeaker environments into three-dimensional sound formations in Wave Field Synthesis and Ambisonics[2]. My work in the field of computer generated and controlled multi-channel acoustic sound composition and installation led to an increased interest in the further development and transformation of the musical material by means of a dynamic spatial sound concept. In order to deepen this interest, I first used wave field synthesis as a method for spatial sound (re-)production because, in contrast to conventional multichannel methods (e.g. stereo or quadrophonic,) it's possible to localize sound events within a so-called wave field in a concert hall or studio space. Thus in 2005, in cooperation with Cologne's Academy of Media Arts, I composed *Aubaine*[3] (32'58'') in the wave field synthesis studio at the Fraunhofer Institute in Illmenau. The studio set up consisted of prototypes, panels with approximately 200 loudspeakers running horizontally. It was possible within the scope of this work to develop the initial ideas concerning spatial sound composition, in which the perception with sound events variable in space, comparable to actors acting on a stage, is confronted. In 2006/2007, as a guest composer at the invitation of Prof. Gerhard Eckel, I developed the Ambisonics space-sound composition *Abandonee*[4] (48'53'') in CUBE, the studio and concert hall at Graz's Institute of Electronic Music and Acoustics. Here I worked with a loudspeaker dome for the first time. The three-dimensionality of the structure and the related shaping possibilities of and with sounds in the laboratory, through both the structure and the CUBE-Mixer[5] [Ritsch et al., 2008], meant facing a different, sculptural presence of electroacoustic sound. Over the course of the system's tests and the

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[2] Wave Field Synthesis (WFS), like Ambisonics, is one of the holophone sound source reproduction methods. While Ambisonics is based on a local sound field reconstruction in/around the coordinates' origin, WFS strives for a global reconstruction. The wave field synthesis approach derives directly from Huygens-Fresnel's principle.

[3] The sound composition developed with Dirk Specht was selected for the "SPARK Festival of Electronic Music and Art 2006" (Minneapolis/USA), received one of three "Honorable Mentions" from the Eastman Computer Music Center (EMC # 25) Rochester (New York / USA) and was presented by DEGEM in the ZKM network radio during the ISCM World New Music Festival 2006 in Stuttgart. The composition was most recently presented in 2008 as part of the exhibition "Geração Transterritorial" in "Paço das Artes" in Sao Paulo.

[4] *Abandonee* was featured on the DEGEM-Webradio in the spring of 2009 and in SWR2 in May, 2009 - at Musik spezial: RADIOPHON. The composition was invited to the New York City Electroacoustic Music Festival in April, 2009.

[5] The CUBE Mixer is a Pure Data programmed control tool for the CUBE.

compositional work taking place on location, an idea developed in which the sound body is projected into the concert room through loudspeakers as a malleable object made of sound, which the composer can shape through further compositional processes. I continued following the idea of sculptural sound shaping[6] through computer controlled sound projection over the next two years and gathered the experience and results into a ten part composition *I_LAND*[7] (49'11") in 2009.[8] Since 2009 the focus was on the IEM icosahedral loudspeaker. Alongside this development I have been artistically addressing installation-oriented practices in public space since 2005. Among other things, I followed the series of works *{kA}: keine Ahnung von Schwerkraft*[9] from 2010 to 2015, during which I focused on acoustic properties of vacant architectures [Sharma, 2013; 2014a; 2014b; Reither et al. 2016]. As a result, the aspect of location as an omnipresent factor when working with loudspeakers was given a higher priority in the conception of all my compositional actions, whether in a studio, in a concert hall, in a single-family house or in an empty office building. For me, after a thorough study of various loudspeaker systems and projection methods over the last 15 years, certain sound layers and arrangements have something spatially definable, so that they amalgamate into sculptural, heterogeneous bodies of sound. Due to the fact that the physical, fixed sound sources, e.g. individual loudspeakers in a studio or concert hall with the use of Ambisonics, are often eliminated, after a short time I hear the sound not only coming from the loudspeaker, but rather take the movements and orientations of the sources projected in the concert environment for granted, and the technical set-up temporarily withdraws from perception. And it seems to me that in these moments certain sounds can be perceived as three-dimensional objects or separate sound zones. In such situations, I no longer point my finger to the source as a point, or merely move from A to B, but can describe an area with both arms and hands. I can follow fields of different sizes and gradations and reconstruct cloud formations and streaks of penetrating sound. [10] These

[6] For the sound sculpture in my previous work cf. Oliver Wiener "Expedition to the Entropic Islands" in [Ungeheuer / Wiener, 2012] and Elena Ungeheuer in [Ungeheuer, 2012]: "Giacometti's Sculpture as a Concept of Spatial Virtuality avant la lettre".

[7] The work was produced after the premiere on April 7, 2009 in the CUBE of the IEM Graz as a binaural CD with limited-edition box. I_LAND was part of the NEU/NOW Vilnius Festival in 2009. A further presentation took place in the context of "next generation" 2011 at the Center for Art and Media Technology (ZKM) Karlsruhe and at the Darmstadt Summer Courses 2014.

[8] The two compositions with the CUBE were each made possible by a scholarship from the German Academic Exchange Service (DAAD).

[9] The series was funded by the Province of Styria, the University of Music and Performing Arts Graz and the SK Foundation Culture Cologne and nominated for the exhibition of the European Sound Art Award in autumn 2016.

[10] In the sense of a blurring of an event just experienced, as a remaining, audible trace of its tonal components in the perception.

extensions can be shaped and leave a three-dimensional impression in auditory perception.

Although similar descriptions from other composers appear, [e.g. Varèse, 1998 (1936); Bayle, 1989; Emmerson, 2007, 147; Smalley, 2007; González-Arroyo, 2012; Nystrøm, 2013], the (graspable) tangibility of these phenomena is problematic. There are fundamental difficulties of reproducibility in both the compositional process and in the performance situation, and in addition, divergences in the audience's perception. Much has been written over the last 60 years about technical setups and software solutions for sound movements and projections; relatively little, in fact, about that which occurs in the perception due to the use of these tools. Moreover, loudspeakers as visual objects at use in concert settings need critical classification in relation to the so-called sound object.[11] In addition, the descriptiveness of three-dimensional sound objects in the sense of fundamental categorization is indeed addressed [Smalley, 2007 Nystrøm 2013], but is not widespread. *Indeed the art of spatialisation has emerged as one of the most important topics in composition today. Even though a formal theory of spatial relations remains to be developed* [Roads, 2015, 281]. And even where there are corresponding attempts at classification, these usually refer to extrinsic phenomena which are borrowed from visual perceptions, and thus are references which often cannot be generalized or translated into auditory perception.

> *How composers conceive musical content and form – their aims, models, systems, techniques, and structural plans – is not the same as what listeners perceive in that same music. In electroacoustic music, the separation between the act of sound making and perception, combined with the specialised nature, proliferation and transience of methods and devices, indicate that technological knowledge cannot be part of any method founded on perceptual consensus.* [Smalley, 1997, 107]

[11] A problem that I will discuss separately in Chapter II. 4.

1.3. Desideratum of this Artistic Research - Towards a Shared Perceptual Space (SPS).

The aim of this artistic research is the conception of a common *space* of the perception of three-dimensional sound phenomena – a domain I have elsewhere called the Shared Perceptual Space (SPS) [Sharma et al., 2015].

> *Even assuming all scientific and technological problems were solved, the question remains as to how we can organize the space in its complex meaning as musical material.* [Stroppa, 1991] [12]

It is therefore a matter of finding parameters for an intersubjective space for the perception of three-dimensional sound phenomena. For the composer, the question arises to what extent a communicable or self-explanatory composition of plastic sound objects[13] is conceptually, theoretically and at all practically possible when faced with changing architectural space situations,[14] different spatial descriptions, and perceptions. Is there then within the field of space-sound composition, in which I myself have worked as a composer for years, a space at the place[15] of the music, where my perception in the compositional process overlaps with both the engineers' and audience's perception? Can at least an approximate circumference of an overlap be described? How and from which sides (linguistic, technical, artistic, etc.) can this field be approached?

1.3.1. SPS: The Acousmatic Paradigm - the Perceptual Situation as an Established State of Exception - Beyond *Mediatized*[16] *Space*

I base my artistic research on the assumption that experiencing electronic loudspeaker music creates an independent listening situation, therefore also requiring specific aesthetic research. Frequently, places where music is reproduced through loudspeakers are referred to as "mediatized spaces" [Smalley, 2007, 45]. In most theories on "mediatization", however, the assumption suggests that reproducing media initially only refer to reality but

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[12] Material and quotations referenced in this translation with English as a source language are presented as such and have been left unchanged. All other material and quotations referenced in this translation have German as a source language, with several instances of source material being translations themselves (e.g. French to German to English.)

[13] See Chapter II. 7.3. Sound as a Spatial Texture.
[14] See Chapter III. 2. Concert Practice as a Research Process.
[15] For the terminology of place cf. Chapter II. 8.3.
[16] The word "mediatized" is understood here in a narrow sense, as used by e.g. Philip Auslander: [...] a particular cultural object is a product [...] of media technology. [Auslander, 2008, 5]

do not produce it [vgl. Sanden, 2013, 4]. However, the initial recording and playback methods have already taken a step further [Katz, 2004, 24]. Original reproduction devices built exclusively for the faithful reproduction of original works changed the playing style of the musicians (for example, more vibrato, shorter breaks in strings), causing the playing style of the classical repertoire to change due to the applied media technology. And because today more people around the world listen to recorded music instead of going to a concert, listening habits and the way we hear score-based music are also changing. As we have heard, this has gradually been shaped by the ever increasing reach of, and later ubiquitous, audio technology [Katz, 2004, 22]. In a subsequent step, recording techniques and studio methods were developed into artistic and poetic practices, allowing for another type of music otherwise impossible, and producing spatial situations in the stereo field, situations which cannot be realized outside of the recording and or by reproducing media at all, for example layered reverb simulations of various instruments.

> [...]*, the disembodied sound of audio reproduction is often interpreted in a framework that is specific to this context. For example, the spatial arrangement of sources in a typical stereo pop song makes no physical sense. We accept the spatial arrangement as an idiom of audio reproduction, a musical-spatial idiom. The immaterial nature of audio reproduction enables auditory spatial art to exploit the spatial schemata of everyday life.* [Kendall/Ardilla 2008]

Sound movements, instrument arrangements, and voice placements were able to be used as artistic settings, but in no way did they have to be related to the actual placement of the instruments on stage in a concert stetting or their techniques. In fact, concert settings were later designed in such a way that only then enabled the studio production to be performed "live." Katz describes these musical products as real and virtual at the same time [Katz, 2004, 9]. Vollmar also explicitly refers to the fact that [...] *these first years of audio production show that the so-called sound reproduction media don't just simply "display" and therefore reproduce, but that the mediatization process could be and was formed like liquid metal* [Vollmar, 2010]. The perception situation in an acousmatic concert is due to the fact that the loudspeaker as a tool and/or instrument creates its own cultural sound environment. This environment sometimes refers to states and circumstances outside the concert setting or the installation (e.g. through the use of sounds one associates with water but aren't necessarily sounds of water), but after more than 100 years of development and practice of filling a room with music by means of loudspeakers—from the laboratory to the living room, the boutique to the concert hall—both the act of listening and thus perception especially in computer music are directed and shaped the moment they are experienced. *Not only do electroacoustic composers have the freedom to design sounds that specifically support spatial effects, but they can also explore ways of creating sound that have no obvious analog in the physical world* [Kendall/Ardilla, 2008]. In the case of an acousmatic concert, it is not a traditional concert hall in which a loudspeaker simply plays music. The loudspeaker in the acousmatic concert does not transmit the formerly experienced, rather it *creates* experience. *Reality is as much about aesthetic creation as it is about any other effect when we are talking about media* [Sterne, 2003, 241].

McKinnon [2016] attests acousmatic context to have an independent and unique form of liveness. *Such acousmatic contexts, while not live in a conventional sense, use sonic immersion, dynamic spatial articulation of sound, and the experience of sound as invisible matter, as means to create a unique form of liveness.* Paul Sanden writes the following about liveness: *Liveness is a perception, guided by the different ways it may be evoked inside cultural discourse and practice* [Sanden, 2009, 8].

This perceptual situation described by Sanden is particularly important in that it requires a different listening attitude from the audience than, for example, the theater or a violin concerto. The performer in the traditional sense has actually disappeared, so that the attention paid to the musical process in practice is addressed differently. The listener is challenged by the technical and artistic composition in the sense of an assembly of various elements to be an active participant. *Loudspeaker music, shifts the centre of gravity away from the performer and towards the listener, reconstituting liveness as listener-determined* [McKinnon, 2016]. In addition, there is a schizophrenic performance situation we cannot overcome, namely the presence of immobile pieces of equipment: loudspeakers that seem to freeze the visual aspect of the performance. Our eyes have nothing or no one to follow. The performance thus takes place between the loudspeaker environment and the listener's ears. The performance shifts inward and therefore the Chionic Visu-Audition [Chion, 2009, 150][17] takes on a central role in this perception situation. The sound objects both produced and producible in this way are sometimes so fragile that small changes, such as technical or manmade sounds in the hall, flickering light, changing the color of the lighting, or noise coming from the

[17] Cf. Chapter II. 4. Dramaturgy and Staging of Sculptural Sound Formations.

audience, can divert and destroy attention because of the lack of an emphatic performer-audience connection. In addition, the physical presence of the loudspeaker cannot be denied. One cannot pretend it is not there. Simon Emmerson rightly asks: *But is loudspeaker music really 'acousmatic*? [Emmerson, 2007, 147]. Even if the loudspeaker almost disappears through the illumination of the performance space, it is considered as a rigid, sometimes clumsy object and cause for, or at least part of the cause for, the spatial sound composition. This tension surrounding acousmatic loudspeaker music has existed since its inception, so it must be understood in research and especially in composition as a part of the nexus of conditions that need to be examined in their interdependence. *[...] I find this enthralling and somatically powerful, yet highly fragile as its auditory objects (both real and virtual) are contradicted by the visible physicality of the objects that give rise to them – loudspeakers* [McKinnon, 2016].

Most studies that deal with sound phenomena in computer music disregard the speaker as part of the generated phenomenon. They also classify the medially generated situation as virtual [Harenberg, 2012; Roads, 2015, 260]. As part of my artistic research I indeed assume that without the presence of the loudspeaker precisely these phenomena and their "liveness" are not perceivable as concrete and real. It requires precisely the interaction between the loudspeaker as an object, the sound generated, the environment and the physical, affective, and interpretive activity of the listener. For precisely at these crossroads the previously mentioned, distinct perception situation is created in a separate, medially[18] specified cultural context. McKinnon as well:

This can only happen in the absence of performer and performance, and in the presence of the loudspeaker. Such liveness is both singular and radical, particularly considered within a contemporary cultural context dominated by multimedia, whether spectacular or mundane. [McKinnon, 2016]

[18] Here medial means: shaped and influenced by the transmission of the speaker.

1.3.2. SPS: Intersubjectivity as the Spectrum of Perception in Mediatized Space – Research Questions

> *If it communicates to me, that's one thing, because I know what my music means to me. Now, if I can communicate something to somebody else, then that's where the excitement of the composition is [...] The job of a composer is to mediate between ideas and the people that make up your audience.* [Field, 2001]

Anyone who has spent a while working in a studio has experienced the specialization of their own perception that has very little in common with third parties' listening experiences and habits. This subjective experience can sometimes also take the form of acoustic illusions. *My experience of teaching composers has often revealed to me that such distortions are frequent* [Smalley 97, 111]. To communicate this impression, approaches for a more stable perception by third parties must be found. Here I am indeed not focused on "the description" or "the precise form" everyone appears to everyone or must appear to everyone the same way. That would be an unacceptable, regressive approach in the field of art/music. So it is not about coordinating perception or the fixation of modes of perception. In this respect this artistic research is often in an intended fruitful conflict with engineers demanding fixation of "auditory objects" in Cartesian space for their models.[19] It is therefore about the layering of different perspectives and their descriptions of plastic sound objects and taking them into account during the compositional process or consciously ignoring them. Therefore in the following methods described and during the research process I try to understand what I induce, i.e. which perception spectrum I provoke and which categories the audience, engineers and I have both for and in the listening experience. My aim is therefore to better understand the variability and through research (constructing models, verbalization, new compositions) to get reacquainted differently with my own sound objects and their conception through an assumed SPS.

[19] See Chapter II. 8.5 .: Scientific Attributes of the Perception of Spatial Dimensions in the Loudspeaker Environment

Based on these considerations and my artistic practice as outlined, the following research questions presented themselves:

- What are sculptural sound phenomena?
- How can the space-sound phenomena be verbalized?
- Can a methodical compositional method with these phenomena be developed?
- How can the phenomena be staged for public performance and made tangible?
- What technical and spatial conditions are prerequisites for such a performance?

2. Tool and Instrument I - Conditions

2.1. The Icosahedral Loudspeaker

The loudspeaker system used in the research consists of a wooden icosahedron (5th platonic solid) with a loudspeaker chassis placed in each of its 20 sides. The cables are located within the housing. The object, mounted on a stand, can be flexibly positioned in space, and is connected to a sound generating computer system via a multicore cable with converter and amplifier unit.

The IEM icosahedron loudspeaker provides bundled sounds in completely freely adjustable spatial directions. This sound bundling should initially introduce an improvement in the quality of acoustic measurements. Through the use of the holophony [Jessel, 1999], natural sound generators can be simulated or the paths of the sound reflection modeled. The idea of using sound sources with adjustable acoustic emission in electroacoustic music was brought up in Paris by a research group at IRCAM in the late 1980s. Thus a well-known concept study "La Timée"[20] was built, a dice-shaped loudspeaker housing six separately controlled loudspeakers was built to achieve freely controllable directivity. [Misdariis et al., 2001]. In 2006, the Institute of Electronic Music and Acoustics at the University of Music and Performing Arts in Graz intensively deepened the research on this topic from a technical point of view, in which Franz Zotter, Alois Sontacchi, Robert Höldrich and Hannes Pomberger played a decisive role. The research resulted in the 20-channel Icosahedral loudspeaker (IKO), which with its separately controlled speaker diaphragms could reach a significantly higher beamforming than the earlier prototypes. This result was born from the initial intention of simulating musical instruments in their lower registers, along with their omni-directional emission, both tonally correct and strongly.

Figure 1: The IKO with stand and amplifier

[20] http://www.entretemps.asso.fr/Timee/ (zuletzt eingesehen: 08/2016)

2.2. Beamforming

Based on the previous experience with the three-dimensional shaping possibilities in Ambisonics, it was natural to use this projection method from the outset for the IKO. By applying the beamforming algorithm developed by Franz Zotter [Zotter, 2009; Zotter/Frank, 2015; Keller/Zotter, 2015] in Ambisonics (3. Order) it is possible to project tightly bundled sounds onto floors, ceilings and walls, so that one not only hears sounds at or from the source itself (such as a violin or most radio devices), but at projected and reflective point (mirror source). Here, individual loudspeakers are weighted by superposition so that sound projection in a desired (main)-direction is possible. Constructive interferences in the desired direction are formed during sound propagation, while the individual signals superimpose themselves where little or no sound projection is desired. These "beams" can be freely set not only in their angles, but also in their position. Thereby, the mirror sources may even be mobilized and superimposed on the reflective surfaces.

Beamforming with the IKO works in a frequency range between 120 to 800 Hz. Changing the Ambisonics orders during projection changes the main beam. That is, with the reduction of order, the main beam's width expands up to omnidirectional, spherical radiation (0th-order). Placing the order again up to 3 narrows the beam, providing greater direction for spatial stimulation.

Ambix- and mcfx-plugins by Matthias Kronlachner [Kronlachner, 2014] were used exclusively for the space-forming work with the IKO during research, as he implemented the IEM research on sound projection from the last 15 years with a standalone tool of its own design. Following the presentation of the plugins at the Linux Audio Conference in 2013, collaborative work to adapt the plugin to the IKO's work situation began. Through much communication, the system stability, computing power, and manageability of the working situation with the plugins. The reason for using these plugins as part of this work lies in the general accessibility[21] and the VST format, which makes it usable in the conventional digital audio workstations (e.g. Reaper, Ardour) and can be used with Mac OSX, Windows and Linux. In addition, the plug-ins can also be implemented in Max/MSP[22].

[21] http://www.matthiaskronlachner.com/?p=2015 (last visited 08/2016)
[22] https://cycling74.com

2.3. Starting Points for Artistic Research with the IKO

2.3.1. Transfer of Previous Experience

As part of this study, experiences and ideas developed from dealing with multi-channel systems, various speaker configurations and different projection methods such as WFS and Ambisonics were applied to the previously little studied IEM Icosahedral loudspeaker apparatus. The composer has the option to differentially layer, move, overlap, and mix sounds from a central point throughout the performance space. This produces three-dimensional electro-acoustic sound formations also or similarly experienceable in other loudspeaker configurations such as circles or domes by use of WFS and Ambisonics. These plastic sound phenomena could be described for a long time only roughly and inadequately, as they were also unstable and seemed strongly bound to the laboratory situation. The increasing practice, however, showed clearly early on that, with closer study of the system, greatly differentiated space-sound compositions with sculptural characteristics could be composed and adapted to different room situations. Thus, in 2009, following conversations with engineers Franz Zotter, Matthias Frank and Hannes Pomberger the compositions *grrawe* und *firniss*[23] came into being, joined by *grafik unten*[24] in early 2014 after the initial studies at the studio for sound research at the Institute for Music Research Würzburg and IMA/Klangdom ZKM. These compositions first served to familiarize oneself with and further develop the technical apparatus for artistic use, and were mainly multichannel compositions for conventional speaker arrays adapted to IKO. Therefore in the first few years I focused on the experiencing of the differences between the systems. In addition, the icosahedral loudspeaker was tested with different sound compositions, sound generating methods, spatial concepts, as an installation tool and in concert setting, and in various room situations. Initial tests and compositions have shown that the mobile IKO is suitable as a versatile electroacoustic composition tool as well as a concert instrument playable in both chamber music halls and larger concert halls. This required, however, bringing together factors including loudspeaker system, computer, beamforming, room acoustics and the audience's perception as a cohesive unit of factors within the composition and intensively

[23] Among other places, *grrawe was presented as part of the Forum Alpbach 2010 and was part of the concert program of the DAFx10 and 2011 at next generation at ZKM. grrawe and firniss were invited to the International Computermusic Conference ICMC 2012 and the New York Electroacoustic Music Festival 2016*.
[24] Work reviews and interpretations of grrawe and grafik unten can be found in [Ungeheuer / Wiener, 2012].

keeping eyes and ears on the interactions within the compositional process.

2.3.2. OSIL (Orchestrating Space by Icosahedral Loudspeaker) AR 328

This following work, started in 2013, is as of May, 2015 part of the Austrian Research Fund (FWF) funded artistic research project OSIL.[25] Many of the results presented here have been published from an artistic and an engineering perspective in relevant magazines and international forums. As of August, 2016, the project's website is www.iem.at/OSIL

[25] Project leader of the PEEK project OSIL (AR 328) is Franz Zotter.

3. Methods and Practices

3.1. Establishment of an Iterative Work Process

An iterative process was followed as part of the work, consisting of text retrieval, composition, terminology research (verbalization), listening experiments and psychoacoustic modeling. This process was repeated several times, meaning information gained from the evaluations informed the further working and compositional process.

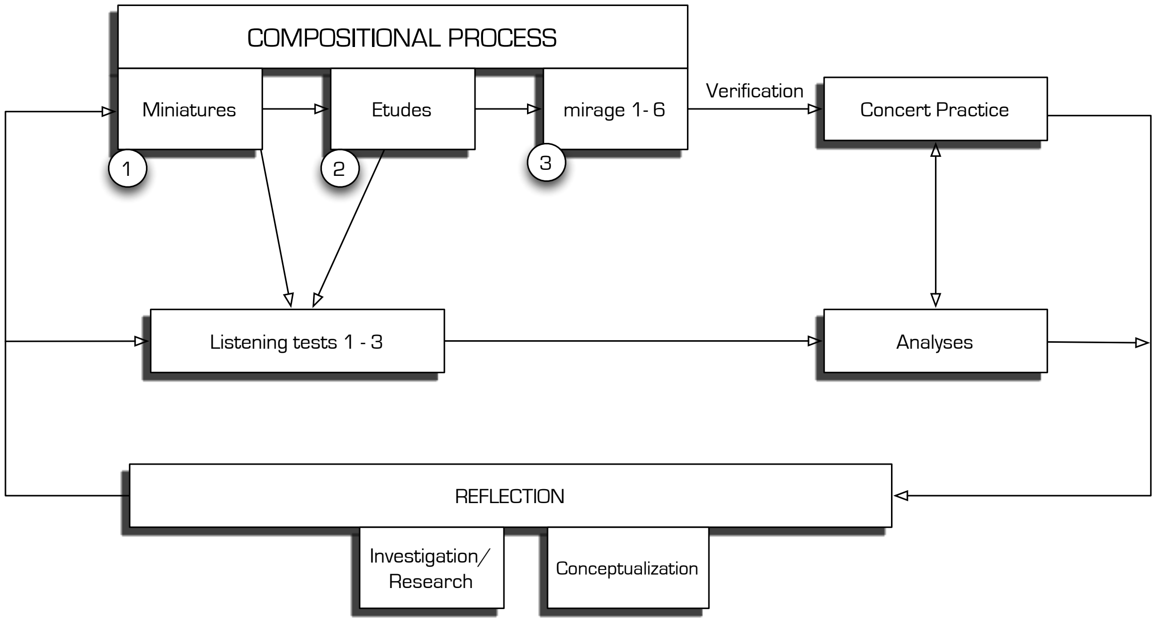

Figure 2: The scheme shows the iterative research process, here always starting from the field composition in threefold repetition. Based on very simple composed spatial-sound constellations (1. Miniatures), first self-tests, later with test persons in the laboratory, then followed by listening tests, the results of which flow directly into the performance and concert practice with the IKO. At the same time, these are evaluated in terms of engineering, in order to arrive at technical explanations of the phenomena occurring in the form of psychoacoustic models, which are then discussed, published and applied in the further working process. The reflection on the possibilities of verbalization of the phenomena, the experiences from the performances, the modeling and results of the self-experiments in exchange with the audience, colleagues and supervisors then flow into the composition of complex spatial-sound definitions (2. Etudes). These then go through the process described above and eventually lead to the composition of independent compositions (mirage 1-6), which in turn are described and interpreted with the terms established in the working process in order to prove the coherence of the artistic research results.

3.1.1. Investigation

It was a continuous and accompanying process. Starting with the review of the terms that I myself have been using for years, and then passing over to those used by other composers, engineers, musicologists and amateurs for the field of research, I have tried to reveal the differences between the terms and to verify the actual suitability for the description of perceptual possibilities in media space within artistic research.

3.1.2. Composition

The first practical step focused on the compositional reduction of plastic sound formations as miniatures, with a length of 30 seconds each. The speaker was positioned in the same room the same way always. The resulting 64 space-sound miniatures were first described by myself from two listening positions using the following categories: used sound material, patterns of movement, speed, produced perceivable form in space. After revisiting further stages in the process, the newfound concepts contour, directionality, and plasticity were added to the description log.[26] These miniatures then formed the basis for the selection of the first stimuli for listening experiments 1 and 2.

The results of listening experiments 1 and 2 were compared with my own experience and fed into the compositional process of more complex space-sound sculptures I refer to as etudes. I then classified the etudes in special respect to their body-space relation[27] (kernel plastic, spatial plastic, kernel-shell principle.)[28] These studies were then examined in two other listening experiments and subsequently make up solid components of independent compositions, together forming the series of works mirage 1 - 6.

The resulting compositions, created over a period of three years, include many of the spatialization models proven by the miniatures and etudes, or have both combined and further developed them.[29] In this case, only the sculptural body-space models were implemented and used as general molding principles. The six finished works were then again subjected to analysis[30] with the aid of the extended terms from the scholastic writings on sculpture.[31]

3.1.3. Scientific Analysis

The experimental design and the implementation of listening experiments 1-3, as well as their evaluations, were carried out by and in cooperation with engineers Franz Zotter, Matthias Frank, Florian Wendt and Markus Zaunschirm. The respective analyses have been published[32] and in turn

[26] See Index of Miniatures, Chapter IV. 1.1.
[27] See Chapter II. 5.1.1. Body-space Relationships
[28] See Index of Etudes, Chapter IV. 3.1.
[29] See Index of Miniatures and Index of Etudes with corresponding references in mirage 1 - 6
[30] See Chapter V. 2. Analyses
[31] See Chapter IV. 4.
[32] Overview: https://iem.kug.ac.at/projects/osil/references/publications.html

included in the artistic work process. The changing artistic and practical requirements of the IKO have also been adopted and implemented in detail by means of the growth of knowledge derived from engineering studies, such as filter improvement, software extensions, simulation and performance stability. At all stages of the iterative process, the historical and musicological analyses have been a part of the conceptual and practical developments in relation to the formulation of conditions for the composition of sculptural sound phenomena in computer music.

3.2. Extended Concert Practice

Since 2013, ten public concerts and demonstrations were given as part of this work with the IKO. These include performances at: *International Summer Courses for New Music Darmstadt* 2014; *Signale^graz 1001*, 2014; *izlog-Suvremenog Zvuka Festival* - French Pavilion, Zagreb 2015; *izlog-Suvremenog Zvuka Festival* - Media Art Gallery, Zagreb 2015; *EPARM Festival* Graz 2015; *Artistic Needs and Institutional Desires* - Symposium Haus der Kulturen der Welt, Berlin 2015; *InSonic2015* ZKM Karlsruhe; as well as a concert with the IKO's new 8-channel loudspeaker simulation[33] at the *New York Electroacoustic Music Festival* 2016 and the *Sound and Music Computing Conference Hamburg* 2016. Each of these performances took place under very different spatial and organizational conditions. The practical experience consisting of audience members' reactions, technical setbacks, site-specific performances, and acoustic surprises, as well as set-up, transportation, and security problems served once again as an important impulse for further scientific and artistic studies. The final evaluations from these studies have been incorporated in the musical compositions and the design of a new IKO. From these findings, numerous standardized processes and methods for an expanded, new concert practice with the IKO and with different audience situations have emerged.[34]

[33] See Chapter III.1.2. The Virtual IKO (ViKO).
[34] See Chapter III. 2. Concert Practice as a Research Process.

3.3. Lectures and Workshops

Since 2013, the status quo of the artistic research has been presented in eleven lectures and been made open to criticism from field experts. Among the events included are: *Lange Nacht der Forschung* Graz 2013/14; *Artistic-Scientific Doctoral School* Graz 2014 und 15; *CUBE-lecture* 2014; *Doctors in Performance Conference*, Helsinki 2014; *Izlog Suvremenog Zvuka Festival* Zagreb 2015; *Music-biennial Zagreb* 2015; *EPARM-Festival* Graz 2015; *International Conference on Spatial Audio*, Graz 2015; *Artistic Needs and Institutional Desires* Symposium Haus der Kulturen der Welt Berlin, as well as *Sweep*, Symposium on Contemporary Sound Research Kassel 2016 and a Hands-on-Workshop with OSIL at the *InSonic2015* conference. These lectures sometimes led to very controversial discussions regarding not only the possibilities of verbalizing such artistic practices, the generalizability of sculptural sound phenomena in the field of loudspeaker music, and the comparability between different sound projection systems and room concepts, but also the IKO's suitability for the concert hall and its allegedly unique position in the field of electronic music. All these aspects are taken up in this work and discussed at the appropriate, respective points in the research process.

Chapter II

Research: Conceptual Fields and their Coordinates

It is astonishing how, for example, so much analysis has been undertaken without a generally accepted foundational vocabulary [Landy, 2007, 220].

The following are frequently used terms for determining the actual object of the investigation of this work, in order to narrow down the research field and to better focus the research questions. These are extracts from the above-mentioned literary studies. For the artistic activity, this classification meant, first of all, the awareness of my own situation, a search for the subject in this field, and, towards the end of the work, the formulation of a personal position with regard to the suitability of existing terminologies, methods of composition, and newly found concepts and their terms. While there has been a lively exchange between science and art since the beginnings of computer music, there has been little interest on the part of the composer about the actual perception possibilities of the audience regarding spatial sound phenomena in the composition. In addition, electroacoustic music contains two diametrically opposed cultures: on the one hand we find the exact sciences of acoustics, computer science and engineering sciences, which primarily define the conditions for sound reproduction and develop corresponding tools for the composition. On the other hand, there is the culture of perception of music with the ear. While the first is strongly characterized by clearly defined terms and corresponding verbalization concepts shared by a community of specialists, the aural, musical aspect, which yields musical thinking and musical perception, cannot fall back on consistent terminology, as far as loudspeaker music and—here especially—space-sound composition are concerned.

There are mainly approaches based on subjective descriptions.[35] This is, inter alia, that art and science have two opposite approaches in formulating. Thoresen describes the dilemma as follows:

> *Thus a fundamental problem within every aesthetical discussion in this field resides in the contradicting approaches of science and art: Scientific discourse seeks to eliminate ambiguity in its terminology and definitions. An artistic discourse would on the contrary often seek to be as polyvalent as possible, suggesting a network of meanings or implications. Thus the scientific ideal is more often than not alien to an*

[35] See Chapter II. 1.

> *aesthetically oriented discourse. However, there is also a need for some intersubjective agreements in the aesthetic field so that music can be meaningfully discussed in words.* [Thoresen, 2006, 4]

This is the first question to be asked in the context of a search for the smallest denominator of descriptive possibilities and perceptions at the interface between the public, the composer, and the scientists. The main fields to be examined in the following are verbalization, sculpture, sound and space.

1. Verbalization

In order to converse with others, we usually use language. But also in the supposedly autistic or egoistic compositional process, the naming of occurring phenomena can help, which are not only related to the mode of production or origin, but are derived from experience and serve the aesthetic formation of ideas.

Many publications in the field of computer music are concerned with technical problems and their solutions. In addition, there are a large number of publications dealing with perceptual aspects in the area of *spatial audio* and their qualitative as well as quantitative analysis [Blauert, 1997; Lindau et al., 2014; Frank 2013; Choisel/Wickelmaier, 2007; Rumsey, 2002, Rumsey/Berg 2001, Marentakis et al., 2014]. This has also been necessary in the last 20 years due to the problems to be solved with regard to system stability, computer performance, loudspeaker layouts and sound projection methods. For an aesthetic debate—from which no art should spare itself—an additional, different knowledge is needed, a conceptual consolidation not only of the craftsmanship, but also of the perceptual phenomena with a degree of generalization needing to be discussed. This requirement is not new or exclusively linked to the development of computer music. A similar verbalization problem can be found in the field of score based music in the 20th century. In contrast to the generally refined notation possibilities of volume, pitches (new signs for microtones or number of cents) and durations - which thereby perhaps become less desirable to read, but clearly describe the facts in question - the timbre of sounds and noises are difficult to depict: the description of timbre is usually done through the instruments that produce it, or the specification of particular playing styles. It is not the sound, but the source or the action, which should lead to a sound.

> *Until now, we have only named the sounds according to their origin. [...]; It has not been possible to name musical sounds by name, such as red or green as we do with colors. When one says oboe, one means the instrument that one has built, and with which one makes sounds. But no one can describe an oboe sound as such among musicians. When musicians hear sounds that they do not know how they are made, they are completely lost. [...] It does not belong to the categories that we can name. This is very important, because you suddenly lose the perception, the orientation. And it creates uncertainty. And uncertainty is not desired. [...] we have a very small, limited reservoir of sounds that we can name, and that is miserable.* [Stockhausen, 1973]

Stockhausen clearly points to the dilemma that in most cases, only that can be named, which makes its naming and the accompanying dispute accessible. Similar problems are currently being discussed elsewhere in the field of contemporary sound production in film sound design. Barbara Flückiger represents a clear position here: [...] *As long as auditory perceptions cannot be translated into language, they are also not accessible to analysis* [Flückiger, 2001, 100]. The language is therefore a crucial interface between the sound and all listeners. It is already implicit in the analysis of sound. In addition, its importance is emphasized in the refinement of perception itself. *The more differentiated the linguistic resolution, the more differentiated is the perception and vice versa.* In this context, the thesis is made that *in our culture [...] an adequate vocabulary for the description of sound objects is missing [ibid.].* Of course there is the absolutely reasonable comprehension among composers that the artist lives in his own world of ideas and reflects them in the work. Whether and how the work is perceived is no longer a matter of the composer's influence and is free, as in the case of every work of art, at the moment of release. *The difficulties that some have in listening to a music that exists only as a sound are completely indifferent to me when I compose* [Chion, 2009]. This is not to be contradicted here, but we have gained a degree of artistic freedom that produces perceptual phenomena whose inter-subjectivity or conditions are strongly questioned because of the lack of general formats, concert settings, techniques and terminology.

> *If a group of listeners finds a music 'rewarding' it is because there is some shared experiential basis both inside and behind that music. We need to be able to discuss musical experiences, to describe the features we hear and explain how they work in the context of the music.* [Smalley, 97, 107]

1.1. 100 Years of Verbalization of Musical Sound Phenomena - Stages and Strategies

With the summary and comparison of different exemplary positions, the aim is to understand the characteristics of different approaches and to develop criteria for one's own productive approach to verbalization in the heterogeneous field of spatial sound composition. Here, a selection has been made, which is based exclusively on the limits of my research field and outside this field cannot be considered exhaustive.

1.1.1. *L'Arte dei Rumori* – Russolo

An early attempt to divide sound material new to the music of the twentieth century into "sound families" can already be found in Luigi Russolo's futuristic manifesto *L'Arte dei rumori* of 1913. At the same time as the construction and the demonstration of the Intonarumori, a group of apparatuses designed to produce noise, Russolo dedicated his own focus on the noise itself, which he divided into six classes [Russolo, 1916, Thies, 1982, 15]. In each class, he summarizes the different sounds, which he considers particularly characteristic. However, the underlying system of order cannot be read at any point in the text. Rather, the author mixes different criteria together. In part, the classes of similar brightness, e.g. whistling/hissing/snorting against murmurs/gurgling. Furthermore, two groups are formed mainly from loud noises such as booming/popping/thundering and screeching/cracking. Again, two other groups are based exclusively on their sound source: banging noises on the one hand, and animal and human voices on the other. This type of manifested noise classification is therefore not suitable for the general description of sounds. It is, however, noteworthy that more than 100 years ago with the construction of noise generators came the need of a concept of verbalization.

1.1.2. Serial Thinking and *Musique Concrète*

Since the advent of *electronic music* and the Musique Concrète around 1950, various classification systems have emerged whose authors are striving for a clearer structure. The various standpoints are also reflected in the initial efforts to give order to the sound material used. Thus, Herbert Eimert [Eimert

1954, 44-45] addressed Helmholtz [Die Lehre von den Tonempfindungen, 1863], by using exclusively stationary features in tone, harmonic complex, tone mixture, noise and consonance. He does not, however, enter into the listening perception that this material contains. For him, serial composing is the focus of action and strategy: *the electronic sound composition presupposes musical thought in series, sequences, orders and proportions, moreover it is simply a part of this statistical-serial thinking* [Eimert 1954, 245].

Pierre Schaeffer designed a linguistic system that enabled the new musical structures of electroacoustic music to be conceived and communicated. In his book, *A la recherche d'une Musique Concrete* [Schaeffer, 1952], published in 1952, he developed a differentiated system for the description of sound objects. The numerous and new listening experiences of the composers and technicians working in the studios at that time required in his opinion documentation and musical theory as well as philosophical reflection to compensate for the growing number of engineering concepts that threatened to monopolize discourse in electroacoustic music [Thoresen, 2006, 2]. Published in 1966, Schaeffer's *Traité des Objets Musicaux* [Schaeffer, 1966] (TOM) summarized his experiences and research results and thus represented the first comprehensive attempt to systematize and verbalize sound-based music [Landy, 2007]. Schaeffer was convinced that new studio practices would inevitably lead to new techniques, produce new sound materials, and require a new-theoretical system. In addition, he believed that musicians would develop a more profound understanding of music—even all types of music—as a social and artistic practice through the careful balance between the new studio practices and their theoretical implications [Thoresen, 2006].

Conventional classification systems based on the technical mechanisms of instrumental sources seemed neither helpful nor appropriate. Primauté de l'oreille, in contrast to abstract forms of musical construction, became fundamental to Schaeffer's perception. As a result, the *Programme de la Recherche Musicale* (PROGREMU) resulted from his experience as a composer in the new electroacoustic environment. PROGREMU comprises a system of five interrelated stages: typology, morphology, characterology, analysis and synthesis. With typology and morphology, sound objects are isolated from their context and both, classified and described. Afterwards, sounds are grouped into genres by means of characterology, and their potential for musical structures can be evaluated by analysis. With this information the composer shall be able to produce new sound objects. Each stage has a specific function, but serves a main goal: the musical composition. *Le Solfège de l'Objet Sonore*, a collection of recordings with audio samples that accompanied TOM and made Schaeffer's theoretical considerations sensual, was also important and remarkable. The collection was published in 1967 by the ORTF as a long-playing record.

> *This solfège 'is not yet music', it is the indispensable preliminary to it. It is embodied in the five operations of the program of musical research - Programme de la Recherche Musicale. Solfège is therefore related to the listening experience as well as classification and analysis, and has primarily been created for the composer.* [Landy, 2007, 97]

For the first time, technically recorded sound examples were provided as evidence, as well as part of a musical theory of sound generation and classification. Unfortunately, one of Schaeffer's most important developments, the codification of all sound categories in an all-embracing diagram, the *Tableau récapitulatif du solfège des objets musicaux* [TARSOM], which, like his PROGREMU, has provided many essential ideas, failed to disseminate, neither in analysis nor in compositional application [Thoresen/Hedman, 2007]. However, there is hardly any theory of musical sound classification based on the listening experience or with preference given to the ear, which was not influenced by Schaeffer's writings. They are thus pioneering and must be included in every consideration of intersubjective verbalization studies.

1.1.3. Listener-Based Terminology Research According to Thies

With comprehensive knowledge of the work by Eimert, Schaeffer, and Fennely [Fennely, 1968], Wolfgang Thies developed a list of adjectives in his book *Grundlagen einer Typologie der Klänge* in 1982, in which he attempts to systematize the sounds describing vocabulary of everyday German language.

> *As the sound repertoire progresses, it becomes more and more difficult to find one's way in the diversity of all available sounds. At least since the advent of electronic music, the problem of systematization and description of sound properties has been shown in new light. A comprehensive, powerful description system is needed to facilitate orientation in the realm of sounds, traditional or electronic devices, and the understanding of the sound world.* [Thies, 1982, 14]

This system of description is based exclusively on the properties of sound perceptible to the ear, without any physical or semantic properties being described. Because the system is to be used by the hearing person, it must be based on the sound properties perceived through listening [Thies, 1982, 37].

To begin with, he compiles a comprehensive collection of sound-describing words, based on the studies of Anneliese Liebe [Liebe, 1958], in which she had listed 1600 words in the German language used for describing sounds. Using a systematic exclusion method (e.g. no purely judgmental adjectives, no meaningful adjectives, no adjectives pointing to sound generating devices, no interregionally unstable adjectives), he reduced the collection to 433 adjectives. The new collection was then divided into categories of onomatopoeia (e.g. grumbling, ticking, thundering), physical characteristics (e.g. hard, rough, mobile), activity (e.g. sliding, chopping, pearling), material (e.g. furry, tinny, velvety) and miscellaneous divided. Within miscellaneous, there is another division between dynamics/intensity (e.g. whispering, held back, violent), clarity (e.g. layered, clear, free) and continuity (e.g. steady, uniform, unstable). Finally, the spatial location (e.g. far, near, high) and the surrounding space (e.g. dry, echoing) are distinguished from one another. Thies also distinguishes between general (e.g. light, unstable, mobile) and specific (e.g. quaking, hissing, rough) features during the further process of analyses [Thies, 1982, 34ff]. In the next step, he developed 32 sounds [Thies, 1982, 77], which were supposed to cover the universe of sounds as comprehensively as possible. These were presented to test subjects in the context of listening experiments in order to record their free descriptions in writing. The listening experiments should clarify the following questions:

1. Are there similarities between different people regarding sound description?

2. How suitable are the colloquial terms for describing sounds?

3. What are the semantic contexts between the terms?

These descriptions were then compared with the previously generated lists and the terms were adjusted according to the frequency of their occurrence. In a second step, a questionnaire with a bipolar scale system was created, on which the subjects could register tendencies between two conceptual contrasts (brilliant vs. matte). The results were statistically evaluated and the terms thus extracted were published as a description system. Thies's typology was never used in the practice of composers or other musicologists, and only a few authors, such as Barbara Flückiger, refer to the study at all [Flückiger, 2006, 106]. However, it is noteworthy that Thies follows his concern to provide guidance on this difficult and unpopular attempt at listener-based research in which he tries to approach the problem from three sides: semantic description, listening experience, and statistics, all three of which methodically synchronized in an iterative process. The author was also aware that this approach would not solve the intersubjective problems of verbalization per se, but he undertook an important attempt to shed light on the problem: *Basically, one should not expect a sound typology to enable rational understanding of the world of sounds; it should merely be an aid for one's orientation.* [Thies, 1982, 40]

The primacy of perception is unassailable
since without it
musical experience
does not exist.
[Smalley, 1986, 63]

1.1.4. *Spectromorphology* According to Smalley

In 1997, in his groundbreaking article "Spectromorphology: Explaining Sound Shapes"[36], Denis Smalley attempted to create a vocabulary and a reference for the aesthetic debate to describe electroacoustic music by establishing spectromorphology[37] as a descriptive tool.

Smalley founded his reference system after observing a deficit: [...] *the lack of a shared terminology is a serious problem confronting electroacoustic music because a description of sound materials and their relationships is a prerequisite for evaluative discussion* [Smalley, 1986, 63]. His concept refers to the categories: sound organization on the micro- and macro level, discourse methods, analysis and representation, new presentation forms (as

[36] *The whole concept was developed in three publications: „Spectro-morphology and Structuring Processes" (1986), „Listening Imagination: Listening in the Electroacoustic Era" [1992], und „Spectromorphology: Explaining Sound Shapes" [1997]*

[37] In his own words he describes Spectromorphology as follows:: [Smalley,1997,106]. *The two parts of the term refer to the interaction between sound spectra (spectro-) and the ways they change and are shaped through time (- morphology)* [ibid.:107]. *When considering the lower-level constituents of spatial texture we are often dealing with sounds which are primitive, or obscured and confused by other activity. Nevertheless, they are both spectral and temporal thus spectromorphological and exist in the context of a larger textural spectromorphology.*

far as spatialization goes), listening experience and classification. Smalley's reference system is not tied to conventional tonality, but includes it as part of a larger system.

Spectromorphology is an approach to the understanding of sound materials and musical structure, which refers to the spectrum of sounds and its change in time. In a previous publication, he states that [...] *spectromorphological composition, like other musical languages, is concerned with expectations gratified and foiled, and such expectations are founded on shared perceptual experience* [Smalley, 1986, 75]. Hence, Smalley insists that the listening experience is the starting point and a target point for all structuring and interpretative processes.

> [...] *today we continually need to reassert the primacy of aural experience in music. The heritage of twentieth-century formalism and the continuing propensity of composers to seek support in non-musical models have produced the undesirable side-effect of stressing concept at the expense of percept* [Smalley, 1986, 63]. [...] *the practice of listening, and the perceptive observation of the listening process must therefore form the foundation of any musical investigation.* [ibid.]

Smalley defines three topics in the system of spectromorphology: spectral typology, morphology, and movement. In addition, he is intensively involved with structuring questions. The entire system has been extensively described and interpreted since 1997 [Hirst 2011, 19], applied, [Blackburn, 2011; Pasoulas, 2011] and criticized [Pedersen, 2011]. Unanimously, all voices feel that it is one of the most comprehensive and modern vocabularies for the description of (not only) acousmatic sound phenomena. Newly developed applications such as EAnalysis[38] by Pierre Couprie for analyzing electroacoustic music as well as OREMA (Online Repository for Electroacoustic Music Analysis)[39] as a forum for the exchange and the discussion of appropriate analyzes make use of this terminology. It is therefore alive.

There are, however, also critics who, because of the extent of the vocabulary and the in part non-uniform demarcations between the categories [Reed, 2008, 37], are of the opinion that Smalley recognized the problem but replaced it with a basically non-practicable system.

> *Smalley also cites a lack of established terminology as a major problem for electroacoustic music analysis. Spectromorphology attempts to address this*

[38] http://logiciels.pierrecouprie.fr/?page_id=402 (last visited: 08/16)
[39] http://orema.dmu.ac.uk (last visited: 08/16)

> *problem. But in its totality, Smalley's extensive system of lists of vocabulary and analytical concepts is prohibitive to practical application.* [Reed 2008, 36]

Also not found are intersubjective studies with regard to the transparency and selectivity of the terms with respect to the material used. Smalley himself sees in spectromorphology an offer for a highly subjective application [Smalley, 1997, 110]. Moreover, despite the abundance of terms and the listener-based approach, there is no collection of sound examples that would support the spectromorphological vocabulary. Only one article [Smalley, 1993] dealing with sound transformations provides sound examples.

1.1.5. *Space-form* and the Acousmatic Image According to Smalley

This text is based on the terminology of spectromorphology and is Smalley's comprehensive attempt to describe and define spatiality in acousmatic music. It is an aesthetic environment, which tries to structure transmodal perceptual possibilities with the help of so-called source-bondings [Smalley, 2007, 35] and spectromorphological relations. In addition, however, it also relates to attributes, which derive from the previous music culture and tradition, e.g. pitch and rhythm. The author develops a phenomenology of potential spatial forms and formations, which can be staged by acousmatic music. His space-form mode of analysis is aware of the co-evolution of time and space in music, but pursues a novel approach: [...] *an approach to musical form, and its analysis, which privileges space as the primary articulator. Time acts in the service of space* [Smalley, 2007, 56].

In this respect, the starting point of his reflections is interesting: on the basis of an auto-ethnographical description of a soundscape scene in a village in southern France, Smalley develops a remarkable taxonomy of analytical terms for the perception of spatial sounds: zoned, proximate, behavioral, perspectival, distal, utterance, agential, vectorial, panoramic, overture/enclosure, approach/recession, diagonal forces etc.. Smalley himself notes that in order to understand space, he first had to learn to differentiate the sound material. Regarding his spectromorphology article, he notes: [...] *we needed to know about spectromorphology before we were in a position to understand space* [Smalley, 2007, 54].

Nowhere in the text does Smalley touch upon existing space concepts of acoustics or sociology. This is, however, the first comprehensive attempt to approach the theme of space as a compository parameter in acousmatic music and to describe this space in detail. It should be noted that these terms have been in part incorporated into the vocabulary of the composers in this field, and various authors [for example: Landy, 2007, 30; Born, 2015, 12; Roads, 2015, 281] refer to these terms, although it is quite clear in the literature that the scope of the system of terms alone makes them not easy to handle. *Several features are notable, not only in themselves, but for what they reveal about the strengths and limitations of distinctive styles of phenomenology of sound and listening* [Born, 2015, 12] and: *[...] Smalley's analysis is a tour de force* [ibid. 13].

It is also problematic here that it is a derivation of the terms from a listening experience, a scene outside the studio or concert space, that is, without a specific loudspeaker environment, which subjectively deduced, refers to nature-related images and situations. The extent to which these images are again personal translations and to what extent these are suitable for the analysis and development of artistic ideas in the mediated space remains open and is not examined in further studies.

> *In Smalley's article "Space-form and the acousmatic image", the evocative text depiction of the Orbieu soundscape would tantalise internal images for many a reader, yet to achieve such in sonic art without 3D sound is, by virtue of the complex couplings of sound, time and space, upon which the description relies, another matter.* [Barrett, 2010]

1.1.6. Perceptually Informed Organization by Repertory Grid

Published in 2012, Thomas Grill's PhD thesis is titled *Perceptually Informed Organization of Textural Sounds* [Grill, 2012]. The central topic of the study is the investigation of perceptually meaningful descriptions of sound textures. The repertory grid interview method has been used to elicit bipolar personal structures that can represent relevant characteristics of these textures. To this end, a large-scale online survey was conducted by means of a multi-stage questioning routine in order to refine and evaluate these descriptions.

Utilizing this model, Grill examines methods for structure recognition in digital audio, specifically the segmenting into slices of coherent content and the semi-automatic identification of representative sound materials. The methods are tested in comparison with two illustrative annotations of known works of electroacoustic music. His main research questions are: How can digital audio material be described using criteria of human perception? How can fundamental steps of music creation in the context of sound-based music practice be supported by perceptually informed tools? It is a remarkable approach to combine musical practice, empirical studies, and computer-assisted statistics. On the basis of Grill's studies, it is also possible to define sound textures as they are often found in acousmatic music.

1.1.7. Interdisciplinary Topology According to Nystrøm

Published in 2013, Erik Nytröm's PhD thesis is titled *Topology of Spatial Texture in the Acoustic Medium* [Nystrøm, 2013], and explores the dynamic fabric of the experienced space in acousmatic music. Its topology of spatial textures is a amalgamation of different concepts [...] *a network of concepts treating music as a flexible, textural space, which deforms, shapes, and transforms in time* [ibid.,13].

Based on spectromorphology and space-form, Nystrøm develops an advanced and comprehensive terminology for describing spatial sound-textures and their behavior, such as propagation and distribution. He understands this as a contribution to all areas of acousmatic music production and perception: [...] *as a contribution to theory in the acousmatic medium, relevant to composition, analysis, and listening* [ibid., 18]. Nystrøm assumes that the space-sound phenomena we encounter in concert are sound conditions that can be derived from visual attributions rather than from their acoustic sources. *In the approach taken in this thesis, as we know them in our minds, are viewed as having a form of graphic spatiality because of their spatial articulation* [ibid, 27]. He consequentially bases his observances therefore on the fact that in spatial hearing we also operate with a perception that is based on experiences of graphic forms of spatial expansion. *Thus, this visualization is highly reliant on intrinsic spectromorphological features, and the manner in which spectral and perspectival space are articulated generally, but also the physicality of textures* [ibid., 29]. However, his observations are only given shape by scientific studies from psychoacoustics surrounding them [ibid, 27, footnote 40]. His approach has yet to be corroborated.

The artistic work developed in the course of the work is intended to provide corresponding examples for a visual approach to research of spatial textures. The terminology is based on compositions for 8-channel loudspeaker rings. Only in a few cases does it refer to other multichannel systems, e.g. the BEAST[40]. Nystrøm's work is currently the most comprehensive offer for the verbalization of spatial textures in the field of acousmatic music. The terminology schemes for texture descriptions (textons, filaments: already compared in [Nystrøm, 2011]), developed by him in accordance with Smalley, as well as their expansion and distribution characteristics, are reasonable and seem to be proven in practice. As a composer in this field, one can comprehend what Nystrøm means, but he does not define space as a concept at all, and so ultimately the spatiality of his explored textures remains open. The fixation on the so-called quasi-visual shapes is also problematic. Here he introduces the concept of "visual listening": *I term the condition where graphic associations have an important role in the acousmatic experience visual listening* [Nystrøm, 2013, 27], but is not directly referring to any studies.

1.2. Summary and Classification

Most of the attempts to verbalize sound phenomena over the last 100 years have been made almost exclusively from the scientific perspective or that of composers. We can conclude that there is a common problem-consciousness. Verbalization is always regarded as essential for the authors to make a deepened and refined work possible in this field. Everyone tries to condense terms from a practice. It is about the generalization of perceptible entities, and then, on the basis of this knowledge, in turn, to become specific and accurate in practice. The question of the describability of spatial phenomena comes up historically at a later date, whereas the audience's perspective, with the exception of Grill's study, stay completely out of the question.

Listener-based research is not totally new within this field. It is, however, the exception rather than the rule. [Landy, 2007, 39]

In the context of artistic research with plastic sound phenomena, it therefore seems necessary to strive for interdisciplinary and intersubjective studies,

[40] http://www.beast.bham.ac.uk/ (zuletzt eingesehen 08/16)

which attempt to determine the field of perception more precisely and to isolate simple, reproducible terms. The starting point for this should always be the concrete listening experience.

[...] *electroacoustic music does not benefit of a unified representation code relying sonorous text with the compositional work of the composer. For this reason, the representation of the listening experience becomes the only mean to understand and study this music.* [Zattra, 2005]

Conceptual compositional considerations are subordinate in this research process, contrary to the conventional composition process, but never absent. The aim is to find an approach to analysis and, above all, composition, which incorporates common formulations and perceptual capacities in order to allow for a more specific, individual and finer artistic articulation and reflection. In addition, demands for such studies can also be observed in other areas, increasingly in the field of ephemeral performance arts. We find a similar approach, the "Incomprehensible" ["Das Unbegreifliche" - Leitfeld, 1986], in contemporary theatrical sciences. Leitfeld's approach explicitly tries to understand the *perceptual capacities* of the audience [Leitfeld, 1986, 121]. Of course, no absolutely accurate selectivity is to be expected from such studies. This path, however, in the sense of a concentrated research procedure promises to provide alternative information, thus enabling the field to be defined more precisely by descriptions.

These problems [of terminological inaccuracy] will not be escaped. However, one's respective basic assumption can be illuminated and the ambiguity of the terminology can be reduced. [Flückiger, 2001, 74]

2. Sculpture, Plastic, Object -

First traces of the sculptural in electronic music

All art confronts us with the historical and cultural dimensions of our judicial practice, as it does not completely fit into any of our presuppositions. [Rebentisch, 2015, 55]

Traditionally, three-dimensional works of art are described as sculpture, plastic, or object [Klant/Walch, 2003, 9], whereby the term plastic is often used synonymously with sculpture. In the German language, it is used as a concept for all three-dimensional works of art, whereas in English, French and Italian, the respective translation of the word sculpture (sculpture or scultura) is used as a generic term. Object art is outlined as an art created in the early 20th century that works with prefabricated objects, some of which are industrially produced [Klant/Walch, 2003, 155].

In the history of electronic music we often find descriptions of sound phenomena, which are projected into a room through loudspeakers and described with various object-oriented terms borrowed from the visual arts, among others, as sculptural, physical, and plastic; however, with very different derivations, meanings and functions for the compositions and not least the perception of a more or less trained audience.

Very early we find such a description from Edgard Varèse:

> *When new instruments will allow me to write music as I conceive it, the movement of sound-masses, of shining planes, will be clearly perceived in my work, taking the place of linear counterpoint. When these sound masses collide, the phenomena of penetration or repulsion will seem to occur. Certain transmutations taking place on certain planes will seem to be projected onto other planes, moving at different speeds and at different angles ... We have actually three dimensions in music: horizontal, vertical, and dynamic swelling or decreasing. I shall add a fourth, sound projection ... [the sense] of a journey into space.* [Varèse, 1998 (1936)]

Here, Varèse first describes his notion of three-dimensional formations delineated and demarcated in space. He describes sound masses and uses graphical descriptions ("planes") of sound emergences that can be projected and moved at different angles and at different speeds. Here, clearly spatial constellations of sounds, detached from a representation or representability in scores, are depicted from a visual perception perspective. It remains open whether this description is meant to be associative or synergetic and by which sound sources these formations are generate. The depictions involuntarily recall expressionist paintings and representations of abstract art, as they are to be found in sculpture and painting at the same time, and a little later in the (sound) installations. Here, such highly object-specific terms are explicitly transferred to the area of the music. Varèse's music was also described by Morton Feldman as "floating sculpture" [Feldman, 1981]. Varèse speaks of the sound projection as the fourth dimension of the music; for him it is a "journey into space". The thematization of space as a part of the compositional action becomes very clear here and is exemplary for a strong movement, both in music, and also the visual arts contemporary at that time. However, in the end it remains unclear what is meant by space. Certainly primarily a concert hall, but the use of the word "journey" suggests a complex, expanded conception of sound-spatiality.

Varèse makes the production or composition of these spatial sound formations dependent on new instruments, which he anticipates in an approaching future. For the then present, he also makes a very differentiated statement as to the state of the art and the specific possibilities for the composer:

> *Today, with the technical means that exist and are easily adaptable, the differentiation of the various masses and different planes as well as these beams of sound could be made discernible to the listener by means of certain acoustical arrangements ... [permitting] the delimitation of what I call 'zones of intensities'. These zones would be differentiated by various timbres or colours and different loudnesses. [They] would appear ... in different perspectives for our perception ... [They] would be felt as isolated, and the hitherto unobtainable non-blending ... would become possible.* [ibid.]

Sound masses, planes and beams allow the generation of defined intensity zones. Again, object-like spatial structures; again sound being projected and formed. It is noteworthy that Varèse makes a clear statement here about what the audience will perceive and how.

Varèse himself, as a matter of fact, was only first able to make use of these technical possibilities in the context of the preparations for the 1958 World Exposition in Paris. In collaboration with Iannis Xenakis and Le Corbusier, he created his Poème Électronique for the Philips Pavilion. It was the first electroacoustic composition to work with such a large number of speakers[41] (over 400) and multiple tape tracks. According to records, the complex control that the Philips engineers had developed made the arrangement of sounds around the audience and the movement along trajectories possible. It

[41] The number of speakers varies in the range between 300 and 500.

is not clear how easily, *easily adaptable* (see quote above) - as Varèse has assumed - these techniques were indeed for the decided composition of the phenomena described by him. Even more difficult is the question of how the perceptibility of an unprepared audience with its previous listening experience may have been or would still be today. I take this to mean not only the possibility of attending such concerts, but also whether and how the formations described so precisely by the composer, which were ultimately the aim of his artistic efforts, would be perceived and described by a different audience member.

Varèse's Poème Électronique featured in the Philips' pavilion at the Brussels World Fair of 1958 and was experienced by up to two million visitors. [...] as with all work of this period (and indeed up until the seventies), it lacked both a simple control system and the support of a comprehensive theory of sound localisation. [Malham, 2003]

Varèse, however, is certain of the reproducibility and existence of such phenomena in the framework of composition. He will have noticed them so. It is not about subtleties, if one asks for the perceptive capacity of the audience, one could even do without it, but then the question would not remain as to the meaning of the manifest-like descriptions of discrete plastic sound phenomena. We can at least assume that the statements of Varèse were, in part, metaphorical expressions or artistic utopias. In any case, a founding myth of a *Spatial Music* [Zvonar, 2004] was created, which subsequently motivated musicians and scientists for a long, busy journey.

Since then, similar descriptions from composers - not just those of electronic music - have turned up repeatedly, such as the movement of sounds in the concert hall and the production of sound zones and trajectories [Harley, 1994]. In addition there is the intensified thematization of space as a musical parameter outside the score and separated from a pitch concept [comprehensive: Ojala, 2009] as well as the orientation toward developments in the other arts, especially the visual arts, with regard to the descriptions of the newly emerging phenomena enhanced by electronic sound generation and spatialization using multi-channel sound projections that were possible [Brech/Paland, 2015].

With the design and construction of the German pavilion at the Osaka World Exposition, Stockhausen, together with the architect Bornemann and the engineer Leonhard from the company *Elektronic* (Zurich), was able to realize a spherical concert hall with loudspeakers running in seven rings all around for the EXPO 70. *Thus, the possibilities of the sound-movement from the* *circular horizontal or from the 4-channel or 8-channel multi-dimensional hearing to the spherical wide shot were perfected* [Nauck, 1997].

The sounds fly freely around the space. In circles, spirals, under and over the listeners [Stockhausen, 1971, 183].

Over time, more mobile units, loudspeaker orchestras have emerged as the playback systems for stereo works. The probably most extensive instrument is the Acousmonium from Groupe de Recherches Musicales (GRM). Designed by François Bayle in the first half of the 1970s, it grouped a wide range of loudspeakers into an impressive spatial layout. Bayle described an aspect of the acousmatic experience as "image of sound" or "i-sound" *[...] an intermediate object which in a certain way includes appearance, where it can be followed and seen to work' – which arises in the process of 'listening without seeing* [Bayle, 2007].

Through the researches and publications of Chowning [Chowning, 1971] and Moore [Moore, 1983] the foundations for the computer-controlled and -generated movement and arrangement of sounds in space were finally spread internationally. In view of these spatial sound phenomena and technical design possibilities[42], which have developed rapidly over the last 100 years and can be viewed as *"more easy adaptable"* in the last 15 years, in order to take up Varèse again, the question arises of their description, describability, and their classification or conceptuality.

Interesting in this context is a text by González-Arroyo about the emergence of a plastic sound object in his work:

> *And then one day it happened, I perceived it there: sound was there, **almost as a touchable object**. I have a vivid memory of this first experience; it was a grainy structure slowly ascending in the middle of the room. Pure subjective perception perhaps, almost a mirage, but magical and extremely powerful. [...] I will just summarize my reflections. I have had the experience **several other times**, sometimes as strongly, others less so, but it is clear to me now that it is the interaction of several of these layers, each one exploring space with its own rules what causes this **strong emergent phenomenon**. It is not merely a spatial operation, it is the interweaving of the qualitative, the temporal and the spatial dimensions of a sound object interacting with others. This is not* surprising after all, it is music, the interrelation of elements, what gives rise to **another perception.**[43] [González-Arroyo, 2012]

[42] An overview is provided in Organised Sound 15, Sound/Space: New approaches to multichannel music and audio, 2010.
[43] Emphasized by the author.

For González-Arroyo, sound becomes an "almost" tangible object in space. This moment was not only experienced once; it is reproducible for the composer. However, he asks himself whether it is purely subjective perception. He also describes the realization from the work process that a co-operation of different factors, which must explore this or that space is necessary to enable this perception. Here too, 70 years later, we are reminded of the three-dimensional space-sound situations imagined by Varèse.

Three terminology groups emerge time and time again in various shades: sound as a sculpture or part of a sculpture, sound as an object, as well as sound and space [cf. Harrison 1999a].

3. Sound as a Sculpture

3.1. Sound Sculptures

> *Sound sculptures have been made for decades and yet the term remains vague.* [Landy 2007, 183]

The descriptions of sound sculptures or *sound plastics* accumulated in the first half of the twentieth century. Here, however, distinctions have to be made. On the sheet titled *Sculptures Musicales* from the *Green Box* from 1934 Marcel Duchamp formulates:

Sounds that endure and emanate from different points and form a sound sculpture that continues[44]*.*

It is a matter of early records of using the combination of a traditionally audibly connoted term and a visually connoted one for the creation of a - here associative - idea of formation.

Since the 1950s various types of sound sculptures have been observed. Around 1952, brothers Bernard and François Baschet began designing sculptures whose metal or glass bars can be made to sound. Since 1957, these objects, with their bells out of metal, obviously have visual sculptural character beyond their function as sound generators. Used in concerts by the group *Structures Sonores*, later set up as playable and self-playing sculptures

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[44] *Sons durant et partant de differents points and formant and sculpture sonore qui dure [Marcel Duchamp, "Sculptures Musicales" [1934], in: ders., Duchamp du signe. Écrits, ed. by Michel Sanouillet, Paris 1975, p. 47].*

in public spaces and put to use in music education and therapy. [see Baschet, 1968; Baschet/Baschet, 1987].

At the same time visual artists' interest in motion intensified. With *Relief Sonore* (1955), Jean Tinguely is considered one of the pioneers of kinetic acoustic sculpture.[45] Engines, toothed wheels and drive belts are assembled into machines which do not serve a specific apparent purpose and whose function is a secret and which, by virtue of their conception, produce sounds whose characteristics first coincide through their construction and are then subsequently shaped by the artist. The resulting noises are part of a tautological function. Tinguely describes his *Métamatics* as "*sounding meta-robot painting machines"* [Gertich, 1999, 145]. The works of Nicolas Schöffer could also qualify as sound sculptures. In his Spatiodynamics, created in 1948, Schöffer is concerned with *"the constructive and dynamic inclusion of space in plastic works of art*" [ibid, 147]. These are often kinetic scaffold constructions with light elements and equipped with loudspeakers.

> *The addition of tone and sound is another means of gaining control of the space. The electronically processed sound sequences taken from the plastic itself can be [...] emitted over considerable spatial distances, while remaining completely in line with the plastic.* [Schöffer, 1963, 135]

The artist Panagiotis Vasilakis, aka Takis, began developing "*Musical Sculptures*" in 1965. For these objects, sounds, among other things, were created by moving needles that vibrated due to the action of magnetic forces. In the 1970s, he extended these works into environments, which he then called *musical spaces*. In 1969/70, Stephan van Huene developed his Totem Tones, a group of five sculptures using wood, organ pipes, metal parts, blowers, lights and computers. *In the case of Totem Tones, the external appearance came not only from the domestic but from the instrumental architecture, the organ pipes* (v. Huene, 1980].

The *Totem Tones* also refer to Helmholtz, the author of *On the Sensation of Tone - Die Lehre von den Tonempfindungen* [Helmholtz, 1865], and finally to Dayton Miller, who has produced synthetic vowels with organ whistles.

These examples have aspects of spatio-musical notation and object-relatedness intended by Edgard Varèse, but do not detach the sound product from the respective sound generator. Objective sound generators and sounds are directly related.

[45] Tinguely sometimes referred to musical forms in his titles, for example Mes Etoiles – Concert pour septpeintures (1958).

There is, in parallel with this development, the treatment of sound as a material (in the sense of a material such as steel, wood or concrete) as part of an artistic, formative approach. With regard to his early investigations on spatial sound movements (1969-1975), Bernhard Leitner retrospectively explained *[...] sound itself should be understood as building material, as an architectural, sculptural, form-creating material - like stone, plaster, wood* [Leitner, 1986, 23].

Bill Fontana names his works, in which he recorded nonlocal sounds, either in real time or as fixed media installations in other places, "*sound sculptures*." He describes the mode of operation as follows:

> *My sound sculptures use the human and/or natural environment as a living source of musical information. I am assuming that at any given moment there will be something meaningful to hear and that music, in the sense of coherent sound patterns, is a process that is going on constantly. My methodology has been to create networks of simultaneous listening points that relay real time acoustic data to a common listening zone (sculpture site). Since 1976 I have called these works sound sculptures.*[46]

Here Fontana includes the surrounding space as a vibrant part of the sculpture and defines a field of perception for the listening situation. The visual artist Michael Brewster has used the term "Acoustic Sculpture" since the 1970s:

> *My works have taken form of sculpture and drawing installations made by sound when restricted to confined space. [...] My use of sound as material [...] began with the realization that the sense of hearing was the most congruent mode for sculptural perception. Unlike vision, which is successive and frontal, or flat, hearing is most like sculpture also simultaneous and round [...]. I make Acoustical Sculptures by physically matching an architectonic volume with sound waves of a size and power that will boost the rooms cavity into resonance. The sculpture that results is a field of palpable sound volumes, of different sizes densities, and rates of excitement.* [M. Brewster after Gertich, 1999, 145]

Here, despite the clear background in the visual arts, there are conceptual parallels to Varèse's text, which are mainly related to the perceptible materiality of sound and the intensity and delimitation of sounds in space. In contrast to Varèse, however, the surrounding space plays a role. This is understood as part of the sculptural work.

In 2003 Bernhard Leitner [Leitner, 2003] published a CD with the written

[46] Artist Statement at http://www.resoundings.org/ (last visited: 08/16)

note that it was only to be heard with headphones. He stated that the CD contained *three-dimensional sound sculptures* that took shape exclusively in the interior of the listener's head.

3.2. Classification of the IKO

In the most prevalent cases, it is assumed in the relevant literature that sound sculptures designate individual objects that offer the recipient a fixed, material counterpart, which can also be viewed and thus conceived as a visual work of art. Whereby, we can see that a paradigm shift has taken place in practice. While it was first about haptic sculptures, which also produce sound, and in which this sound is an integral part of the sculpture, the haptic materiality has been completely dissolved. The concept of sculpture is later applied only to the otherwise ephemeral sound.

Fontana and Brewster basically use the term in such a way that it always positions itself in relation to its surroundings, as would otherwise be typical for representational sculptures. Here, the basic conception assumes site-specificity or site-dependency. If the situation with the IKO is taken into consideration, it is noticeable that the loudspeaker itself, because of its rare construction, is a visually striking object and thus in the context of a performance should not be ignored in the overall composition. However in the scope of this work, the IKO functions mainly as a compositional tool and concert instrument. The device itself is not understood as a sculpture, although it is obviously a visible installation. The loudspeaker, as prominent as it may be, is not the product of artistic work with space and sound. Rather, it provokes the subsequent question of the visual meanings a loudspeaker can have in concert:

4. Dramaturgy and Staging of Sculptural Sound Shapes

4.1. Visuality

For the forthcoming discussion, two of Chion's concepts are to be introduced.

Audio-Vision

> *Denotes the type of perception that is characteristic of cinema or television, in which the image is the conscious focus of attention, but in which the sound adds at every moment a series of effects, of sensory impressions, attributed to the picture and seemingly emanating from it. [...]* [Chion, 2010, 145]

Although the definition first describes the perception situation in television and film, it is precisely the situation that can arise in the concert hall, the situation which the composer has to consider when working with loudspeakers and the composition of sculptural sound phenomena so that the eyes, as is often the case with the IKO, do not constantly wander over the surface of the unusual 20-sided object. The danger arises that the conscious visual focus on the static object dictates the audible perception of the movements and formation processes in space. Complex spatial sound phenomena are hardly perceptible in the electro-acoustic concert setting as soon as the hearing is subordinated to the visual sense through strong visual concentration.

The corresponding contrast - Visu-Audition

> *Denotes the type of perception that is intended to focus on the auditive, but in which the hearing is accompanied by a certain visual context, which influences it as certain perceptions are projected onto it, accompany it, amplify it, and-one could say-parasitically occupy it.*[...] [Chion, 2010, 150]

Visu-Audition is to be strived for when staging the IKO, as well as most other loudspeaker concert settings. The composer has to include the visual context in his composition, or at least imagine it at the composing stage, in order to be able to direct the perception to the spatial sound phenomena. The finer the sonic emergence, the finer the possibility of audible concentration must be. This can be done by lighting, but also stage set-up, audience placement, and basic location selection for the performance. For this purpose, two examples of conscious sculptural dramaturgy and productions in sonic art/music are to be investigated:

1. Gerhard Eckel: Stele[47]

Kinetic sound sculpture. GMD, Sankt Augustin, 1998

The kinetic sound sculpture "Stele" combines plastic and sound elements into a hybrid object. The sculpture's static visual form and its dynamic acoustic appearance form a contrast that amplifies the two aspects. The loudspeakers stacked in a fragile column serve as the building blocks of a (archi)tectonic sculpture oriented toward minimalistic approaches. On the other hand, they form an acoustic prism in their linear arrangement, which allows sound projections of particular nuances. (Gerhard Eckel)

Figure 3: Installation view Stele by Gerhard Eckel

Stele (ancient Greek στήλη stélē, column, tombstone) means, since ancient Greece, a high, free-standing pillar. The title already refers to the thematization of the visual object. Because of the algorithm written by Gerhard Eckel, sound is projected into the performance room in such a way that, contrary to the visible fixation of the column, one has the audible impression that a column of sound tilts back and forth. Here, in the artistic setting, two pillars for the senses are placed under tension. Because the column stands alone, the audio-vision is therefore a strong aspect, a design medium within the composition.

2. Marco Stroppa

Totem Acoustique from the opera *Re Orso*, *légende musicale*, world premier: May 19, 2012.

The column, composed of eight loudspeakers, is centered above the stage. The loudspeakers are rotated by 60° forming a spiral. The sounds can be radiated in all directions and moved with different movement patterns around the column, along the column from top to bottom, and in jumps. Here, too, we have a visible technical apparatus that projects and reproduces sounds. The loudspeaker, however, does not hang there as an exhibition piece, but is part

[47] http://iem.at/~eckel/art/Stele/Stele.html

of the overall activity between the singers who enter and exit, conductor, and orchestra entrances. The central hanging scheme above the stage and its inclusion in the scenography again point to the fact that the visuality of the object was deliberately understood as part of an overall composition in which it is perceptible, but is consumed in the perception spectrum by being embedded. In this case, the aspect of Visu-Audition within the composition is controlled and used in the work. To this extent, this order of work with the IKO comes very close, especially regarding the question of the relationship between sound and apparatus.

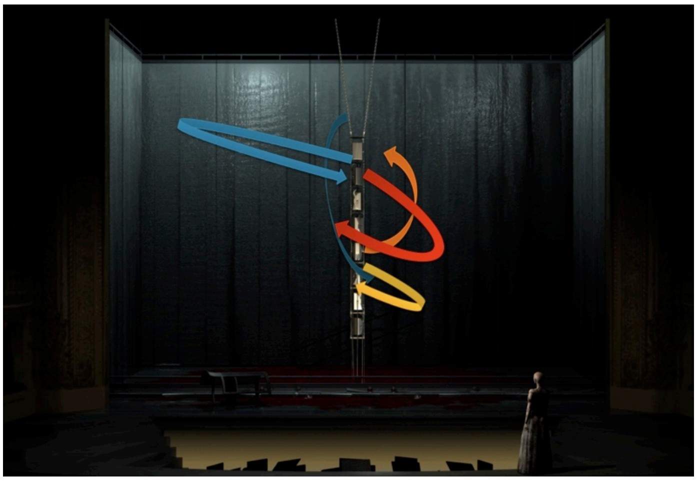

Figure 4: Graphic stage presentation: Totem Acoustique

4.2. Staging the IKO

The IKO itself, however, is more difficult as a visual object: it recalls the design and construction of the seventies, refers to the visual clichés of science fiction films and, due to its unusual design, can influence the listening perspective on the sounds and how the audience makes sense of the music. In addition, it is known in geometry as the fifth platonic body, and Rudolf von Laban has chosen this geometric body as the basic form in his teachings on the space harmony of dance [Laban, 1991]. Therefore, the form is conceptually loaded by other uses and contexts. This burden will not disappear. It is rather the task of the composer to deal with this conflict that we have in every concert setting with media technology, with the tension between audio-vision and visual-audition, as long as he wishes to focus more attention on the resulting sound. The comparison of the two presented productions by Gerhard Eckel and Marco Stroppa shows that supposedly similar apparatus sound constellations and their dramatizations produce very different auditory holdings and thus also form the perception and perceptibility of the sculptural spatial sound phenomena. Depending on the set emphasis on the scale between Audio-Vision and Visu-Audition, different subtleties in the staging of the loudspeaker and in the dramaturgy of the overall process are to be elicited. In the phenomena investigated in the course of the present work, the sculptural sound is examined in the acoustic laboratory exclusively as audible three-dimensionality, with the IKO being used in all listening experiments and not simulated. The audiovisual aspect of the IKO is consistently taken into account in the practical studies of staging in concert, for which its presence must be considered as a condition of the perceptual situation.[48]

5. Suitable Terms for the Description of Sculptural Spatial Relationships

Despite the prevalence and precisely because of the heterogeneous use of terms, the suitability of terms for sculpture in electronic space-sound composition remains to be verified.

As has been shown, the concept of sculpture in the area of music and sound art has frequently surfaced over the last 80 years. It refers both to a spatial formation of visual and/or auditory elements, as well as the activity - the way of dealing with sound. One instance of the latter is in the name of the software developed and distributed by IRCAM for editing and manipulating sound: *AudioSculpt.*

One of my early desires as a musician was to sculpt and organize directly the sound material...[Jean Claude Risset][49]

However, the use of the concept of sculpture per se is just as problematic as the strong connection to the visual, the audio-vision as an artistic product, the superimposing on the visual impression. For the latter has carried out a transformation in the external-musical art history, making a classification of objects in the fine arts - what is sculpture and what is not - also very difficult for experts today. The definition of the term sculpture has radically changed since the 1950s, which for the classification of Rosalind Krauss impressively

[48] See Chapter III. 2. Concert Practice as a Research Process

[49] Jean Claude Risset Laboratoire de Mécanique et d'Acoustique, CNRS, Marseille, COMPUTER MUSIC: WHY? http://liberalarts.utexas.edu/france-ut/_files/pdf/resources/risset_2.pdf (last visited: 08/2016)

demonstrates in her authoritative essay *Sculpture in the Expanded Field* [Krauss, 1979]:

> *[...] But in doing all of this, the very term we had thought we were saving - sculpture- has begun to be somewhat obscured. We had thought to use a universal category to authenticate a group of particulars, but the category has now been forced to cover such a heterogeneity that it is, itself, in danger of collapsing. And so we stare at the pit in the earth and think we both do and don't know what sculpture is. [...] At this point modernist sculpture appeared as a kind of black hole in the space of consciousness, something whose positive content was increasingly difficult to define, something that was possible to locate only in terms of what it was not. [...] The expanded field is thus generated by problematizing the set of oppositions between which the modernist category sculpture is suspended."*

Because of this vast extension of the term since then, it seems questionable whether the concept of sculpture as a field in music or sound art still creates relevant selectivity if it has already touched on its source of origin a while ago. Especially since the use of the notion in music and sound art cannot be derived from a successive history of a work aesthetics.

5.1. Body-Space Relations

If, however, one looks at the traditionally developed models of different historical body-space relations in sculpture, they can be useful for orientation in the medially generated loudspeaker space. These relationships contrast the physical mass with the space. Both exist in a relationship of reciprocal relations. If one observes the development of sculpture in the history of the visual arts in this context, one can see how the volume of the body gradually opens up towards the space, tries to conquer it, and at last almost dissolves in it. Therefore, the space is not only space and a shell, but also an active co-designer of the sculpture since the modernity. [Krämer, 2011, 17].

These body-space relationships are first divided into three groups:

5.1.1. Kernel Plastic/Body Plastic

This category is usually described as monolithic, manifesting itself in perception as a mass. In this respect, the attributes closed, *space-superseding*, and *space-repelling* are given to it [Klant/Walch 2003, 12; Krämer 2011, 17; Rawson, 1997, 66]. Example: Auguste Rodin, *The Thinker* (1880 - 82)[50]

A subcategory is kernel plastic with an opening mass volume, which (partially) bulges into the space. This is referred to as *expansive* or *consuming*: Example: Auguste Rodin, *John the Baptist* (1877 - 80)

5.1.2. Spatial Plastic

This category is described as tending to convert a spatial situation (*Space Cages*, Rawson 1997, 69) or create it through connections of different coordinates [Klant/Walch 2003, 12; Krämer 2011, 18]. To this extent, the attribute *space-encompassing* is given. Example: Naum Gabo, *Construction in Space Nr. 2* (1959/60)

As subcategories, a spatial mark with the attribute *space-binding* is singled out: Example Sol LeWitt; *Open Cube* (1968), and as a variation thereof, spatial curve or spatial delineation [Klant/Walch 2003, 12; Krämer 2011]. Example: Alberto Giacometti, *L'Homme qui marche I* (1960)

5.1.3. Kernel-Shell Principle

As a derivation of the two principles, the kernel-shell principle is listed, which is given the attribute *space-constituting.* The combination of spatial plastics and kernel plastics results in a tangible state of tension between these spatial poles [Krämer 2011, 17]. Example: Henry Moore, Mother and child (1977)

[50] For legal reasons, it is unfortunately not possible to photograph all the sculptures listed here. However, entering a work's name in an internet search engine leads to a corresponding figure.

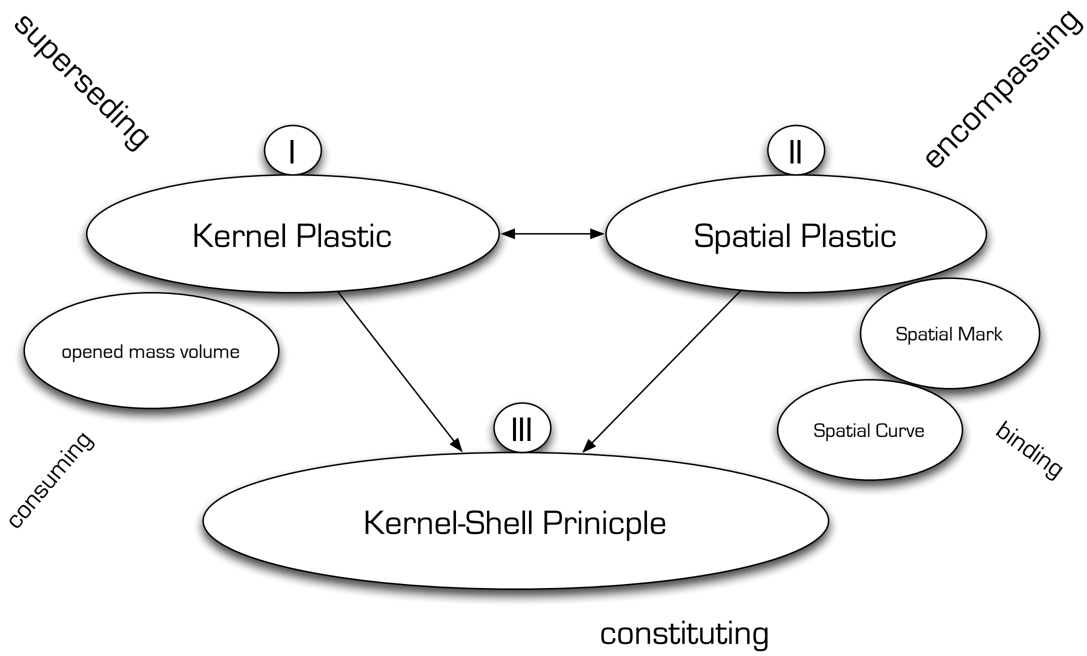

Figure 5: Overview of the sculptural body-space relations: The kernel plastic (KP) acts basically as space-repelling, or space-superseding but can also occur with an open mass volume, then perceived as consuming. In contrast, spatial plastic (SP) is basically perceived as encompassing the space, with spatial delineation and spatial mark as subcategories, which are perceived as space-binding. When emphasized, KP and SP are in a tangible state of tension, which is referred to at simultaneous appearances as a kernel-shell principle with the attribute space-forming.

If the attributes were interpreted as effects, they could be applied to the ratio of different sound arrangements and sound masses in the studio or concert hall. In this respect, there would be a derivable connection of the design principles, which would suggest a description of the plastic sound phenomena produced by loudspeakers as sculptural or even as sculptures.

What also indicates such an application is that traces of similar experiential descriptions are found in the new literature on spatial design principles in acousmatic music: for the description of spatiality, Nystrøm presents three nearly congruent categories [Nystrøm, 2013, 22ff].[51]

[51] Cf. the detailed examination of these categories, Chapter IV. 3.4.

5.2. The Sculptural in the Context of this Work

The terms sculpture and sound sculpture found frequently in part very different uses in the recent history of sound composition. They are therefore not clearly transferable into the field of three-dimensional sound projection with loudspeakers. However, traditional and conceptually manifested body-space relations lend themselves for the conceptual classification of certain electroacoustic space-sound phenomena, as far as one can detect these by listening experiments as acoustically perceptible. The sound projecting IKO may be a sound sculpture in the narrower sense and a sculpture in a wider sense[52], but it is not the main object of the investigation; it is the artistically placed (acoustic) field[53] and the phenomena in which it co-produces and is a part of.

In order to avoid leaving an existing descriptive problem--one caused by a technical setup as well as a lack of visualization of the processes and unexplained perception situations--open by the introduction of another vague notion (sculpture?), it must be explored within the artistic research to comprehend the *sculptural as a composition* and to methodically examine it in the laboratory as well as in concert mode in order to be able to extract generalizability. To this extent, one can even assume an *expanded situation*, as Seth Kim-Cohen elaborates in his reading of Krauss, for the sculptural phenomena in computer music, provided the factors which determine their origins and their relations are better understood: *The expanded situation represents a new constitution and conduct of the sculptural object, which now must "perform" for, or interact with, the viewer and the environment—both components of the expanded situation* [Kim-Cohen, 2009, 44].

In order to be able to apply sculptural body-space relations to this situation, these space-sound formations must also be perceived by persons other than the composer and be reproducible under certain, specific circumstances. Therefore, in the context of the space-sound miniatures[54] yet to be composed, the descriptions must be applicable for the composer and the space-sound phenomena must be provable in the listening experiments. In addition, they would have to be staged in concert mode where terminology for compositionally acceptable performance precision must be derivable.

[52] Likewise, this could be said of a loudspeaker circle or a loudspeaker dome.
[53] See Towards a Shared Perceptual Space (SPS), Chapter I. 1.3.
[54] See Index of Miniatures Chapter IV. 1.1

6. Sound as an Object

A further trace of plastic sound phenomena leads to the question of the object properties of sound. The association or actual use of sound as a part of sound sculpture or even as sculptural material can be traced historically to a further development, which is aimed primarily at the composition of perception. For this, one must once again return to Pierre Schaeffer and read his work against this backdrop: Parallel to the above-described changes in the visual arts, the radio engineer Pierre Schaeffer and the composer Pierre Henry experimented with everyday sounds in the Paris of the early 1950s, which were first put on records and later recorded on tape. They designed new sound collages with this "concrete" sound material.

With the technical possibility of sound storage and manipulation on tape, a completely new working method was developed, one which radically altered the instrumental compositional process that had previously been in place: Instead of the centuries long tradition of splitting work - the elaboration of a score and its interpretation with instruments - composition and interpretation are now combined. Composer and interpreter merge with each other in personal union, as Henry and Schaeffer have demonstrated in their *Symphonie pour un homme seul* (1951). Here, too, there is a parallel to the studio and the working language of the visual artist, who selects, manipulates, shapes and joins his material with his hands. The traditional compositional process, in which the initial abstract of an artistic idea is finally penned in the to the score, appears exactly the opposite: a concrete sound object has been altered to an abstract structure by manipulating its material-immortal properties until the original source of the sound is no longer recognizable.

This media-specific compositional approach was presented in theory by Pierre Schaeffer in his 1966 book *Traité des objets musicaux*. Schaeffer, for the first time, has designed a linguistic system that allows the new sounds of electroacoustic music to be captured and communicated. The raw material is the sound object recorded by means of a microphone and stored on tape. The *Object Sonore* [Chion, 2010, 147] differs from a pure and abstract sound event. Using an analysis method developed by Schaeffer, this sound object is classified typologically, whereby its properties are determined by a systematic listening analysis by the composer. Necessary for this is the "reduced listening" (écoute reduit) proclaimed by Schaeffer.

> *A term inspired by Husserl 's concept of phenomenological reduction, which refers to the decision to listen; listening for their sake, the type of listening tied to the*

observation and description of sound phenomena in their sensible qualities of the mass, grain, duration, material, volume, etc. [...] [Chion, 2010, 149]

Thus sound, regardless of its real origin, is conceived as a purely phenomenological object. Attention is directed to the characteristics of the sound, but not to its origin. This approach attempts to grasp the object in consideration in isolation from its contextual meaning as a thing-in-itself and to experience its inner structure as a field of possibilities that can be worked out in composition.

6.1. The Shaping of Listening, the "Auditory Impression"

This kind of composition is intended to influence one's listening in a direct way, not only by directing it, but by shaping it. Regarding this, Elena Ungeheuer writes the following:

> *What Pierre Schaeffer had in mind in his musique concrète deserves an oxymoron as a title: Medial immediacy. For it is exactly the gramophone's shaping conditions or the tape serving as a playing device for music stored on phonograms, which is to allow a new kind of listening, which immediately penetrates into the nature of the musical. [...] The loops, either realized by means of the closed groove or a tape loop, also serve to undermine the sounds recorded with microphone in the repetition of their integration into situational circumstances so that they no longer refer semantically to the context, rather - as a result of a listening process - in their pure soundness. Also the splicing technique, the way of assembling sounds together according to tonal aspects, forms the way sounds are listened to.* [Ungeheuer, 2010, 23]

Thus, in the history of music sound becomes an object in two respects: On the one hand, it becomes a concrete, "tangible" piece of material, a visual object that can be formed by hand and is available as "frozen time." In addition, the sound object is comprehended as a parameterizable structure, composed of properties such as matter, form, grain and motion, which can be technically altered by the composer as variables. *In order to have a chance to create or capture this* ***something***[55]*, and to give it meaning, there will never be any means other than sound fixation, which does not make an accidental incarnation of an intention from the sounds but* ***real objects****[...].[*Chion, 2010, 23]

[55] Emphasized by the author.

However, the idea of a sound object, and not least its prerequisite, *reduced listening*, has been criticized. For the latter has to be practiced and the audience is, in most cases, not used to doing so: *Schaeffer's reduced listening theory is more concerned with the aurality of sounds than their source. This is, in fact, for many listeners not an easy thing to achieve.* [Landy, 2007, 73]

The strictness with which Schaeffer links reduced hearing as a condition for the experience of his music seems strange today, since it leads to a school-like restriction on the audience before a piece can be perceived at all. In the context of an acousmatic sound composition, the goal would rather be to place the audience in a nearly association-free and spatially-aware listening attitude through artistic settings, which then allows them to perceive the composed sound phenomena.

[...] *it would be absurd to think that one could expect listeners to adopt a particular listening mode prior to hearing a work, not allowing them to form a relationship of their own with the music. It is of course a voluntary listening behaviour that comes naturally only if the music actively lures listeners in that direction.* [Nystrøm, 2013, 31]

6.2. The Sound Object within the Scope of this Thesis

For the classification within the scope of this present thesis, it is important to take over the terminology of the sound object as a structure in electroacoustic space-sound composition regarded as a sound observed independently from its origin, yet spatially considered and questioned. In this respect, I do not at any point touch on production methods of different sound materials. Also, no reference is made to the terminology of the object used in the scholastic writings on sculpture, for example *readymade*.

However, after years of experimentation in the 1950s Schaeffer himself had rejected the idea of a three-dimensional sound object or even *Spatial Music* in *Traité des Objets Musicaux*.

> *There are no multi-track devices that do not have a germ of spatialization. New degrees of freedom, however, are the result of the availability of loudspeakers, whose interconnection or distribution in the playback room allows for movements from one loudspeaker to another*

> *(cinematic sound projection). This spatialization is often mistaken for an inexplicable myth of "spatial music."* [Schaeffer, 1966, 409][56]

He even goes a decisive step further and comes to the conclusion that *the location of the sound object hardly plays a role, but the perceptibility of the sound objects can improve and refine the diffusion over several loudspeakers.*[57] This view, as shown, contradicts the experience of many composers to this day, but it is all the more important because Schaeffer had apparently come to a frontier which we are still looking at today: *The issue of whether diffusion is a legitimate continuation of the compositional process or merely a random throwing-around of sound which destroys the composer's intentions continues to be a matter of great debate* [Harrison, 1999a].

To determine the prerequisites of a three-dimensional sound object, it must be clarified how this must and can be of such a nature so that it can be used both as compositional material and in the context of a compositional technique. Here it is not only the composer's perception and the assumption of "reduced listening" that are decisive prerequisites for the composition's perception.

It is therefore desideratum to compose space in such a way that during the course of the composition the audience is made sensitive to spatial processes. This approach corresponds somewhat to the repetition of the theme in the classical sonata. If the theme is impressed, the motivic spin-offs can be better understood. For this purpose it is necessary to clarify what is perceived as a "spatial sound object" in perception-oriented investigations. Only then can the forming of an *auditory impression* in the sense of direct influence on listening be spoken of.

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[56] *[...] il n'y a pas de lecture multipiste sans l'amorce d'une spatialisation. Mais de nouveaux degrés de liberté apparaissent dans la disposition des haut-parleurs, leur couplage ou leur dispersion dans l'espace sonore de restitution, les mouvements eventuels des sons de l'un à l'autre des hautparleurs (cinématique spatiale de projection sonore). Cette spatialisation, souvent confondue avec on ne sait quel mythe de 'musique spatiale'* [Schaeffer, 1966, 409].

[57] Translation according to [Malham, 2003, 18].

7. Compositional Material

7.1. Tone, Sound, Noise

But after all what is music but organized noises?
And a composer, like all artists, is an organizer of disparate elements.
[Varèse, 1966]

Even today the score is regarded by many as the "true place" of musical work and the piece. The ability to read and write music in a notational system is still regarded as an indispensable prerequisite for composing [cf. Delalande, 2007]. However, the search for the trail and the classification of this thesis must inevitably be based on a different musical field, since writing down the electroacoustic spatial sound composition with loudspeakers in a notation system does not help. Leigh Landy has, in order to make a distinction from the traditional, note-based music, recommended introducing the expression of the so-called *sound-based music* [...] *the art form in which the sound and not the musical note is the basic unit* [...][Landy, 2007, 17]. This thesis revolves around exactly this other basic unit.

Sound is often associated with music or "pleasant sounding" acoustic events. The Master's program *Sound Studies* at the UdK Berlin offers in its contribution no less than five meanings of sound: as a source, as an object, as a signifier, as a remainder, as an affect [Papenburg, Schulze, 2011, 10]. In the case of physical acoustics, the following description is familiar: *A periodic sound pressure curve is designated as sound with the period duration T whose frequencies (harmonics) are in an integral relation to the fundamental frequency f(1)* [Maute, 2006]. And there one also finds a possible delimitation from noise: *A sound is a strict periodic process of any form. A non-periodic process produces a continuous frequency spectrum and is called noise* [Gerthsen/Meschede, 2010].

Sound was also used ambiguously in music theory from the 19th century. On the one hand, Helmholtz coined the meaning of the concept as a synonym for a (periodically oscillating) complex tone (in contrast to the aperiodic vibrating sound) and a [*pure*] tone = sine wave. On the other hand—in the theory of harmony, especially according to Hugo Riemann [Riemann, 1919]—sound was spoken of as an abstract harmonic reference unit (overtone, undertone, parallel sound, change of the leading tone, etc.), which was generally represented in the form of a chord. Regardless of whether a complex tone consisting of two or more sine waves is designated as sound, such as in the tradition of Helmholtz, or if a state is formed from several such complex tones, one can assume that every sound event can be determined inductively or deductively: It can be composed of single components, by additive synthesis in electronic music, or in the opposite process from a sound mixture, in electronic music by means of filters made from white noise or a different sound mixture. One consequence of the development of all conceivable shading between pitch and noise structures in music after 1945 is that the sounds constituting a sound event can no longer be limited to harmonic partial-tone structures as in Helmholtz, but rather must comprise all intermediate stages between clearly determinable pitches and noise, cracking, or throbbing, which elicit in no way pitch perception. The line separating sound and noise into different categories has lost its sharpness against the background of compositional history from the past 60 years and thus its analytical value.

Within the scope of this thesis no separation is made between the terms tone, sound, and noise. The term "sound" is used as the conceptual term, irrespective of its generation and origin, as well as its vibrational properties, and must be described contextually case by case for classification and within the scope of the investigation. It is also important for this work that one understands during the research process what the participants (composers, scientists, test persons) in their perceptual process take sound to mean when asked about "plastic sound phenomena." For this purpose, however, the term must be as broad as possible so as not to exclude any results.

Contrary to the general assumption, in the fine arts sculpture is a largely static object in a frozen state. It has at least one temporal structure that it shows through the multiple perspectives of the spatial possibilities of observation. Its contours can be experienced successively.[58] In the art of acoustics as a time-based art, the sculptural must fundamentally be introduced over time and several states. It is therefore a question of sensitization to a sound-space form in time or in several parallel times.[59] In the sense of this present thesis, it is beneficial for the appearance of the plastic auditory impression that there are as few visual indications as possible that may refer to the origin of the production of the sounds, and that there are no sounds which clearly refer to a non-musical origin. Only through the deliberate denial of these indications can there be in the here and now

[58] Cf. the term Contour, Chapter IV. 4.1.3.
[59] Cf. the three temporal levels in the sculptural sound composition, Chapter IV. 4.3.

spatial formations in the acousmatic environment as mentioned by composers over and over again and described by the audience and subjects. In summary, a synergetic question must be asked: What turns sound into plastic material in the composition process?

Again on the basis of practical experience over the last few years, it can be established that

> *it has to do with repetitive sound structures which can be experienced as plastic by means of overlapping or movement in the loudspeaker space. These could have cyclic or self-similar internal structures and have the unique characteristic of acting as filaments or concatenations of coherent sequences of sound elements, so that after a short time the perception undergoes a kind of saturation, relying then on an overarching or composite form, interpreting the sound event as a cloud, deposition, or streaks in the performance space.*
>
> (Excerpt from the lab notes, Gerriet K. Sharma, 2015)

7.2. Sound as Texture

This unrefined self-description refers to the use of sound textures as described by Smalley [1997], and examined by Grill [2012] and Nystrøm [2013] in recent years. In Smalley's listener-centered conceptual world of spectromorphology, *texture* is a basic condition for the shaping of musical structures. Grill defines five conditions for textural sound structures based on the studies of Saint-Arnaud [Arnaud, 1995], as described in Strobl [Strobl et al ., 2006], and Schwarz [Schwarz, 2011]. Accordingly -

1. Sound textures are formed from basic sound elements, or atoms..

2. These atoms occur according to a higher-level pattern that can be periodic, random, or both.

3. The high-level characteristics must remain the same over long time periods.

4. The high-level pattern must be completely exposed within a few seconds ('attention span').

5. High level randomness is also acceptable, as long as there are enough occurrences within the attention span to make a good example of the random properties.

The sound textures for the miniatures, etudes, and listening experiments were designed and composed in accordance with these conditions.

7.3. Sound as a Spatial Texture

These textures can then be composed into spatial textures. The concept of *spatial texture* first appears in Smalley's publication "The Listening Imagination": *[...] spatial texture has a role in the mediation of spectral texture, and 'concerns the topological content of the real/imagined space – its size, the relationships of the dimensions of sounds to their localisation, the density of distribution of sounds, the connectedness of the sounds in space (spatial continuity/contiguity), and actual spatial movement* [Smalley, 1996, 92-3].

These spatial textures arise in the merging of perspective field [Smalley, 2007, 48] and spectral space. While the perspective field must always be understood from a listening position (vantage point), the spectral space is dependent on the frequencies of the audio signals or their superimpositions in the respective textures. One can also speak here of spectral verticality [Nystrøm, 2013, 20]. The perceptual relationship between frequency and vertical height has been demonstrated experimentally and thus goes beyond the often claimed metaphorical linking of cultural conditioning. The verticality perceived in the frequency spectrum was already researched by C. C. Pratt around 1930 and has been known since that time as "Pratt's Effect." Pratt let test subjects estimate the height of a covert source that played sine waves, and found a direct link between pitch and verticality [Pratt, 1930]. Roffler and Butler [Roffler/Butler, 1968] confirmed the relationship in further studies and also found that this was also seen in those blind from birth, which indicates that it is not exclusively a visual relation. In addition, they were able to prove this ratio formation even among small children, to whom the conceptual and linguistic association between high and low frequency was unknown. "Pratt's Effect" was also shown in *un-pitched noise bands* [Cabrera/Tilley, 2003; Susnik et al., 2005] and complex harmonic sounds [Cabrera/Morimoto, 2007].[60]

Also interesting in this context is that Roffler and Butler [Roffler/Butler, 1968] found that for each vertical location frequencies of more than 7 kHz must be present in one sound. Therefore research results suggest that

[60] A summary of all studies on this topic can be found in: [Cabrera at al., 2005].

frequency has a much more distinct influence on perceived vertical orientation than the physical positioning of sound sources [fundamental and comprehensive: Blauert, 1997]. The height (elevation) of the perceived sound source and the frequently connected spatial sound expansion as a counterpart to an expansion of the sound horizon in the horizontal is thus not necessarily dependent on the tangibly present or physically generated sound source. Overhead directional hearing is very inaccurate compared to front-back and sideways [cf. Kendall, 2010b, 231]. Directional hearing below the body is even less precise [ibid.]. It has been shown in the laboratory that the acoustic hearing perceptions for height, which are influenced by the auricle, can be disturbed and superimposed by the spectral characteristics of the sound sources [Bloom, 1977; Roffler/Butler, 1968; Blauer, 1997; Susnik et al., 2005].

In general, it can be said that spatially elevated high-frequency sounds are perceived as higher up than low-frequency sounds. Thus, it can be stated that both loudspeakers, which are attached overhead, as well as mirror sources elevated through projection can only seldom be located there by hearing. Vertical panning usually only works with very broadband signals or percussive sequences of transient "clicks", as long as few to no loudspeakers produce sound on lower loudspeaker levels[61]. Experience reports from the Sonic Lab in Belfast show that, on the one hand, only low-frequency, narrow-band sources and sources with sharply introduced transients are located below ground, and sources via the ceiling loudspeakers can only be localized if these have high frequencies or play sharp transient sounds [Kendall, 2010, 236].

From this it follows further that, for composing in loudspeaker environments, it is fundamentally important that spectral verticality, unlike the perception in the perspectival field, is not directly dependent on the position of the listener, since the ratio of high and low and vice versa remains independent of the spatial position and the listening direction of the listener. Perspectival field and spectral space with respect to the vertical make up the forming conditions for three-dimensional sound textures. It is this moment in space-sound composition in which spatiality and time merge, in which time takes on a spatial function and through residue in the perception spatial plastic structures appear in the sound.

[61] Cf. also for the IKO: Miniatures 49 - 52

Spectromorphologies, which not only have spectral contours, but also extend in perspectival space, become more like three-dimensional visual forms, with width, height, and depth. In addition to the temporal shaping of spectra, spatial textures acquire a purely spatial, non-temporal, approximation of shape,[...] textures have spectral and perspectival contours, sizes, and scales, which are not necessarily directly tied to temporally-evolving aspects of sound, such as motion and growth.

[Nystrøm, 2013, 30]

7. 4. Conclusion: The Raw Material for the Sculptural Sound Composition

Sound objects in the form of sound textures are the raw materials for the composition of sculptural sound phenomena within the scope of this work. The spatialization of these textures takes place through a compositional connection of the aspects of the perspectival field and the spectral verticality. It is important to conceptually consider both position-dependent and independent factors of the material during production. As the specified research shows, an artistic idea has difficulty counteracting the listener's actual perceptual capacity. These spatial sound textures are then available to the composer for the composition of sculptural arrangements, provided that the performance conditions are stably designed and staged for their perceptibility.[62]

[62] See Chapter III.2.

8. Space

Space is existential,

existence is spatial

[Merleau-Ponty, 1966 (1945)]

Sounds are perceived not only as characteristics of a sound source and thus as indicators of their location, but they can become more or less self-sufficient objects with real physical properties. The result is a listening space, the dimensions of which are in a confusing relation to the real space. [de la Motte-Haber, 1991]

Taking possession of space is the first gesture of living things, of men, and of animals. The first proof of existence is the act of occupying space. [Le Corbusier, 1946]

8.1. Traces in (Computer-)Musical Application

Space is another term that plays a central role in the compositional work with sculptural sound phenomena. Again, the research process begins with a search for clues. Along with the introduction of the multi-channel technique and the first performances with complex loudspeaker arrangements, e.g. at the 1958 World's Fair, the subject was increasingly discussed in the field of composition.

[...]*In the context of analogue tape composition, the composer tries [...] to shape the direction and the movement of the sounds in space and to develop it as a new dimension for the musical experience. [...] We notice more and more that all musical ideas are becoming increasingly spatial.* [Stockhausen, 1958, 153]

The term space is not always used consistently in computer music. [...] *the notion of "space" has become the paradigm of electroacoustic music. However, the terminological framework of electroacoustic "spaces" is not clearly defined* [Harley, 1994].

There is most of all a consensus that space plays a central role in acousmatic music. *Acousmatic music is the only sonic medium that concentrates on space and spatial experience as aesthetically central.* [Smalley, 2007, 35]

Chion distinguishes between *internal space*, which is created in the composition, and *external space* that arises during the performance [Chion, 1988]. Risset describes the fragility of an *illusory space* produced by the composer and the *real space* of the performance in which the *illusory space* is presented [Risset, 1998]. Smalley counts over 20 different spaces in electroacoustic music, for example the composed space, the listening space, and the superimposed space [Smalley, 2007, 35ff]. Emmerson speaks of *nested spaces* [Emmerson, 1989] and *space frames* [Emmerson, 2015], and Roads distinguishes between *virtual* and *real spaces* [Roads, 2015, 261].

In the standard work *Was ist elektronische Musik?* by Werner Kaegi, spatialization by means of multi-channel loudspeaker arrangements is explained as a *spatial arrangement of sound sources*, but space itself is not addressed [Kaegi, 1967, 23].

In the last chapter of his 1998 book, *Elektroakustische Musik & Computermusik* [Supper, 1998, 121], Martin Supper deals with space. It is interesting to note here the quotation by Rudolf Carnap, which proceeds the chapter titled "Music and Space": *In my dissertation "der Raum" (1921), I tried to show that the contradictory theories about the nature of space represented by mathematicians, philosophers, and physicists stemmed from the fact that the authors talked about completely different things but were using the same term, "space."*[63] In the footnote, Supper makes it clear that he concentrates mainly on architectural space in his explanations. This reduction implies that there are various uses of the term space, the consideration of which would, of course, exceed the scope of the chapter space. The following subtitles in Supper's book are then: *Space as an Instrument, Virtual and Simulated Space,* and *Movement of Sound in Space*.

In the field of musicology, space has historically been mainly attributed to pitch ratios. Gunnar Hindrichs speaks of musical space as *an order of the constellation of musical sounds, which in their network of relationships make the identity of each one in the music possible and creates spatial comparative variables. On the one hand, this results in the fact that music does not only sound in space, but also creates its own kind of space in itself* [Hindrichs, 2014, 161]. In the book Musik und Raum, published in 2005, Karen Gloy describes space as a basic phenomenon, which is composed from the superposition of various space types. She describes *tuned space, action*

[63] Rudolf Carnap, Mein Weg in die Philosophie, Stuttgart: Reclam, 1993, p. 18 f, cited in Supper 1998.

space, perceptual space, mathematical space and metaphorical space as possible basic types. [Gloy, 2005, 11].

Due to the fact that the concert space could be designed and played in differently by the positioning of loudspeakers, other spatial concepts were considered. Pierre Boulez speaks in favor of exploring more flexible spatial concepts that can change over the course of a piece:

> *It seems to me that one of the most urgent objectives of present-day musical thought is the conception and realization of a relativity of the various musical spaces in use.* [...]*[T]he time has obviously come to explore variable spaces, spaces of mobile definition capable of evolving (by mutation or progressive transformation) during the course of a work.* [Boulez, 1971 (1963)]

8.2. Spatial Turn

The versatile use of the term is not surprising, considering the fact that, parallel to the development of music, the concept of space has been given interdisciplinarily new and historically noteworthy consideration, so that one speaks of the so-called *Spatial Turn.*

An initial, very simplified definition of the spatial turn should take into account that something astonishing happened in the last decade of the 20th century, such as what might be regarded in the 21st century as one of the most significant intellectual and political events of the late 20th century. Some individuals, among them scientists, began to think about space and spatial elements of human life seriously and critically, similar in a way to what has long been thought about time and the historicity of human life. Over the last 150 years, we have become accustomed to seeing the world through a historical lens rather than a space-based one. But what happened now happened on an interdisciplinary, transdisciplinary, and, if so, a pandisciplinary level. In the late 20th century, space-related thinking broke out of the traditional disciplines - geography, architecture, urban development, regional sciences, and sometimes sociology and art history. The sudden width of the spatial turn is remarkable beyond all measure. [Soja, 1989, 243]

In view of the historically unique changes in dealing with and thinking about space, it would be desirable if the acoustic arts also had a different spatial concept. One which, on one hand, is less metaphorical and therefore more conceptually generalizable, and on the other hand, not only "Cartesian", and rather therefore more interdisciplinarily oriented.

8.3. Three Space Theories for the Constitution of a SPS

But which type of space, definition, or concept can make a practical contribution to composing with sculptural sound phenomena? Since computer music has always been interdisciplinary, it is obvious to include extra musical considerations of space in the composition of different spaces. If one wants to investigate plastic sound phenomena with a loudspeaker system conceived for mobile use and to be used in different situations, one must develop an understanding of room acoustics as well as the different spatial ideas and their conditions for the sound resonating therein.

> *Sound and space converse by multiplying and expanding the point of attention, or the source of a sound: the materiality of a given room shapes the contours of sound, moulding it according to reflection and absorption, reverberation and diffraction.* [LaBelle, 2006, ix, xi]

> *[At the same time] sound makes a given space appear beyond any total viewpoint: in echoing throughout the room, my clapping describes the space from a multiplicity of perspectives and locations, for the room is here, between my palms, and there, along the trajectory of sound … What we hear in this clapping is more than a single sound and its source, but rather a spatial event.* [ibid., x]

Here, models of psychoacoustics and room acoustics are superimposed with philosophical and sociological models of how we construct space in our perception. While electroacoustic music and with it the development of audio software and hardware in the last decades mainly follow the idea of Euclidean space, other spatial ideas are oriented away from this or understand physical space as a condition but more in the sense of a foil with other spaces unfolding in front of it.

The following three representatives introduced can provide a direction for further reflections on the compositional and performance practice of plastic sound objects and their exploration within the scope of this work: Henri Lefebvre, Michel de Certeau and Martina Löw.

Henri Lefebvre [Lefebvre, 1974] and Michel de Certeau [Certeau, 1980] developed their theories of space in the 1970s, which are well received today in architecture, geography and the social sciences. The sociologist Martina Löw developed her approach in her dissertation on *Raumsoziologie* in 2000 [Löw, 2001]. The starting point for all three approaches is a relational understanding of space.

The general theory of space distinguishes between absolutist and relativistic concepts of space. In the absolutistic concept space exists independently of matter. Movable bodies and things are in a space that remains unmoving itself. The space exists continuously, for itself, and forms an equal, homogeneous basis for action for all. This idea of a container space has been replaced in science with the development of the relativity theory of relativistic spatial concepts. However, it still characterizes the everyday understanding of space and is usually an indispensable condition for psycho-acoustical studies and ingenious scientific research in the area of spatial-audio. In the relativistic concept of space, the space does not exist independently of the bodies. Instead, space is understood as a relation, as a relational structure between bodies. The bodies, whose arrangements give rise to one another, are in constant motion. Thus the space itself is no longer static, but becomes processual and constantly changes over the course of time. Since the arrangement of bodies cannot be thought of independent from the observer's reference system, space is not absolute, rather always exists relative to the consciousness of the observer.

8.3.1. Three Dimensions of Space Production by Henri Lefebvre

Lefebvre sees space as a communally produced, social product. He distinguishes three levels of the production of space, each connected dialectically.

Lefebvre describes the first dimension of spatial production as *spatial practice* [Lefebvre, 1974, 335]. The starting point is the material dimension of the space. The material elements and objects, which form the space are perceived sensually and linked to a spatial order of simultaneousness. *Spatial practice* refers to everything that humans do in and with space: what things and objects they build, how they move these and themselves in space, how they deal with topography, and how and why they use the space. To this end, in musical practice it would include the arrangement of stage and audience, the design of the stage, the installation or suspension of reflectors and the seating or design of passages in the context of installations, as well as the arrangement of musicians and loudspeakers on the basis of various principles of organization, including room acoustics and concepts such as audio vision and visu-audition. I also include the composition, arrangement and movement of plastic sound *objects*. All these are elements of *spatial practice*.

Lefebvre's second dimension of space production is *conceived space* [ibid., 336]. The connection of individually perceived, material elements to a space presupposes mental effort, having an idea of space. These *representations of the space* include linguistic descriptions, pictoral representations, maps, plans, and scientific definitions. Representations and definitions of space are based on social conventions and are negotiated discursively. Each in-depth investigation in the field of space-sound composition must deal with the definitions of space in its own fields accordingly and the adjacent fields, and, if necessary, offer terminology. Since, as shown above, these conceptions differ widely in the field of music and musicology, and space is not adequately defined, other concepts of spatial attributes must be used to classify the artistic results. These originate from the scholastic writings on sculpture, space theory and engineering sciences. It is also necessary to consider how the laboratory situation can be visualized and later evaluated graphically in the context of the test design and the presentation of results.

The third level of the production of space is the lived space, the level of meaning of the *symbolic content* [ibid.]. This level is decisive for the experiencing of spaces. Spaces are occupied by symbolic content; they can describe something outside themselves. The symbolic meaning of spaces expresses itself, for example, in the architecture of sacral spaces or spaces representative of political power. They show the importance of cultural landscapes in how a country sees itself, as well as places that are important for the individual biography. The construction of concert halls points to a certain superior or bourgeois attitude toward art, or to a certain musical tradition, meant to sustain and ensure its livelihood.

> *The choice of space and the spatial design of concert venues reflect the ups and downs of the autonomy of this art. The location of where music is practiced is often legitimized in a way foreign to music.* [Kirchberg, 2009, 156]

> *Even if the concert hall is described as the "place of realization of autonomous music", such a place is always a "social institution".* [Heister 1996: 42, 44]

> *Symptomatic of this is the inscription on the Neuen Gewandhaus "res severa verum gaudium" - the serious thing is the true joy.* [Kirchberg, 2009, 157]

This structure of reference is changing through the described changes in the conception of music, whether by the construction of loudspeaker clusters or spherical constructions or the invention of mobile loudspeaker orchestras (almost) without human performers, self-playing instruments and installative sound machines, or even the design of a new concert hall rebuilt and furnished in versatile and unconventional ways. The change of awareness in staging media art and theater has left traces in all musical disciplines, e.g. the use of video screens, light installations and illuminated (!) loudspeaker domes (ZKM). This leads to references to extrinsic coherences such as media technology, film and television, as well as politics, sciences, and other arts. In addition to this, concerts are increasingly being held at untypical places: foyers, old factories, empty department stores, basement vaults, shops - just to name a few examples. They form *symbolic spaces* through their original purpose. The symbolism is therefore also to be included in the reflections of the composition, if the place of the performance is to be regarded as decisive for the work, especially if it is conventionally visually stimulating. The audience's behavior will be guided by the expectation and the perspective of what is offered. If I play a loudspeaker concert in a gallery without any chairs, the acoustic characteristics combine with the dedication of the place differently than of the same concert in a chapel with benches.

Space arises therefore out of the interplay of these three poles. It is not to be understood as an arrangement of material objects and artefacts, but as the practical, mental, and symbolic establishment of relationships between these objects. Space is not dormant, immobile, or given, but a multi-layered fabric which is constantly produced and reproduced.

8.3.2. Spaces and Places by Michel de Certeau

Spatial sound composition with the IKO incorporates the acoustic potential of places in the form of concert halls, entrance halls, gallery rooms, laboratories or shopping centers. Michel de Certeau's approach to *practices in space (practiques de l'espace)*, in which he differentiates space and place one from another [Certeau, 1980, 217], provides a suitable framework based on everyday circumstances. His place and space concepts are embedded in his sociological theory of everyday life [ibid., 219]. In that sense, place is defined as its own, actually the original, which separates itself by definition from what it is not. Compared to such a stable constellation, space is a dynamic concept. Space emerges from place and indeed as an intervention, which makes the action theoretical framework of Certeau's argument plausible. Space is a *result of activities that give it a direction, making it temporal.* The use of directional vectors, which make the space function as an ambiguous *unity of conflict programs and contractual agreements*, shows clear proximity to formulations of the actor-network theory. In their texts, Michel Callon and Bruno Latour adopt multistep processes of the generation of consistency in networks, in the course of which different actors develop their interests and goals, change their course of action, assume plans of action and counterplans, and reintroduce, redefine or remove actors [cf. Schulz-Schaeffer, 2000, 187]. The conventions, negotiations, or, more generally speaking, the communicative exchange conducted with the aim of the establishment of situations is not only metaphorical for the composition of an acoustic spatialization of a place: acoustic conditions of the performance space, the IKO as a tool, reflectors, audience and audience seating are "actants" who program the appearance of spatial sounds and sound spaces as a result of their mutual influence. Certeaus' paradigm for the transformation of a place into space is the image of one walking, which dynamizes the geometric determination of a place [Certeau, 1980, 218]. The IKO also practices this transformation, in that sounds that react to specific existing locations become performers, which in their movement coin new vectors and thus create space.

8.3.3. Spacing and Synthesis by Martina Löw

Martina Löw also develops her theory of space from a sociological perspective. Her position serves as an example for the current "spatial turn" in the humanities and social sciences. Löw understands space as a *relational arrangement of social goods [*Löw, 2001, 158]: of material elements and human beings. Space is not given, but is produced by arranging elements (in relation to other arrangements), that is, by means of actions. The constitution of space is to be understood as a process. Löw distinguishes two different processes of spatial constitution: *Spacing* (furnishing) and *Synthesis*. These are comparable to *spatial practice* and the *conception of space* by Lefebvre. Spacing refers not only to the placement, erection, construction, or positioning of buildings, but also of moving goods. Through processes of perception, imagination and memory, the individual elements placed in the space are linked together and combined into *spacings* [Löw, 2001, 166]. Here, similarly to Lefebvre, the placing of plastic sound objects, their movement, arrangement, and separation are the practices of *spacing,* which constitute space. Composed sound can thus help to connect the different spatial components in the sense of furnishing [Brüstle, 2009, 115]. The so-called "concert" would arise when buildings, instruments, performers, loudspeakers, media technology and audience are arranged and placed in a specific, intended relationship to one another, and are linked together by the people who move in it and perceive it as space. Löw calls this linking process a *synthesis*. In everyday practice, the two processes cannot be separated. Building, constructing, and moving in space is not possible without the simultaneous linking of the surrounding elements. Conceptions of what a space is and can be (for example, a street or a place), determine what and where to build.

Spacing and *synthesis* are repetitive in everyday life. The arrangement of elements for a specific type of space follows one ordering principle. The elements that form the space "road" are always arranged and perceived according to a comparable pattern. Those processes of spatial constitution, which take place according to predetermined rules, which are socially and institutionally secured, form spatial structures. Space, understood as a relational arrangement, as a relationship between elements, has no material quality. It is, however, experienced as an object when the formation of relations, that is, the arrangement of the elements, is institutionalized, therefore always following the same rules.

In this respect, a study on plastic sound objects would have to look for a rule based on the perception, provided one expects a synthesis capacity from the listener: A stage and audience seating refer to a concert setting. Even though the installation and use of a loudspeaker system may be over 50 years after the Philips Pavilion and "Poème Eléctronique", They can count as a synthetic space. It becomes problematic when we work with sound objects whose descriptions and experiences diverge and even in expert circles are unequally dealt with. Thus the institutionalization is minimal and detached from other "shareholders," such as the audience.

A compositional spatial synthesis can therefore only occur when the elements used are perceptible, placeable and lead to a description. This definition corresponds to the descriptions in the electroacoustic space-sound composition literature, e.g. Nystrøm's description of his *distribution schemas* [Nystrøm, 2013, 46]. But Emmerson's *space frames* [Emmerson, 2015, 13] are also able to perform these synthetic tasks. The *spacing,* placing, building, and setting up of elements are tied to a specific place. This specific, mostly geographically marked, concrete place makes the emergence of different spaces possible. It is only in the synthesis of these elements that Varèse's *zones of intensities* or Bayles' *region of influence* [Bayle, 2007, 243] and Emmerson's *area of interest* [Emmerson, 1999, 138] can appear.

8.4. The Concept of Space within the Framework of this Thesis

> *The space beyond the framework of the body may appear to be a priority to most people, but in fact it must be traversed to be properly grasped. The movement of the body, the movement of objects, the movement of other people - all of these contribute to an understanding of space through spatial actions and behaviours.* [Kendall, 2010, 232]

I use a relational concept of space within this work. This is, on the one hand, tied to spatial practices but takes into account conceptual spatial concepts and the symbolic. Therefore space does not exist independently of the bodies. Instead, space is understood all the more as a relation, having the structure of the relationship between the bodies. I understand spatial concepts to mean the sound objects along with their spatial extent and placement by the composer who must be present during the compositional process in order to be able to compose the sculptural sound objects, the IKO and its placement, those who research the phenomena, the audience and the description of spatial phenomena as spatial concepts. Thus, the SPS is a necessary condition for the emergence and perception of sculptural sound phenomena, which in turn first form this space. There is therefore a relationship of mutual dependency. This applies to sculpture's classic body-space constellation:

> *The importance of the all-round totality of a full three-dimensional piece is that it should "take possession" of its space by one means or another.* [Rawson, 1997, 66]

> *This does not mean simply occupying space; all objects do that. It means developing its shapes and their implications so as to build in readable connections between the piece and the spatial environment.* [ibid. 67]

As well as for sculptural sound phenomena in computer music:

> *We must note here in passing the reciprocal tie, which unites the space inhabited by the senses and the spatial sense, so that to understand what a thing is, is to work out the space suggested by the dimensions of that thing; and in the same way, listening to it involves a space and time for the object listened to.* [Bayle, 2007, 242]

In this respect, I contradict the often-accepted view in acousmatic music, that it is an art dealing with "music in space" or "sound in space."[64] Instead, against the background of Smalley's debated spectromorphological space definitions and Nystrøm's elaborated topologies of spatial textures, as well as the depicted spatial practices from Lefebvre and Certeau to Löw, I plea here for the fundamental assumption that electroacoustic space-sound composition is "music as space" in the sense of a space-forming art in which, in particular, the sculptural sound phenomena are capable of constituting space.

8.5. Scientific Attributes of Perception of Spatial Dimensions in Loudspeaker Environments

Both Löw and Lefebvre presuppose general terms for the conception of the space or its synthesis. Therefore at the descriptive level, concrete terms from audio technology must be included for space constitution in a loudspeaker environment, which as mentioned, must start from a static spatial model in order to obtain spatial concepts, e.g. by technically measured and mathematical determination of spatial attributes. There is a long history of studies linking different attributes of spatial experiences to terminology [Zacharov/Koivuniemi, 2001; Rumsey, 2002; Berg/Rumsey, 2003]. In this context, the exact description of the spatial representation suggested by Rumsey in his article from 2002 for stereophonic reproduction systems is important: he initially defines dimensional attributes such as distance, width, and depth, and then immersive attributes, which he distinguishes between presence, as in an enclosed space [ibid., 662], and various kinds of envelopment, such as the surrounding by sound. Kendall [2010b, 230] differentiates and extends the list by applying it to electroacoustic sound projection's situation. He also distinguishes between dimensional attributes such as:

- Direction
- Distance
- Extent: width and depth, and height

And then immersive attributes like:

- Presence
- Envelopment

[64] Cf. as an example: next generation symposium report 2007

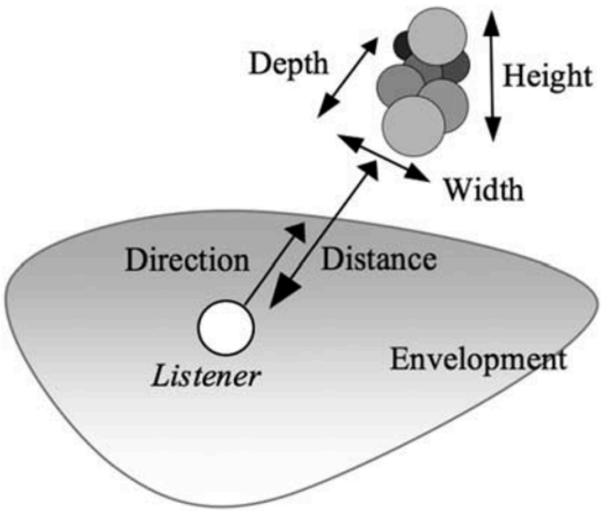

Figure 6: Attributes of spatial experience according to Kendall, [2010b]

Similar concepts can be found when we look at Emmerson [1998] and Smalley [2007]. The Rumsey/Kendall model allows us to think more about the spatial arrangement of three-dimensional sound objects: enveloping, grouping, superimposition. The "immersive" envelopment in a sound field or "listener envelopment" has been discussed extensively in recent years in connection with spatial acoustics and laterally reflected sound. Berg and Rumsey [2003] distinguish between "room envelopment" as a measure of the way we feel surrounded by reflected sound, and "source envelopment" as the degree to which we feel surrounded by sound sources. In the source envelopment, the listener consciously perceives directional indications and "looks" either at a sound scene or out from one of them. This scene can, for its part, consist of a complex combination of directional and diffuse information of sounding objects and reflections of the environment.

With the attributes presented here, spatial constellations can be described in auditive medial space, whereas the height and depth or the extent in these directions can be described, as shown above, by the research on spectral space and perspective field. These terms will reappear accordingly in the analyses.

8.6. Space and Spatialization

> *In electroacoustic music, the acoustic experience has often been a reference point, but the technology of electronic reproduction expands the scope and complexity of spatiality in a radical way. Even though the apparatus may be located within a physical space and even though our spatial hearing has developed within a physical world, electronic reproduction creates the potential for an art of spatiality.* (Kendall/Ardilla, 2008)

> *Spatialization, the synthesis of spaces and spatial properties of sounds for a listener [...]* [Peters et al., 2011]

> *It is necessary to ask, 'Why is this gesture meaningful, and why should I be placing this sound three meters off to the right, or underneath me? There must be a musical rationale behind sound diffusion.* [Field, 2001, 22]

The concept of spatialization or spatialization of sound is not used unambiguously. It is, however, generally assumed that we can distinguish between two basic traditions: the loudspeakers and the concert hall can be understood as the environment of the composition, or the loudspeakers and the surrounding space become the vehicle to create certain spatial sound phenomena (Kendall 2010, 233). My work follows mainly the second tradition. Because of spatial perception's dependence on the spectral space in regards to the vertical as shown above, I distinguish between two orders of spatialization:

8.6.1. Spatialization of the First Order

The *spatialization of the first order* arranges the sound objects in the frequency spectrum or composes them in a certain frequency range. The perception spans the extent of the created space between the highest and the lowest frequency and will locate the sound object therein. In most cases, this happens independently from the assignment of a sound texture to a specific loudspeaker (top, bottom, side) and software generated movements of the (mirror) sources. Therefore, before composition of trajectories by means of beam fixation, panning or rotation, as well as the generation of staggered fields can even be considered, spatialization of the material takes place, which defines the vertical of the space thus created. Depending how the material is organized in time, this can be quite dynamic (e.g., sweep).

Listening example 1: *Spatialization of the first order* - mirage 2/T4: 6:21- 6:45

Graduations (above-below, but middle empty) are possible in these verticals by temporal overlays of different sound objects.

Listening example 2: *Spatialization of the first order* - mirage 1/T2: 2:50 - 3:23

8.6.2. Spatialization of the second order

The spatialization of the second order is then in the arrangement and dynamization of the sound textures in the perspectival field, whereby, of course, vertical movements of sound sources and synergy with the *spatialization of the first order* also play a role (see the Index of Miniatures.)

It is only through the deliberate combination of these two orders that spatial textures and ultimately sculptural sound phenomena can be composed from sound textures. This division is independent of both the loudspeaker system and projection method used.

> *We might have a sensation of perspectival spatiality when a complex perspectival field is present – if, for instance, the layout of zones and trajectories of motion have an emphasis on horizontal extension. Or, spectral spatiality may be emphasised in the presence of an elaborately developed spectrum: for example, how it is morphologically occupied; how textures are stratified.* (Nystrøm, 2013, 22)

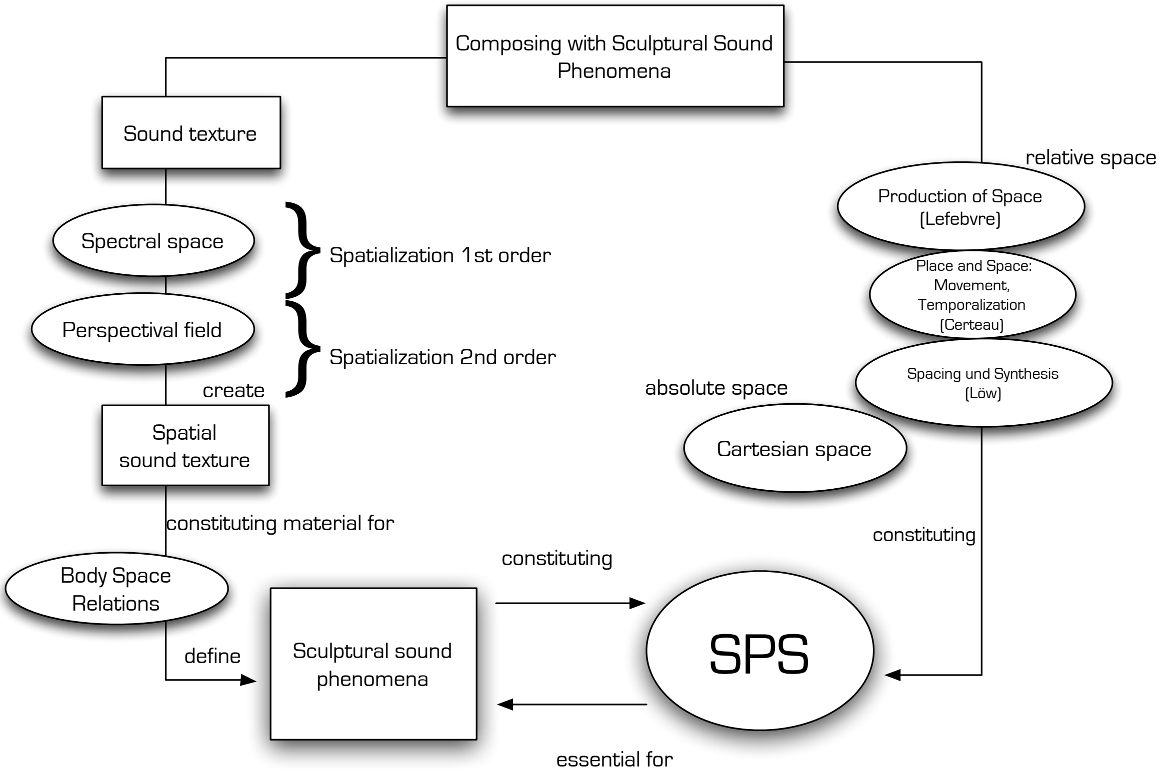

Figure 7: Overview of the conditions for the composition of sculptural sound phenomena in SPS

8.7. Summary

For composing with sculptural sound phenomena, two paths must be taken into account (see Figure 7). On the one hand, it involves the production of sound material, which passes through the processes of *spatialization of the first and of the second order* in order to be able to build a sculptural body-space relation. The path across the other trail must take into account the various requirements of the absolute and relative space for both the composition and later on at the performance. The latter is decisive for forming the SPS, which in turn is a necessary condition for the perception of the sculptural sound phenomenon arising in it. The sculptural sound phenomenon, which is defined by the body-space relation, is at the same time a constitutive factor for developing the SPS, since spatial definitions of the SPS, such as direction, extent, and envelopment are articulated only by the sculptural sound phenomenon.

CHAPTER III

Research in the Current Practice of Spatial Sound Composition

1. Tools and Instruments II - Environments

> *In recent years, various forms of surround sound have been added to the diffusion systems many have employed thus far. Virtually all publications have described how these systems work and what the advantages are between one and another from an acoustic point of view.* [...], *very little consideration has been given thus far to the musical and, more specifically, sound-based musical advantages of these spatialization systems. Furthermore, many of these discussions pay little attention to the diversity of spaces and the quirks thereof where these sound systems are being installed.* [Landy, 2007, 220]

> *There are at least three reasons why the spatial potential of electroacoustic music is not always realized: 1) misconceptions about the technical capacities of spatialization systems, 2) misconceptions about the nature of spatial perception, especially in the context of such systems, and 3) a lack of creative engagement, possibly due to the first two issues.* [Kendall/Ardilla, 2008]

1.1. Classification in the Field of Current Multichannel Loudspeaker Systems

In 2011, Peters, Marentakis and Weiss published the comprehensive and historically first study on the dissemination and use of spatialization in computer music: *Current Technologies and Compositional Practices for Spatialization: A Qualitative and Quantitative Analysis* [Peters et al., 2011]. This shows that in the 2000s, the interest of the composers in working with multi-channel loudspeaker systems increased strongly and the interest in stereo productions decreased. It is also shown that playback systems have improved in quality and are more common than in the 1990s. Almost half of respondents consider spatialization to be a compositional paradigm, not just a technical extension. However, the study also shows that the few composers in the field of acousmatic music have sufficient access to appropriate systems, and they often work with their headphones or fundamentally in stereo [Peters et al., 2011, 14].

From the point of view of the validity of research results for a broader public for the purpose of generalization, the question arises why the present work was not carried out with an 8-channel ring most popular among festivals [Lyon, 2008] or the increasingly disseminated loudspeaker dome. This would be a standardized research environment. There are, however, good reasons for using the IKO. On the one hand, it has been shown in dealing with the IKO that one can once again tackle and exacerbate exemplary problems that play an important role in the electroacoustic space-sound composition but are sometimes less pertinent, or even looked over or ignored. This allows the compositional and concert practice to be reviewed against the backdrop of a quest to find the conditions for a SPS. Examples of this would be the loudspeaker as a visual object in a concert setting, its role in the compositional process, different loudspeaker qualities and the effects on the sound material used, the sweet spot problem, the handling of different acoustic locations and the placement of the audience. In this respect, the IKO serves as a burning glass on the status quo.

In addition, my artistic research still has a future-oriented perspective: There is indeed a worldwide trend towards greater use of multichannel loudspeaker systems and corresponding spatialization tools [Otondo, 2008; Peters et al., 2011, 25]. This is also confirmed by concert halls and studios with ring or dome arrangements built in recent years. But there is also criticism on how these systems are conceived and the artistic content, which I share:

> *It is surprising [...] to discover how small the "sweet spot" is on most multichannel diffusion systems. The composer or the person at the mixing desk and the mixing desk itself tend to take up a large portion of this special position. The further away one is from this center position, on virtually all systems, the more skewed the diffusion is. This cannot be right.* [Leigh Landy, 2007, 220]

Moreover, despite the proliferation of multichannel loudspeaker systems and the standardization of their control, the compositional concepts do not seem to have developed any further:

> *[...] Barrett considers that 'the spatialisation equipment and technology have become readily available, but the users haven't caught up'.* [Barrett nach Otondo, 2007]

> *[...] despite a considerable development in the technological tools available for the spatialisation of sound, this has not materialised in the electroacoustic music we hear nowadays in concerts.* [...] *the understanding of spatial issues among composers is still not so advanced'.* [Barrett in: Otondo, 2008]

It is therefore questionable whether, despite the further dissemination of corresponding loudspeaker systems, real assimilation has resulted in an extended understanding of spatialization [Otondo, 2008, 80]. In addition, the distribution of the rings, domes and arrays also copied their problems: high acquisition costs, followed by a high maintenance effort, in solving regular accessibility problems for students and non-academic artists, resulting in an encapsulation and foreclosure of current artistic influences and a "monoculture", as well as expensive rehearsal times. The installation is often found in multifunctional rooms with, to some extent, difficult acoustic and political situations. This can be the case if different institutions and institutes with different interests have to share these premises (for example the Ambisonics Dome in the Ligeti Hall at Mumuth Graz, Wave Field Synthesis in the TU Auditorium in Berlin). Furthermore, the transferability of compositions to other performance situations and other loudspeaker systems remains questionable and is not rehearsable in most cases. In addition, non-uniform formatting in 3D audio [Peters et al., 2011, 16] is also a problem.

It is therefore also a question of finding an alternative way of composing with sculptural sound phenomena, if one would like to hold on to an artistic and aesthetic update of medialized space as a SPS. Due to the IKO's burning glass function described above, the results of this search are intended to contribute to an extended and better informed handling of all loudspeaker systems and the composing of space-forming loudspeaker music. For this reason, over the years, the idea crystallized that my artistic research would have to be devoted to a mobile device that can be adapted to different architectural and acoustic conditions, be used for composing in the studio, and serve in the concert hall as a reproduction unit, all the while remaining the same tool. The IKO in this way also broaches the subject of the loudspeaker as an important part of the composition itself, which is rarely the case in the relevant scenes, despite how established loudspeaker music now is. In barely any study in recent years is the loudspeaker's function in the artistic work process questioned. Rather, it seems to be a neutral "thing", like a pipe into which water runs up and down again. Against the backdrop that there can be no neutral transmission in the medial work process [McLuhan, 1968, 99; Latour according to Schulz-Schaeffer, 2000, 187], this seems to not only be artistically important. When working with the IKO, these questions arise precisely because it is a prototype, new and permanently dealing with different architectural spaces and audiences. Therefore, the questions that arise when working with the IKO concern all areas of acousmatic music and loudspeaker concerts. The questions and answers pertaining to SPS are therefore also applicable to other loudspeaker systems with regard to the composition of sculptural space-sound phenomena. Through the artistic and scientific cooperation at the IEM, the loudspeaker, including the software and the transducer amplifier system, has been further developed in the last three years in such a way that the IKO can be produced serially with considerably reduced production costs. In March 2016, the company *sonible*[65] was commissioned to produce a second, licensed IKO. The first tests with the new loudspeaker system were carried out on July 1st, 2016 in the CUBE. This should serve as the start of serial production and enable international sales. In the spring of 2016, mobile reflectors, which would make the IKO more adaptable to different room situations, were also built. The construction of these fixtures also resulted directly from the concert and experimental practice of the last years,[66] and thus continues to meet the requirements of transport, concertizing, and various installation environments. In this respect, the IKO is now an ideal research situation for all questions concerning SPS. Concert performances with loudspeaker rings and half-spheres have other advantages, such as, for example, the possibility of enveloping the audience to a greater degree. However, it has been shown in the context of comprehensive studies [Peters et al., 2011] and various personal experiences in this field that this practice leads to considerable limitations with regard to the development and implementation of artistic ideas, the perceptibility of these ideas, and the dissemination of this music. The IKO opens up a new field in acousmatic music, which brings up questions of both artistic and scientific issues, whose solutions, in turn, affect all areas of loudspeaker music.

1.2. The Virtual IKO (ViKO)

> *We also saw the demand for technology to give composers a feeling of the venue acoustics while working in the studio.* [Peters et al., 2011, 25]

Due to my concert practice with the IKO as well as other loudspeaker systems, the desire arose for a spatial simulation of the corresponding performance rooms developed in order to be able to carry out concert preparations on the spot in the absence of sufficient rehearsal time.[67] But a kind of spatial sketch book was also necessary for the continuous compositional process with sculptural sound phenomena in order to, on the

[65] http://www.sonible.com/de/
[66] See Chapter III.2.
[67] The concert on June 17th, 2016 at the New York Electroacoustic Music Festival was an example of this: For a multi-channel piece with the length of 10'26 " there was exactly 14'00" of "rehearsal time."

one hand, not become dependent on permanent access to loudspeaker technology and, on the other hand, to confine the process to the studio. The virtual IKO (ViKO) was developed as part of OSIL's research in 2016 [Zaunschirm et al., 2016]. This is a plug-in for a binaural headphone environment that can simulate the IKO with its spatialization effects in various spatial situations, e.g. room size, reflective properties, and various listener positions. The ViKO is generated on the basis of recordings of space impulse responses, successively stimulated by the IKO's 20 loudspeakers with 32 channels of the EM32 at the desired listening positions and the IKO's position. The listening examples included in the work are, correspondingly, all binaural with the ViKO, rendered from two listening positions. In addition, a simulation for IKO compositions was developed, which allows these compositions to be performed without the IKO, or at least spatializations with the IKO-typical spatial effects, e.g. in a standardized 8-channel ring.

2. Concert Practice as a Research Process

> *It is a question not only of composed structure, but also of concert diffusion, where the composed space(s) of a work must be negotiated with the acoustics of the performance space.* [Nystrøm, 2013, 16]

2.1. Origins - Composing in the Laboratory

The IEM icosahedral loudspeaker was a scientific measuring tool before it was considered an instrument for the composition of sculptural sounds in computer music. For this reason, the device was first tested exclusively in a studio-laboratory setting. Most of the research up to 2015 was done in the IEM's CUBE[68], a 120 square meter room with a permanently installed loudspeaker dome and absorbers for concert mode. A seminar room with, in part, highly reflective window fronts, a wooden floor and large blackboard panel has been used since 2015. Visual aspects of the staging with regard to the concentration on spatial auditory impressions or the distraction thereof were not considered in the laboratory situation. In order to be able to work with the beamforming algorithms, and thereby produce perceptible reflections in the low-reflection CUBE, ordinary mobile whiteboards were

[68] http://iem.kug.ac.at/services/raeume.html

initially arranged at different distances from the loudspeaker. This enabled different distances of reflecting surfaces with different sound materials, projection angles, and spatial sound layers to be tested. Within this process, an "IKO near-field"[69] was defined as an area in which the wall reflections and the resulting three-dimensional sound objects are predictable and consistently perceptible, with a further "IKO diffuse-field" adjacent thereto, in which the contours and trajectories of the sounds blur. It was clear from these experiments that strong reflections are fundamental in producing clearly perceptible and stable three-dimensional sound objects with the IKO, and that these conditions can be produced in dry, low-reflective environments using reflector walls, such as those used today in concert practice.

The resulting assumption was that this new sound projector can be used in computer music not only under studio conditions, but also in places normally not intended or suitable for loudspeaker music. This led to questions of how to put this laboratory knowledge into practice, such as, for example, with longer reverberation times, special architectural cuts and spaces, as well as having the audience placed specifically, and how knowledge about this can be integrated into future compositions. Accordingly, since 2009 the IKO has been tested in various performance situations by trying to reconstruct the laboratory situation at different locations or to learn from the differing experience. A second strategy was the performance of the same compositions in different spatial situations in order to gain experience with the range of the beams, in order to understand sound-layering possibilities in larger spatial volume with the inclusion of longer reverberation times and the demands of higher sound levels, thus empirically testing the stability of the three-dimensional sound objects.

[69] See Chapter III.2.3.

2.2. Exemplary Space-Sound Stagings in Concert

In the last seven years, the IKO has been tested in 16 performance situations, four of which, described below, are selected from the time during the doctorate.

2.2.1. signale^{graz} 2014

The concert took place on November 11th, 2014 in Mumuth's Ligeti Hall at University of Music an Performance Arts Graz as part of the concert series signale^{graz}[70]. The hall has a surface area of 511 square meters and a ceiling height of up to 13 meters. The reverberation time is approx. 1.8 seconds. The concert was given in two parts. In the first, three pieces were played for and with the IKO, pieces which had been derived from the laboratory settings and multi-channel compositions since 2010 (*grrawe*, *firniss*, *grafik unten*[71]). In the second part, the Higher Order Ambisonics (HOA) piece I_LAND[72], which was composed for the 29-speaker dome, was performed. This combination had the goal of contrasting the two approaches towards spatial sound projection in the same concert situation and making them experienceable. The question was to be asked how the IKO can be integrated into the established computer music concert mode with an outer-to-inner sound system. For organizational reasons, the seating had to be set in one direction, and therefore the decision was made to choose a classic concert set-up with the stage at the front. The audience was placed in a block in the center of the loudspeaker dome to take full advantage of the dome's sweet spot. The IKO was placed at the end of the hall

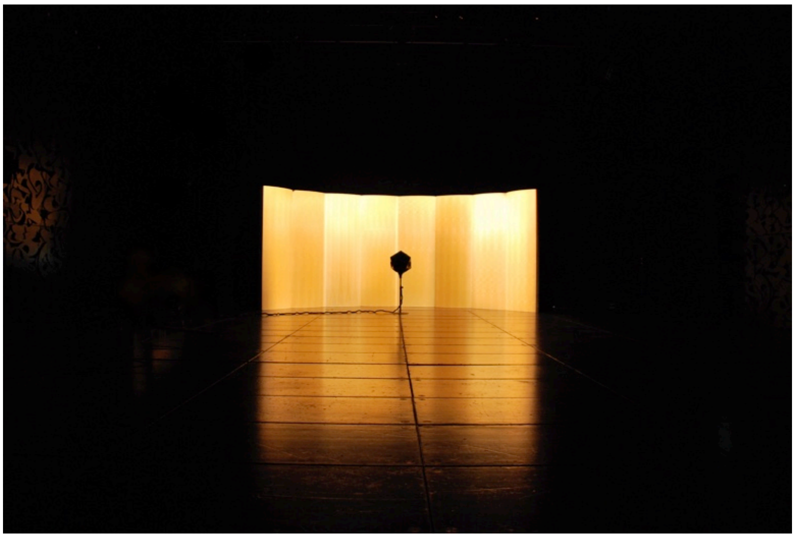

Figure 8: IKO with reflector screen in Ligeti Hall at MUMUTH Graz, 2014.

[70] www.signale-graz.at
[71] Cf. all three pieces as binaural ViKO renderings: on the enclosed SD card or List of Download Links, p. 175.
[72] http://www.gksh.net/portfolio/i_land

in the middle of the area where a string quartet would normally be placed. The first rehearsals showed that the IKO was lost in this spatial volume and produced only weak, unpredictable reflections. The spatialization trajectories fell back into the icosahedron, hung on its surface, and the sound graduations and layers composed in the laboratory turned into an indefinable blur in the reverberation. The sculptural compositions fell apart. After the IKO was moved closer to one of the hall's corners during the rehearsals, the reflections from the walls could indeed be better controlled. It became clear that a reflective sound stage setting of about 4.5 meters in diameter had to be created in order to be able to set up the tool and the composition in this architecture. This was achieved by the fact that the reflector panel in Ligeti-Hall, which is normally used for ensemble concerts, was set up behind the IKO. The results were surprising. The contours of the sculptural sound formations became more pronounced at once, revealing the compositions' original spatial sound structures.

Further rehearsals revealed that even the reflections from the high ceilings could be included in order to stabilize the spatial auditory impression in the vertical (top, top-left-right). In keeping with these results, the audience rows were moved further backwards by about 3 meters in order to lose more of the IKO's frontal direct sound. In this way the audience's attention could be directed to a wide, relief-like left-to-right panorama created by the reflector screen along with reflections off the walls of the hall (left-right) and ceiling reflections so as to make the IKO sink into the background visually as well as acoustically in terms of direct sound.

The lighting was used to support the staging. By darkening the hall during the concert and illuminating only the reflector panel (see Figure 8), the loudspeaker was visually reduced to a black silhouette whose contours were quickly identified as being given and visually unproductive. That means that by deliberately setting up the elements of staging at the performance venue in the sense of a spatial practice, the perception of the three-dimensional sound compositions in the space thus created was purposefully aligned and involved.

2.2.2. Izlog Suvremenog Zvuka Festival 2015 Zagreb

The Izlog Suvremenog Zvuka Festival 2015 - Showroom of Contemporary Sound - took place from the 6th to 9th of May in Zagreb. The performance concept was to play two concerts with the same program in two different rooms in order to make the fragility of the spatial parameters in the compositions comparable. Through the two opposing spatial situations, the ratio of dependency on sound projection, architecture, spatial acoustics and composition was to be better understood[73].

French Pavilion

The French pavilion was built by France in 1937 for the Zagreb Trade Fair and was renovated and reopened in 2014 after several redevelopments. It is a cylindrical high-rise structure, which nevertheless has angled wall structures and closes at a height of 13 meters by a thin steel roof with a diameter of 32 meters, in the center of which a round skylight has been inserted. The walls consist of a concrete base and wooden structures, which are perforated all around by high window fronts, through which light falls into every corner of the seemingly sacral hall. One can enter the hall from three sides, so it therefore has no front-rear orientation. The main perspective from all directions is the center. The floor is made of sanded concrete slabs. With a reverberation time of 6 seconds, it is almost impossible to perform music that was not composed for this room. The reverb make every conversation exhausting and blur the articulation.

Figure 9: IKO in the French Pavilion Zagreb, 2015.

The first impression would be to place the IKO directly in the middle of the building, directly under the skylight in the high roof. Visually, this would create symmetry, with the IKO in the central axis from all perspectives in the space assuming a balanced relationship with the architecture. Acoustically, however, this would eliminate precisely the peculiarities of the loudspeaker

[73] Both concerts are available in a binaural audio documentation, cf. SD card .

system, since the distances to the reflecting surfaces, with the exception of the floor, would be too great to align the beams in the audience's direction, and it would also be questionable where the audience would be placed. After a test phase, the IKO was installed de-centrally near a wall in order to use the concave curvature of the wall of the cylindrical building as a reflector. Because of the church-like hall, it was predictable from the outset as part of the performance concept with two different performance locations that the three-dimensional sound objects of the compositions would be difficult to produce. But surprisingly after further tests, in which different distances to the nearest reflective wall were tried with different beam movements, similar spatial sound phenomena became perceptible in the opposite half of the hall. Naturally, these were strongly influenced by the described characteristics of the building. Nevertheless, object-like phenomena, stratifications and movements could be perceived, which also seemed to have their main source more so in the center of the building than in the place where the IKO actually was. In addition, the parabolic convexity of the metal ceiling could be controlled in such a way that the auditory impression could be stabilized. For the concert, the audience was placed on the opposite side of the hall, on the opposite side of the IKO, according to the experience gained during the rehearsals. As expected, the result in the concert was very different from the laboratory situation; because of the acoustic characteristics of the place, completely different space mixtures and contours were produced. But the experiment clearly showed that the IKO can also be adapted to problematic spatial situations if one takes into account the architectural setting and learns to use it. In addition, the concert program was changed because the composition *firniss* contains too fine of volume levels between transient, fluctuating burst chains, which are perceived near the IKO itself and whose volume cannot be increased above a certain point without distorting the system. The composition would then disappear almost completely; it cannot be adapted to the place so that the sculptural sound phenomena appear at all. This made it clear that for more stable spatial compositions, further research on the source characteristics of signals with different onset and release times and their respective potential to articulate the acoustic conditions of the respective performance space are necessary. Also, studies had to be made on which sounds are perceptible closer to the IKO using beamforming and which are perceptible from a greater distance. In addition, it became clear that spatial simulation would be necessary if one was to prepare compositions for different room settings with little rehearsal time.

Multi-Media-Art Gallery

Two days after the first concert, the IKO was placed in a rectangular gallery with a surface area of about 130 square meters, a ceiling height of 4 meters, and a reverberation time of approximately 1.1 seconds.. The loudspeaker was placed in the right corner of the room, opposite the entrance, in order to take advantage of the reflections off the brick walls and a part of the ceiling made from glass and wood. After a few minutes, it was able to produce the same listening setting as in the laboratory. The audience was later placed on benches on both sides of the room, leaving the center free. At the beginning of the concert, it was also announced that the audience would be free to move around the room during the performance and find their own listening point. This was an attempt to make the sculptural sound phenomena more perceptible through possible changes of location. The setting, much more intimate than in the pavilion, encouraged the audience to change their location several times during the concert and listen to the sound sculptures from several positions. After the concert, visitors made similar statements about the perceptibility of the sculptural sound formations and their spatial definition and delineation in sound zones, sound layers, and trajectories. These were recalled as sounds but not so blurred and diffuse as perceived in the concert in the pavilion. The experience gathered at the Multi-Media Art Gallery Zagreb has raised new questions about the nature and composition of the sound material used and its spatialization in relation to the performance space, and how the resulting phenomena can be classified for the performance setting as well as the compositional process. Since there are apparently sculptural pieces that work in one space but cannot be performed in another, you would have to estimate in advance based on space simulations or data (room size, reverb time, seating, ambient noise, etc.) and predict the spatial indices of pieces during the compositional process. This also underscores the specific instrumental character of the loudspeaker system used and the intrinsic connection with the composition of space.

Figure 10: IKO in the Media Art Gallery Zagreb, 2015.

No one would think of performing Luigi Nono's Prometeo in a small chapel or a classroom, or Bach's Chaconne from Partita 2 in D minor in a football stadium.

2.2.3. InSonic2015 Conference at ZKM Karlsruhe

At the ZKM, the IKO concert was scheduled to open the final evening at KUBUS. The performance hall has a reverbe-ration time of 1.6 seconds, with the walls partially covered in Molton fabric. All other pieces performed that evening featured the 43-channel loud-speaker dome, supplemented by performers on the front stage and a front-end WFS speaker ar-ray. Therefore, as at the concert at *signale* in 2014, the seating was fixed and directed forward, with the focus on the stage. As a result of experience gathered through the laboratory and stage settings in recent years, five mobile reflector walls were about two meters behind the loudspeaker in a semicircular arrangement, with a gap of approximately 1.5 meters between the individual walls. After 20 minutes of rehearsal, the adjustment of beams and the distances from the reflectors to the IKO, the edge of the stage and the audience, the sculptural space-sound phenomena could be perceived quite exactly, similar to the laboratory experience at the IEM. Even with full seating and with the audience sitting as a block in front of the stage, the contours of the compositions were clearly delineated and the spatial sound movements could be traced far into the hall. Although at a certain distance from the stage (about 8 meters), the spatial staggering lessened and the panorama somewhat broadened, but without sweeping away the plasticity.

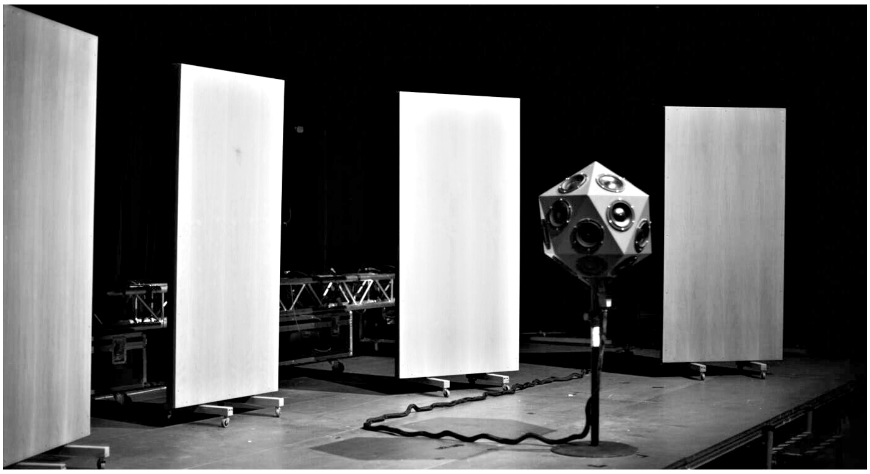

Figure 11: IKO with reflectors in KUBUS at ZKM Karlsruhe, 2015

2.3. Evaluation of Practical Experiences

2.3.1. Differentiation of Performance Concepts

The practical experience gained with the IKO in this way led to investigations with space-sound models in the laboratory setting in order to better understand the conditions that make it possible to compose space as a parameter in electronic music and reproduce it reliably in different places. In recent years, two basic performance and staging concepts from an artistic perspective have proven plausible. The first (Figure 12) looks for proximity to corners in typical rectangular spaces, the second uses concave arrays of reflectors behind the IKO.

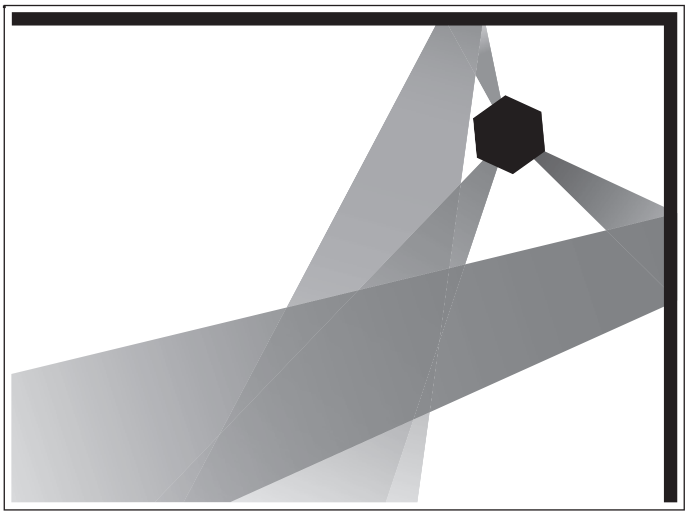
Figure 12: IKO in the rectangular performance setup

These deliberate loudspeaker room arrangements influence the propagation paths in concert settings and thus the number of discretely localizable directions. The rectangular performance setting with the IKO placed in a corner allows the orchestration and balancing of at least two pronounced wall reflections in relation to the perceptible direct sound. For this purpose, the distance from the IKO to the audience should be at least as great as to both walls. The IKO has been used in the past in such constellations at, for example, the DAFx 2010 (glass walls), the International Summer Courses for New Music Darmstadt 2014 (various materials) and the Izlog Suvremenog Zvuka Festival 2015 (brick wall). Rectangular spaces often provide further useful reflections, e.g. ceiling, floor and further distant side walls as well as room reverberation effects. They also, at the same time, cover the risks of blurring through spatial geometries and wall materials in interplay with the sound materials used. Therefore, it would be advisable for compositional practice to compose pieces so that they can be adapted to different spatial situations, still with the aid of the ear and corresponding software tools. This would have the effect of changing the velocities of movement at rotations and fades as well as angles and radii of the beams at the respective location in such a way that each piece can be molded by the interplay of the acoustic properties of the performance location, the audience placement and the IKO's orientation to create a conditional relationship between SPS and a sculptural sound composition. This was almost impossible in the original versions of *grrawe*, *firniss* and *grafik unten*, because the sound material could hardly be matched to the movements and trajectories as well as the speed of the beams, and therefore the compositions allowed little spatial graduation of sounds with the IKO. Although individual passages were differentiated in the elevation, in the sense of *spatialization of the second order,* these mirror sources could not be realized practically in the respective performance space because either hardly any ceiling reflections could be produced or the sound material used for the generation of mirror sources was not designed for that and was thus stuck to the surface and the IKO's north pole.

Concave arrangements (Figure 13) of reflectors behind the IKO result in a large number of usable and distinct reflections. The arrangement behind the IKO should preferably have a radius of 5-7 meters, while the loudspeaker itself should be placed in the symmetry axis of the arrangement with a distance to the central reflector somewhere between 1.5 and 3 meters. This arrangement increases the otherwise limited number of reflections (stage back, side walls) to a plethora of possible directions between stage and audience space. The audience should sit about 5 meters away from the IKO to allow for a balanced perspective towards the spatial sound objects first formed by the reflections. This IKO *near-field* varies, of course, in size with the increasing reverberation of the performance location. The above-mentioned blur, which eliminates possible differentiation of the three-dimensional sound objects in the IKO *diffuse-field*, sets in when the distance to the IKO *near-fie* is too great. Visibility also plays a part in the perception of the sculptural sound objects, which focuses less on the IKO at a greater distance and turns from a more observant visual perception into a kind of stare, which in turn enhances the auditory impression for the

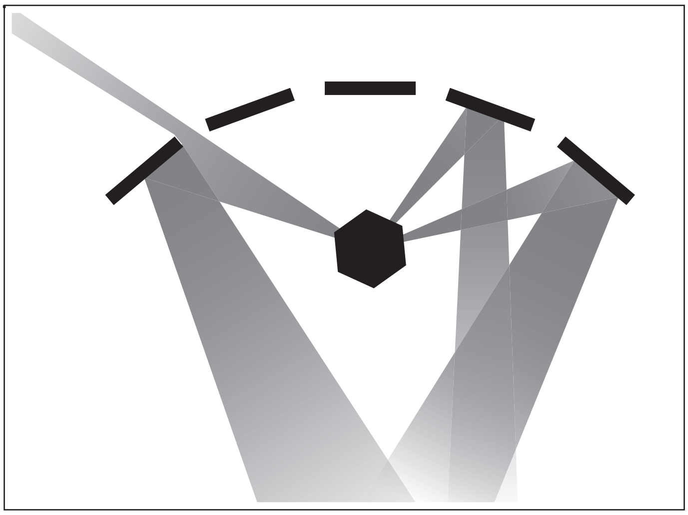

Figure 13: IKO in the rectangular performance setup

surrounding space. This also means that a stable IKO *near-field* and Visu-Audition can create tension which must be balanced at the respective performance locations. Illumination can be helpful to the extent that during the concert, the concert hall is emphasized more strongly than the IKO.

2.3.2. Audience Placement - Forgoing Arranged Seating

If the fixed seating plan is replaced by an open seating plan where the audience can choose for itself, the way one focuses on the piece is altered. This results in a flexible social space constitution, since the visitors not only orient themselves towards the loudspeaker and the spatial sound constellations, but also interact with each other differently. The spatial practice of spatial composition is now altered. It may happen that in these movements of alignment, attention is paid less to the spatial sound phenomena than to the other listeners. At the same time, it was possible to ascertain that the different sound zones and movements from different perspectives could be perceived better by independent movement in the performance room than with frontal seating. Therefore, with respect to the experience of the space and the forming of very fragile "fixtures", the capability of synthesis can become a more delicate one by eliminating the focus on a singular stage perspective. Again, the seating arrangement should be adapted to the piece and the latter to the architecture. For example, the listener won't move during very soft sounds so as to not interfere with the composition by making noise with his own body. This in turn leads to attention being focused on extremely quiet sculptural sound formations in such situations. It may also be the case by an open seating arrangement that drawn out sound textures must still be lengthened so that they can be "viewed" from several listening positions. Thus, the question of audience placement must play a role in the compositional process.[74]

[74] See also below the aspect of staged time, Chapter IV. 4.3.

2.3.3. IKO-specific Sculptural Bass Phenomena

In the bass range (<100 Hz), the IKO is used omnidirectionally, meaning all loudspeakers from this frequency range on play the same signal. This allows the IKO to stimulate larger volume as a powerful subwoofer. It becomes apparent, which is important for the *sculptural spatialization of the first and of the second order*, that "loud" is often perceived as "larger". In the octave above 100 Hz, beams can already be weakly aligned and moved, so that low-frequency sounds above this frequency limit can be moved in space. Such sounds are often perceived as weakly locatable sound clouds, which can hover as flexible zones in space. Therefore sculptural sound phenomena are formable with the IKO in the bass range, not only as a grounding or pedestal in the vertical formation of space, but also in the perspectival field. This differs from other loudspeaker systems in which the bass is mostly radiates omnidirectionally in mono and without beamforming, thus making it almost impossible to locate.

CHAPTER IV

Research, Modeling, and Determining of Terms in the Laboratory

The more that we understand about the complex relationship between spatial sound systems and the listener's spatial thinking, the better we will be able to harness the capacities of such systems for artistic purposes. [Kendall, 2010, 229]

The results of the compositional studies and the related listening experiments are described in the following chapter. It was always of utmost importance that the results of the investigations were included in the compositional practice in order to arrive at more exact acoustic, as well as terminological, descriptions of sculptural space-sound phenomena.

1. Miniatures

At the beginning of the iterative research process, 64 miniatures[75] were composed as the basis for further experiments. Static, as well as time-variant stimuli that perform the same spatialization applications with different sound material were generated. These miniatures were first described in terms of their sound material using the spatialization of the second order. In a self-directed experiment, each miniature was formulated from two listening positions (see Figure 14) as a spatial auditory impression.[76] In a second trial[77], taking place one year later, the terms developed over the course of the research, were then again applied to the miniatures in order to check their suitability regarding the initial space-sound constellations.

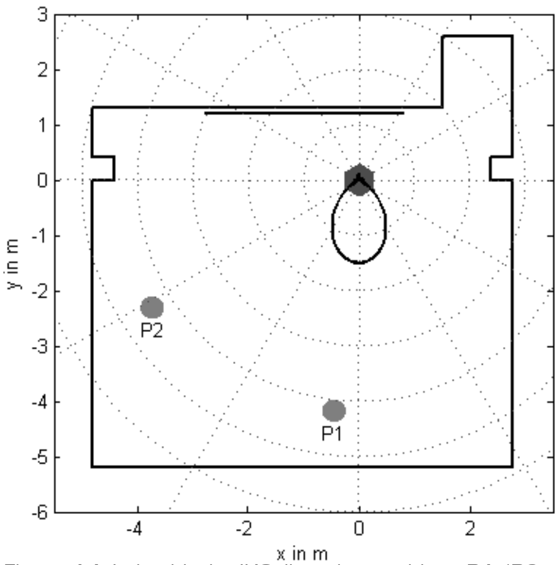

Figure 14: Lab with the IKO, listening positions P1/P2

[75] Miniatures Ia - IIId (12) + 52 = 64
[76] See Index of Miniatures A. in APPENDIX
[77] See Index of Miniatures B. in APPENDIX

1.1. Index of Miniatures[78]

The records were tabulated in the *Index of Miniatures* to make all steps of the systematic procedure comprehensible. Moreover, this set-up makes it possible to juxtapose the existing relationships between sound material, spatialization patterns, and spatial effect for different degrees of complexity.

1.2. IKO-Basic Pattern of Spatialization

These initial studies with continuous use of the Kronlachner plug-ins, as well as with unchanged spatial laboratory conditions, have resulted in the following basic patterns of spatial composition with the IKO:

(a) Fixed Beam [Miniatures I-III]: This basic pattern of spatialization produces a strong reflection on a surface, depending on the direction and material. In this way, space zones can be divided in directions. Broadband signals are more suitable for this than transient *bursts* or *grains*[79]. Additionally, fluctuating sequences are more difficult to locate than even chains. Broadband signals can also be perceived both farther away from the IKO and with distinct wall reflections; transient-rich ones remain closer to the IKO, meaning they can hardly be used as mirror sources. Beams are particularly strong in the equatorial height and in the direction of the ground (e.g., elevation -45°). Good perceptibility is present at the wall opposite the listener. It is weaker, but still differentiated, when lateral to the IKO as a direction. With beams in the direction of the listener, attention is strongly fixed on the IKO itself, with stronger changes of tone color as the position changes. At length, this leads to stronger contouring[80] of the spatialized sound texture, because the reflection path varies depending on the listener's position but can only be experienced by their own body movement.

(b) Circular motion/rotation around the equator at different speeds

[78] Listed in APPENDIX. See also List of Download Links, p. 175.

[79] The terms burst and grain are used here initially to designate transient, discrete sound events. Where the burst is a pulse-like, sudden release of high energy - and this virtually over the course of no time. Bursts have virtually no onset and release times. A grain is considered in computer music as elemental sound (sound grain) with duration of 5 to 20 ms [Supper, 1998, 48]. By stacking or overlapping grains, new sounds can be created. In the context of this work, however, grains are above all the smallest, discrete, "point-like" individual sounds that can occur in chains. They have longer onset and release times, making them less impulsive than bursts. See Index of Miniatures e.g. Miniatures II and III.

[80] Cf. derivation and transmission of the term contour, Chapter IV. 4.1.3.

(ba) "Beacon" (Perception primarily at the IKO). This basic pattern of spatialization is caused by slow movement of the beam in the case of broadband signals with a hazy trace on the reflecting surfaces in the surroundings. With high-pass filtered noise, the center of gravity can shift away from the IKO[81]. Circular motion is anticipated.

(bb) “Spatial beating“ (Perception primarily in space; on the reflecting surfaces)

This basic pattern of spatialization is generated by fast movement of the beam in the case of broadband signals. It is not perceived as a full circle, but rather produces punctual reflections ("beatings") on the walls in a circular trajectory, which makes a regular pulse with a spatial direction perceptible in the rotation.[82] Depending on the listening position, *spatial beating* can also lead to pendulum motion if only two distinct reflections are perceptible. Therefore, despite a uniform rotational movement around the equator, the perception of forward and backward movement of the signal between two coordinates occurs.

(bc) “Spiral“ as a special rotation

This basic pattern of spatialization is generated by the additional modulation of the elevation value during the rotation. It leads to swirls around the vertical axis with material-dependent propagations around the equator of the IKO, which is not synonymous with a clearly perceptible (graphical) sound spiral. The main focus is on *spatial beatings* and point-to-point sound coordinates in the *IKO near-field*. Spiral effects are difficult to predict, but can be learned experimentally and are reconstructible depending on the spatial situation and choice of material.[83]

(c) Panning and Fade

(ca) This basic pattern of spatialization is created by amplitude panning between two fixed beams.[84] It works well at different panning speeds for broadband signals and leads to strong contours of the sound event at different listening positions. It's more difficult with transient and fluctuating or irregular textures, because they are so close to the IKO that neither latitude

[81] Cf. Miniatures 21 - 31
[82] Cf. Miniatures 2, 8, 25, 38, 39, 49
[83] Cf. Miniatures 32 - 35, 40
[84] See also Miniatures 46 - 48, but also listening test 2., IV. 2.5.

nor depth can be shifted noticeably. By amplitude panning, however, burst chains can be activated as three-dimensional spheres around the IKO.

(cb) The second variant is a distance fade by changing the Ambisonics order (0th - 3rd) with a fixed beam direction with additional fade in volume: [85] This works from different listening positions as a movement from outside into the IKO through subsequent amplitude reduction, even in the direction of movement through the IKO, as long as one stands on the axis of movement.[86] In the case of broadband signals with wall reflection, an axis shift occurs from the wall in the direction of IKO and, if the case may be, back again. However, unlike the amplitude panning between two beams, the movement is not perceptible at all of the listening positions as a fade movement (trajectory with decreasing loudness) or axis shift, meaning the contouring of the sculptural shaping is performed less strongly. In the case of transient signals, there are occasionally only changes in volume and tone color, which can be used sculpturally, above all, for relief formation.[87]

(d) Pendulum: This basic pattern of spatialization is a variant of fade or circle and can be generated both in the perspective field and in the vertical. It can be generated by fast beam rotation or fade movements perpendicular to the IKO or around the equator. Therefore the actual trajectory is not perceived as such, but occurs alternately between two points of attention. This spatialization pattern can rarely be implemented stably, since controllable ceiling and ground reflections or corresponding wall reflections are a prerequisite for this. The optimal setting with the ceiling and floor is difficult to produce, even in a studio. [88] Stabilization through ceiling reflectors would be conceivable. However, with broadband signals at high rotational velocities, spatial beating can occur at the top and at the bottom of the IKO. Transient sounds and textures produce slight changes in the directionality[89] (more at the top of the IKO or more below the equator), depending on the event density, but are so subtle that they will hardly be usable in concert practice. They have not been used in any compositions in mirage 1 to 6. Pendulum motions in the perspective field left/right or front/rear also depend on the rotational speed and the room-dependent reflection points on the beam's

[85] Cf. Miniature 41 - 44
[86] Cf. Miniature 41 - 44 each from position 1 and 2, as well as mirage 6
[87] Cf. in detail for the derivation of the relief 4.1.1.
[88] Cf. Miniatures 49 - 52
[89] Cf. the derivation of the terms of directionality, Chapter IV.4.1.4.

trajectory, but can be realized when the two placement variants for the IKO are observed.[90]

1.3. Factors of Spatialization of the Second Order

In all miniatures, the sound material was first described, then the spatial processing was recorded and the auditory impression from two listening positions was recorded in writing. There are five different factors, the use and combination of which, according to the miniature studies, can be counted as the basic space-sound means when composing with the IKO. These are also the decisive factors of *spatialization of the second order*:

1. The distribution of the phantom sources[91] in space
2. The movement of these sources
3. The speed of these movements
4. The character of the sound material used
5. The volume adjustment

The personal descriptions of spatial sound phenomena suggest that there are percepts that also form stable space-sound formations from different positions. The stability is apparently also material-dependent and was examined accordingly in listening experiments. In addition, without consistent terminology the resulting phenomena in SPS are poorly described or distinguishable. The terms derived from the scholastic writings on sculpture in the research process could be helpful in this case.[92]

2. Listening-based Research through Listening Experiments in the Laboratory

Even if one can personally select the terms from the scholastic writings on sculpture and use them meaningfully in the compositional process, one has to ask the question how intersubjectively these terms are or can be. Qualitative proof of sculptural sound phenomena can only be achieved by carrying out

[90] Cf. Miniature 2, 3, 5
[91] *Phantom source usually means the position of the perceived source between two speakers. Here the term means the perceived position of the sound in the performance space.*
[92] See Index of Miniatures B: Body-space relationship, contour, directionality, plasticity. Chapter IV.1.1.

systematic listening tests, but this is rarely the case in the field of computer music [Landy, 2007; Sharma et al., 2015], which means no other studies could be used here.

2.1. Classification in the Field of Research

Fundamental approaches to the investigation of spatial perception can be found in the literature on psychoacoustics. Blauert [1997] deals with the entire subject comprehensively. Of further importance for work with the IKO is the work of Rakerd and Hartmann [Hartmann, 1983; Rakerd/Hartmann, 1986; Hartmann et al. 1989], which deals extensively with the localization of sound in reverberant environments. One of the important phenomena for this research is the so-called precedence effect. It encompasses a series of phenomena that are responsible for how, for perception and localization, the competition between intermittent delayed sounds and partial coherences, e.g. direct sound and reflection, can be resolved. Comprehensive summaries of work dealing with the precedence effect can be found in Litovsky et al. [1999] and Brown et al. [2015]. In addition, localization effects generated by the IKO in rooms can be derived in part from the research by Frank [2013] and Stitt [2015] on localization in ring-arranged loudspeaker arrays with decentralized listening positions. More specific studies dealing with the properties of sound objects produced by variable directivity in rooms are very recent, e.g. Schmeder [2009]; Zotter et al. [2014]; Sharma et al. [2014]; Zotter/Frank [2015]; Frank et al. [2015]; Laitinen et al. [2015].

The sections of the pieces *grrawe, firniss,* and *grafik unten*[93]*,* composed for the IKO since 2009, which consisted of the first attempts to transfer already existing multichannel compositions with their sculptural sound phenomena to the IKO or to reproduce the latter, are made up of a large number of interconnections of three-dimensional phenomena. A first attempt to demonstrate details in complex plastic sound textures as intersubjective was carried out already in 2013 in a listening experiment with seven test persons and stimuli, which were extracted from the first compositions. The results of this first study [Sharma et al., 2014] showed that individual objects could be named, but the extent of the complexity levels in finished compositions proved to be so great that it became clear that three-dimensional localization, propagation, and form had to be examined separately and more specifically.

[93] See List of Download Links (Pre_mirage.zip) p. 175 or enclosed SD card.

The starting point for the considerations presented here is that sculptural sound objects are phenomena produced in the compositional process consisting of different time-variant spatio-spectral elements. If, after the first experiences and the miniature studies, one considers the multiplicity of combinatorial possibilities, a comprehensive investigation seems to be impracticable. Thus, derivations for the compositional process would not be possible at the end. In order to limit this problem, and based on practical listening experience with the IKO, in concert settings as well as in the laboratory, and dialogue with the scientists involved in OSIL, a three-level hierarchical model of the space-sound phenomena that can be generated is proposed, one that mirrors the methods of my artistic research from miniatures, etudes and compositions:

2.2. Hierarchical Model of Space-Sound Phenomena

The observed phenomena were divided into three categories. *Spatial-sound phenomena of level 1* represent a single static percept. This is due to the composition of stationary sound material which, however, does not have to be completely static, but rather can also be a texture with temporal and spectral properties. These phenomena are generated by the previously mentioned time-invariant spatial sound projection. These very basic percepts can be examined on the basis of psychoacoustic research. Listening experiment 1 evaluates the perception of the phenomena of level 1 accordingly.

Space-sound phenomena of level 2 consist of time-variant projections of similar sound materials with different spatial attributes, e.g. trajectories such as circles, pendulums, particle clouds from grains of different spatial forms. The perception of these phenomena can be examined against "Auditory Scene Analysis" [Bregman, 1994]. Listening experiment 2 evaluates the perception of the phenomena of level 2.

Space-sound phenomena of level 3 consist of the layering of different *phenomena of levels 1 and 2*. This creates space-sound objects, which can be used as sculptural sound phenomena within the framework of artistic conceptions of spatial formations. The preliminary test 3 and the listening experiment 3 are concerned with the distinguishability of different sculptural types located on level 3.

2.3. Test Persons and Laboratory Room

For the listening experiments a group of students from the so-called IEM Listening Panel was brought in, a group of people (studying composition and sound engineering) who had not previously heard the IKO, or above all in a musical capacity. All experiments were carried out in the same laboratory room with the dimensions 6.8 x 7.6 x 3 meters with a reverberation time of 0.6 seconds. The IKO was always placed at the same position near a corner of the room so that a rectangular performance situation corresponding to the first variant of the above-described placement standards was generated. In order to examine the effects of the listening position on the perception of the three-dimensional sound phenomena, all tests were performed from different positions. Figure 15 shows the room's floor plan with the position of the IKO and the different listening positions of the subjects (listening experiments 1 and 2: P1 - P2, listening experiment 3: Pa - Pf). In addition, the materials of the six surrounding's surfaces are described, as well as the directional pattern of a third-order Ambisonics soundbeam.

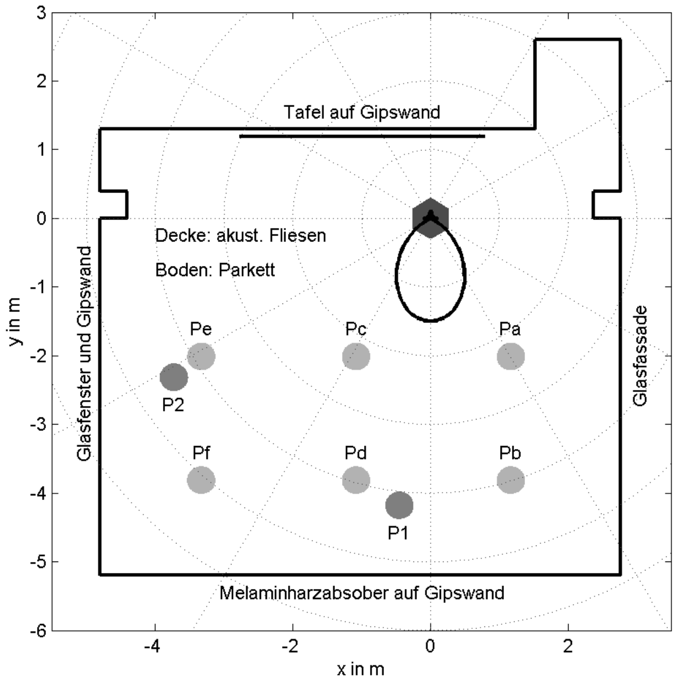

Figure 15: Experimental setup of listening tests 1-3 with IKO.

2.4. Listening Experiment 1:[94] Perception of Local, Static Sound Projections

The first listening experiment[95] examined the perception of static sound beams with different azimuth angles. The sound projection was generated with four different Ambisonics beams of the third order with the azimuth angles 0°, 90°, 180° and 235° (see Figure 17). The structure thus resembles the basic miniatures 0. (Ia - IIId). The sound material used for the stimuli corresponded to the sounds of the first 20 miniatures.[96] The stimuli 1 to 4 consisted of pulses of pink noise in combination with two different onset lengths as well as release times (t_{short} = 10 ms, t_{long} = 500 ms). Each stimulus is represented by a symbol whose shape indicates the corresponding course. For example, stimulus 2, which has a slow onset time and a short release time, is symbolized through ◀ (see Figures 16a and b). Sound 5 (represented by +) consisted of a fluctuating sequence of irregular bursts and sound 6 of an even chain of fine grains (represented by •). For each trial, each subject was placed at two listening positions (P1 and P2). They could look at the IKO and move their heads. The subjects were asked to indicate both the azimuth angle and the distance from the dominant auditory object to the loudspeaker in an IKO-

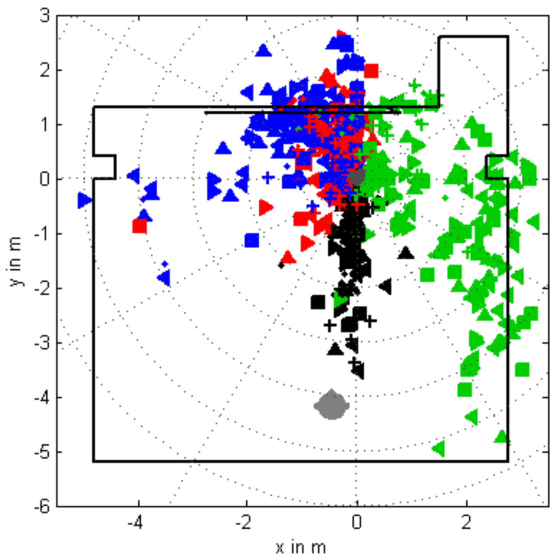

Figure 16a: Symbol cluster of all answers P1

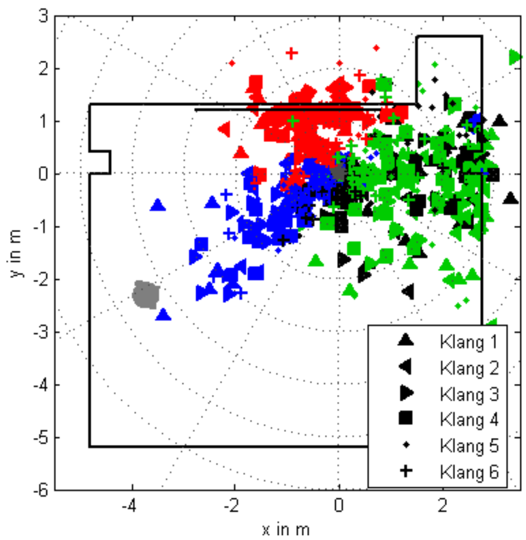

Figure 16b: Symbol cluster of all answers P2

[94] See SD Card or List of Download Links, p.175 for all stimuli of the following three listening experiments.
[95] Cf. stimuli of Listening Experiment 1 and Listening Experiment 2 as binaural listening examples.
[96] Index of Miniatures I - III (Chapter IV.1.1.) and 1-20

centered coordinate system on a touchscreen. In this case, seven stimuli, which can be selected by the subject, were displayed on a screen together with randomly selected directions in order to allow for comparative matching of the responses. The seventh stimulus was always a randomly selected repetition of one of the other six stimuli listed on the screen. With four such pages per listening position, each of the 15 subjects gave 2 to 4 responses per stimulus. All listeners gave altogether a total of 420 responses per listening position (see Figures 16a and b). The marker shapes symbolically represent sounds, and the perceived beam directions are represented by the colors.

As can be seen from the individually colored symbol clouds in the x/y coordinate system, there is obviously an intersubjective perception of different projections. This is also supported by the analysis of the two-dimensional median values in Figure 17a and b. A pairwise analysis of the variance (ANOVA) of all azimuth angles for each beam direction confirms this assumption. For both listening positions, six stimuli gave at least three directions ($p < 0.05$), while in some cases neighboring directions were statistically identical ($p > 0.95$). According to ANOVA for P1, the beam directions 0° and 90° have the tendency to coincide, as well as for P2 the directions 180° and 235°.

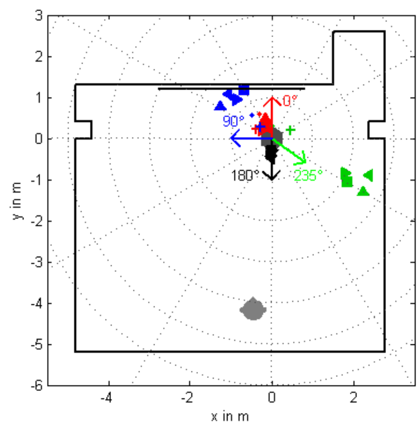

Figure 17a: Directions perceived from P1

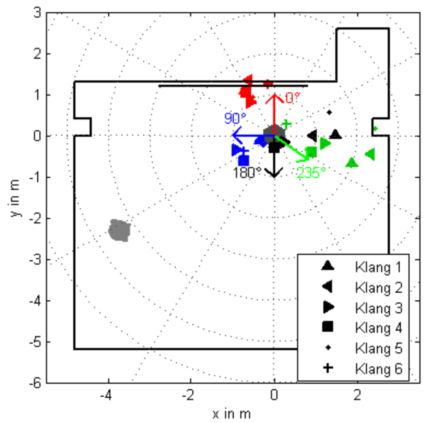

Figure 17b: Directions perceived from P2

The second aspect examined in this listening experiment is the distance from the sound objects to the loudspeaker or their distribution in the room. Figure 18a shows the median and 95% confidence interval for all directions. Here we can make two fundamental observations: The perceived distance of the sounds 1 to 4 (S1 - S4) depends on the length of their onsets (ANOVA: $p_{S1S2/S3S4} = 0.0017$). This is similar to stimulus 6 (S6), which was localized closer to the IKO than stimulus 5 (S5). This can be explained by the fact that S6 contains a higher proportion of transient signal components. Both dependencies (onset, transient ratio) confirm research results in the field of the precedence effect with transient signals [Hartmann, 1983; Hartmann et al., 1985].

In addition, we can determine that sound objects heard from P2 were closer to the loudspeaker than P1 ($p_{P1/P2}$ = 0.002). A combined representation of the azimuth angle and the distance depending on the onsets (long onset: at S1 and S2, short onset: at S3 and S4) is shown in Figure 18b, where the angular distribution of the median distance for P1 is shown. Except in the area behind the IKO, S3 and S4 are perceived as closer to the IKO. These results show that the IKO is capable of displaying individual sound objects in the room using beamforming. Depending on the IKO's placement and the respective listening position, different zones around the loudspeaker can be defined. Thus, an important condition for the provable intersubjectivity of sculptural sound phenomena in the SPS would be fulfilled. The perceived distance and, accompanying it, the spatial extent of the sound object is signal-dependent. Furthermore, it could be shown that transient sounds, e.g. signals with short onset times, tend to be perceived as closer to the IKO than those with longer onset times.

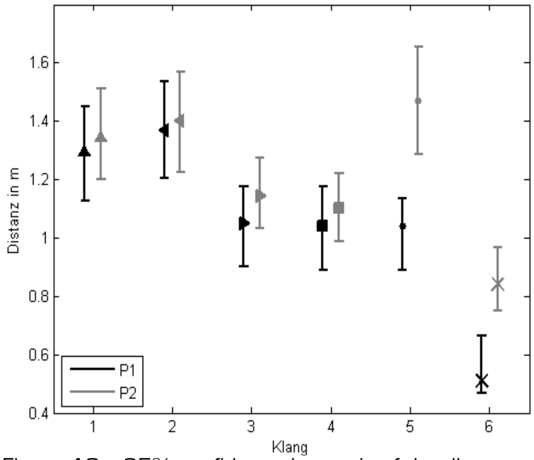

Figure 18a: 95% confidence intervals of the distance for all directions.

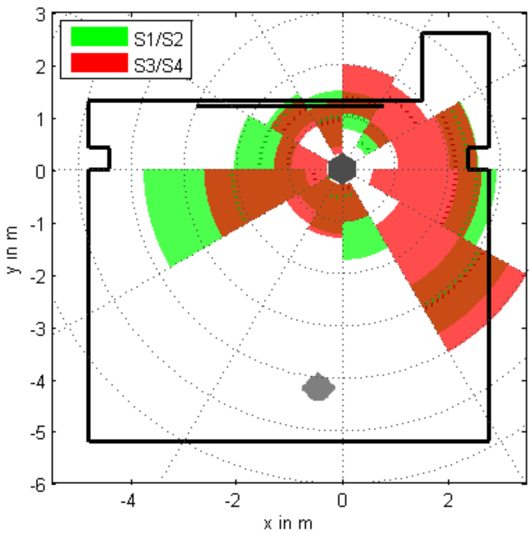

Figure 18b: Azimuth angle and distance

This can be explained with the precedence effect: The more transient the sound, the more pronounced is the effect. Therefore the location is dominated by the position from which the sound comes first. And this is always the IKO itself. If the sounds become more stationary, the temporal sequence becomes increasingly unimportant and the energetic directional distribution dominates. And exactly this is controlled by beamforming.

2.5. Listening Experiment 2: Perception of Sound Trajectories

The second listening experiment investigated the perception of trajectories of sound beams. The creation of spatial sound projections varying in time represents another possibility for the sculptural treatment of sound textures. A narrow beam moving along the IKO's equator, as in the miniatures 1-10, would be a simple example. Five different implementations of these trajectories were investigated: two semi-circular movements, clockwise (cw) and counterclockwise (ccw), one full circle movement and one left-right fade (related to P1) and a distance fade created by the seamless change of Ambisonics orders from 3rd to 0th and back. Each trajectory had a length of 5 seconds. The beam trajectories for the rotations and the left-right fade began at 90°; the distance fade was set to 180° for all four stimuli with a beam. The subjects sat facing a screen and were asked to place 10 markers at half-second intervals during playback. The markers glowed one after the other in sequential order matching the playback and, with the use of a mouse, could be placed on a graphical surface that depicted the laboratory space from a bird's eye point of view. The test persons were allowed to repeat the process until their placement of the markers coincided with the positions they perceived in the room. Because of the dependency ratio of onset-length and perceived distance to the IKO determined in listening experiment 1, two variants of stimuli with pink noise were first tested. Stimulus 1 consisted of a uniform pink noise running the entire length of the movement to produce a continuous space trajectory. Stimulus 2 consisted of 200 ms long bursts of pink noise, each with a 10 ms long fade-in and fade-out and each with 100ms of silence between them. In addition, a series of irregular bursts (Stimulus 3) and a chain of fine, steady grains (Stimulus 4) known from listening experiment 1 were tested again. The listening experiment was carried out again with 15 test subjects. Thus, the basic sounds of the miniatures (I. - III. and 1-20) were also used in listening experiment 2. The fundamental motion patterns were partly derived from the miniatures.

2.5.1. Semicircle and Full Circle

For the representation of the collected data, a two-dimensional representation was selected for every step which shows the respective median value in the 95% confidence interval (see Figure 19a). The circular trajectory is mapped as an almost perfect circle around the IKO generated by the averaged values of all collected data. In addition, the 95% confidence areas are distributed almost evenly around the loudspeaker. This, however, is in contrast to the results from listening experiment 1, in which the localization could not completely encircle the IKO. Not only does the full rotation give uniform results, but also the half-circles (clockwise and counterclockwise) shown in Figures 19b and 19c represent the impression of spatial motion. In contrast to the almost complete movement of the full rotation, however, one can observe that the perceived trajectory of the semicircular motion is farther than the actually traversed semicircle. This displacement of the trajectory in one's perception could be associated with the rate of the beam's movement slowing down to half as fast as the full circle in five seconds, or with the psychoacoustic phenomenon of the "Auditory Representational Momentum" (Getzmann/Lewald, 2007) which describes the offset perception of the end positions of moving sound sources in the direction of their movement. Furthermore, for all trajectory perceptions, the *Image Schemas* discussed by Lakoff and Johnson which cover most of our basic spatial patterns [Johnson, 1987; Lakoff, 1987; Lakoff/Johnson, 1999] can be used as an explanation. Both the semicircular and the full-circle movement have the effect that the sound object, due to the different reflective properties of the walls, for example only fragmented, is projected unevenly but still

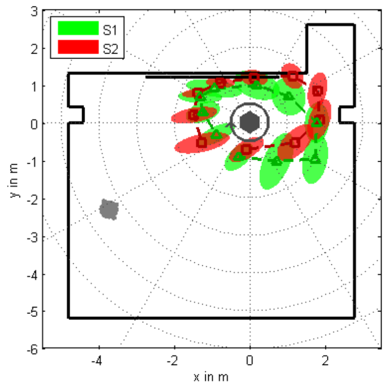

Figure 19a: Full Circle CW from P2

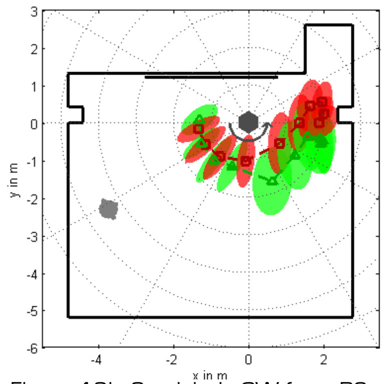

Figure 19b: Semicircle CW from P2

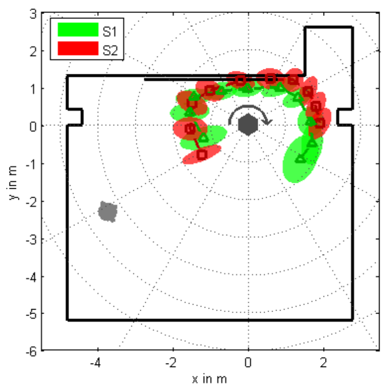

Figure 19c: Semicircle CCW from P2

perceived as contiguous.[97] We take *Image Schemas* to mean recurring structures in our cognitive process that establish patterns of recognition and understanding. The term is explained both by Johnson [1987] and by Lakoff [1987] and by Rudolf Arnheim in *Visual Thinking* [1974]. In addition, Kendall describes the connection to Auditory Spatial Schemata according to Johnson [1987] as follows:

> *[...] spatial schemata have a particularly important role in spatial hearing because the schemata give coherence to spatial information that may otherwise be faint or incomplete. Spatial schemata are particularly important for audio reproduction when no other sensory information may collaborate the auditory spatial content. Our spatial schema for PATH gives coherence to motion effects that can otherwise be quite fragile. As the listener endeavors to make sense of spatial relationships, a spatial organization emerges.*

Fragmented spatial information becomes continuous chains in order to be classified into umbrella categories of spatial representations. This also corresponds to Simon Emmerson's reflections on: *The illusion of the impossible flight*. This is about the phenomenon of perceived trajectory as a sound movement through space, which according to Emmerson has three attributes: *perspectival*, *direction* und *partition* [Emmerson 1999, 137].

These research results can also be supported by practical experience with the use of reflectors and use of the IKO in both concert and the laboratory. The closed semicircular arrangement of reflectors behind the IKO, as used for example in Mumuth[98], became much more sparse in further practice. Therefore reflector elements were placed farther and farther apart in concert, as could be demonstrated in the InSonic2015 concert at ZKM, without dissolving the sculptural textures. The length to which the reflectors can be set apart has, of course, a limit which must be figured out at each concert location.

[97] See here also Index of Miniatures, for example 1-20.
[98] See Chapter III. 2.2.1.

2.5.2. Panning and Fade

For the evaluation of the fade movements, the pink noise impulses were taken as an example. Each trajectory lasted for 5 seconds. Here, too, 15 people were asked to mark the positions of the generated sound object in intervals of five seconds by freely positioning 10 points on the screen interface using mouse pointers. Again, the listeners could repeat the playback until they were satisfied with the consistency between their placements of points and their perception. Figures 20a and 20b show the averaged results for each interval for two trajectories from both listening positions:

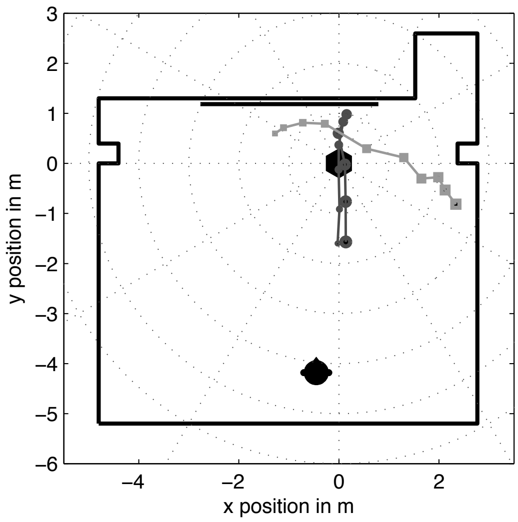

Figure 20 a: Distance and amplitude panning P1

(light gray) left-right amplitude panning between a beam pointing to the left (90°) and a beam pointing to the right (235°),

(dark gray) distance panning with a beam movement in the direction of the back wall, starting from a beam in the direction P 1 (180°). Distance panning is produced by gradually changing the Ambisonics orders of the beam from 3rd to 0th and back again [see Laitinen et al., 2015].

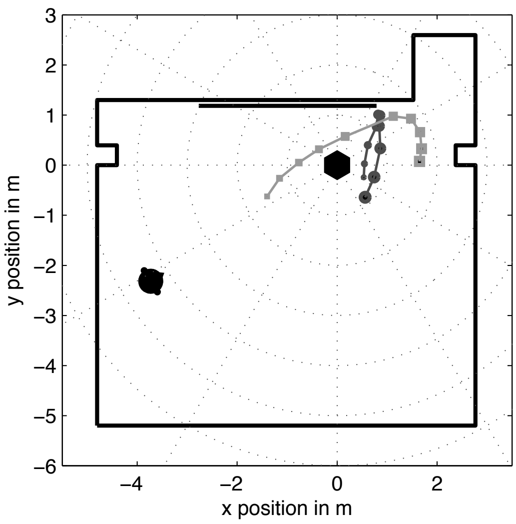

Figure 20 b: Distance and amplitude panning P2

The movement from left to right is perceptible from both listening positions. Distance panning works better from listening position 1, but it can also be localized from listening position 2. This experiment also shows that the IKO not only produces sound objects with a perceptible direction, but also with respect to its location. However, there are qualitative differences in the perception of fade movements that pass through the IKO. For compositional practice, this enables an accurate movement along the axes by amplitude panning, which is then perceived from several listening positions as such or even as pendulum motion. This also allows the sounds to be sucked up by the loudspeaker by increasing or reducing the Ambisonics orders, and integrating an omnidirectional room excitation by altering the directional effect, which then again emerges as bundled from the IKO and marks a directional focus point with maximum directivity.[99]

2.6. Conclusion

It was determined in listening experiment 1 that there is an intersubjective perception of different projections. For listening position 1, the projection directions 0° and 90° coincide in the target direction, and for listening position 2 the directions 180° and 235°. Furthermore, listening experiment 1 has shown that the IKO, when using beamforming, is capable of producing individual sound objects statically. The definition of different spatial zones around the IKO is dependent on its placement and where the listener is positioned. Comparing all collected data from listening experiments 1 and 2, one realizes that the perception of trajectories cannot be explained entirely by the extrapolation of static beams, as is the case in listening experiment 1. Listening experiment 2 shows that hard onsets are not necessarily heard as closer to the IKO and softer ones as farther away. Listening experiment 2 suggests that the listener tries to interpret the movement while it's still in its course. This process of grouping sensory data into mental representations is known as "auditory streaming" and has been researched by Bregman [1990], among others, as part of "Auditory Stream Analysis".

The results can also be read as "space constituting" against the backdrop of space theories. Because distinct zones can be generated under different signal-dependent conditions, various and distinguishable objects can be "established" in a space and thus define the space in the perception. Since trajectories can have clearly traceable directions for certain signals and certain room-acoustic conditions, a place can be made temporal and a space can be given a direction that makes it experienceable only as such.

[99] See also mirage 6: Section 1 and Section 4

3. Etudes

Through the composition of 35 etudes, the concept of sculptural body-space relationships derived from the previous research was investigated. Here, the individual passages were already implemented in a spatial composition, meaning the textural material was composed, conceived, and arranged in relation to all spatial aspects. Both *spatialization of the first order* and *spatialization of the second order* were used to create sculptural sound phenomena. In this way, each etude was created using one of the three categories of sculptural body-space relations - kernel plastic, spatial plastic, and the kernel-shell principle. One can tell from the Index of Etudes that Etudes 1 - 23 were so, or in a similar form, integrated into the later compositions mirage 1 - 4.

3.1. Index of Etudes

(The times in brackets refer to the later use in the respective space-sound composition)

Kernel Plastic	Spatial Plastic	Kernel-Shell Principle	Space-sound Composition
KP1 (06:30 - 06:56)	SP1 3:35 - 3:45 SP2 1:23 - 1:45*	KSP1 (01:22 - 01:45) KSP2 (02:13 - 02:49) KSP3 (05:45 - 06:08)	mirage 01
KP2 (00:00 - 00:39) KP3 (01:42 - 01:56)	SP3 (08:11 - 08:31) SP4 (00:00 - 00:21)**	KSP4 (01:56 - 02:18) KSP5 (04:24 - 04:45)	mirage 02
KP4 (00:39 - 00:48)	SP5 (06:57 - 07:45)	KSP6 (03:21 - 03:49)	mirage 03
KP5 (06:17 - 06:45)*° KP6 (00:00 - 00:25)	SP6 (02:00 - 02:24)°° SP7 (02:47 - 03:05) SP8 (05:13 - 05:33) SP9 (00:44 - 01:03)	KSP7 (01:56 - 02:11) KSP8 (02:56 - 03:19)	mirage 04

Table 1: * without grains RP2; with grains KSP1; ** without drone; °° without clicks; * ° without beats

Preliminary Test 3[100]: Triplets for Mono Experiment

Triplet	A	B	C
1	KP1 mir01 (26)	KSP5 mir02 (21)	KP2 mir02 (39)
2	KP3 mir02 (14)	KSP6 mir03 (28)	KP5 mir04 (28)
3	SP2 mir01 (29)	KP5 mir04 (28)	KP6 mir04 (25)
4	KSP5 mir02 (21)	SP4 mir02 (21)	KSP8 mir04 (23)
5	KSP3 mir01 (23)	KSP4 mir02 (22)	SP8 mir04 (20)
6	KSP3 mir01 (23)	KP3 mir02 (14)	KSP6 mir03 (28)
7	SP2 mir01 (29)	SP3 mir02 (20)	KP5 mir04 (28)
8	KP1 mir01 (26)	SP5 mir03 (48)	SP9 mir04 (22)
9	KSP3 mir01 (23)	SP3 mir02 (20)	SP8 mir04 (20)

Table 2: KP = kernel plastic; SP = spatial plastic; KSP = kernel-shell principle; mir = mirage; ( ) = Length in seconds

The etudes were listed as Mono-triplets in the listening examples (Table 2), as long as they were used in preliminary experiment 3. All the etudes have been incorporated into the compositions mirage 1- 4 (Table 1) and are marked accordingly in the table with their placement in the piece (in Min.: Sec.)[101]. In addition, each etude with its composed sculptural body-space relation can be found in the commentaries of the respective interpretations of the finished compositions.[102]

3.2. Preliminary Test 3 - Intersubjective Distinctness of Spatialized Sound Objects

In preliminary test 3, the distinction and distinctness of different spatial sound objects, which in this context were understood as sculptural sound arrangements (*space-sound phenomena level 3*[103]), were investigated. The preconceived concept of organizing space-sound phenomena hierarchically from level 1 to level 3 and the approach of establishing different perceptible sculptural distinction categories formed the basis for the stimuli composite for this experiment. Three different groups were created that each fall under

[100] Stimuli on the enclosed SD card, or List of Download Links, p. 175
[101] They are therefore not listed again in the accompanying listening examples.
[102] See Chapter V. 2.
[103] Cf. above Chapter IV. 2.2.

a sculptural category: 1. KP (kernel plastic), 2. SP (spatial plastic), 3. KSP (kernel-shell principle). The stimuli used for this experiment were prepared from the above-mentioned etudes. These had different lengths and used pre-composed sound material. The stimuli were organized in triplets[104] according to the three-alternative-forced-choice (oddity) method [Kingdom/Prins, 2010], each with two stimuli of the same sculptural body-space category and one stimulus of another. In the subsequent selection process by the test persons, it was necessary to always indicate the respective stimulus that differed from the others by its spatial appearance.

In the preliminary test, the 9 triplets were presented to the 6 test persons in a mono-version with headphones. The results of the evaluations are listed in Tables 3 and 4:

Triplet	Stimuli		
1	KP	KSP	KP
2	KP	KSP	KP
3	SP	KP	KP
4	KSP	SP	KSP
5	KSP	KSP	SP
6	KSP	KP	KSP
7	SP	SP	KP
8	KP	SP	SP
9	KSP	SP	SP

Table 3: Preliminary test 3 - Stimuli with their respective body-space relations in the respective mono-triplet

Results of Preliminary Test 3 in Mono

Triplet	Ratings		
1	0	5	0
2	1	4	0
3	5	0	0
4	0	5	0
5	2	0	3
6	0	5	0
7	0	0	5
8	4	0	1
9	3	2	0

Table 4: Preliminary test 3 – Mono-ratings of the subjects

The results overlapped almost completely with the sculptural body-space relations previously composed for the spatial stimuli and their organization in

[104] See SD Card Stimuli Listening Experiment 3 or List of Download Links p. 175.

each respective triplet. This evaluation came as a surprise since one would have expected a serious discrepancy between the mono-evaluation and the underlying sculptural categories, since the *spatialization of the second order* could not be effective due to the lack of the IKO's use and the mono-headphone output. The results show that similarity classes were immediately formed due to the composed material. Therefore *spatialization of the second order* as spatial articulation or disposition of spatial sound textures can hardly be explored with these composed stimuli, since there is a close connection between *spatialization of the first and second order* and this influences the evaluation here too strongly. This almost identical result in the monographs led to a new composition of other three-dimensional stimuli, the sound textures of which were less strictly composed according to criteria of *spatialization of the first order*, but were aimed at sculptural body-space relationships in the sense of a *spatialization of the second order*.

3.3. Listening Experiment 3: Intersubjective Distinctness of Spatial Sound Objects

The new sound material used for listening experiment 3 and its 12 stimuli[105] was composed of four different sound families. This was based on the idea of using simpler idioms that sounded closer to the stimuli used in the first two listening experiments than in preliminary test 3, but also pointed to musical structures in order to transform the laboratory setting into more of a concert one.

The compositional assignments I made of the stimuli to the body-space relationships were as follows:

Kernel plastic (KP) = A I - IV

Spatial plastic (SP) = B I - V

Kernel-shell principle (KSP) = C I - III

The stimulus composite is shown in Table 5. Each stimulus had a length of exactly 30 seconds.

[105] See SD Card Stimuli Listening Experiment 3 or List of Download Links p. 175.

Stimulus	Element1		Element 2	
	Sound1	Trajectory	Sound2	Trajectory
AI	CBN	180° static		
AII	LFD	180° static		
AIII	FMet	0° static		
AIV	LFDcut	210° static	FMet	210° static
BI	CBN	Rotation CCW 237°/s		
BII	LFDcut	Rotation CCW 140°/s		
BIII	FMet	Rotation CW 180°/s		
BIV	CfG	Rotation CCW 270°/s		
BV	LFD	Rotation CCW 120°/s		
CI	CBN	Rotation CCW 180°/s	CBN*	Rotation CW 180°/s
CII	CBN	305° static	CBN**	Rotation CW 180°/s
CIII	LFDcut	Rotation CCW 180°	FMet	Rotation CW 180°/s

Table 5: (CBN = constant brown noise; LFD = low-to-mid-frequency drone: LFDcut = low-to-mid-frequency drone (high-pass filter 236Hz); FMet = frequency-modulated, time-stretched metallic sound with long on- and offset times, CFG = Chain of fine uniform grains; CCW = counterclockwise; CW = clockwise; * High-cut at 2.4 KHz; ** starts after 15 seconds.

In order to check the possibility of the basic distinctness of the sculptural categories, the listeners were once again made known of neither the hierarchical organization of the percepts (*levels* 1 - 3)[106] nor the composer's own classifications in the three sculptural body-space relations. This should have avoided the possibility of interpreting language-specific terminology during the auditory experience.

The distinctness of sculptural forms was again determined by a three-alternative-forced-choice (oddity) method [Kingdom/Prins, 2010]. Each stimulus triplet was composed of two stimuli of the same category and one stimulus of another. Only in Control Triplet 3 were all stimuli from the same category. All triplets were presented in a joint listening session. The listeners were asked again to name the stimulus, which differs from the others in its spatial appearance. Table 6 shows all the triplets tested. The stimulus deviating in every triplet is marked.

[106] See Chapter IV.2.2.

Triplet >	1	2	3*	4	5	6
Stimulus 1	AI	AIII	BII	BIV	***CII***	CIII
Stimulus 2	***BI***	AIV	BV	BI	BIII	CI
Stimulus 3	AII	***CI***	BIII	***AII***	BV	***AII***

Table 6: All triplets from 1-6 with the stimulus deviating from the group. * Triplet 3 = control triplet

The listening experiment was carried out twice with 6 listeners each. In order to observe the possible influences of the listening position, the listeners were distributed in the room (Pa - Pb, see figure 15) and changed their position after the first round. Previously, 5 of the 6 listeners judged the same triplets again in a mono-version with headphones. The results are shown in Table 7. It can be clearly seen that the evaluations differ from the different stimulus of the group in contrast to preliminary experiment 3. This means that the sound material itself was no longer suitable to enable a stable distinction between the three categories.

Triplet >	1	2	3	4	5	6
Stimulus A	0	0	0	4	***1***	1
Stimulus B	***0***	0	0	1	4	4
Stimulus C	5	***5***	5	***0***	0	***0***

Table 7: Results of the mono-triplets from listening Experiment 3

The responses to the spatial stimuli of listening experiment 3 are presented in Table 8. The listeners were in agreement on almost all triplets reproduced with the IKO.

Triplet >	1	2	3*	4	5	6
Stimulus A	0	1	0	0	***10***	0
Stimulus B	***12***	0	5	0	2	0
Stimulus C	0	***11***	7	***12***	0	***12***

Table 8: Results of the IKO spatialized stimuli-triplet. * Triplet 3 = Control Triplet

This means the listeners were able to determine which triplet differed from the basic sculptural form according to the composer. Control triplet 3 purposefully contained no clear difference and the listeners‘ evaluations were split between two triplets. The listeners’ evaluations on the mono-triplets were divided similarly across all triplets (≥ 90%), yet with noticeably less agreement in terms of sculptural form. This serves to prove the effectiveness of *spatialization of the second order*. Only Triplet 2 showed agreement regardless of its playback method.

The results show that intersubjective perception of complex space-sound phenomena exists. Although none of the listeners were aware of the composers' classification of the space-sound phenomena (KP = A, SP = B, KSP = C), nearly all of them rated the phenomena accordingly.

3.4. Summary and Classification

It was possible to examine and verify the distinctness of the spatial sound phenomena through the listening experiments. Listening experiment 1 examined individual static percepts (*space-sound phenomena of level 1*) generated by the projection of the IKO. Depending on the position of the IKO, various space-sound zones could be perceived and distinguished. The results revealed where knowledge from psychoacoustic research is applicable to auditory objects. For instance, distance to the IKO is highly dependent on onsets and envelopes. This relationship is known from studies on the precedence effect [Litovsky et al., 1999; Brown et al., 2015]. Listening experiment 2 investigated more complex phenomena from time-variant spatial sound projections (*space-sound phenomena of level 2*). In contrast to static sound beams, the use of trajectories involves perceptual properties indicated in studies on auditory motion (Getzmann/Lewald 2007). The perception of trajectories can be approximated by a more comprehensive mental representation, which we know from Auditory Scene Analysis [Bregman, 1994]. Preliminary test 3 and listening experiment 3 investigated the superposition of various phenomena with static and time-variant properties (*space-sound phenomena of level 3*). It has been shown that space-sound phenomena composed using the aspects of the three basic categories from the scholastic writings on sculpture can be intersubjectively identified.

In addition, the body-space relations verified in this way coincide with other space-related descriptions in the relevant literature, which we can now refer to. Nystrøm defines [2013, 22] *spatiality as qualitative impressions, which summarize the spatial experience* [...] and also distinguish a three-part experience of composed space:

> *I have identified three basic schemas which are to be regarded as perceptual concepts [...].* [Nystrøm, 2013, 22]

> *The first two – interior and exterior – belong together. Interior spatiality refers broadly to the 'inside' of texture, and the sense of containment invoked when textural spaces surround us as listeners, or where our attention is drawn into a textured space, although physically we do not inhabit it.* [Nystrøm, 2013, 23]

Here, there are strong parallels to spatial plastic as a space-encompassing or binding sculptural body-space relation.

> *Exterior spatiality implies a sense that only the surface of a texture is available for us to perceive: it has no depth or volume, and it is too dense or homogenous for us to be able to penetrate it and find a rich interior.* [ibid.]

This description comes close to kernel plastic with its space-superseding, space-repelling attributes.

The third schema – relational spatiality – incorporates the other two in that it concerns spatial situations that are primarily dependent upon relationships among textures rather than the textures themselves. Thus relational spatiality emphasises the voids among sounds, where some textures acquire a spatial role only because of what they are contrasted with. [ibid.]

This is a nearly identical description of the kernel shell proportions from the scholastic writings on sculpture, which creates space in the tangible state of tension of the two poles.

Without having performed or mentioning listening experiments in his own work and in no relation to sculptural categories, Nystrøm confirms these attributes by establishing a three part system of compositional (!) space definition by providing similar descriptions of their modes of action.

The three sculptural basic forms have the advantage that they systematically integrate the compositional treatment of space by means of sculptural sound phenomena from spatial textures and have developed over centuries in the history of artistic space practice.

The exploratory movement of the artistic research has again reached a comparative field through the research of space theories as well as appropriate attributes of spatial descriptions of sculptural sound phenomena and their investigations in the framework of listening experiments, in order to find their results confirmed in almost identical descriptions.

4. Introduction of Other Terms in Space-Sound Composition with Sculptural Sound Phenomena

For more detailed descriptions of the sculptural sound phenomena in SPS, further terms can be introduced on the basis of the results from the listening experiments, in addition to the body-space relations. All terms used in the following are derived from the scholastic writings on sculpture [Rawson, 1997; Klant/Walch, 2003; Krämer, 2011; Wood et al., 2007].

4.1. Intended Perspectives and Aspect

Two-dimensional artistic works, such as paintings or videos, frequently provide viewers with a particular vantage point from which they shall view the artwork. This two-dimensional compositional arrangement is approximately comparable to the musical production for stereo with respect to the so-called "sweet spot", the ideal listening position in the equilateral triangle of loudspeakers and listeners. The ideal listening position or the "sweet field", when several listeners are present, still plays a decisive role in the perception of three-dimensional sound objects in the common multi-channel sound projection methods. The technically induced paradigm of the sweet spots is the place where the composer had just sat in the studio during the multi-channel composition and production of the work. The ability to adjust exactly this situation in the electroacoustic concert business has always been controversial. And after more than 60 years of collective concert experiences in this field it is questionable how practicable compositions are, which demand an absolute listening point for a small group of people, but need great volume of space with a high number of powerful loudspeakers [Landy, 2007, 220; detailed for all common projection methods: Bates, 2009, 60 ff].

Therefore, for organizational reasons, it is accepted in almost all concerts with these systems that only a part of the audience actually hears what was developed in the spatial composition process. Thus, independently of the manufacturability and refinement of three-dimensional compositional material, performance practice often confronts SPS. Here the question must be asked whether one cannot and should not proceed in principle with another strategy. This thesis deals with the composing of sculptural sound phenomena and their perceptibility in SPS. With regard to the linguistic differentiation of the occurring phenomena in this context, it has proved useful to transfer the notion of the *intended perspectives*, here better the *aspect* (the terms are used synonymously) from the scholastic writings on sculpture, to better describe the compositional scope for these phenomena in SPS. A sculpture can have one or more valid *aspects* from which it is accessible. Therefore by walking around, or changing the sculpture's position or setup, different aspects of the same three-dimensional object present themselves [Klant/Walch, 2003, 14].

In his essay "Where, There or Here", Michael Brewster describes the many-sidedness of sculptures with regard to hearing and the multi-perspective listening situation:

> *Hearing is well suited to the tasks of sculpture. It occurs in the round, sensing all directions and dimensions simultaneously, unlike Seeing which is frontal and singular in its attention. It is difficult to see a sculpture fully, its always a bunch of sequenced frontalizations. If sculpture is to achieve its potential it ought to occur in the round, all around you, simultaneously.* [Brewster, 1999]

Composition of sculptural sound phenomena in the sense investigated here deals with the conceptual involvement of different auditory perspectives or different "viewing" angles - "Vantage Points" [Smalley, 2007] - the variability inherent in composition as different aspects of a spatial sound composition.

Listening example 3: Listening perspectives - Miniature 12 or 23 respectively from P1 and P2

Listening example 4: Listening perspectives - mirage 4/T1: 0:00 - 1:40 from P1 and P2

This means that in the context of a composition with plastic sound phenomena, several aspects of different listening positions and distances can be possible, as long as these have been examined in the working process and different listening perspectives have been considered. This is also regularly demanded for classical sculpture, where it is customary in the production of sculptural aspects: *in environments that visitors can traverse, pieces may be required to be effective from near and far* [Rawson, 1997, 59]. This places new demands on the compositional process and also requires other aids. The ViKO, with the possibility of listening to the sculptural sound phenomena from different listening positions in an A/B-comparison, therefore approaches the work on different aspects of sculptural sound phenomena.

4.1.1. Relief

The relief usually has a *single vantage point*. The term *relief* describes a sculptural work in which the material in its plastic form stands out from a background. It is a sublime form, prominent or jutting out from a surface. All plastic moldings refer to a base area [Krämer, 2011, 13]. By means of so-called *undercuts*, the so-called *high relief* can be placed in the vicinity of the full-plastic figures and, like this, again make several vantage points useful.

Since it has been shown in the artistic research practice of recent years that the IKO should be placed in front of at least one reflecting surface depending on the spatial situation, the opportunity presents itself to transfer the concept of the relief to SPS in the form of an *undercut*. The concept of the relief can thus describe space-sound situations, which span a wide screen[107] (e.g. left-right beam with amplitude fade), which is perceived from the frontal perspective as a change of emphasis between left and right, but more than emergence and disappearance[108] when sitting on only one side (far left or far right). In addition, transient chains of bursts or clicks which are strongly perceived on the surface or near the surface of the IKO can be described as *relief-forming* because, especially when they are rotating or oscillating with the detected trajectories (up/down, left/right) or by fades, produce a raised non-uniform surface structure, which acts sometimes more, sometimes less, in the depth of the produced space.[109]

Especially pieces, which are composed for traditionally furnished, front-facing concert performance are usually arranged in a relief-like manner. However, it is also possible that a sound sculpture cannot be circulated due to the local conditions, so that during the setup it is possible to attempt to transform certain formations, at least with an *undercut*, into a relief-like listening situation. This of course, only if the piece, with its underlying spatialization strategy, allows this. Suitable here is a work that has already been created strongly with *spatialization of the first order* and has fewer aspects in the perspectival field or has a *uniform contour* because the sculptural form is then less affected by a restriction in depth gradation. However, even pieces with uniform beam rotations, taking into account the material used, can be converted into reliefs so that the full circle is converted into a semicircular trajectory.

[107] Cf. the term screen in acousmatic music, Bayle [2007, 243]
[108] Cf. Listening Experiment 2, Panning and Fade, Chapter IV.2.5.2.
[109] Cf. Index of Miniatures: Miniatures 5, 9, 10, 11, 18, 30

The concept of the *undercut relief* can be helpful in that a background structure with a plastic foreground design in SPS can be described in a tangible way. When composing sound sculptures, it is possible that foregrounds and backgrounds change. In the space-sound composition, these changes depend on the current attention of the audience and the variation of the above-described five factors of *spatialization of the second order*[110]. An introduced element alone can attract all attention and unfold its spatial mode of action, and then, by the layering of a more prominent, not necessarily new, but more attention-intensive sound, it can be pushed back into the background without terminating or decaying. Therefore, there may be a change of attention between the two spatialized textures, depending on the arrangement in time, change in volume, and spectromorphology.

Listening example 5: Change of emphasis - mirage 6/T4: at 9:40 - 12:10

Listening example 6: Change of attention - mirage 5/T2: 1:55 - 3:35

The term relief thus also binds the foreground and background in the handling of sculptural sound phenomena in SPS. This is followed by another term:

4.1.2. Plasticity

Plasticity is technically referred to as the difference between the highest and the lowest relief points [Hann, 2015, 49, 29]. The sculptural character and physicality of the sculpture depend on it [Klant/Walch, 2003, 16]. With stronger plasticity, this difference is large, at a low level when weak. Depth-gradation in the sense of plasticity, created by layering and overlapping, has always been considered a characteristic of sculptural design:

> *Carefully devised sets of overlaps are basic element in all sculptures [...] To invent sets of defined overlaps of many kinds among both notional bodies and the edges of their parts introduces a sense of notional depth, even deep space. A sculptor can produce a powerful sense of spatial depth, even within a minimal actual depth, by devising an arranging series of overlaps within a tenor, as part of the topic development, [...].* [Rawson, 1997, 78]

We read from the results of the listening experiments that under the conditions described there, depth-gradation of spatial textures is possible by movement, direction, and distance from the IKO depending on material and

[110] Cf. Factors of Spatialization *of the Second Order*, Chapter IV. 1.4.

onset offset behavior. The term plasticity is thus applicable both to the one-sided form of the relief in the form of a broad left-right screen, which occurs at greater distances from the IKO or at the threshold between the IKO's *near-field* and the IKO’s diffuse-field, as well as to fully plastic sound arrangements with different depth-gradation and propagation, thus multiple *aspects*. In this case, high plasticity can be talked about in spatially, clearly separated sound gradations and less in homogeneous or weakly varying texture propagation. In addition, a degree of change (stronger/weaker plasticity) can be described over time.

Listening example 7: Much plasticity - mirage 3/T1: 3:23 - 3:49

Listening example 8: Little plasticity - mirage 3/T1: 0:00 - 0:04

Listening example 9: Change in plasticity - mirage 2/T3: 3:56 - 5:41

4.1.3. Contour

With sculptures, the so-called *contour*, the outline (see Figure 21), similar to a silhouette, also changes with the location of the observer. The contour is a *special form of the sculptural aspect.*

Figure 21: Three different perspectives show three aspects and the different contours of the same sculptural form.

When the viewer changes his position, a space-consuming figure can suddenly appear to be closed off, or the impression of rest can replace one of movement [Krämer, 2011, 14]. In sculptural space-sound composition, we are concerned with phenomena which, when using texturally stable material constellations, alter their spatial form depending on the spatial properties and the viewer's position. They then have several *aspects*. The listening experiments have shown that certain spatial directions and distances from different positions are perceived differently. In addition, the spatial propagation is material-dependent and certain neighboring beam angles coincide in the perception.[111] A *contour* can then be described in SPS if the basic sound propagation and formation with its coordinates remain in the room, but changes in perspective or sound color with the location of the listener. In this respect, the concept of contours can be a further addition to the vocabulary in SPS in the composition of plastic sound phenomena. Contours exhibit, for example, a beam positioned in one direction with a nearly static broadband sound texture defining a particular direction, propagation, and thus zone of the space. Depending on where the listener is in the room, a spatial zone with different colorations will result from the reflections of the walls or the shading of the IKO. Contours in this sense are, therefore, position-dependent extensions of the same spatial texture (= several aspects), while I designate a continuous spatial position (1 *aspect*) *uniform* from all positions. This would be, for example, a spatial sculpture in the form of a spatial mark[112], which is composed of a high, sinusoidal sound mainly from *spatialization of the first order* and is equally perceived from every position in space. The same would be assumed for an encompassing spatial sculpture without distinct coordinates.

Listening example 10: *uniform contour* - mirage 5/T6: 9:14-9:38 Pos.1 vs. Pos. 2

Listening example 11: *strongly contoured* - mirage 5/T2: 1:55-3:36 Pos.1 vs. Pos.2

EXCURSUS: Echolocation

The work with the IKO has shown how the site-specific characteristics of the location are in part clearly influencing the composition, and in the particular auditory situation of the acousmatic concert automatically integrated by the audience as a part of the whole. In addition, it was found that processes, such as the movement of distinct sound textures, produce space through temporalization and direction in perception. A compositional means, which

[111] See Chapter IV. 2.4., Listening Experiment 1
[112] See above the body-space relationships, Chapter II.5.1.

over the course of time has proven itself to be space constituting in sculptural composition, is *echolocation of the first and second* order. Since this is not terminologically derived from the scholastic writings on sculpture, it is treated here as an excurse. Blesser and Salter [Blesser/Salter, 2006] describe the so-called *navigational spatiality* as the aural experience of the space, which allows the individual to *visualize* a space, and even to navigate through objects and geometrical structures of the space. Sending acoustic signals for this purpose is called echolocation (Blesser/Salter, 2006, 16). Emmerson describes *echolocation* as something that people do quite naturally and at any time:

> *[...] humans practise it all the time. One of the best examples of the auditory system working beyond our conscious control is simply the decoding of the 'feeling' of the room we are in.* [Emmerson, 1989, 137]

Human echolocation is also described as a technique that is specifically used by blind people to make an approximate "picture" of their environment. Passive echolocation uses the sources present in the environment and their echoes to produce a vague idea of the environment. The echoes are perceived by the user as an acoustic signal and must be processed intellectually. The active echolocation of the click sonar, on the other hand, is a technique in which sound emitted by means of a subtle tongue click are evaluated by the echoes that elapse, comparable to the echolocation used by bats and dolphins. After regular training, it produces an image of the environment comparable to vision in the visual cortex of the brain. The brain separates the echoes, as visually useful information, from the other acoustic information and processes them in the respective brain realms. Echolocation is also a highly functional means of dealing with the overcrowding of incoming or existing information:

> *The problem with the voices of things, below the level of expression and communication, is that too much is presented. In bespeaking the possibilities of nature, of shapes, surfaces, interiors, surrounding spaces, there is too much "truth" as Merleau-Ponty observed. We have to interrogate with specific questions, specific actions, if we are to learn the possible lessons of the world. We do this, of course, without necessarily being fully aware of it. For example, we actually rather constantly "echolocate" as we now call auditory spatial orientation.* [Ihde, 2007, 194]

Already in 1968, sound artist and composer Alvin Lucier wrote, under the influence of the basic works on the navigation of bats by Donald R. Griffin, a performance piece titled *Vespers - for an arbitrary number of persons who* *would like to show their respect to all living creatures that populate the dark and have developed a great accuracy in echolocation over all the years [...]*. With the help of sondols, small technical devices that emit clicks, or other signaling devices, the participants are able to orient themselves exclusively acoustically in space in an artistically controlled situation [Lucier, 2005, 74].

Echolocation of the first order

Already used in the first seconds of *grrawe* (2010) was a rhythmic sequence of clicks, which changed its radiation direction four times at the IKO's equator.

Listening example 12: *grrawe* 0:00 - 0:53

This results in a spatial texture, which should initially draw attention close to the IKO's surface. In addition, a front and a rear are defined by both the different directions and through the IKO's shading, as well as a lateral extension. A simple introduction to pin the hearing to a coordinate and to show it around and thus to prepare for future events. The sequence then ends in a spiral of a frequency-modulated, bright, metallic sound, thus opening the space in all directions and spectrally in the vertical. However, the spatial click texture is interrupted beforehand by small pauses. And that is the moment at which the ambient space responds, stimulated by the impulsive transient signal, in the form of reverberation. This response depends on the acoustics of each performance location. In this way, the architecturally induced spatial boundaries can become part of the compositional spatial structure. Of course, the clicks are not given by the listener. In this respect, the process does not correspond to the actual idea of active echolocation. But by the listeners' attention directed to the IKO and its function at the acoustic place of the performance, a spatial relationship is established by this modified form of localization, which informs the listener at least subconsciously about his environment. I describe this application as *echolocation of the first order* of sculptural sound composition.

Listening example 13: *Echolocation of the first order* - mirage 1/T3: 3:23 - 4:16

Listening example 14: *Echolocation of the first order* - mirage 4/T4: 7:12 - 7:38

Echolocation of the second order

Echolocation of the second order uses impulsive transient sounds within a sculptural sound layer with other spatial textures. This is done, on the one hand, in order to shape or redefine[113] the directionality of the respective body-space relationship, and to get the listener to concentrate on the respective contour. Here, echolocation functions mainly through the degree of envelopment into simultaneously sounding sound textures. Depending on their assertiveness in the sculptural composition, the clicks are markings for an interior (superimposed and weaker in perception) or a passage (stronger in perception, less superimposed). This is mainly because of their ability to immediately and irresistibly capture attention. Therefore, the listener is unconsciously led around or orientated in the composed sound space. As in the case of active echolocation in supposedly empty spaces, an image of the acoustic conditions of the sound space that has just been produced and is being produced is perceptible. The composer has thus the possibility to mark the condition of the composed space over the time.

Listening example 15: *Echolocation of the second order* - mirage 2/T3: 4:21 - 5:24

Listening example 16: *Echolocation of the second order* - mirage 5/T1: 0:07 - 0:36

Listening example 17: *Echolocation of the second order* - mirage 5/T2: 3:44 - 3:55

EXCURSUS End

4.1.4. Directionality

If the texture is spatialized according to both orders, modification is possible by superimposing it with other textures and changing the beam directions or movements in propagation and distribution. However, in the relational field of various processes and texture layers, the orientation can be problematic in the sense of directing attention in the resulting SPS. The influence of source characteristics on the perception of three-dimensional sound phenomena is also important for the compositional process with regard to the production of spatial textures. These properties could not be further investigated in the listening experiments, but they were further investigated in other areas of

[113] Cf. the term directionality below, Chapter IV. 4.1.4.

science and are therefore to be considered more precisely here for application in compositional practice: Spatial listening depends on many factors, namely strongly from the onset characteristics of the respective sound. Sharply introduced transients produce an instantaneous energy burst over all audible frequencies and thus the highest stimulation for the perception of the listener [Kendall, 2010, 236]. The attention is focused directly on the event, unless it is integrated by similar, simultaneously sounding sounds into an overall event of such varying sounds and is lost through saturation.

In general, our hearing has difficulty with the localization of sine waves, but it can very well perceive those with transient onsets [Rakerd/Hartmann, 1986]. In addition, we can see that spatial reflections dramatically degrade the localization accuracy of continuous sounds without sharp onsets. In general, one can say that the more transient the source, the easier the spatial reflections are obscured (precedence effect). Broadband signals have a shorter echo threshold[114] than band-limited signals [Blauert/Col, 1992] and very narrowband signals weaken the localization dominance [Braasch et al., 2003]. Therefore, the first spatial impression caused by a sharp transient onset can have a fundamental influence on the listener's perception, where he places a sound in space. Regardless of the character of the continuous signal, the original decision about the location remains until an impulse, acting with equal force, attracts attention.

In the case of slow, continuous sound developments, the listener's perception may be fixed on or even lag behind what is called the instantaneous location [Hartman et al., 1989; Etlinger, 2009]. However, when a new transient attack is introduced in another continuous sound event, the attention, and thus the perception, can be reoriented. Sound events with continuous transients have the property of constantly re-informing the perception of space. These basal properties of spatial hearing with respect to the source characteristics can be used in composition. In complex weaves of frequency-modulated drones, which form a *spatial plastic*, a transient burst can be used to direct attention to the IKO and to a weaker signal (see also *echolocation of the second order*), in order to start there with a new spatialization, while the spatial plastic weave is maintained, but no longer draws focus from listener. In contrast, the linking of fine grains can produce a net-like structure around the IKO while a

[114] The echo threshold or the threshold of echo perception describes the minimum delay (time difference) that reflections of a sound may just have to be perceived as a separate auditory event (echo) after the direct sound. Below the echo threshold, the reflections are perceived as reverberation.

rotating sinusoidal beam, which would not form a sharp trajectory per se, with a softly-blended noise at a corresponding speed, produces clear coordinates between the *beacon* and the *spatial beating* on the reflecting surfaces.

Listening example 18: *Beacon* - Miniatures 22, 31, 40

Listening example 19: *Spatial Beating* - Miniatures 2, 8, 49

Listening example 20: *Spatial Beating* - mirage 3/S1(b): 2:25 - 3:18, at 3:00

The directionality of a plastic is the dominance of extensions in one or more directions. The directionality is closely linked to the relationship of the body to the space [Klant/Walch, 2003; Krämer, 2011]. Hence, an expansive body is generally directed outwards from its center, a space-superseding inward, toward an imaginary or actual center. The directionality also provides information on the balance, statics and dynamics of a work [Klant/Walch, 2003; Krämer, 2011]. By directionality in the field of sculptural space-sound composition, one can first understand the situational directing of the listener's attention by the spatialization of the sound. Here, as time-based, there are always moments of construction and reorientation. It is, however, also possible at the bracing of such moments to perceive corresponding dominant expansions in one or more directions as a unit. In relation to the time, it is then also possible to speak of "changed directionality" (see mirage 6/T1: 0:22 - 0:48). Such changes and their tendencies can refer to directionality from outside to inside, from bottom to top, to the depth and to the center of gravity in the panorama. Through this term sculptural sound phenomena are assigned to the spatial attributes of Rumsey and Kendall.[115] Directionality thus does not describe the process but the instantaneous result of the formation of space in the sculptural sound composition in a loudspeaker environment. The IKO is the center of the action most of the time. The sound projections, however, do not have to be IKO-centered depending on the on-site facility and audience placement. The careful staging and dramaturgy in SPS allows precisely this temporal disappearance of the apparatus in the perception by the superposition of the events and the production of more attention-intensive stimuli in the sculptural sound structure.

Above all the intended perspectives and effect of the contour as well as directionality are therefore mainly responsible for "guiding one's view", which

[115] See Chapter II. 8.5.

pre-structures the order in which individual parts are to be perceived and determines whether and where the attention ultimately lasts [Klant/Walch, 2003; Krämer, 2011]. Nevertheless - and this is essentially due to the use of the terms in SPS - the listener is, of course, free to decide how and whether he will allow himself to be led. Through the verbalization of this principle of guided attention, which is found in many both musical and non-musical compositions, the direction of artistic perception and action is also linguistically comprehensible and verifiable for the composer. Auguste Rodin said the following, "*The sculptor, so to speak, compels the spectator to follow the development of a process in the individual parts of a figure one after the other* [after: Klant/Walch 2003].

4.2. Proportion – Large Plastic und Small Plastic

> *The scale of an individual piece depends very much on the sculptor's intentions with regard to its setting and its expressions in that setting. [...] The match between scale and viewing distance can influence the visitor's assessment of whether particular surface features are meant as texture or specific shaping*. [Rawson 1997, 55]

The plastic proportion of the sound elements depends not only on their frequency spectrum (in the sense of a room span in the range of pitch, which cannot be suppressed, since the aural impression is interpreted appropriately above and below)[116] by a decisive proportion to their volume and a corresponding ratio to the material of the in part simultaneously used sound objects. This also plays a role in how closely the sounds are perceived at the loudspeaker. The miniature and etude studies have shown that sounds perceived close to the loudspeaker at low volumes correspond to a very small plastic figure (small plastic); whereas loud and at a greater distance to the loudspeaker correspond to a broadening body-space relationship (large plastic). Louder broadband signals also stimulate the room, which in turn points to a more powerful, more expansive and therefore larger plastic. Hence, the extent of the spatial propagation of the perceived sound object is closely related to the volume (loudness). Spatial volume is created by, among other things, acoustic volume. In order to be able to assess these effects in terms of scale, the composer has to assume different positions in the performance space, in contrast to conventional studio productions, in which he is usually tied to a fixed listening position with keyboard and screen, in order to learn to understand and judge the dimensional propagation of the

[116] Cf. spectral verticality as the basis for spatialization of the first order, Chapter II. 8.6.1.

sculptural texture. This also applies to the evaluation of contour and directionality. *The sculptor usually works close to the piece and tends to keep assessing its shape from that distance, but it is important that he or she back off frequently to check the work at its intended scale and distance* [Rawson, 1997, 55].

There is no simple formula for this, but it helps to know the factors and to deal empirically with the effects, in order to be able to deliberately adjust them on the spot depending on the performance situation.

> Listening example 21: *Large plastic* - mirage 3/T4: 8:58-10:20
>
> Listening example 22: *Small plastic* - mirage 3/T3(b): 7:55 - 8:55
>
> Listening example 23: Transition from *large plastic* to *small plastic* - mirage 5/T6: 11:16-12:05

4.3. Temporal Levels in Sculptural Sound Composition

In the classical scholastic writings on sculpture one proceeds basically from static objects, to which however dynamic attributes are assigned. In the case of classical sculpture, it is possible to represent either a flow of movement or a moment of standstill within a sequence. The concept of the "fruitful moment", which describes a moment in an action sequence from which the previous activity can be reconstructed and the following thoughtfully anticipated comes from ancient times [Klant/Walch, 2003]. In space-sound composition, these static moments can be produced by, for example, a drone with fixed beam orientation or a uniformly distributed texture built up on perceptible repetitions with uniform rotation around the equator. In modern kinetic sculptures, whose body-space relations can be subject to constant changes (e.g. mobile works by Alexander Calder), even actual movements of plastic elements are possible. Correspondingly, in space-sound composition, sound objects can be moved around the listener or, in the case of the IKO, via the reflecting surfaces, and thus different mobile sound objects, similar to a mobile, can be set relative to each other.

Within the framework of space-sound composition, time is first placed in the service of space. Time becomes a spatial function. Smalley [2007] provides the following consideration:

> [...] *Possibly the most important strategy in arriving at an holistic view of the space-form [...] is that I disregard temporal evolution: I can collapse the whole experience*

into a present moment, and that is largely how it rests in my memory.

Rightly, Barret [2010] notes critically:

> *[...] science and aesthetics agree that our understanding of spatial information is primarily immediate and less concerned with temporal processes. Yet the second part of Smalley's discussion presents a contradiction in pointing out that identity unfolds through time and deduction is a slow process contingent on, rather than disregarding time.*

However, both in the perception of classical sculptural arrangements as well as sculptural sound phenomena in SPS, temporal sequences play a role in the formation of the spatial impression. For example, *spatial beating*,[117] as the IKO's *basic pattern of spatialization* for generating coordinates on reflective surfaces, needs direction and repetition in order to be perceived as such. Thus it makes sense to think of time as a spatial function:

> *One noteworthy element [...] is the role of time: it acquires a spatial function. Trajectories leave continuous spatial contours behind in our listening imagery; densifying micro-temporal sounds agglutinate into spatial surfaces; temporal durations become spatial distances.* [Nystrøm, 2013, 18]

In this case, three temporal levels can occur simultaneously:

1. The time in which a sound projection follows a particular motion or takes a particular direction (e.g., rotation: 180°/s = *spatialization of the second order*). Here time has a *direct spatial function*.

2. The time, which within a recorded sound or in the context of a generative process of sound generation is filled by the material and its course of events (for example pitch-drop or sweep = spectromorphology). I call this *enclosed time*.

3. The time in which a listener directs his attention to different sound objects. I consider this *staged time*.

Hence, one must distinguish between time developments in the sound event as an *event* [Kendall, 2008] and his spatial behavior, which can also be static (e.g. a fixed beam at 35°) or in motion, and the times at which the listener perceives it in his own time.

The movement of the observer, which for in the case of multi-faceted works it is called for to move around or to change the position, is added on the third

[117] See Chapter IV. 1.2. IKO-Basic Pattern of Spatialization

level as a further temporal function of the space. That is, the time outside the work can become part of the shaping process of perception. For classic sculpture, this form of time can be defined as follows: *the movement of a body in space can only happen within a certain time, and vice versa, the time in the sculptural work can only be defined by the movement of bodies in space* [Klant/Walch, 2003].

This form of compositional design is often the least influenceable aspect. As soon as the seating arrangement is removed, the audience is able to move around freely. However, this movement and independent placement will always take place within the framework of local conditions. Hence, the decision whether to work with the IKO at all in the seated or free positioning of the audience should be included in the composition of the spatial formations and their timelines, so that the conditional relationship between SPS and sculptural sound phenomena on site of the composition can be correspondingly produced. This has not only been the case since the invention of the stereophonic "sweet spot", whose paradigm of an ideal listening position is being questioned here in an artistic way (not in scientific engineering). The positioning of the work and, connected with it, the perceptions of the audience is always also a temporal staging with regard to different possibilities of perception. *Rodin's violent disputes with purchasers of casts of his Burghers of Calais is relevant. He objected to their raising and isolating the work on high plints, because he had designed it to stand at ground level, with the idea that public should be able to enter among the group of figures* [ibid. 61]. In the time a listener can take to walk around a sculptural sound composition, he can discover different contours and aspects as such that he can perceive from only one listening position in the performance room. Conversely, there are space-sound constellations which collapse by the movement in space, hence which do not arise in the self-directed and self-timed movement of a listener.[118]

Concert practice with the IKO in recent years has shown, however, that the possibility of movement for the audience has in some cases increased attention to the spatial sound phenomena, because the listener who is free to wander about the room directs his listening to that which is perceptible rather than to the IKO as an object. Therefore, the problem of visual paralysis or distraction of one's listening can be overcome by the freely chosen perceptual path, provided that the composed spatial sound phenomena are stable enough. We can now also consider strong momentary directionality

[118] Cf. commentary on mirage 1- 6, Chapter V. 2. Analyses.

and multiple contouring as stable. Brewster emphasizes the particular sculptural aspect that can be experienced by moving:

> *Walking through it in its resonant state provides an experience similar to perusing a landscape but from the inside, with all of your body instead of from the outside with just your eyes. It shows us the "near field". Like a solid it has volumes, edges, planes, fullnesses, flatnesses, roundnesses, and hollows: the works. It comes "fully equipped" to elaborate our experience sculpturally.* [Brewster, 1999]

CHAPTER V

Composition and Analysis

1. mirage 1 - 6

The last step deals with compositions that practically implement the previous research and at the same time function as musically independent works. The spatial sound compositions mirage 1 - 6 composed for and with the IKO contain the knowledge gained from the findings of the miniature studies, which has consolidated itself in the composition of etudes and has subsequently been implemented as an artistic act in the piece.[119] Over the course of the research process, the questions of engineering and musicology, which came up and were answered in the research process, played an important role in all compositional considerations. From the artistic point of view, I have focused on the usefulness of scientific research in the artistic cognitive process, particularly on Rheinberger: [...] Scientific activity is only and precisely scientific in nature when it is a generator of surprises on the way to the unknown, so that it produces future [Rheinberger, 2001, 71].

The sculptural sound phenomena arise as "epistemic things" [Rheinberger, 2001, 73] in the conceptual representation space of these experimental systems, which thus shape the forming conditions for SPS. Artistic research, therefore, leads in the last step to art, and as a poetic action and as an aesthetic object it must be able to stand out from its models so that it can always be art at present. The compositions mirage 1 - 6 were binaurally

[119] The etudes were implemented in mirage 1 - 4 (2015), mirage 5 and 6 (2016) summarize the results of the listening experiments and the derived IKO basic patterns of spatialization.

rendered from the listening positions P1 and P2 with the ViKO and the impulse responses of the auditorium at Petersgasse 116, in which almost all research and compositions were performed. They are available as binaural stereo renderings on the enclosed SD memory card or can be downloaded online.[120]

2. Analyses

In the last part of the thesis, within the scope of the research the conditions for sculptural sound phenomena were examined and commented on in their application and effect. The focus of the analyses is on the interactions between the SPS and the sculptural body-space relations (KP, SP, KSP) as well as their attributes (space-superseding, space-encompassing, etc.) as implemented in mirage 1-6. Instead of a further listening experiment, the analyses of the completed compositions are intended to demonstrate the suitability of the concepts of *directionality, contour, and plasticity*. The aim was also to examine the potential of these terms as to how they are capable of describing sculptural shaping processes, meaning temporal aspects, as spatial functions, without having to ignore distinct events in the spatial description. The analyses are subdivided into (points of) time, descriptions of, and commentaries on the respective spatial sound constellations. Here too, the binaural renderings with the impulse responses of the laboratory environment serve as documentation. They are not studio productions in the sense of conventional CD production. Due to the research results of SPS and the development of a ViKO as an additional production environment, these simulations are able to present the spatial impression of the listening situation in the laboratory from different listening perspectives. In the sense of "state of the art", they are capable of reproducing the interaction of body-space relations in SPS in a comprehensible manner.

[120] Cf. List of Download-Links, p. 175

mirage 1 2015

Length: 13’13’’

5 Sections

KP = Kernel Plastic, SP = Spatial Plastic, KSP = Kernel-Shell Principle, CCW = counterclockwise, CW = clockwise, IKO-Spat-BP = IKO-Basic Pattern of Spatialization, Ev = Elevation, Az = Azimuth

Section	Time	Description	Commentary
1			
	0:00	Starts with single, faded in bass pulses (0:05, 0:14, 0:21), builds fragmentary, successive coordinates through (the) spreading and arranging of similar elements around the IKO. Space exploration. By spreading itself out omni-directionally, the bass seems larger than the IKO. Moments of silence serve as demarcation, allowing the acoustic environment to be recognized as a spatial boundary.	Indicated KP, superseding space. *Evenly contoured* shape, little *plasticity* due to a lack of depth gradation. Core building. Integration of local sound events in the sculptural shaping process.
	0:28	Frequency modulation with a slow rotation (Spiral) of 90°/s CCW opens up the space upwards vertically while the bass expands downwards.	Indicated SP as spatial mark, space encompassing. *Spiral* as IKO-Spat-BP. *Directionality* is temporarily set upwards.
	0:34	Again, bass pulse, and again at 0:39, 0:49, 0:55	
	0:42 0:57	Percussive, rhythmic structure in a barely perceptible range with a high pitched sine wave and middle range click punctuates the span of space created, depth gradation. Runs concurrently with bass pulse (0:55). Runs alone, extricated.	*Plasticity* is increased. *Echolocation 2nd order*, the room in the sound space is elicited by superimposition and *Echolocation 1st order*, by isolation the performance space is elicited. Contouring through position-dependent perceptual emphases.
	1:02-1:06	Frequency modulation rotates 90°/s CCW around the kernel, opens the space upwards, and then aborts.	Similar to 0:28: Indicated *SP* as spatial mark, space encompassing.
	1:08 -	15 seconds of silence empties the previous sound space without destroying it. Tension is maintained, draws attention to search for the previous SPS, such as volume or spatial formation.	Re-inclusion of the sound environment in the exploration of the sculptural space.
	1:23-	Reuse of frequency modulated texture, this time with a clear	*KSP* 1 from Index of

	1:45	rotation of 90°/s CCW as a figurative lining of the previously spanned borders by way of expanding the kernel in all directions, space superseding, then encompassing. Marking of different focal points within the rotation.	Etudes 1. Strong contouring through the position-dependent broadening of the perception of the sculptural shape (without grains: SP 2 from Index of Etudes).
	1:33	Consistent linking of Grains rotates CW, ensures the redirection of attention to the center and near the IKO as well as the depth gradation of the sculptural shape, until the entrance of an>	Increased *plasticity* and tension between both textures create a kernel-shell constellation.
	> 1:49	expansive kernel-shell plastic on various graduating levels: vertical (middle/and high ceiling) as well as in the perspectival field, with CCW rotation. Strong spatial displacement over the course of time. Ends as a statuary sculptural from on bass pulses.	KSP > KP, low plasticity. Monolithic, large-scale sculptural form.
	2:03	The now louder returning chain of grains rotating CW, dissolves the direction and binds the attention to the IKO's surface. Shrinking of the sculpture in both amount of frequencies (narrow bands) and volume (small-scale sculptural form.)	Dissolution of the kernel *uniform relief construction*, change of directionality. Low *plasticity*.
2 (a)	2:15-2:42	Three opposite rotations (Spiral CCW 250°/s, Rotation CCW 100°/s, Rotation 180°/s CW) on three different spectral levels (80 Hz - 400 Hz, 500 Hz - 700 Hz, 750 Hz -11 KHz) initially shape a shell (SP) around a cavity with simultaneous depth gradation. In addition, the space is lifted upwards.	*SP* as space sculpture, encompassing the room. *Spatialization 1st order*, sets *directionality* between the outer orbital track in the perspectival field and the vertical-above.
	2:27	Entrance of bass modulation (at 137 Hz) establishes the kernel, grounding of the sculptural form vertically. Emphasized inward-outward tension. Disappears at>	*SP > KSP* 2 from Index of Etudes, *contouring* through position-dependent expansion of the shape, *beacon* as a special rotation from the IKO-Spat-BP. Increased *plasticity* through graduating levels of depth in the textures.

	> 2:45	rotation of one single texture remains, disentangling itself from the previous sculptural weave. Directs the attention to the IKO's near-field, but with varying distances to its surface.	Transformation into SP as spatial mark. Low depth gradation diminishes the *plasticity*, strong *contouring* through a s*piral* with different perceptual emphases.
(b)	2:50	Entrance of a high pitched sine (4500Hz) that interferes with a second, lower one (at 875 Hz), thereby drawing the vertical line. The previous space collapses in this point.	*SP with a uniform contour* as a demarcating line shows the narrow vertical.
	3:03	Entrance of grains as horizontal coordinate builders (set at 90°). Functions as a transition to 3. High pitched sine stops (3:23).	Marginal increase in *plasticity* through gradation of the sound objects.
	3:16	A second, identical chain of grains is added and turns 96°/s CCW. Increase in volume at 3:24 shifting attention on the equator.	Change of *directionality* from vertical to horizontal. Low *plasticity* due to lack of depth gradation.
3			
	3:23	First, attention is focused on the IKO due to the rotation of the grain chains, with different directions at the IKO for 30 seconds, causing the establishment of spatial texture and saturation of the spatial form in the perception.	*Sculpting a relief with a uniform contour*. *Direction* is IKO-centered. Space is miniaturized.
	3:53	Prominent onset-click marks the onset of a new occurrence and draws the attention from the established grain chain to the entrance (onset) of the beams with a >	*Echolocation 1st order* through stimulation of the environment.
	3:54	sequence of fluctuation bursts, rotating in opposite directions at 180°/s CW.	Strong contouring through fast rotations and shifts of directed awareness of the IKO.
	4:03	Prominent onset-click marks a new occurrence and draws the attention from the established grain/burst-weave to the beam with >	*Echolocation 1st order* through stimulation of the acoustic environment, simultaneously changing the weight within the depth gradation of the sculptural kernel-shell form. *Plasticity* is increased.
	4:04	an identical burst sequence, but as a spiral-rotation and with 300°/s, CW. Attention jumps to another orbital path.	*Spiral* as a special rotation from the IKO-Spat-BP.
	4:08	The same prominent onset-click marks a new occurrence and	*Echolocation* 1st order

		draws attention temporarily to a coordinate on the IKO.	through stimulation of the surrounding space.
	4:16	Once again, this onset-click marks another occurrence and draws attention to a different coordinate on the IKO, leading to the establishment of the sculptural shape being formed by the same occurrences marked at 4:03, 4:08, 4:16.	Depth gradation through superimposing similar burst sequences creates plasticity. Strong contouring of the delicate SP due to penetrating spiral rotations.
	4:25	Delicate chain of grains (compare with 2:50) appears on the IKO as a clearly audible set coordinate (225°) and tightening the grainy texture into a shape. The latter is consolidated by saturation. Core is produced by tissue and spatial gradation through the IKO. Gradual development of a core of plastic with different spatial layers and corresponding expansions and emphases distribution.	Forming of the kernel porous) through centering towards the IKO. Undercut *building of a relief*.
	5:07	Prominent onset-click marks new occurrence and draws the attention from the established grain/burst-weave to the beam with the >	Now *Echolocation 2nd order* as consequence of embedding in the created acoustic environment.
	5:08	entrance of a drone (compare with Miniatures 20 ff and Index of Etudes II), rotation CW 180°/s creates a kernel-shell principal through the space-sculptural forming of outer coordinates on the orbital path. Increase in volume pulls the drone into the foreground of attention; burst texture sinks into the background. Bass grows stronger at the IKO and slides under the texture. Formation of vertical space through spatialization 1st order. Again, lengthy settling time, space rhythm (beating) produced by rotation and formation of coordinates on the reflective surfaces. Establishment of the sculptural form up until the point of saturation, attention jumps between the spatialized textures.	*KSP, Spatial Beating* as special rotation of the IKO-Spat-BP. High *plasticity* through depth gradation of the textures. *Directionality* set to the outer orbital track through rotation, attenuates due to saturation. Strong *contouring* through position-dependent morphology of the sculptural body-space relationship. Beginning at 5:28, almost frozen time and dissolution of *directionality*. The space begins to dissolve due to the lack of clear direction.

	5:41	Entrance of broadband noise (HighCut,1,5 KHz), beam with outward rotation of on 97°/s CCW. Prevails discreetly and immediately draws attention to the rotation forming an outer orbital track further than the drone. The slower rotation is identifiable as an even circle. With this, the previous sculptural shape moves to the background and is surrounded by a shell.	*KSP* 3 from Index of Etudes. *Beacon* as special form from IKO-Spat-BP . *Directionality* is newly set by rotation. High *plasticity,* strong *contouring*. Kernel-shell formation as large-scale sculptural form.
	5:52	High pitch expands the room upwards into a small point.	*Spatialization 1st order* expands the KSP upwards.
	6:08	Sudden stop. Space collapses and is led twice by suddenly released burst-equences around the IKO with the rotation of 90°/s CCW. Attention is redirected to the IKO's surface. Rotation ends at ca. 40° in a fixed, set beam with a chain of grains. The sculpture vanishes at a coordinate.	*Directionality* is focused on the horizontal and the center. Outward to inward motion. Loss of plasticity and the contour as well as the resolution of the core and shell, reducing the SPS to 0.
	6:21 - 6:31	Again long lasting silence after repeated saturation of the attention in 3 in order to direct the expectation to the new space. The listeners' ears blend exterior noise into the composition.	
4			
	6:32	Low sine wave as an omnidirectional bass (at 52 Hz) at the IKO-center with a slight tendency against 330°, above which frequency modulations (280 Hz and 515 Hz) are arranged vertically, which stretches the space upwards (*Spatialization 1st order*). Fade out, small rest at 7.30.	*KP* 1 from Index of Etudes, vertically space encompassing in part.
	7:33	Bass's second entrance shifts the beam's direction left to ca. 45°, causing partial different excitation of the environment by shifting emphases. First audible after the bass's new onset. Above which expansive, slowly rotating (CCW 100°/s) frequency modulations at 7:45 form a kernel-shell constellation which flow back to the kernel during the breaks.	*KP>KSP>KP*, slight c*ontouring* through change of beam's direction with identical material. *Contouring* of the static formation now begins. Low *plasticity* due to slightly weak depth gradation.
	8:34	Ends similarly, with the same grains and fixed as in 3, but this time to the rear right at 330 ° and disappears into a point in space (coordinate).	Here the momentary plasticity is increased by the superimposition of a new texture introduced over previous textures now fading out. *Directionality* changes from center to the

			coordinate at the rear right.
5			
	8:42	Rotation (180°/s CW) of the interferences produce a spatial sculpture on a narrow level (1440-1900 Hz) with the expansion in the perspectival field, with differently perceived distances to the IKO. Elevation overhead, but with little stretch vertically. Weave floats above the ground.	*Spatialization 1st and 2nd order* create a space encompassing SP.
	9:32	Hardly noticeable entrance of a second rotation in the opposite direction (spiral CW 340°/s) with slightly staggered identical material. Beats are amplified through the growth of interference between the rotations. Broadening of the texture horizontally.	*SP* 1 from Index of Etudes. Contouring of the material; rotations in opposing directions create different position-dependent broadening emphases. Low plasticity due to lack of depth gradation.
	9:56	Entrance of chain of fine grains to fix coordinates to the rear right at 290°, poking again and again through the texture, shifts of attention between the foreground and background. Saturation through the length of the penetrant and repetitive material. Almost no changes to *Spatialization 1st and 2nd order* for 2. 5 minutes (!).	*Kernel-shell formation:* The space is spanned between two poles that define the space by relative tension. Strong directionality to this point. *Plasticity* is increased, reinforcing the *contour*. Again, a standstill in time due to saturation. The space solidifies.
	12.20	Minimal change attracts attention to the IKO: The fading of grains to the beam at 90° leads to a change of the spatial reference point, trajectory when moving along the right-left axis.	Compare the *IKO-Amplitude-Fade* with Miniatures 50ff und Listening Experiment 2. Change of *directionality*, shift of emphasis from foreground to background: Relief-style gradation.
	12.40	Superimposition of the beams with identical Grain chains at 90° and 220°. Simultaneity of slight displacement of the entrances leads to the formation of axes (left-right) between the coordinates. Attention wanders between the set points and the sculptural beats. Slight emphasis to the front left. Sudden stop makes the space collapse; Beats mark again the last vanishing point in space in which they disappear.	Decentered kernel-shell formation: directionality is reset. Superimposing the beams with respect to the beat level creates gradation in the depth of the material, plasticity is increased and the contour changes strongly.

Note: In a listening position outside the near-field IKO, sections 3 and 5 work mainly as undercut reliefs.

mirage 2 2015

Length: 8'31''

4 Sections

KP = Kernel Plastic, SP = Spatial Plastic, KSP = Kernel-Shell Principle, CCW = counterclockwise, CW = clockwise, IKO-Spat-BP = IKO's Basic Pattern of Spatialization, Ev = Elevation, Az = Azimuth

Section	Time	Description	Commentary
1			
(a)	0:00	Begins with low-pass filtered noise as a rotating beam CW 100°/s, simultaneously a drone with strongly beating interferences and distortions: beam is directed to and stabilized at 90°, builds up over time to form a monolith. Successive increase in volume over 56 seconds up to one's pain threshold, causing spatial displacement; consumes the noise after 13 seconds. The surrounding space is animated toward the left rear wall, so that over time a differentiation between in front of and behind the IKO can be made. The sculptural formation takes place clearly behind and slightly to the side left of the IKO and binds attention there. The whole place is however gradually "flooded" by the volume. After abrupt discontinuation the superseded space is restored at this point.	*KP* 2 from Index of Etudes I, space superseding. *Directionality* set to the rear left. Position-dependent *contouring* through IKO-masking. Low *plasticity* due to lack of depth gradation.
	0:57	After the abrupt stop, silence assumes a spatial dimension in the form of emptiness. Over time it becomes a transition for further spatial expansion:	Silence as a spatial component of the sculptural shaping of sound.
(b)	1:00	Low-frequency frequency modulation with sub-bass rotates CCW in a simple orbit around the equator at 90°/s. Expands in all directions in synch with the spectral modulations and contracts elsewhere on the orbital path. At times, strong, physically tangible excitation of the room between 55 and 80 Hz. The sculptural shape is spun into the space. Bass is perceived partly as a spatially defined structure both at the listening position and towards the walls at 0° and 270°. The attention shifts between the different moments of excitation in the space.	*KP* 3 from Index of Etudes I, space-consuming. *Rotation* as IKO-Spat-BP. Strong contouring by position-dependent reflection paths. Low plasticity.
2			
	1:57	Constant, low-pass filtered noise (compared with?? mirage 1?) with a long on- and offset is stationary, directed at 290°. Creates an IKO decentralized coordinate and draws attention to the side-right-rear.	Fixed beam as IKO-Spat-BP 0. Spatial depth gradation creates plasticity. KSP 4 from Index of Etudes.

		After 10 seconds, entrance of a mid-high-frequency modulation plane with harmonious proportions, barely perceptible rotation also CCW 90°/s. In proportion to the noise, it pushes itself into the foreground. The spatialized texture is mainly perceived above the IKO (Spatialization *1^{st} order*). The minor perspectival propagation is generated by the rotation depending on the position, but remains close to the IKO (spatial demarcation). Indication by the formation of foreground and background – kernel-shell configuration. From outside the IKO near-field, formation of a relief. At the >	Directionality shifts between the two focal points. Contouring by IKO-masking of the fixed beam and position-dependent mixing ratio of the fixed and the rotating beam.
	> 2:22	amplitude fade, noise-beam remains at 90°. The emphasis of the sculpture and the attention paid to it are moved dramatically, horizontally to the left. The sculptural form persists, but receives a different orientation. Continuous rotation around the IKO.	*Amplitude fade as* IKO-Spat-BP, *Directionality of the sculpture is reset.*
	2:36	Again amplitude fade on the beam at 220°, which strongly shifts the attention to the front. The rotation is momentarily in the background, then at >	New *directionality*.
	> 2:50	the third fade returns to the original coordinates of 290°. In this way, the perspectival boundary of the space is marked successively on the basis of each emerging beams' mirror-source and briefly clearly traceable trajectories. Inside and outside are contrasted: the noise and outside. Interior bright sound texture in rotation, pushing upwards. Seems simultaneously limited in its upward scope.	*Contour changes with time and with the listening position. Plasticity caused by spatial depth gradation of textures and spatialization 1^{st} order.*
	3:18	Frequency modulated texture with a slight time-stretching; beam set at the IKO's highest point. Attention is detached from the originally strong coordinates; the constructed space is resolved. Like an echo of section 2's kernel as an expansive kernel plastic as small-scale sculptural form at and above the IKO.	*KP, no plasticity, uniform contour.*
3			
	3:56	Spiral: broadband sound mixture with rhythmic beating interferences and filter-changes over time ensures spatial rhythm by constant, fast (CCW, 250°/s) modulation-assisted rotation which varies in elevation over time, with multi-stage (up and backwards-forwards, lateral) priorities of reflections (beating).	*Spiral and spatial beating as* special rotation of the *IKO-Spat-BP.*
	4:21	Layered, rich in transients, and continual "rattling noises" with two beam directions of 90° and 220° and a rotation of 90°/s CCW form coordinates at the IKO, but form no homogeneous core; nevertheless serving as coordinates for the spatial plastic enclosure and are therefore experienceable both inside and outside.	*Echolocation 2^{nd} order*, *KSP* 5 from Index of Etudes. Depth gradation of textures creates *plasticity. Directionality* changes between inside and outside.
	4:34-5:22	Entrance of a fragmented fm-texture faded in and out with upward glissandi movements. Initially integrated	*Spatialization 1^{st} order*, strong *plasticity* through clear depth

		into the sculptural form, is not strong enough in terms of presence to serve as a kernel. Acts like synchronized turbulence to the main band (with a spiral) but aligned vertically upwards, opens the space upwards through second rotation above the recent sounds, builds the highest coordinate in the space. In fact, the beam is set and fixed to 330° (!). Rattling sounds at the kernel continue as before, but fall into the background texture until >	gradation of the three textures. Strong *contouring* through position-dependent variations on the form of the kernel-shell-structure.
	> 4:53	the texture urges briefly to the foreground at 5:12, forming a kernel, before receding again at 5:23.	New kernel-shell-conception of the spatialized textures.
	5:24	Spiral stands alone after abrupt suspension of two other textures. Spatial plastic as large-scale sculpture, shift of attention towards the rotation, directions emphasized through reflection. Stops at 5:40.	*SP* as a spatial mark, space encompassing, *Spatial beating* as a special rotation of the IKO-Spat-BP. *Directionality* is moved from above and outside towards the IKO. Strong *change of contour* throughout the process through spatial beating and constant rotation in the spiral (above, below, left, right, in front/behind.)
	5:41	*Small-scale plastic* made from material heard at 4:34 is released. Elongated, vertical spatial form (550-620 Hz), attention is directed (beam stands at the IKO's highest point, but is not to be located there) upwards. From 5:55, pedestal-sound as amplitude-modulated support for texture, very softly in the background (beam set at 300°).	*RP*, as *spatialization 1st order*, *plasticity* increases with the second texture. *Uniform contour* until the entrance of the second texture, then light c*ontouring* through a second beam at the far right.
4	6:21	Space is spanned by shrill, glaring frequency modulations and time-stretching between 1600 and 6000 Hz and shifted upwards as spatial plastic. Timing of transient oscillations and decay matches the CCW rotation of 90°/s. The resulting spiral encloses the space and seems to strive in the turbulence against the edges of the listening space. Stays with long decay as a streak in the spectral space. The sculptural form is not grounded.	*SP*, space encompassing, *spatialization 1st and 2nd order* set the *directionality* above all upwards. Low *plasticity* due to lack of depth gradation of the material. Light *contouring* through the temporary position-dependent perception of the rotation.
	6:46	Entrance of an amplitude-modulated, very faint shimmer of three staggered tracks of the same material with beams set at 290°, 90°, and 220° with the main frequency of 1600 Hz. Builds the perspective of "background radiation" for the sculptural form in the	Stronger *contouring* through the three temporally displaced and spatially spread beams. *Plasticity* is slightly increased through the depth gradation

		foreground, at the same time "grounding" as base point (plinth) in space for the spiral.	of the textures.
	7:05	Change in the movement of direction of the “streaked beam” to 100°/s CW through opposing fade-in and fade-out. Trajectory not comprehensible at all positions. Fades out at 7:58. Shimmer remains the only track in the space, attracts attention from the outer trajectory of the rotation in the frozen zone close to the IKO.	*SP* as spatial curve/delineation. No *plasticity* due to a lack of perceptible depth gradation of the materials. *Contouring* created through the staggered entrances of uniform material in combination with different beam directions.
	8:13	Ends similar to section 3 with the same material as spatial plastic, scales through the echo to the tracks in section 4 as small-scale plastic. Attention is given to the end to ever shrinking spatialized sound structures until it dissolves the space in a fast fade.	*SP* 3 from Index of Etudes. *SP as* a space-binding spatial mark. No *plasticity*. *Uniform in contour*.

mirage 3 2015

Length: 10’30’’

4 Sections

KP = Kernel Plastic, SP = Spatial Plastic, KSP = Kernel-Shell Principle, CCW = counterclockwise, CW = clockwise, IKO-Spat-BP = IKO’s Basic Pattern of Spatialization, Ev = Elevation, Az = Azimuth

Section	Time	Description	Commentary
1			
(a)	0:00-0:04	Swirling of a frequency modulated “sound streak” with harmonious proportions in the effective area of beamforming between 245 Hz and 800 Hz through a spiral rotation at 250°/s CCW, causing quick, locally changing reflections and thus different areas of attention, coordinates of the space are generated (front/rear, side). Therefore, the rotations as such are clearly noticeable, but the artifacts that they generate (spatial coordinates, trajectories) are primarily perceived. Next, opening of the space upwards (spatialization 1st order with focal points at 245 Hz and 600 Hz) is supported by the swirling.	*Spiral* as a special rotation of the IKO-Spat-BP. *Contouring* through position-dependent perception of the sculptural form’s propagating artifacts. Little *plasticity* due to lack of depth gradation.
	0:04-0:16	Silence (but not a rest!), three times as long as the previous event, emphasizes the "exhibition" of the sculptural body-space relationship in the acoustic environment of the performance location. Calls concentration and attention to what is coming. Expectation is modeled by low information density.	Silence also forms the sculpture.
	0:16-0:23	Entrance of a second spiral, similar sound material, same spatialization (trajectory and speed), confirms the spatial plastic as an implied wrapping for the center.	*SP*, space encompassing
	0:23-0:39	Silence, (but not a pause!) - passage for ambient noise. Ambient or audience noises are clearly perceived and identified as an external coordinate or "foreign" and set in relation (spatial, causal) to the sculptural event. No echolocation, but still incorporates the acoustic properties of the environment by "implosion".	The dissolution of a seating could lead to the listening to your own body (steps). Relations between sound body, environment, and audience’s bodies can be felt as tension.
	0:39-0.48	Entrance of a third spiral, again similar to the previous. Reappearance of the spatial plastic, but then the use of bass (focus at 60 Hz) at 0:43 indicates the other end of the vertical and extends it toward the ground. Therefore, two directions along the perpendicular are brought into attention, and the space is spanned and established between the sculptural shaping. Bass structure is apparent but clearly	KP4 from Index of Etudes. SP > KP, temporary depth gradation increases plasticity for the moment, contouring as before. Directionality changes between the spiral

		space encompassing for the moment; consumes the spiral. The spatial sculpture becomes the kernel plastic that opens up towards the space/environment.	trajectory and IKO-centering.
	0:48-0:54	Silence (but not a pause!) is made obvious as a compositional method. More concentration is called for and finely bound. Utilization of "acousmatic schizophrenia": One sees no parts of a performance such as the drawing of a bow or the setting down of an instrument. A percept is however currently expected, even demanded. Here, however, no stimulus is initially "delivered", although one is situated in the state of active listening.	So point the respective entrances to sculptural traces as an implied spatial mark and the silence takes on the spatial dimension of emptiness.
	0:54-1:00	Fourth entrance, spiral shaped spatialization 2nd order, same sound material, but this time the bass as a short onset. Return of the spatial plastic wrapping.	*SP*, space encompassing, contoured, low plasticity
		ALL entrances have very faint, specially setup onset-clicks as spatial pickups just above the audible threshold. Therefore, attention is irresistibly and immediately pulled out of the silence to a point at the IKO in order to "enter" the spiral movement there. Clicks are only consciously perceptible by paying close attention to the space. Entrance number four also has an offset-click, which draws the attention from the turbulence back to the IKO.	No *echolocation* 1st order through the clicks due to a lack of sufficient intensity. But *echolocation* 2nd order in the sculptural structure between the silence and the spatialized textures.
(b)	1:00-1:14	As a compositional element, silence “saturates” the attention. The space is threatened to disintegrate. At this point a new, minimal element can be introduced as an event:	
	1:14 - 1:23	New element (amplitude-modulated sound plane) begins with onset click, then slow rotation CCW 100°/s, much quieter than the previous entrances, no spiral, rather a circular motion. Enclosure of an inner space at the IKO is indicated.	*SP*, low *plasticity*
	1:23-1:38	Silence as a void, probably just hard to physically endure here.	
	1:38-2:00	Fresh entrance, same spatialization (rotation, direction) double in length with successive increase in volume, establishes the small-scale plastic, filigree sculptural form. Implied bass at 70 Hz as a pedestal. Event takes up more space accordingly both in perspective and vertically. Fade out, again to>	Space encompassing S*P, as small-scale plastic* with low *plasticity*. Strong c*ontouring* through position-dependent perception of the perspective propagation.
	>2:00-2:14	silence, but shorter than before.	
	2:14-2:25	Significantly louder entrance using a frequency-modulated surface with a long fade-in, pulsation and fade-out follow. Similar situation to 0:16, the same principle but with other material. Small-scale plastic. Strongest space excitation since 00:56, then collapses again.	*SP*, as spatial mark. Stronger *contouring* of the sculptural form through pulsation on the orbital path.
	2:25-3:18	Onset-click, then slight frequency modulated sound mixture in the range between 500 Hz and 1300 Hz. Beam is set vertically at the IKO's highest point. In the elevation, however,	*SP as* spatial demarcation. *Directionality* is set vertically, no direction of

		the sound is only perceived as "above" in spatialization 1st order. Rotation with 180° CW, with a low-noise mixture around the center. Short stop at 3:00 - then again the entrance of the bright sound mixture but now with the rotation of the (non-reentering) noise. The circular movement gives the previously rigid and vertical sculptural form a spiral shape, making it more perceptible in the perspectival field. The rotation gives the sound mixture a rhythmic structure and spatial expansion horizontally.	perspective. *Spatial beating* as special rotation of the IKO-Spat-BP, *contouring* through *spatialization* 2nd order, almost no *plasticity* due to a lack of depth gradation, space encompassing *SP* near the IKO.
	3:18-3:23	Silence, but so short that the next entrance is surprising though it is at a low volume and doesn't excite the room.	
	3:23-3:49	Significant break: resolution of the tension in a delicate kernel-shell structure of multiple opposing rotations of different materials (noise, grains, fm-mixture) that, with an increased density of events, summarizes the scattered previous sculptural traces. Opening the space upwards with rotations around the recent interior at the IKO, filled with a chain of fine grains (see miniatures and listening experiments) as a static core texture (beam set at 220°, front right). Again a break.	*KSP* 6 from Index of Etudes. High *plasticity*, strong *contouring* through a set beam and opposing rotations occur through position-dependent perspectives on the sculptural form. *Directionality* is centered on the IKO.
2			
	3:53-6:49	Onset-click directs attention back to the IKO. Here barely noticeable rotations of very quiet narrowband sound mixtures with long settling times follow, which appear only very occasionally like filaments. Just so that it is clear that "something" is there: here as a very fragile spatial structure, but with elevation (spatialization 1st order) and sporadic azimuth coordinates in the perspectival field through the turbulence. The silence is "composed into" the spatial formation. Forming of spiral by interleaving two opposing, faster rotations, but as such only touch the material shortly, thus forming small streaks that disappear immediately. Nevertheless, space is suspended by the pitch (*spatialization* 1st order) and is orients itself at the respective emergence of spatial demarcation in this direction and with these coordinates. At 4:47, the repeat of onset-clicks for the "retention of attention" and as a catalyst for the following spiral movement.	*SP* in the form of a spatial demarcation, as a space binding structure. No *plasticity*, almost *uniform in contour*. *Directionality* is only sporadically identifiable. Sculptural molding sinks again in silence and thus spatially into the void.
3			
(a)	6:57-7:47	Stagnant tone at 620 Hz (D-sharp) over a modulating sound mixture. Rotates slowly CCW at 90°/s. Small-scale plastic at	*SP* 5 from Index of Etudes. *SP as* spatial demarcation,

		the center of the IKO.	space binding, but more present than in section 2 and with stronger c*ontouring* from different perspectives, as spectrally and over time diffused more strongly and spread throughout the room.
(b)	7:55-8:55	Small-scale plastic, quieter than (a), starts as spatial demarcation: stagnant tone at about 1060 Hz (c with a sporadic emerging of a pulsating coordinate at the IKO. Turns successively into a kernel-shell-formation through the entrance of broadband noise whose volume is below the initial two elements and is first noticed when it abruptly stops at 8:20. At its reentrance at 8: 22, the movement of the rotation and the thus enveloping shell formation is perceived more strongly. After further stopping at 8:47 set free as a spatial demarcation.	*SP > KSP > SP. Directionality* changes through shifts of attention from the spatial demarcation, which appears primarily vertical, towards the shell in the horizontal field of rotation around the IKO and back.
4			
	8:58-10:20	Loud entrance. The same sound mixture with frequency modulation, as in 3 a) with exactly the same basic pattern of spatialization (rotation CCW with 90°/s) but 15 dB louder. This creates a large-scale plastic sculpture that opens the space outwards to the brim and "illuminates" the perspectival field by rotation, but strongly defines the space from the core. Stops at 10:20. Space is emptied abruptly, one's ear is searching for cues and is directed to:	Space encompassing *KP* with low *plasticity*, little *contour*.
	10:20	texture – lasts only 4 seconds – with noise ratios fixed at the IKO at 270°, draws the attention to this point in which the perspective of the space disappears abruptly.	

Note:

The piece can fail due to a noisy environment. But it can, therefore, be performed in places with little wall reflections, since the spatialization 2nd order does not have as great of an impact as 1st order. Performable in concert only under special conditions, such as a small audience (noise level) and not too large of a hall (audience must be in or close to the IKO near-field. Suitable for an installation in loop form; then 30 seconds of "emptiness" must be inserted between the end and beginning.

mirage 4 2015

Length: 7'39''

4 Sections

KP = Kernel Plastic, SP = Spatial Plastic, KSP = Core-Shell Principle, CCW = counterclockwise, CW = clockwise, IKO-Spat-BP = IKO-Basic Pattern of Spatialization, Ev = Elevation, Az = Azimuth

Section	Time	Description	Commentary
1			
(a)	0:00	Onset click marks the beginning, both by excitation of the environment as well as focusing attention on the one starting point as a coordinate in the perspectival field. Sculptural construction begins with spatial plastic as a space-enclosing formation: in the meantime, a simple rotation becomes a spiral with 80 °/s CCW. After ten seconds, condensation becomes so strong in the center around the IKO that the sculptural body-space relation is compressed to kernel plasticity. Uniform click chain (0:20 - 0:25) supports the direction of movement and thus the contour. At 0:42, the kernel plastic's process aborts.	*Echolocation* 1st order, *SP*> *KP* 6 from Index of Etudes I, expansive. *Spiral* as a special rotation of the IKO-Spat-BP. Through the click chain, the supposed amorphous receives position-dependent, sculptural structuring with a clear direction. Strong contouring by adding a transient element. *Directionality* shifts between *echolocation* 2nd order in the sculptural sound space itself.
	0:44	Again onset click, new entrance, counter rotation of the same material, also a spiral at double the speed 160 °/s CW, but slightly quieter and with less bass, thus less IKO-centered than before: Creates other space coordinates, is imperceptible as a rotation in the difference to the first rotation. That means what happens on the screen is not heard as a trajectory, but perceived as as a plastic texture. An offset click ends the process and draws attention to the spot in the room, where, after 3 seconds, >	*Echolocation* 1st order, *SP* 9 from Index of Etudes I, space encompassing, contoured slightly weaker. No *plasticity*. *Directionality* outwards.
(b)	>1:05	the counter rotation CCW with similar, but further spread spectral material as an fm-surface (metallic tone) enters. That means the vertical is emphasized. At 1:14, between 60 Hz and 90 Hz, a bass is introduced as an extension of the room and demarcation on the floor/foundation. Spiral rotation with different	*Spatialization* 1st order, *SP as* spatial mark, space encompassing. Almost *uniform in contour*, low *plasticity*. *Echolocation* 2nd

		accelerations creates different focal points in the perspectival field. Long on-offset times of the texture create streaks that flow around a space. No stable kernel formation. 1:24 - 1:27 thematic resumption of the uniform click chain with rotation CW also at 160 °/s. Attention is tied to the IKO center and briefly reversed. Then again use of the metallic, space encompassing sound streaks with different places where attention is focused. Ends again with offset click (1:36), which is also an onset click for a high, constant, IKO-bound tone at 950 Hz (ends 1:42).	order through a click chain, short-term increase of *plasticity* by depth gradation of the material. *Contouring* by counter-rotation of the clicks. Again as above *Echolocation* 1st order, *SP as* spatial curve.
(c)	1:44	Construction of a porous kernel through the rotation of a fluctuating click/burst-chain with a distinct trajectory CW 160 °/s. Simultaneously looped frequency-modulated texture as vertical overlying space opening, CCW moves nearly undetectably below the equator. Actually uniform in contour, but through the clicks integration into a plastic, overall formation with attention focused close to the IKO.	*KSP*, space-consuming. *Plasticity* by depth gradation of the heterogeneous material.
	1:54	Switch to fast bass pulse with a synchronized click chain as a spiral with 90 °/s CCW. Bass is clearly perceptible at the IKO, pulsates omnidirectionally evenly into the environment and, depending on the acoustic properties of the room, excites the location differently, while the clicking on the spiral trajectory with different distances and localized points of focus moves the attention over the IKO surface. From 2:01 the entrance of glittering, metallic f-m and amplitude-modulated sound mixture between 6500 and 11,000 Hz, rotates through a light and linear increase in volume over 30 seconds from the center upwards. Emphasizing the height of the room vertically above the bass plinth. Attention is saturated through repetition. Sudden break empties the room and dissolves it instantaneously.	*KSP* 7 from Index of Etudes. Upward *spiral* as a special rotation of the IKO-Spat-BP. The orbital tracks are *uniform in their contour*, but staggered in space with the other textures. *Plasticity* through depth gradation of the material at the IKO. *Spatialization* 1st and 2nd order creates *contouring* of the space constituting sculptural form by the rapid movement of clicks.
	2:24 - 2:30	Silence, clearly longer than the previous interruptions. Serves as transition and thereby a concentration amplifier. Raises the attention again for the next sculptural shaping:	
2			
	2:30	Begins with an onset click, realignment of attention at the IKO. First, construction of a simple, spatial plastic formation by two opposing rotations of two drone textures:	
	2:32	Entrance 1	*SP*, space encompassing,

		establishes slow motion at 97 °/sec CCW, but as a spiral with different acceleration moments.	*spiral as a special rotation of the IKO-Spat-BP*
	2:47	Entrance 2 rotates evenly but faster 160 °/sec CW, this leads to shell gradations, which through	*SP* 7 from Index of Etudes I
	>3:01	the linking of transient, uniform and percussive clicks are meshed into a kernel-shell formation, similar to 1c). Direction of movement changes three times (3:08 CCW, 3:21 CW, 3:40 CCW) at the end of a semi-circular movement along the equator. As a result, the kernel takes on different directions and thus the overall structure receives different emphasis of attention. The various shell-kernel rotations emphasize different spatial gradations of the material by the various reflection paths and direct sound, which also change the background and foreground.	KSP 8 from Index of Etudes. Contouring through kernel rotation, increased *plasticity* through depth gradation of the textures. Change of *directionality* as a function of the kernel rotation. Broadening of the panorama as *relief formation* outside the *IKO near-field*.
		Similar to 1, ends abruptly, but on a transient-rich very quiet miniature sound, which redirects the directionality back to the center, where the space then disappears from attention in one spot.	*Directionality* set to the center.
3			
	3:49 4:05	Entrance begins below the last level of volume with the same (see 2:01) f-m and amplitude-modulated sound mixture between 6500 and 11,000Hz, but as subtle spatial curve, just audible enough to bind the attention centrally over the IKO. Successive construction of another spatial plastic. Through opposing rotations, initially slightly offset: Over-directed noise texture (1) with bandpass between 450 and 550 Hz, CW spiral and high-pass filtered, strongly amplitude-modulated texture (2) between 600 Hz and 2200 Hz CCW both form distinct mirror sources on the reflective surfaces with different coordinates as spatial boundaries.	*SP as* spatial curve, space binding through *spatialization* 1st and 2nd order, uniform in contour, no plasticity, *Directionality* is set towards the center and the vertical (above). Uniform in contour. Opposing *spirals* as special rotations of the IKO-Spat-BP create an *SP as* spatial mark, space encompassing. At times a *beacon*.
	4:17	Alternating again (2)	
	4:24	Again (1), focused attention shifts continuously in the mesh.	The high noise components in both textures and significant amplitude modulations make *spatialization* 2nd order easy to perceive and create strong *contours* of the spatial plastic. The *directionality* constantly wanders along the

			reflections on the outer surfaces and the respective trajectories; especially between left and right in the panorama and behind.
	4:29	Entrance of the same texture (3) as in 1 at 0:43 but with much faster rotation (180 °/sec CW). Creates third rotation plane in the spatial plastic texture. All rotations in this part move differently in time and direction, which, depending on the shielding by the IKO, produces filter effects and, through the sound character of the wall reflections, leads to different spreads of the sculptural form in the perspectival field, with attention focused on different spots.	High *plasticity* through depth gradation of the material. Strong contouring through position-dependent perception of the spatial expansion of the sculptural process.
	4:38	(1)	
	4:47	Layering of (1) and (2)	For the first time in the piece, no transient sounds are used for alignment or structuring.
	4:55	Termination of (1)	The sequence consists of several sliding movements around a cavity that varies in spatial volume.
	5:03	Termination of (2) and (3)	Due to the swirling, there is no unique position-dependent *directionality*. There is only a varying inside and outside though the sound gradation.
	5:03	Ends with the same sound object as in 1:38 (1b) as spatial delineation; pulls the space in one point upwards. Narrows vertically.	*SP as* space binding spatial delineation.
4			
	5:13	Direct wrapping as tissue from beats between 2100 Hz and 9000 Hz, above the equator, spiral 160 °/s CW. No grounding of the sculptural form, a plane is drawn in the room. Attention span shortens though burst chain and clicks at>	*SP 8* from Index of Etudes, as a space encompassing body-space relation, low *plasticity* but with different *contours*. *Spatialization* 1st order opens the space vertically, *spatialization* 2 order locates the sculptural shaping in the perspectival field. Outside the *IKO near-field*, significant shifts on the screen between left-right-left.

	> 5:50	directed to the IKO center, the sculptural shaping is fragmented, then broken off. Offset click.	*Directionality* is set to the IKO. The space is pulled together, the sculptural form is dissolved.
	6:06-6:09	Silence as a void. Transition	
	6:09	Onset click draws attention back to the IKO, new starting point for the guiding of one's attention. Fresh entrance of the texture from 5:13 as a floating plane.	*SP*, see above.
	6:20	Entrance of a dark texture between 100 Hz and 200 Hz radiates omnidirectionally and marks the other end of the vertical at the ground, creating an attention-grabbing kernel at the IKO which almost fills the floating texture's envelope. Attention switches between the outer tracks and the kernel of the two textures.	*KP* 5 from Index of Etudes, but here as *KSP*, since the first texture prevails in capturing attention. Depth gradation of textures increases the *plasticity*. Strong contouring.
	7:14	The large sculptural formation is complete. By alternating counter-rotating semicircle movements, a series of bursts and clicks creates at the end a small-scale plastic that draws attention to their details and shows various aspects of contouring in low plasticity.	*Echolocation* 1st order incorporates the acoustic properties of the environment, connecting them simultaneously by emphasizing different directions on the equatorial plane in a sculptural object. *SP as* space binding spatial mark.
	7:32-7.38	Finely textured sound mixture around 7200 Hz draws complete attention to itself and thus upwards toward the ceiling. As a result, the room merges together again to one point and disappears there when the sound stops.	*SP as* spatial delineation, space binding, *Spatialization 1st order* sets the directionality in elevation to a point above the IKO. No plasticity, uniform in contour.

Note:

Most used onset / offset clicks are not heard outside the IKO near-field. This results in less depth gradation and coordinate formation. But, therefore causes clear left-right relief formation with undercuts as well as foreground and background formation in the rotations.

mirage 5 2016

Length: 12'36''

6 Sections

KP = Kernel Plastic, SP = Spatial Plastic, KSP = Kernel-Shell Principle, CCW = counterclockwise, CW = clockwise, IKO-Spat-BP = IKO-Basic Pattern of Spatialization, Ev = Elevation, Az = Azimuth

Section	Time	Description	Commentary
1			
(a)	0:00	Burst as quiet onset click: the place with its acoustic properties is stimulated and thus directly included in the composition as a space. At the same time, attention is drawn directly to a point at the IKO. Direct connection of a rotating, even chain of clicks as space-consuming small plastic, gathers the attention at the IKO with different local emphasis on the trajectory 160/° CCW.	*Echolocation of the first order*. *KP,* expansive, rotation as IKO-Spat-BP. Directionality put at the center, strong contouring despite low volume and little propagation in the perspective field.
	0:04	Entrance of fm-sound-mix (metallic rays) opens the space upwards (between 550 and 1200 Hz). Spiral shaped swirling 190°/s CCW alternately above and below the equator, generates coordinates, accentuates them by rhythmic beating in the perspective field with different distances to the IKO.	*SP,* as spatial mark, space-encompassing, *Spatial Beating*, *Spiral as a special rotation*, creates weak c*ontouring*. No plasticity. *Directionality* set upwards on the vertical.
	0:07	From here again the same clicks and bursts as markers (0:07, 0:10, 0:13, 0:22) of different directions (frontal/sideways/behind) with different spatial effects: as coordinates in the interweaving of the indicated kernel-shell formation in the ongoing fm-sound-mix of 0:04 and as the room stimulant, as at the beginning. Change between inside and outside, foreground and background sets the accents for a position dependent shape in the perspective field. Simultaneous entrance of: mineral hissing at 10 KHz as a barely noticeable but spatially isolated boundary of the sculptural space in the height, continuous height information as elevation.	Brief *KSP*, *Echolocation* 1st and 2nd order. *Directionality* is put briefly on the equator and then again on the shell. *Spatialization 1st order.*
	0.36	Fade out of the fm-surface from 0:04, silence, then clicks, switch to room excitation and marking of three different coordinates on the IKO's surface.	Again, *Echolocation of the first order*
	0:43	Reentry of the fm-surface, but with diagonal rotation through the vertical over azimuth 90°/ -90° between 225° Ev (front right) and 45° Ev (rear left). Less reflective surfaces are animated, sound is situated at the IKO, slight pendulum movement up/down. Attention is thereby IKO-centered.	*SP,* as spatial delineation, space-binding. *Uniform contour*, no plasticity due to a lack of depth gradation.
	1:24	Loud clicking as a free, onset-mark puts attention to the front at 180°. At the same time it animates the environment much	*Directionality* is placed on the front of the IKO, *Echolocation of*

		more than before. Omnidirectional centering of the directly adjacent noise on the IKO's center. Beam is fixed above the equator.	*the first order*, *uniform contour*, no mirror sources, no plasticity.
	1:29 1:41	Reentry of the mineral hiss, very softly. Space is merged in one point by the texture just above the auditory threshold. Barely perceptible, must be adjusted depending on the performance situation.	1:24 - 1:50 Sounds are worked out of silence: Implied SP as spatial mark. Small plastic.
	1:44	Again noise omnidirectional as before, barely any room excitation, attention is tied to the IKO.	
	1:47	Frequency modulation emerges as an implied musical theme, which opens up the space and repeats this again subsequently at 2:29 and 3:57.	
2			
(a)	1:55	Three different beams with noise loops (8-second-long basic units) emphasize through superimposed spatializations (spiral locally at 270°, rotation vertically as before at 0:43, fixed beam at 90°) different directions of an amorphous spatial texture, which spread over and over again and partially collapse. This leads to different emphases of attention. First laterally, then with propagation rear-front, with different foreground and background shifts.	Expansive large plastic, direct as *KP* with much *plasticity*, and multiple *position dependent contours*. Play with *directionality* through the ups and downs of noise bands.
	2:53	Then swelling fm-drone, pushes into the center of the mesh, spectral with focus at 340 Hz, thereby generating an indoor/outdoor order. Spatial formation of the noise texture with alternating directionality (above, middle, side) around the drone drilling in the room, which through successive increase in noise raises more and more on the until now established noise beam horizon and still the core of the kernel-shell proportion remains without being able to exhibit itself alone. The noise bands are too established and are also raised in volume. However, the textures then change foreground and background and thus core and shell. That means between 3:13 and 3:29, the drone envelops the raw texture that becomes the core. At 3:30 the noise stops and the drone returns to the IKO with a long fade-out as the core.	*KSP*, high degree of p*lasticity* due to depth gradation of the textures, changing *Spatialization* 1^{st} *and* 2^{nd} *order*. *Directionality* is put from the kernel to the shell and back again.
	3:35 - 3:40	Isolated core with emphasis of attention at 0° to the backside. Break.	*Directionality* is set to the background.
(b)	3:44 - 4:01	Slowly CCW rotating, softly faded-in texture opens the space upwards (400 - 1900 Hz), gets louder, fixes the attention above the IKO, and emphasizes the vertical.	*Spatialization of the first order*, SP as spatial curve, space-binding.
	3:51 - 3:55	Slow CCW rotating chain of clicks supports the trajectory at the IKO and sets a core-plastic relationship for a moment. Space has no grounding, is oriented upwards from the equator (clicks). At 3:57: Bracketing - the motif of the end 1 (1:43) reappears with the same spatialization pattern, again as the conclusion of	*KSP*, *Echolocation of the second order* Again *SP*

		the sculptural formation.	
	4:03 - 4:16	Entrance of bass drone (42-118Hz), slowly faded in. First as an extension of the room downwards, then louder and louder, it consumes all other sounds and displaces the previous space entirely.	*K-KSP,* space-superseding, *uniform contour*, no plasticity
3			
	4:17	Forming of a staggered grain structure of several directions of motion at the IKO, which is spatially consumed in an omnidirectional bass drone, which initially acts as enveloping and thus establishes a kernel-shell constellation.	*KP-KSP*, *Plasticity* through depth gradation of the sound textures *Directionality* IKO-centered.
	5:13	After the break of the grain construction (gutting) the bass drone raised in volume over time remains monolithic in space and has no internal structure, similar to the drone at the end of section 2 with even greater space excitation/displacement.	*KP*, space-repelling, no plasticity, *uniform contour*
	5:14 5:36 - 539	*Directionality* in the kernel plastic is produced by recurrent, faint transient clicks, which as a core are too small and too few, but gather the attention. Already at the beginning (0:01, cropped there as *Echolocation of the first order*) introduced grain chains on the orbital path give the drone depth gradation and inform about the spatial conditions through their consumption in the kernel plastic.	*Plasticity* is generated selectively. Brief contouring. *Echolocation of the second order*. At a distance from the *IKO near-field*, strong *relief formation* with foreground and background.
4			
	5:49	Opposite to section 3, plastic spatial formation of circular (various rotations through the vertical with 280°/s) fine, very faint grains. Bind the attention firstly to the IKO.	Omnidirectional *KP* or r*elief formation* without *plasticity*
	6:05-7:56	Entrance of fluctuating, gleaming fm-textures (1) with string onsets, rotate CCW 160°/s. Leads to envelopment, the grain structure almost disappears from the attention, but continues. At >	Becomes a SP as spatial mark, space-encompassing. *Contouring* through position dependent perception, Propagation in the perspectival field.
	> 6:34	the entrance of faint, pulsating bass (30-70 Hz) and high tone (2) (around 1700 Hz) marks the vertical in both directions, spanning the space in which the sculptural form is clamped:	*Spatialization of the first order*.
	6:35 - 6:40	The omnidirectional noise of section 1 (1:24, 1:44, etc.) appears closely at the IKO and briefly forms a coordinate in space.	*Plasticity* is raised.
	> 6:46	Texture (1) is used in conjunction with (2) for the spatial delineation until the entrance of the drone bass known from 3 at >	*SP,* as spatial delineation, space-binding
	>7:20	, which lays first behind and then around the plastic, until it consumes them completely and pushes itself into the foreground as in section 3.The grains become factors of plasticity of the newly emerging kernel plastic, which will then be replaced with>	*KP*, space-superseding. *Plasticity* is raised through reappearing grain structure.

	7:38 - 7:43	again omnidirectional radiating noise from section 1 (1:24, 1:44, etc.)	*KP plasticity* is raised.
	>7:49	with the sound of the bass suddenly plummeting into the IKO and ending there with the original spatial plastic texture (1).	*SP,* space-enveloping, *contoured*, little plasticity
5			
	7:59	Cropped texture already indicated in section 1 (1:49) and section 2 (2:29; 3:57) as stratified bands of frequency modulations with exactly the same spatialization as before. Slow rotation CCW 90°/s, opens up the same space expansion and definition, but now as a spatial plastic with bass as a pedestal. Attention is focused on different emphases in the perspective field. Use of directional markers: basses as heavy markings on the vertical foundations at 8:27 and 8:52 and clicks at 8:43 and 9:03, and finally a chain of grains 9:11 - 9:13, again focusing the directionality on the IKO, thus emphasizing a coordinate in space draws to form a starting point for section 6.	*SP as* spatial mark, space-encompassing, d*irectionality* follows the rotation, position dependent c*ontouring*. *Echolocation of the first order*. Temporarily raised *plasticity*.
6			
	9.14 - 9:38	Sphere of click sounds, which by their interlinking and mixed-in noise focus attention around and close to the IKO, is generated by constantly changing beam positions above and below the equator as well as varying rotational speeds.	*Uniform contour of relief*, no plasticity. Implied *SP,* as spatial mark.
	9:29	Faint entrance of bass-drone as hum marks almost imperceptibly the lower end of the vertical space.	*Spatialization* 2nd order
	9:55	Entrance of high-frequency fm streaks (5600 Hz) at the pain threshold, draws attention upwards to the vertical, >	*SP as* spatial delineation, space-binding, *uniform contour*, no plasticity due to a lack of depth gradation of the material.
	> 10:31	followed by in the cents ascending detuned sound textures in the mid-range area, which move the space upwards, and through the uniform rotation (188°/s) create an outer vector, which functions as an envelope as well as a rhythm generator over the passage of time in the state of the sculptural formation. At the same time a static bass-drone holds the foundation on which the sculptural structure is based. It gradually becomes louder over 60 seconds and completely fills the space below the rotation.	*KP*, *first expansive*, then space-superseding, *spatial beating*, s*piral as a special rotation* of the IKO-Spat-BP. *Uniform contour*, little *plasticity*.
	11:35	Cent-wise tuning down in 4 seconds, the sculptural shaping ends a bit above head height. Bass also drops.	
	11: 58	Ends with small plastic made of rotating grain chains with different lengths that mark different directions of the sculptural form and mesh around the IKO a spatial plastic mesh. The attention jumps with the different entrances and follows the trajectories. The completely superseded environmental space is now again selectively stimulated and thus part of the shaping of the plastic.	*SP as* spatial mark, space-binding. *Directionality* changes multiple times at the IKO's center. *Contour*ing through a rotating *change of emphasis. Echolocation of the first order*.

mirage 6 2016

Length: 12'14''

4 Sections

KP = Kernel plastic, SP = Spatial plastic, KSP = Kernel-Shell principle, CCW = counter-clockwise, CW = clockwise, IKO-Spat-BP = IKO-Basic Pattern of Spatialization, Ev = Elevation, Az = Azimuth

Section	Time	Description	Commentary
1			
(a)	0:00	Starts with a kernel-shell constellation with changing attentional direction through the beam's rotation. No superseding body-space relationship despite kernel formation, rather intermittently involving, with different attention emphases in relation to shell and kernel. Through short, clearly looped sequences in low frequencies, attention is tied and fixed to the core. After this locating act serves as an introduction, the situation changes >	*KSP* as small plastic The directionality of the sculptural form takes on a spatial initial constellation in the center.
	> 0:07	directly into the sculptural state, which consists of a mixture of superimposed frequency modulations that expands the space upwards and outwards and then pushes into the foreground as a kernel plastic for the moment. It is clearly possible to hear the "beating" of the interferences, which gives rhythm to the passage of time and structures the texture. The beam comes from over the front-right counter-clockwise and at >	Kernel formation, with IKO-centering
	> 0:18	is fixed at 180°. There it stays, and then the orders are seamlessly reduced over a period of 70 seconds and then raised again (3-0-3).	*Distance fade* as IKO-Spat-BP, cf. also Listening Experiment 3. Little plasticity due to a lack of depth gradation.
	0:22-0:48	The core is dissolved through the initial raising and lowering of the orders: the omnidirectional radiation takes the intensity out of the center and emphasizes the periphery. The radiation gets an immersive character (in the sense of an envelope of sound) that emphasizes a spatial plastic body-space relationship. This dissolves once again as the order increases. The emphasis of attention is again on the IKO, almost going into it.	*KP*, space-repelling becomes SP as space-encompassing body-space relationship. Change of *directionality* inward-outward-inward. During the fade, *contouring* due to the position dependent coloring of the orders-distance fades. Omnidirectionality in the 0th order causes *uniform contour*.
	0:53-1:03	Through the second reduction, the space-encompassing state of the envelopment is again brought about by simple repetition of the movement pattern. Again, the beam is at 180°, having therefore the least reflection on the side walls.	Weak *plasticity* due to a lack of depth gradation, but renewed contouring of the sculptural phenomenon, since the intensity of the envelopment is

			position-dependent. The formation of the plastic is perceived as a *relief* outside the *IKO-near field*.
	1:04	Then the beam is faded vertically under and through the IKO, while the order is reduced to 0 again. Meaning at this moment, the fade due to a lack of directivity is not heard. Only when the beam is at 0° is the order increased again and the beam goes back to 180°, while the directivity is increased again and thus the sculptural weighting at the IKO bundled. Attention is gathered until the beam >	Change in *directionality*. *Uniform contour* of the transition into the next sculptural condition.
	> 1:26	moves from its position 180° with 3rd order at the equator CCW and clearly perceptible on the surface to behind the IKO, where the trajectory is briefly lost (1:44) because the wall reflection at 0° throws the sound back directly onto the IKO until the beam reappears at 90°. >	*Distance fade* and *panning* as IKO-Spat-BP
	> 1:50 - 2:09	Until there, the beam is followed. It then fades out over 20 seconds. Attention is gathered on the far left between 45° and 90°.	Overall in 1 (a) low plasticity. Weak *relief formation* when distant from the *IKO near-field*, then due to a lack of envelopment, no depth gradation and also little distribution on the horizontal is perceptible. Therefore the dimensional attributes are omitted outside the near-field.
(b)	2:13	Starts with a similar sound mixture as in (a) but with less defined highs, but more noise in the beam. This is fixed at 270°, i.e. opposite the end point of (a). The noise can be heard far outside in the direction of the wall as a mirror source, shifts the focus of attention smoothly to the right and thus forms a spatial-plastic coordinate, which can be heard from several positions in the room with different propagations. Bass elements are fixed at the IKO. Then the order is once again reduced to 0, so that the focus is shifted to the left on the IKO and even breaks out on the left. This movement is comprehensible from several listening positions with different propagations of texture.	Horizontal *axis fade* (right to left) as IKO-Spat-BP. Or slow *pendulum movement*. *Kernel-shell-constellation*. Image scheme "path" activated "auditory motion looming." Contouring of the body-space relationship.
	2:30 - 2:45	Here the movement lingers for a moment and then fades out by re-increasing the order on the right back to the original coordinate at 270° on the right wall, where it stops and clearly gathers the concentration again, until >	*Directionality* shifts on the left-right axis.
	> 2:49 - 3:03	From here the beam goes around the front left, CW up to 0°. The noise can be heard far outside, forming a slowly moving outer texture and defining a spatial plastic envelopment. >	*Beacon*, *SP,* space-encompassing
	> 2:59	The entrance of the fm-metallic ray (see Miniatures 37 ff and listening test 3) with a beam rotating CCW at 141°/s opens the sculptural alignment upwards and defines the room height, simultaneously changes the position at the core, and is circumnavigated by the noise and thus formed and defined as an interior.	*KSP*, *spiral* as IKO-Spat-BP, *directionality* changes, *plasticity* created through depth gradation of the sound levels.

	3:03 - 3:55	The low frequencies remain consistently at the IKO. At the end, the beam with the noise components moves slowly CCW back to 270° over a period of 21 seconds, where it stops and forms the established coordinate on the outside right again, until it disappears there by way of a fade.	*Directionality* is set to an outer coordinate at the end.
	3:30	The metallic rays are replaced by a transient, rhythmic chain of amplitude-modulated clicks, which are localized at the IKO and lower the ceiling height with their entrance. Through the perception of this transient-rich texture, attention is temporarily focused on the center. There is a brief increase in the plasticity by means of rapid spiral rotation, the depth gradation becomes clearer, but the slowly pulsating bass with a slight CCW rotation and noise with the spatial coordinate to the right (270°) ebbs. This turns the kernel-shell formation into a nucleus that attracts attention to the core. The bass emphasizes the pedestal of the new sculptural kernel formation.	*KSP > KP. Echolocation 1st order* involves the surrounding space in the sculptural form. *Plasticity* is raised, *Directionality* changes with the rotation outwards, then to the center.
	3:37 - 3:56	Metallic fm-streaks are spirally threaded around the center, staggered between the bass and the percussive sequence (spiral CCW, 183°/s) of the clicks, simultaneously reopening upwards in alternation with the bass, swirling through to a heterogeneous tissue.	*Plasticity* is high, strong contouring, *Spiral as a special rotation* of the IKO-Spat-BP.
	3:56 - 4:04	Pulsating bass leads into the second part, capturing the attention in the space and reducing the sculptural shaping back to the kernel. The sculpture is oriented vertically towards the ground.	*Directionality* is placed on the center and towards the ground.
	4:08 - 4:16	Second streak returns as a motive, supports the focus on the center and newly marks the vertical with the bass (above/below).	
	4:17 - 4:24	Entrance of a second percussive element with high-frequency transient components, also emphasizing IKO centering, scales the plastic to small plastic, changing the direction of attention. By alternating strong structuring successively over time and through spatial layering, plasticity and contouring are reduced.	*Echolocation of the first- and second order* animates the environment, but is partially overlaid from below by the bass-layer. *Large plastic* becomes a *small plastic* with a *uniform contoured* shape.
	4:24 - 4:42	18 seconds of silence to re-activate the place superseded by the sculptural forms in 1 and to send one's ear on a search for the sound in the surrounding space. The intensity of the events of the first 4.5 minutes is completely undermined by the length of the silence, in order to set up the concentration for a second sculptural shaping through tension.	
2			
(a)	4:42	Entrance of a distant, faint sound; omnidirectional, only beating, nearly vocal, humming, with faint bass elements. Formation takes place in the bass's mid-range between 150 and 400 Hz. The implied kernel decays in the lower frequencies, followed by an	*Spatialization of the first order*, in the plain static at first. *SP as* spatial curve, raises the *plasticity*,

		opening upwards through the high sine wave of 1700 Hz, depth gradation between the two elements, supplemented by >	*uniform contour* of the shape.
	5:29- 5:35	a short sequence with noise CCW panning pendulum motion, bypasses the center, reflections mark spatial boundaries, and leads over >	*Pendulum* as a special rotation of the IKO-Spat-BP, *contours* the sculptural shape.
	> 5:36	a new motive, coordinate placement through slow CCW rotation, rhythmically spotted, mallet-like around the IKO, with little distance to the surface, little depth gradation of the spatialized (2nd order) material.	SP, as spatial mark. Dissolution of *plasticity*.
	5:56	Ends at the IKO through a faint, transient chain, which set at 270°, is perceived as on the surface. Directionality falls back to a point where it is directly replaced by: >	*Echolocation of the first order* stimulates the environment in this direction.
(b)	> 5:58	Digital crackling, fluctuating. Spiral centering around the IKO with the material different distances to the surface. Attention follows the position dependent emphases of the rotations.	*Relief formation*, *spiral shaped* rotation increases *plasticity* in the material.
	6:07 - 6:13	Spatial plastic through rotation 1, frequency-modulated surface - pushes spirally outwards and upwards on the vertical. Position dependent emphases on the reflective surfaces	*Beacon*, SP. Change of *directionality* from inward to outward and *spatialization of the first order* opens the space upwards. No plasticity, strong *contouring*.
	6:14 - 6:26	Digital crackling with the same sculptural propagation. Attention is concentrated again toward the inside.	*Directionality* changes from inward to outward.
	6:27 6:32 6:50	CCW sequence of 3 spirals (similar to rotation 1) on outer orbital path trajectories. All spirals with exactly the same rotation pattern successively create different spacings around a cavity.	*Spiral as a special rotation* of the IKO-Spat-BP, creates SP. Weak *contouring*.
3			
(a)	7:01 - 8:23 at 7:20	Frequency-modulating, organ-like sound affects space-binding in the foreground with vertical directionality upwards. Simultaneous entrance of: fluctuating burst chain moves CW from 270° to 0° at the IKO and stops there. Surrounding space is stimulated, then the bursts are superimposed by the organ sound and entangled in a sound space. Thereby no kernel formation at the IKO. Simultaneous entrance of soft bass pulses as a pedestal for the sculptural sound shaping in the vertical (until 7:13 and then again from 7:18). No kernel formation due to the volume gradation between the elements and also through the bass. Second entrance of the bursts enveloped/limited by carpeting surface sound.	*SP as* spatial delineation, through *spatialization of the first order*. Echolocation 1st and 2nd order describe the space. *Uniform contour*. *Echolocation of the second order*
	7:33	Barely perceptible CCW rotation with a sound object around 690 Hz, remains as an acoustic horizon in the background, slightly changes the sculptural form in width and depth.	Faint changes in *contour*

	7:40	Implied space gradation through a noise drone fading in and out. Overall, static alignment in the vertical outweighs the fixation at the highest point in the surface of the organ sound.	*SP takes on a core and loses it again. Plasticity* will be increased briefly. At the end again for a moment spatial delineation (8: 09-8: 11). Directionality set on the vertical.
(b)	8:12	"Organ" sound dies out, becoming a background. FM-modulated midrange interferences (around 330Hz) slowly rotate CCW from 0° to 180° to 200°, lowering the room and focusing attention on the IKO. Space-superseded material trajectories (8:45: - 8:55) from the rear right over the zenith to the front left, back over the zenith, in half the time to 270° and from there under the IKO after 90°. This movement is not heard as such, but it turns into a spatial streak, which can be perceived as a bow movement or bulge from the kernel into the surroundings and back.	*SP,* spatial delineation becomes a KP with opened mass volume, directionality changes from outwards to inwards and upwards in the direction of the middle. Little depth gradation, little *plasticity*.
	8:46 - 8:54	Two sinusoidal, sweep-like downward runs complete the sculpture and focus attention at hip height at the IKO.	*Uniform contour* spatial texture, merged into a point in space.
4			
	8:57	Drone (see miniature 20 ff) with noise starts with CCW spiral rotation 180°/s, thereby scanning the spatial boundaries and circumscribing the contour of the outer shell. Bass forms second center statically as the kernel at the IKO until >	*Beacon*, KSP, depth gradation creates *plasticity*.
	> 9:18	There it stays at 180°, concentrating attention on the IKO at that point and then in 5 seconds at 9:20 moves under the IKO as a linear trajectory, which is perceived as a significant shift of emphasis to the back. This creates a filter effect that colors the kernel differently.	Change in *directionality* through vertical *panning*. Depth gradation through *panning* and simultaneous *rotation* of the heterogeneous sound material. Strong position dependent contouring of the sculptural form on the floor and the walls.
	9:31	The drone breaks off at the back and draws attention to the (8:57) parallel running, counter-rotating trajectories (high-frequency noise as a slow circular movement and bright sound mixture with harmonic proportions as accelerated spiral movement). These penetrating rotations are perceived as a small plastic element above the IKO. Fade-out of the sculptural form, the space is briefly emptied.	Core is omitted. *Spiral as a special rotation*. Space-enveloping SP remains. *Directionality* shifts from behind/below, towards the center and spectrally into the height.
	9:36	At this point the recapitulation of 1 a) takes over at this spatial position with the same sound material and identical spatialization.	
	> 10:47	The recap, however, gets another center or is superimposed by an	*KP* becomes *KSP*,

		elevation coordinate and modeled in height. Organ-like sound from 3 fades in. Change depending on order and trajectory between foreground and background between the two textures. Ends on the organ-like sound with a high sine wave as the space's outermost point (above)	increasing *plasticity.* Nearly *uniform contour* through Orders-Distance fade. Then transitions to an SP as spatial delineation.
	12:09	with full attention retained, and thus full directionality. Panning to the right side (260°) and back again to the middle as a clear but short contour change towards the end point.	*Spatialization* of the first- and second order

3. Summary and Closing Observations

In this work sculptural sound phenomena in computer music are examined as repeatedly described since the early years of space-sound composition with loudspeakers. This first began with a search for clues, starting in my own field of experience, such as concert and compositional practice thus far, the handling of different loudspeaker systems, special interest in the IKO, and initial compositional analyses. This research-based movement was driven by my artistic interest in space, meaning the sensitization of space through art and in art. The work saw itself from the outset as involvement in a search for a different - auditory - spatial aesthetic.

The central question was whether others could even comprehend the space-sound phenomena I composed in the laboratory situation. An uncertainty in the current practice of concerts with loudspeakers that constantly arises. This uncertainty was unsatisfactory for my compositional practice because the reference to and the refinement of perceptions with the means of the electroacoustic space-sound composition is impossible without a thorough knowledge of this perceptibility. From this uncertainty I formulated the question of the intersubjective space of perception of these sculptural phenomena, since the desideratum arising from it has taken shape as *Shared Perceptual Space (SPS).* To be able to describe this space, the search for references had to be extended to the adjacent fields of music and engineering sciences. In my practice of artistic research, this has always happened through provocation from experiences in the areas bordering terminology. At the same time, I regularly came across the question of whether spatial listening experience in the area of loudspeaker music is able to be made objective and, as a result, can be communicated. A fundamental problem of sound research. If I would like to share the results of my work with other researchers in order to foster an exchange of thoughts and to examine my own results (for example the index of miniatures) I must find an interchangeable manifestation of this experience. This is difficult in the absence of a generally accepted vocabulary regarding spatialized sound objects. Therefore I had to carve out terms that I could verify on account of their generalizability and make available for use in the vernacular. For this purpose, extensive investigations into the basic concepts of sound, sculpture and space, and research into the state of the verbalization of sound and spatial sound in the history of sound art and computer music was carried out. Although many basic texts, such as the Schaeffers or Smalleys, are widely known and commented on, it was essential to read them with my research questions in mind and to relate them to the approaches of younger authors.

At the same time, the question was also to be asked about how to objectivize knowledge about a research object that is ephemeral, changes its consistence in time, and can hardly be visualized. In the history of science, a text or image as the basis for a gain in knowledge, its mediation and critical discussion is traditionally required. But how do we research "something" whose object is difficult to create objective distance to? Salomé Voegelin describes the problem similarly:

> *Sound's ephemeral invisibility obstructs critical engagement, while the apparent stability of the image invites criticism* [Voegelin, 2010, xi]. [...] *Seeing happens in a meta-position, away from the seen, however close. And the distance enables a detachment and objectivity that presents itself as truth.* [Voegelin, 2010, xii]

And further:

> *Hearing does not offer a meta-position; there is no place where I am not simultaneous with the heard. However far its source, the sound sits in my ear*. [ibid.]

In order to be able to develop research questions, methods and conclusions in the sense of an epistemic research process outside the visual transformation of the research object, a research environment had to be created which places the subjective listening experience at the center of interest in order to investigate the spatial experience of sound objects, and thus to make the critical debate possible at all. How this was achieved is exemplified by the preliminary experiment 3: Although in Mono, the stimuli derived from the spatialized etudes led to an evaluation by the subjects, which coincided with the original body-space relations of the etudes. Though this confirmed the close connection between the *spatializations of the first and second order*, it could not say anything about the perception of the "spatial" outside the spectral verticality. The results obtained in the preliminary experiment 3 led as a reflex, however, to the artistic question of the composition and the spatial impact of the compositional material used. Therefore, in the research practice, the iterative process, which was originally established for the structuring of the project, became an analogous overall movement, which considers the aspects of individual stages simultaneously and works on their implementation.

Because of the listening experiments, we now know that there is an intersubjective perception of spatial sound objects. A hierarchical model of the complexity planes 1 - 3 was introduced to structure the abundance of possible space-sound constellations. On the third level, the body-space relations derived from the scholastic writings on sculpture were identified, which I have described as sculptural sound phenomena.

The historical investigation of sound sculptures served to classify the IKO as an object and sound projector in this area. The IKO was not the main object of the investigation.

Rather, it was about the artistically placed (acoustic) field and the phenomena that the IKO co-created and is a part of. The IKO had thereby a burning glass function because it is suited to bring topics of composition and performance practice in the field of computer music to a head. Therefore without an appropriate discussion of the potentials and effects of this media technology, SPS cannot be described and composed as a common space for the perception of the audience, scientists, and composers.

We as composers have never confronted a machine of the collective, networked, and externally defined media perception design as we experience it today. So what do we share with our audience, the engineers and scientists working on perceptions in media spaces, and how can we still detect potential for aesthetic experiences and make them useful for the acoustic arts? It seems to me unavoidable that this question causes us to fall back on our ears and the reflection of what is experienced and experienceable in situ. As shown, a specific cultural context arises in the perception situation of the acousmatic paradigm. That which is conceptualized and that which is experienced in the studio or the laboratory is not played back in the sense of a discretization of the former. Rather, the *present* is made differently *experienceable*. In order to support the search for the shaping conditions for this aesthetic experience, I have pointed out that the concept of space has changed fundamentally over the last century. However, in computer music composition the term is stagnant and largely unproductive. Taking into account different approaches to the absolute and relative concept of space, I have elaborated upon criteria of the spatial description in this work in order to be able to determine the SPS and the phenomena possible therein more accurately. As a result of the presented text, the six space-sound compositions mirage 1 - 6 are available, which make the findings from the laboratory and the composition and performance practice of the last years in turn experienceable as - *sound as space*.

List of Figures

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AUDIO

All audio recordings can be found on the accompanying SD card and can be downloaded online (10 GB). Data format: 44.1 KHz, 24 Bit, Wav, impulse responses, Lecture Hall - Petersgasse 116, Graz, binaural rendered stereo files.

List of Compositions for the IKO

Pre-mirage: Compositions for the IKO before the listening based research process

(www.gksh.net/downloads/Pre_mirage.zip) or SD-card

1.) grrawe, 10'37'' (2010)

2.) firniss, 11'34'' (2012)

3.) grafik unten, 18'06'' (2014)

mirage 1 - 6

(www.gksh.net/downloads/mirage1_6.zip) or SD-card

Studies and Listening Experiments

or SD card

Listening examples

The listening examples should serve as a direct explanation of each respective term and as well support one's orientation while reading the thesis. Each term also contains additional examples of use in the *Index of Miniatures* and the analyses from mirage 1-6.

(www.gksh.net/downloads/HB.zip) or SD card

List of Download Links

www.gksh.net/downloads/Indx_Miniaturen.zip

www.gksh.net/downloads/Pre_mirage.zip

www.gksh.net/downloads/gksh_HV1_3.zip

www.gksh.net/downloads/mirage1_6.zip

www.gksh.net/downloads/HB.zip

www.gksh.net/downloads/Zagreb_GAL_PAV.zip

SD card

The attached SD card contains all the compositions and listening examples. The main concern here is binaural renderings or binaural recordings. Please use headphones when listening.

Folder structure

A

01: Index of Miniatures, all miniatures from two listening positions (P1 / P2)

02: All stimuli of listening experiments 1 and 2, as well as of preliminary experiment 3 and listening experiment 3

03: All the listening examples listed in the text at the appropriate places (1- 23)

04: The compositions grrawe, firniss and grafik unten, which were created for the IKO before the listening-based research.

05: The compositions mirage 1-6

06: The composition mirage 1 in two spatial versions: Binaural rendering with the impulse responses of the French Pavilion Zagreb and the impulse responses of the Media Art Gallery Zagreb.

B

As further proof of my spatial researching, artistic activities during the period of the dissertation without the IKO are also on the SD card:

07: Documentation (PDF) of the building-sound composition {kA}: Oblivious to Gravity, commissioned by the Zagreb Music Biennale 2015.

08: Audio documentations of the building-sound composition Zagreb 2015.

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APPENDIX - Index of Miniatures

Length of stimuli 30 seconds each.

Ia - IIId: Static basic descriptions of spatial textures (*Space-sound phenomenon level 1*).

1. - 52: Trajectories and combinations of trajectories and static elements (*Space-sound phenomenon levels 2 and 3*).

Abbreviations:

Stat = Static, Rot = Rotation, Pan = Panning, CCW = counter clockwise, CW = clockwise, Ev = Elevation, Az = Azimuth

KP = Kernel plastic, SP = Spatial plastic, KSP = Kernel-Shell-Principle

Contour[121] = Outline of the same spatial texture dependent on position.

Uniform contour = 1 Aspect = Shape of spatial texture identical from all positions.

Plasticity[122] = Difference between highest and lowest point in the relief.

During the research period, the IKO was placed in the laboratory as shown in Figure 14. This ensured the same listening conditions and situation at all times. Whereby the direction 260° always sounds a bit brighter and higher in altitude than the blackboard side at 0°. This can be attributed to the material-related harder glass reflection in contrast to the chalk board. 90° has weaker wall reflections because the wall is farther away from the IKO and consists of different materials and a height absorber. 180° is missing due to the distance, the attached absorber and the direct focus on the listener at position 1 as a distinct reflection with its own color. Mobile beams deliberately do not consistently start at the same position.

The following table was created in two phases:

A. Summaries of hand notes until October 2015.

B. Application of the terminology derived from scholastic writings on sculpture on the basis of further studies from November 2015.

[121] See Chapter IV. 4.1.3.
[122] See Chapter IV. 4.1.2.

\A. \ B.

Miniature	Sound	Beam	Spatial Processing	Description P1	Description P2	Body-space relationship	Contour	Directionality	Plasticity
Ia	Pink noise	1	Stat 0°	High frequencies clearly behind the IKO with reflection from the blackboard, slightly to the right of 0°. Low frequencies directly at the IKO	On the left side of the board, slightly lower frequencies overall. Low frequencies directly at the IKO	KP, space superseding	Stimulus has a slightly different spread depending on the position. Slight contour differences noticeable.	Attention is focused on the wall, second emphasis at the IKO.	Low plasticity arises despite relative beam homogeneity in relationship between the IKO and wall reflection.
Ib	Pink noise	1	Stat 260°	Clearly to the front right on the glass wall, brighter than Ia, low frequencies closer to the IKO	In front of one's head, behind the IKO on the glass wall, slightly to the right, narrower source, low frequencies at the IKO	KP, space superseding	Depending on the position, stimulus has a slightly different spread, making slight differences in the contour perceptible.	Attention is directed to the wall to the right, second focus at the IKO.	Like Ia, even weaker plasticity in position 2, as the focuses almost coincides.
Ic	Pink noise	1	Stat 180°	Strong in front of the head, right in front at the IKO. Narrow source.	Distinctly discolored, wider source, slightly to the right of the IKO and strongly in front of one's head from the glass wall. Even slight reflection from the back wall to the right.	KP, space superseding	Depending on the position, the stimulus has a significantly different spread, making it possible to perceive pronounced contour differences.	Attention is drawn directly to the IKO in position 1, in position there are two slightly offset centers of gravity, but they almost coincide.	For position 1 no plasticity, no depth gradation. Position 2 even more plastic-like due to offset mirror source.
Id	Pink noise	1	Stat 90°	Left at the IKO and somewhat from the front of the blackboard. Weak, slightly lateral reflection to the right of the glass wall. Low frequencies at the IKO.	Everything in front of one's head, directly on the IKO, very narrow source	KP, space superseding	Stimulus has significantly different spread depending on the position. Strong contour differences noticeable.	At position 1 attention is tied between IKO and background on the left, at position 2 it is drawn directly to the IKO, barely perceptible side effects.	Position 1 by slight depth gradation more plastic than position 2, there only surface.

IIa	Even chain of fine grains	1	Stat 0°	Head to 0°, closer to the IKO and slightly to the left of 0° on the blackboard	Left at the IKO, quieter	SP, as a spatial mark, space binding	Hardly any spatial spread, but changes in tone color and localization shift when changing position lead to contour differences.	Attention is focused exclusively on the IKO.	No spatial depth gradation in the sound event.
IIb	Even chain of fine grains	1	Stat, 260°	Quieter than IIa, straight and right at the IKO, barely from the wall	In front of one's head, wider and louder at the back of the IKO and from the glass wall	SP, as a spatial mark, space binding	Hardly any spatial propagation at position 1, but at position 2. Change in tone color and shift in localization when changing position lead here to striking differences in contour.	In position 1 attention exclusively at the IKO. In position 2 center of gravity extension through the reflection of the glass wall. Remains but IKO-centered.	No depth gradation in the sound event.
IIc	Even chain of fine grains	1	Stat, 180°	Right in front of the head on IKO front, loud, narrow. No clear wall reflection.	Directly on the IKO and right in front of the head, no clear wall reflection	SP, as a spatial mark, space binding.	Both positions are IKO-centered, with no noticeable spatial or tonal changes. *Uniform contour*.	Attention is bound exclusively to the IKO.	No spatial depth gradation in the sound event.
IId	Even chain of fine grains	1	Stat, 90°	Quieter, left at the IKO and slightly from behind at the IKO	Directly on the IKO, in front of your head, louder and narrower	SP, as a spatial mark, space binding	Slight spatial propagation at position 1, none at position 2. Change in tone color and shift in localization when changing position lead here to striking differences in contour.	Attention exclusively on the IKO, in position 1 slight extension of emphasis in the IKO's background, but remains IKO-centered.	No spatial depth gradation in the sound event.
IIIa	Fluctuating sequence of	1	Stat, 0°	Straight ahead on 0°, behind the IKO	Left at the IKO and partly from the	SP, as a spatial mark,	Similar to IIa BUT farther away	Attention is focused towards the IKO slightly	Although burst chains are

	irregular bursts (Soft crackling is neglected in the self-test.)				blackboard, at 35°	space binding	from the IKO's surface	offset from the surface.	staggered in time, spatially they remain constant as a coordinate.
IIIb	Fluctuating sequence of irregular bursts	1	Stat, 260°	Right in front of the head on the IKO and slightly to the left, narrow source, slight glass wall reflection	Behind the IKO in front of head, narrower source than IIIb1, slight glass wall reflection	SP, as a spatial mark, space binding	Similar to II b, but perceptible farther away from the IKO's surface	Attention is focused towards the IKO slightly offset from the surface.	Like IIIa
IIIc	Fluctuating sequence of irregular bursts	1	Stat, 180°	Right in front of the head on the IKO, narrow source	Directly at the IKO, discolored, front and right 180°, slight glass wall reflection	SP, as a spatial mark, space binding	Similar to II c, but noticeable farther away from the IKO's surface	Attention is focused towards the IKO slightly offset from the surface.	Like IIIa
IIId	Fluctuating sequence of irregular bursts	1	Stat, 90°	Left at the IKO and something, on the left behind it on the wall	Directly on the IKO head, narrow source, louder than IIId1	SP, as a spatial mark, space binding	Similar to II d, but perceptible farther away from the IKO's surface.	Attention is focused towards the IKO slightly offset from the surface.	Like IIIa
1	Pink noise	1	Rot, CCW, -45°/s	Circle shape perceptible as CCW, nearly uniform. Low frequencies at the IKO, high frequencies with slight formations towards the walls. Blackboard emphasizes centers. Almost hole at 90°.	Circle shape CCW perceptible, even, sounds louder, a bit more bass at the IKO, glass wall emphasizes heights, blackboard emphasizes middle with volume increase.	KP, expansive	Due to the different reflections and paths, a orbital path morphology occurs when the position changes = contour change.	Attention wanders along the orbital path, but falls back heavily on the IKO if it obscures the orbital path or the wall reflection is too little	Different colorations of the same material as well as layering between IKO and wall reflection produce weak plasticity over time.
2	Pink noise	1	Rot, CCW, -180°/s	Circular form in CCW motion harder to perceive, more fragmented than 1, circle falls back and to the right into the IKO and comes back in the front and to the left.	Circular shape just audible. Blurred pendulum movement between glass wall to about 260° and blackboard at about 45°. Fewer coordinates, less	KP, expansive	Different spatial texture spreads and their colorations lead to different contouring depending on the position.	Depending on the position of the mirror sources CCW, along the coordinates.	Weak, but like 1

				Mirror sources form individual coordinates, which regularly "appear" depending on the speed = *Spatial Beating,* in the first moment pendulum movement is between back right and front left, then goes habitually to the orbital path.	"Spatial Beating"				
3	Pink noise	2	a) Rot, CCW, -45°/s b) Rotation, CW, 180°/s	Difficult to grasp pattern, turbulence coincide again and again, slight lateral shifts between the right front CW and CCW. Vertically increased accumulation on the IKO itself. This results in two elements (static/mobile).	Similar to 3a, but with displacements at 90° and 35°. Also two elements, as IKO is emphasized.	KP, space-repelling	Different spatial texture spreads and their colorations lead position-dependent to different contouring.	The focus is on the pendulum centers and deflections on the walls and then again on the IKO.	Almost homogeneous structure with little depth gradation, thus very low plasticity between static and mobile moments.
4	Pink noise	2	a) Rot, CCW, -180°/s b) Rot, CW, 180°/s	Uniform spatial rhythm, seesaws, front/rear turbulence, lying 8 left, right, front, with brighter background noise. Partially two movements identifiable.	Similar spatial rhythm as 4a, but with more emphasis between blackboard at 45° and direct sound at 90°.	KP, space-repelling, with expansion into the room.	Different spatial texture spreads and their colorations lead position-dependent to different contouring.	Like 3 but with more regular coordinates and corresponding continuous fixed attention.	Swirling of the same material leads to depth gradation. Plasticity of the sculptural form is created.
5	Pink noise	1 + 1 after 15s	a) Stat, rear right, 310° b) Rot, CW, 180°/s	a) Reflection on the back wall, audible diagonally to the right, IKO conceals slightly, slight side reflection glass wall. b) Entrance and CW rotation clearly noticeable, shortly after overlapping with	a) Reflection clearly perceptible in the corner panel/glass wall. b) Entrance clearly perceptible, but rotation rather than pendulum movement between direct (90°), panel and window	a) KP, space superseding b) KP, with expansion into the room.	Like 4, but with additional change of spatial texture in time.	The center of gravity changes with the rotational speed from static rear right, over right front to left front. Both stimuli are still identifiable by the lag in time. Attention jumps between the orbit path and coordinate on the	Like 4, but with additional depth gradation, since a) has been established and can only be identified in the

				a) you hear the IKO-edge in front right.	wall. 180° is almost eliminated due to absorbers. Emphasis on the front left edge.			blackboard.	background as a background. *Relief forming!*
6	a) Even chain of fine grains b) Pink noise	2	a) Stat, rear right, 310° b) Rot, CCW, - 90°/s	a) Audibly fixed, in the back right corner and at the IKO. b) CCW rotation perceptible as a principle, circle with reflections, from slightly left to clearly front right, right back, then falls into the IKO (obscured) and comes to the left front again. Two distinct processes.	a) Audibly fixed, left, but only at the IKO. b) CCW rotation less perceptible but present. Right dissolves, glass wall discolors brightly, blackboard increases the volume of the reflection and emphasizes the mid-range frequencies. Two processes.	KSP	Slight contour change due to positional coordinates and path change	Focus changes between static rear right and the IKO as center and outer track of the beam.	3 levels of gradation, grains, reflections wall and IKO itself, produce differentiated plasticity.
7	a) Even chain of fine grains b) Pink noise	2	a) Rot, CW, + 180°/s b) Rot, CCW, - 90°/s	Two movement directions and speeds are perceptible: Grains inner circular motion at the IKO, outer circular motion of noise with wall reflections.	Counter-movements harder to detect, outer circle breaks in at 180°, sounds only at the IKO and comes back at 30°.	KSP	Increased position-dependent contour change in tone color and spatial extent of the texture	Attention jumps between the opposite directions, multiple focuses, tilt, depending on the reflection left/right or front/behind. Nevertheless, IKO strongly centered.	2 gradations, grains at the IKO through the rotation and reflections on the wall, increase the plasticity (see 6).
8	a) Pink noise b) Even chain of fine grains	2	a) Rot, CW , + 180°/s b) Rot, CCW , - 90°/s	Rapid outer track of noise's orbital path perceptible, *Spatial Beating* 3-4 coordinates. Inner Grain movement audible, but change in speed compared to 7 hardly noticeable, the direction of movement just as difficult.	The outer track is rather elliptical to swirled as the shape of a lying eight. Clearly four coordinates in *Spatial Beating*. Inner grain movement audible, hard to comprehend speed and direction of movement.	KSP	Like 7	Attention as opposed to 7 more on the enveloping shell: Another point of emphasis through acceleration	2 levels: Grains constant on one level at the IKO, reflections on the wall with jump from the reflective surface to the IKO and back.
9	a) Even chain of fine grains	2	a) Rot, CW , + 180°/s	Grains stick to the IKO surface and move about 20 cm above its	Grains stick to the IKO surface and move about 20 cm above	SP as a spatial mark, space binding	Uniform contour	Complete focus on the IKO with slight propagation variations of	A plane with occasional surface

	b) Even chain of fine grains		b) Rot, CCW , - 90°/s	surface. Hardly any depth gradation. Occasional edge movements from right to front (CW).	its surface. Hardly any depth gradation. Occasional edge movements from right to front (CW).	OR *relief forming*		the emphasis. Attention to environment fades.	changes. Due to the rotation, the self-similar texture gets depth.
10	a) Even chain of fine grains b) Even chain of fine grains	1 +1 after 15s	a) Stat, vertical above, 0/93Ev b) Rot, CW, 180°/s	a) Arrives directly static from the IKO, elevation not consciously perceptible b) Insertion and direction clearly perceptible, after one revolution only one process of rotation perceptible. Micro-rhythm formation between the staggered grains from a) and b) plus rotation rhythm formation.	No difference	a) SP as spatial mark, space-binding b) *Relief formation*	Uniform contour	Complete focus on the IKO. Attention to environment fades After 15s left-right shifts.	Coordinate becomes surface with temporary surface change. After 15 seconds, depth gradation in the material emerges.
11	a) Even chain of fine grains b) Even chain of fine grains	1 + 1 after 15s	a) Stat, rear right, 310° b) Rot, CW, 180°/s	a) Fixed as a coordinate at the back of the IKO and with slight wall reflections from this direction. b) Entrance perceptible but difficult. After two turns blurring of the event. Slight rotation rhythm formation.	Similar, with a bit more surface modification	SP as a spatial mark, space binding OR as *relief forming*	Slight contour change due to the reflection on the blackboard	Concentration on the IKO and slightly behind it. Fluctuating propagation of emphasis after rotation. Attention to environment fades	Like 10
12	a) Fluctuating sequence of irregular bursts b) Even chain of fine grains c) Pink noise	3	a) Stat, behind right , 310° b) Rot, CW , 180°/s c) Rot, CCW , - 180°/s	All three sound levels separately audible. Triple spatial gradation. Clearly a) stationary behind at the IKO. Also clearly c) with CCW and wall reflections; difficult is	All three sound levels audible separately. Triple spatial gradation. a) Distinctly stationary left in the corner - panel glass wall. Rotation c) immediately	KSP	Contour change by coordinate jump a) and orbit morphology at c)	Attention shifts swiftly back and forth between the three levels.	High plasticity through depth gradation and clearly perceptible heterogeneous material.

				the direction of movement of b), but foreseeable with concentration. c) initially as a pendulum movement between the front and rear of the IKO. When acclimated as a rotation, CCW motion perceptible.	noticeable as rotation with other wall reflection centers. b) similar to 12.1.				
13	a) Fluctuating sequence of irregular bursts b) Even chain of fine grains c) Pink noise	3	a) Rot, CW , 180°/s b) Stat, above , 0/93Ev c) Rot, CCW, - 90°/s	a) Not to identify bursts as rotation, rather than pendulum movement between front and back, with different distances to the IKO. b) is static, spatially fixed directly at the IKO. The elevation is imperceptible. c) Rotation of the noise CCW, good audible. Three sound events layered in space with different distances to the IKO.	Very similar to 13.1. only the noise rotation c) is somewhat more emphasized by the blackboard. This will slightly shift the center of gravity to the board. a) and b) are almost identical.	KSP	Slight contour change due to orbital path morphology, otherwise predominantly *contoured* shape	Attention jumps between inside (a and b) and outside c), then follows c) in the pendulum movement between front and back.	High plasticity through depth gradation and clearly perceptible heterogeneous material.
14	Fluctuating sequence of irregular bursts	1	Rot, CW, 180°/s	Bursts perceptible at various distances from the IKO, circular orbit difficult to identify. No clear wall reflections. Rather pendulum movement between front and back with different coordinates.	No difference	SP, as a spatial mark	*Uniform contour* from both directions	Attention is directed with each new burst on the respective position/coordinate, so it shifts along with them.	Due to the fluctuation and different burst intensities, a depth gradation in the material is created, which thereby becomes plastic.
15	a) Fluctuating sequence of irregular bursts	1	a) Stat, above, 0/93Ev After 15s	a) is clearly static at the IKO heard, elevation imperceptible.	a) is clearly heard at the IKO, elevation imperceptible. b) Change is	SP as a spatial mark	*Uniform contour* until the change. Then, depending on the position,	Attention is shifted to the area behind or laterally when switching from the IKO.	No depth gradation, only at the moment of change is a

	b) Fluctuating sequence of irregular bursts		change to b) Stat, rear right, 310°/s	b) Change to the rear 0° audible and spatially identifiable.	perceptible but not easy to locate. Sounds like 15.1.		different spatial propagations occur.		short-term spatial texture with deep structure created due to the overlapping of the old and new impression.
16	a) Fluctuating sequence of irregular bursts b) Fluctuating sequence of irregular bursts	1	a) Stat, below, -93Ev after 15s change to b) Stat, above 0/93Ev	a) is perceived statically at the IKO, but direction unidentifiable. b) Change perceptible but not locatable.	a) is perceived statically at the IKO, but direction unidentifiable. b) Change perceptible but not locatable.	SP as a spatial mark	*Uniform contour* from both directions.	Attention is drawn to the IKO. No transformation due to the change.	No spatial depth gradation in the sound event.
17	a) Fluctuating sequence of irregular bursts b) Even chain of fine grains	2	a) Stat, below, -93Ev b) Stat, above 0/93Ev	a) and b) are clearly audible as two static events at the IKO, but indistinguishable in the elevation.	a) and b) clearly distinguishable as two events at the IKO but indistinguishable in the elevation	SP as a spatial mark, space binding	*Uniform contour* from both directions	Attention is drawn to the IKO.	No spatial depth gradation in the sound event
18	a) Pink noise b) Even chain of fine grains	2	a) Stat, below, -93Ev b) Stat, above 0/93Ev	a) and b) are clearly audible as two static events at the IKO, but indistinguishable regarding elevation. Noise seems to be in the background.	a) and b) are clearly audible as two static events at the IKO, but indistinguishable regarding elevation. Noise seems to be in the background. Weak discoloration of the noise.	KP, space superseding OR *relief forming*	*Almost uniform contour* from both directions, but slight coloration changes in the vertical due to listening position.	Attention is drawn to the IKO. Spatially creates a foreground and background event.	Slight depth gradation through the different materials, creates more plasticity.
19	a) Even chain of fine grains b) Even chain of fine grains	2	a) Stat, below, -93Ev After 15 s change on b) Stat, above 0/93Ev	Direction of a) and b) cannot be located. Slight change of tone color.	Direction of a) and b) cannot be located. Slight change of tone color.	SP as a spatial mark, space binding	*Uniform contour* from both directions	Attention is drawn to the IKO.	No spatial depth gradation in the sound event.

20 bass and movement	a) Even chain of fine grains b) Drone	2	a) Rot, CCW , -180°/s b) Stat, below , -93	a) CCW rotation perceptible close to the IKO, b) bass static at the IKO, Beam direction imperceptible, higher drone frequencies seem spatially slightly above.	Somewhat quieter: a) CCW rotation close to the IKO perceptible, b) Bass static at the IKO, beam direction imperceptible, higher drone frequencies seem spatially slightly above.	KP, space superseding	*Uniform contour* from both directions	Attention is drawn to the IKO. Slight layering in foreground and background events and in elevation leads to continuous, minimal shift of attention.	Depth gradation: Plasticity is created through the different materials and the spatial spread.
21	Drone with gradual volume increase,	1	Rot, CCW, -45°/s	a) bass, static at the IKO, b) CCW "Drone-Wind" rotation perceptible, two events spatially distinguishable.	a) bass, static at the IKO, b) CCW "Drone-Wind" rotation perceptible, two events spatially distinguishable.	KSP	*Uniform contour* from both directions. Light circular orbit morphology due to different reflections and occlusions by the IKO.	Attention is strongly tied to the IKO, but then repeatedly distracted and reoriented by the wandering reflection of the beam, jumping between two poles.	Low plasticity is caused by the different colors between IKO and wall reflections.
22	Drone, with gradual volume increase, LowCut 236 Hz	1	Rot, CCW, -45°/s	CCW rotation perceptible, "beacon", significantly less emphasis in the center at the IKO	CCW rotation perceptible, "beacon", significantly less emphasis in the center at the IKO. Slight change in the orbital path due to the changed reflection paths.	SP, space enveloping	Almost *uniform contour*	Attention is focused on the environment, follows the beam.	No spatial depth gradation in the sound event.
23	Drone with gradual volume increase, LowCut 236 Hz	1	Stat, back right, 310°	Is perceived statically, IKO-centered, omnidirectional, direction imperceptible.	Is perceived statically, IKO-centered, slightly offset to the left in the direction of the blackboard, with increasing volume significant shift in emphasis.	KP, space superseding	Changes the contour slightly with the position and while volume increases.	Attention is focused on the IKO and slightly shifted out of the center at position 2 while volume increases.	No spatial depth gradation in the sound event.
24	Drone with gradual volume increase,	1	Stat, back right, 310°	Is statically perceived on the right side of the blackboard.	Is perceived static on the wall to the front and the left.	KP, space superseding (small plastic)	Changes the contour with the position and while	Attention is focused on the spot on the wall	No spatial depth gradation in

	LowCut 236 Hz						volume increases.		the sound event.
25	Drone with gradual volume increase LowCut 236 Hz	1	Rot, CCW, -180°/s	a) bass, stat. at the IKO, b) CCW "Drone-Wind" rotation perceptible, faster rotation well perceived regarding direction and movement, indicated *Spatial Beating*.	a) bass, stat. at the IKO, b) CCW "Drone-Wind" rotation perceptible, faster rotation well perceived regarding direction and movement, slight *Spatial Beating*. Orbital path coordinates altered by changed reflection paths.	KSP	Changes the contour with the position and while volume increases.	Attention is strongly tied to the IKO, but then distracted and reoriented by the wandering reflection of the beam; jump between two poles.	Slight depth gradation due to the spatiality of the texture.
26	Drone, with gradual volume increase, LowCut 236 Hz	1	Rot, CCW, -180°/s	Repealed IKO centering. Rotation well perceived regarding direction and movement.	Repealed IKO centering. Rotation well perceived regarding direction and movement	SP, space enveloping	Different contouring due to different reflection paths.	Attention is tied to the wandering reflection of the beam towards the walls.	No spatial depth gradation in the sound event.
27	Drone with gradual volume increase LowCut 236 Hz	1	a) Stat, below, -93 EV Change after 15s to b) Stat, front, 180° Az	a) static, direction not locatable, fade barely perceptible, only the volume increase pulls the impression slightly forward, overall IKO-centered.	a) static, direction not locatable, fade barely perceptible, only the volume increase pulls the impression slightly forward, overall IKO-centered.	KP, space superseding	*Uniform contour*	Attention is tied to the IKO.	No spatial depth gradation in the sound event.
28	Drone with gradual volume increase, LowCut 236 Hz	1	a) Stat, below, -93 EV Change after 15s to b) Stat, front, 180° Az	a) static, direction not locatable, fade better perceptible, b) locatable, overall IKO-centered.	a) statically perceptible, direction not locatable, fade better perceptible towards the back wall, b) locatable at IKO, overall IKO-centered.	KP, space superseding (small plastic)	Slight contouring during and after the change	Attention is tied to the IKO.	No spatial depth gradation in the sound event.
29	a) Even chain of fine grains	2	a) Rot, above, CCW , 62Ev,	CCW rotation a) comprehensible,	CCW rotation a) comprehensible,	KSP	*Uniform contour*	Attention is tied to the IKO.	Significant depth

	b) Drone with gradual volume increase		180°/s b) Stat, below, -93Ev	elevation imperceptible. Bass static, no direction, IKO centered, envelops a).	elevation imperceptible. Bass static, no direction, IKO centered, envelops a).				gradation at the IKO itself creates plasticity.
30	a) Even chain of fine grains b) Drone, LowCut 236 Hz	2	a) Rot, above, CCW , 62Ev, 180°/s b) Stat, below, -93Ev	CCW rotation of a) easier to hear b) at the IKO but no direction perceptible, no enveloping of a).	CCW rotation of a) easier to hear b) at the IKO but no direction perceptible, no enveloping of a).	KP, space superseding (small plastic) OR *relief forming*	*Uniform contour*	Attention is tied to the IKO, foreground/background formation between a) = front and b).	Inverse depth gradation compared to 29
31	a) Even chain of fine grains b) Drone, LowCut 236 Hz	2	a) Rot, above, CCW , 62Ev/ -180°/s b) Rot, CW, 180	Both rotations are clearly perceptible, a) closer to the IKO, b) *beacon* a) inside, b) outside.	Both rotations are clearly perceptible, a) closer to the IKO, b) *beacon* , a) inside, b) outside. Orbital path with other coordinates because of changed reflection paths.	KSP	Slight contour change when changing position	Attention is first bound by the grains and their movement to the IKO, but then tied to the outer track of the beam. Then shift back and forth.	Spatial layering creates plasticity.
32 spirals	Grain loop with bass pulse	1	Rot, CCW, -180 /s	Rotation of grains well noticeable CCW. No reflections on the walls, but spiral shape with a distance to the IKO audible. Bass pulse remains static at the IKO, with slight bulges in the surrounding space. Two spatially staggered events.	Almost identical to 32.1. Grain loop clearer in the movement at the beginning because it starts at 90°. But then uniform.	KSP	*Uniform contour*	Attention IKO-centered, but with depth gradation between bass pulse and spiral.	Plasticity is created by the spatial gradation of the sound material at the IKO.
33	Grain loop with bass pulse	1	Rot, CCW , above , 62Ev, -180°/s	Elevation imperceptible. Smaller propagation radius in the plane. Otherwise like 32.	Elevation imperceptible. Otherwise like 32.	KSP	*Uniform contour*	Attention IKO-centered, but with depth gradation between bass pulse and spiral.	Plasticity is created by the spatial depth gradation of the sound material.

34	a) Grain loop with bass pulse b) Even chain of fine grains	2	a) Rot, CW, 180°/s b) Rot, below, CCW , -90Az, 90°/s	a) Rotation grain loop CW perceived as a spiral, Bass static, same as 32. b) Rotation below, CCW weakly noticeable, but finer grains settle in the background as a reference point/coordinate, sounding closer to the IKO than the bass. Three spatially separated events.	a) Rotation grain loop CW perceived as a spiral, Bass static, same as 32. b) Rotation below, CCW weakly noticeable, but finer grains settle in the background as a reference point/coordinate, sounding closer to the IKO than the bass. Three spatially separated events.	KSP	*Change of contour depending on the listening position.*	Attention IKO-centered, but with depth gradation between the bass pulse, chain of fine grains and spiral. Emphasis shifts continuously between the three levels after their establishment.	Plasticity is created by the spatial depth gradation of the sound material, whereby it is interesting that the bass is spatially between the spiral (farther out) and the fine grains (completely inside).
35	a) Grain loop with bass pulse b) Even chain of fine grains c) Pink noise	3	a) Rot, CW , 180°/s b) Rot, below, CCW , -90Az, 90°/s c) Stat, back and right, 310°, Change after 15s to the front, 180 Az	a) CW rotation perceptible. Bass like 34. b) Rotation, no longer perceptible below. Fine grains come through over the noise, but lose the trajectory. c) clearly statically perceptible on the rear wall to the right. Change to the front at the IKO also perceptible.	Like 35.1. However, c) is left in the corner of the blackboard/glass wall and the change after 15s is not as clear as from position 1. Noise then sticks to the IKO at 180°.	KP	Change of contour depending on the position in that the noise beam changes direction. Depending on the position, a different spatial formation results.	Attention jumps between the levels, but is initially aligned by the fixed beam on the back wall, then directed forward to the IKO or at position 2 on the right outer IKO surface.	Plasticity is high due to the different spatial gradations of the sounds. However, louder noise presumably would cancel out the differentiation that the trajectories of the individual sounds would blur and thus coincide spatially.
36	a) fm-modulated metallic radiance with long attack and release time b) Even chain of fine grains	2	a) Rot, above. CCW 62, EV, -180°/s b) Rot, below. CCW Az-90/Ev -61/-90/	a) noticeably perceptible as expansive turbulence clearly above the IKO, now and then identifiable in CCW direction. b) perceptible as rotation at the IKO,	Like 36.1.	KSP, space constituting	Uniform contour	Attention jumps between inside (grains) and outside (rays), after 15s instantaneous alignment to fixed coordinate at IKO.	Plasticity is created by spatial layering, conditioned by the material: difference in elevation (frequency) and propagation

			Change after 15s to Stat, vertical, 0/93	clearly behind and under a). Change to the static also perceptible, but not spatially regarding elevation, rather more in one point at the IKO.					(onset/offset, trajectories): left/right, back/front, inside/outside.
37	fm-modulated metallic radiance with long attack and release time	1	Rot, CW, 180°/s	Perceptible as turbulence above the IKO, distinct spread around the vertical of the IKO but with different depths. Encircles a cavity. CW orbit just foreseeable.	Like 37.1	SP, space enveloping	*Uniform contour*	Attention is directed around an interior. In doing so, clear orientation to the height/elevation of the sculptural object in the resulting space.	Different expansions of the material over time produce weak plasticity
38	a) Drone with gradual volume increase, LowCut 236 Hz b) fm-modulated metallic radiance with long attack and release time	2	a) Rot, CCW. -180°/s b) Rot, CW , 180°/s	a) rotation, perceptible as CCW. Reflections on the walls produce weak *Spatial Beating*, bass close to the IKO, b) Rotation, perceptible as CW, sounds above the IKO and behind the drone.	Like 38, but the reflection paths change the orbital path perception with their coordinates.	KP, space superseding with expansive moments.	Contour changes because of the different reflection paths and materials of the surfaces while changing position.	Attention is centered on the IKO. Clear spatial displacement with orientation regarding elevation. Due to the reflections of the drone beam occasional shifts of concentration outwards, but not enveloping.	Very dense spatial formation, with little depth gradation.
39	a) Drone with gradual volume increase, LowCut 236 Hz b) fm-modulated metallic radiance with long attack and release time	2	a) Rot, CCW. -180°/s b) Rot, CW , 180°/s	a) Rotation as turbulence well perceptible, CCW foreseeable, b) very noticeable CW rotation, with *Spatial Beating* on the surfaces.	Similar to 39.1., but with other orbital path emphases on the filtered drone.	KSP	Contour changes because of the different reflection paths and materials of the surfaces when changing position.	Space is opened upwards and aligned, at the same time enveloping movement around an interior.	Clear spatial definition and simultaneous identifiability of the materials creates strong plasticity.
40	a) Grain loop With Bass-Pulse b) metallic radiance	4	a) Rot, CCW. -180°/s b) Rot, above. CCW , 62Ev/ -180°/s	a) Bass static at the IKO, with spatial extension beyond the IKO's dimensions. Rotation of the grain loops CCW,	a) as in 40.1, b) similar but with other extensions over time, c) has another orbital path morphology,	KSP	Different spatial aspects when changing position lead to different contouring.	Attention jumps back and forth between the levels. The fixed point is the burst beam on the outer edge. a) opens the space upwards while the	Complex plastic structure with different spatial dimensions and gradations.

	c) Pink noise after 15s d) Fluctuating sequence of irregular bursts		c) Rot, below, CCW. az -90/ -60 EV, -90° d) Stat, back right, 310°	perceptible like a spiral. b) Rotation, perceived as turbulence above the IKO, hardly noticeable in CCW direction. c) CCW is perceived as a beacon, not regarding elevation. d) Static beam with bursts, on the back right of the IKO and on the wall.	d) Bursts mark a coordinate in the corner blackboard/ glass wall.			bass pulse is pointing downwards. When noise is introduces, the events are enveloped.	
41	Pink noise	1	Distance fade with orders (3... 0... 3): a) front 180°, fade to center b) front 180°, fade to the rear with decrease in volume c) front 180°, fade again to the rear, front 180° fade to the rear in less time, with decrease in volume .	a) well locatable, sound is drawn into the IKO and lingers in its middle. b) easy to locate, sound drives through the IKO on the back. c) Faster movement even more comprehensible.	a) difficult to understand as a movement, discoloration of the sound discernible in particular, less spatial information, but still more focused on the IKO's center. b) better understood than a), sound tends to move from the right (180°) to the left (0°) without escaping on the left side. c) faster fade right-left better to track.	KP, space superseding, partially expansive.	Trajectory is perceptible from both positions, but with different tonal expressions. Therefore different contours arise.	Attention is directed along the trajectory of the fade to the middle, to the front, through the IKO, back to the front, etc. In this way, the emphasis of the attention can be aligned tangentially.	Although different coordinates are described, the spatial gradation of the material does not arise as a result.
42	Uniform chain of fine grains	1	Distance fade with orders (3... 0... 3): a) front 180°, fade to center b) front 180°, fade to the rear with	a) perceivable as a difference in volume, not spatially locatable, b) seems spatial only in connection with the decrease in volume, otherwise rather diffuse, c) slightly more clearly perceptible than b)	Very similar to 42.1., However, in b) and c), the movement as a shift tendency right to left and back again is comprehensible.	SP, as spatial mark	Similar to 41, but only weakly perceptible	Very fragile movement, probably difficult to understand, hardly usable.	Hardly any spatial gradation, material produces less audible spatially differentiated textures.

			decrease in volume c) front 180°, fade again behind, front 180° fade to the rear in a shorter time, with decrease in volume	due to the faster fade to the back.				
43	Fluctuating sequence of irregular bursts	1	Distance fade with orders: a) front 180°, fade to center b) Front 180° fade to the rear with decrease in volume c) front 180°, fade again behind, front 180°, fade to the back in shorter time, with decrease in volume	a) Fade clearly noticeable up to the middle of the IKO b) clear fade behind the IKO c) increased spatial impression due to the acceleration	a) Perceptible as a movement, but not exactly localized at the IKO. b) comprehensible as a lateral movement c) more noticeable as a right- left movement	SP as spatial mark	Fades are perceivable from different positions as directions with different resolutions and colors. Strong contouring.	Attention follows the direction of movement tangentially. Accordingly, the directionality can be changed.	Fluctuating bursts are perceived at different distances from the IKO's surface. In conjunction with the fade movement, an effect of spatial depth gradation is generated. The plasticity of the spatial texture is hereby reinforced.
44	Pink noise bursts	1	Distance fade with orders (3… 0… 3): Front 180°, 2x fade to the back with decrease in volume and back	Clearly audible path through the IKO to the rear and back to 180°. Strong room excitation by hard on- and offsets.	Reduction is noticeable, but left-right movement is not as clear as the front-back like 44.1. Strong room excitation provides reflections of glass wall and back wall (!), which overlay the spatial tracking of the trajectory temporarily (beginning	SP as spatial mark (*large plastic*)	Less stable sculptural phenomenon, but can be guessed from both positions, contouring at least present.	Attention is directed directly into the IKO and into the background at position 1, in position 2 diffuse perception of a movement up to the volume reduction and in the return fade in the direction of 180°.	No spatial depth gradation in the sound event.

					and end of the fade).				
45	Pink noise bursts	1	Rotation, vertical, behind, below, front, above - behind	Well perceptible slow movement with changing colors. Also interesting are the changing colors of the floor-wall reflections. Space excitation produces almost second sound event.	Rotation only fragmentary perceptible, but in the unique position perceptible as an event.	SP as spatial mark (*large plastic*)	Trajectory is more stable than at 44, which is probably related to the longer trajectory in the same time. Under these spatial conditions, a vertical rotation is thus representable and quite contoured.	Attention is aligned along the trajectory dependent on position, shift in emphasis is precisely comprehensible.	No spatial depth gradation in the sound event.
46	Pink noise	1	Pan, at different speeds, horizontal. 90° CCW to 180°, back CW to 0°, back CW to 180°, back CCW to 260°, CCW to 180°, back CW to 90°	Movement cycle is perfectly traceable horizontally in all stages and directions. If the movement stops, the wall reflection on this point increases.	Motion cycle is traceable only on the less reflective 180° back wall, the beam falls back into the IKO.	KP, with expansion into the room	Position dependent perception of the consistent spatial texture, strong contouring by reflection properties of the surrounding space.	Attention is directed horizontally around the IKO in different directions. Successive shift in focus with accumulations at the respective pause positions.	No spatial depth gradation in the sound event.
47	Uniform chain of fine grains	1	Like 46	Movements perceptible on the IKO surface, similar to 46.1. only more fragile, sometimes with gaps in the trajectory, but still completed by the perception.	Trajectories difficult to detect at the IKO. 90° and 260° work , 0° and 180° hardly.	SP as spatial mark, space binding	The spatial texture decays very differently depending on the position. Contouring thus barely detectable.	From position 1: Attention is directed horizontally around the IKO in different directions. Successive shift of emphasis. Position 2 generates no consistent perception situation.	No spatial depth gradation in the sound event.
48	Fluctuating sequence irregular bursts	1	Like 46	Trajectories are unreasonable because of the fluctuation and	Trajectories also incomprehensible. No horizontal shift	-	Like 47, even more unstable, unidentifiable as	Attention jumps depending on the position and loses its	No spatial depth gradation in the sound event.

				irregularity of the textural atoms. No horizontal shift is perceptible, but rather pendulum motion between changing coordinates.	perceptible.		a spatial texture.	orientation in between. Therefore no directionality determinable.	
49	Pink noise	1	Rot, vertical 180°/s, 5x in front, above, behind, below, 1x slowed down	Rotation as such is imperceptible, more likely a pendulum movement between the reflection point 0° on the blackboard and 180° directly on the IKO (*Spatial Beating*). Slowed circular motion perceptible.	Completely different spatial extent than 49.1., Closer to the IKO, no consistent trajectory comprehensible. No Pendulum. Rather lateral movements. Slowed circular motion perceptible.	-	Uniform contour, since there is no consistent spatial texture.	At position 1, the attention jumps back and forth between points of emphasis. Position 2 largely disoriented. Could possibly be strengthened or compensated for both positions through ceiling reflector.	No spatial depth gradation in the sound event.
50	Uniform chain of fine grains	1	Rot, vertical 180°/s, 5x in front, above, behind, below, 1x slowed down	Volume and tone color changes close to the IKO are very perceptible, trajectory indeterminable	Even weaker perceptibility of movement and shift of focus	-	Uniform contour, since there is no consistent spatial texture.	Barely perceptible	No spatial depth gradation in the sound event.
51	Fluctuating sequence of irregular bursts	1	Rot, vertical 180°/s, 5x in front, above, behind, below, 1x slowed down	Volume and tone color changes closer to the IKO, but noticeable at different distances. Trajectory foreseeable by the repetition, but rather acts as a front-rear pendulum movement.	Barely perceivable spatial changes	-	Uniform contour, since there is no consistent spatial texture.	At position 1, the attention jumps back and forth between the points of emphasis. Position 2 largely disoriented.	No spatial depth gradation in the sound event.
52	Pink noise bursts	1	Rot, vertical 180°/s, 5x in front, above, behind, below, 1x slowed down	Strong room excitation due to hard on- and offsets, movement can be traced successively through the combination of wall reflections and IKO masking, even more	Strong room excitation due to hard on- and offsets, movement can be traced successively through the combination of wall reflections and IKO shading, even more	SP as spatial mark (*large plastic*)	Different contouring results from position changes due to changed reflection paths and corresponding color differences.	Attention is clearly fixed on the movement of the beam and accordingly follows the formation of the emphasis on the respective reflection surface or on the IKO itself.	There is no depth gradation along the trajectories in the material.

				pronounced when decelerating.	pronounced when decelerating. However, change in emphasis by other reflection paths and lack of direct beam. Trajectory more difficult to identify than at 52.1.				