Sonic art for intersensory listening experience

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Abstract

In recent years, the relationship between sound and the human body became a more important topic for musicians and artists. In total, there has been much artistic research dealing with inter-sensory perception between sound and image, but relatively little dealing with audio-haptic relationships in art and music. This paper attempts to provide a theoretical framework of audio-haptic experiences by examining work utilizing space, the somatosensory system, and electroacoustic music.

In the history of sound art the establishment of sound installation was an important epoch, which deals with the auditory space perception involving audience's active physical participation. Audience experiences the auditory constructed space in specific location having chance to react actively by walking in/around it. The audience's corporeal activity becomes an essential part of the whole experience of sound installation, however, the awareness of bodily perception appears rather as result of the required physical involvement for the spatial aural experience. The main issue remains to listen to the external space.

The clear focus on the bodily perception stimulated by sound was developed by works with intension to involve our somatosensory system. The differentiation between sound installation and the types of works, which involves audio-haptic perception, can be pointed regarding the definition of the space. While sound installation deals with the external space, the latter concentrates on the inner space of the body. The "inner" space of the body can be defined as the sensorial space, which you can perceive through haptic. It involves medium (skin tissues, flesh and bones) and signal transmission in the nervous system. Vibrotactile stimuli cause mechanical deformations of the skin tissues and it is perceived by mechanoreceptors, which are located in different layers of skin tissues. Furthermore vibrotactile stimuli can be mediated through bone conduction directly to inner ear without exciting tympanic membrane and one can "hear" the vibro-tactile sonic signal.

Technically vibro-tactile stimuli can be generated by subwoofer and so called vibro- acoustic transducer. The tactile sonic wave generated by these two types of devices differs in its means of transmission: Subwoofer uses air borne sound transmission in low frequencies and transducer mediates sonic vibration directly to the body surface.

Electroacoustic composition plays a central role for the development of this type of artistic approach. Beside the fact that electroacoustic musicians (or collaboration with EA musician) have been developing it, methods of composing and playing EA music can be perfectly integrated to the creative process. Sonic wave covers in nature not only audible range but also haptically perceptible frequency range. Sound generation method by electro acoustic music

can contribute active and flexible control of the haptic signal, in particular vibrotactile stimuli in frequency and intensity.

Work examples *Sonic Bed* by Kaffee Mathews (2005), *STiMULiNE* by Lynn Pook/Julien Clauss (2003), and *Sound Capsule* by this paper's author (2008) have different types of technical application in order to mediate the sonic wave, however, they all use electroacoustic music as their source material and core intention is to mediate the sound to the body.

The foundation of the sensory model, which appears characteristically at the works, is the relationship between auditory and haptic modalities. This interaction between auditory perception and haptic suggests a new ground of musical space – the integration between imaginary (musical) space and physical (corporeal) space. Musical imagination, which is established through the long history of aural culture, coexists here with the corporeal awareness. Further application of this type of works, for instance for live performance of electroacoustic music, integration of the emotional response of the audience by means of psychophysiology and biofeedback, or compositional collaboration with electroacoustic musicians can extend the diversity of the audio- haptic sonic experience.

Introduction

"Music isn't only for aural, but also for bodily perception". This notion is based on consideration about a particular type of artistic practice, which deals with our bodily sensory system utilising sound.

In our everyday life, we never experience our environment with single sensory modality separated from others. We are constantly exposed to stimuli simultaneously in different sensory modalities such as vision, hearing, smell, taste and touch. The brain integrates these sensory cues, in order to arise unified inter-sensory perception.

The inter-sensory perception is natural ability of human being, to grasp our environment tangibly. When we think about the experience of artistic work, its sensory model seems to be rather extraordinary, compared with the one in our everyday life. Audience concentrates on one or some particular sensory channel(s). Any type of medium for artistic expression itself is connected to a particular sensory modality, typically vision in field of painting, photography and audition in music. There are also much more complex art forms, which involve multiple sensory modalities, such as film, theatre and so on. From the point of view regarding involved sensory modalities, these multi-sensory artistic expression is based upon audio-visual relationship. In reality, we don't completely isolate other sensory modalities other than hearing and/or vision, while we experience the work. For instance, when we listen to music at a concert hall, we pay the most attention to our aural perception, however, we still see the performers, stage and so on. Although it seems to be trivial, temperature in the hall and the comfort of the seat also play a role, in order to be able to concentrate on hearing.

Of course when we talk about the music, these factors don't become a target of the argument, as they don't have direct link to the target sensory modalities for the artistic practice. However, the sum total of the perceived sensory information constructs our lively memory. The sense of touch, our bodily perception, seems to be a key for a tangible, intimate experience of our environment. With this paper, I examine the notion of "bodily space" by the works, which utilise electro acoustic sound for the bodily perception. In order to clarify the unique aspect of the bodily space as artistic medium for sound mediation, I attempt to

integrate it with the notion of musical space within the musical expression, which in particular utilises electro acoustic sound, including sound art.

Sonic art and bodily perception

When we think about sound art in the relationship with bodily perception, the establishment of sound installation was an important epoch. It deals with the auditory spatial perception involving audience's active physical participation. Audience experiences auditory constructed space in specific location, where he can walk in and around. Thus audience's corporeal activity becomes an essential part of the whole experience of sound installation. Although the active corporeal approach towards the auditory composed space plays a crucial role for the experience of the sound installation, the bodily awareness appears rather as result of the required physical involvement and not as main issue. The main issue remains to listen to the external aural space.

The clear focus on the bodily perception stimulated by sound was developed by works, which intend to involve our somatosensory system. In recent years, the relationship between sound and the human body became a more important topic for musicians and artists. In particular several musicians and artists, who uses electro acoustic music presented similar types of works, which directly deal with the theme: "Music for Bodies", as British artist Kaffe Mathews calls one of her projects. These works propose us a new type of experiencing sound, which goes beyond our common understanding of sound as the medium of the sense of hearing. They enable us to experience sound via our bodily sensation and thus the interaction between our sense of hearing and touch occurs in a unique way.

Our bodily perception, so called somatosensory system is a complex of sensory modalities, which utilises the combination of a number of receptors at the cutaneous and subcutaneous levels. Cutaneous senses, which are also called tactile senses, provide an awareness of the stimulation, which is provided through skin, such as pressure, vibration, temperature and pain. Proprioception, which is also referred as Kinesthesis, provides an awareness of the inner space of our body through neuromuscular feedback.

Physically sound is mediated as vibration through diverse medium, normally through the air. The vibration within our hearing range is perceived as sound with our auditory sensory organ, ear. The vibratory stimulation can cause mechanical deformations of the skin and it can be perceived by mechanoreceptors located in different layers of skin, depending on the frequency and amplitude.

Each of the four receptor types has specific role in the vibro-tactile detection. Pacinian corpuscle is the largest and located about 2-3mm depth in the skin. The sensitivity of the Pacinian corpuscle has "U" shape with maximum sensitivity occurring in the 250 to 300 Hz. Another receptor Meissner corpuscle is located just below the epidermis and sensitive to low frequency vibration below 300 Hz and most sensitive to the frequencies between 20 to 50 Hz.

These two receptors are responsible to vibratory signal detection. Other receptors such as Merkel cell and Ruffini ending operate also towards vibratory stimuli, however, the sensitivity is much lower than the first two. They are slowly adapting and sensitive to constant pressure.

These four receptors are categorised as unit each by its adapting speed and receptive field.

- FA: refers to "fast adapting" and no response to sustained stimulation;
- SA: refers to "slowly adapting" and responding to sustained stimulation;
- I: small receptive field;
- II: larger and diffuse receptive field.

FA I has its end with Meissner corpuscle. FA II with Pacinian corpuscle. SA I with Merkel Cell and SA II with Ruffini ending. These each unit corresponds also to four physiological channels.

- NP I (non-Pacinian) channel with FA I;
- NP II channel with SA II;
- NP III with SA I;
- And P (Pacinian) channel with FA II.

This four-channel model was established by Bolanowski, as the result of the investigation of sensitivity threshold in frequency and intensity of vibratory stimulation. The threshold curve shows the combination of involvement of different channels[1].

- 0.4-3.0 Hz without change (NP III channel);
- 3-40 Hz with gradual decrease of threshold (NP I channel);
- 40-500 Hz U-shaped curve with maximal value around 250 Hz (P channel).

As Weinstein pointed out, the sensitivity of our tactile perception on our body differs depending on the location. He investigated threshold of tactile perception with various parameters. He measured for instance pressure discrimination threshold on the whole body both male and female[2].

Temperature also influences the sensitivity of the vibrotactile stimuli. When the skin temperature is between 25 and 40° C, no change under 40 Hz is recognized and the U-shaped curve is shifted to higher frequencies with a maximum value at 40° C of 400 Hz. The maximum value with the U-shaped curve between 15 and 20° C was 200 Hz. This is the result of different involvement of the Pacinian corpuscle, which is located in deeper tissue, and non-Pacinian channel. When the skin temperature is higher, the involvement of Pacinian corpuscle is more notable. With lower temperature, non-Pacinian channels pull the U-shaped threshold curve to the lower frequency.

This basic knowledge about the sensitivity of vibro-tactile perception is helpful, when we involve the vibratory component for composing electro acoustic music.

Terminology for the type of works

By the way, we are lacking of a particular term, which describes the type of works for auditory and bodily perception, which we are arguing here. One of the candidates is "audio-

[1] For a representation of the four-channel model of sensitivity to vibrotactile stimuli based on research by Bolanowski *et al.*, see E. Bruce Goldstein (ed.), *Blackwell Handbook of Sensation and Perception*, Malden (MA, USA), Blackwell Publishing, 2005, p. 553.

[2] For diverse tactile sensitivity thresholds for men and women, see S. Weinstein, "Intensive and Extensive Aspects of Tactile Sensitivity as a Function of Body Part, Sex, and Laterality", in *The Skin Senses*, Dan R. Kenshalo (ed.), Springfield (IL, USA), Charles C. Thomas, 1968, pp. 195-222,.

tactile", as sound artist Lynn Pook uses for her work *STiMULiNE*. (Her work utilises only the vibrotactile stimuli, so that audience experience "purely" tactile sound without any air-borne sound transmission.)

Considering the vibratory perception, work examples, which we take insights later, utilize vibratory component which is felt not only in tactile receptive field, namely superficial and deeper area of skin tissue, but also even deeper in our bodily space. Therefore we need a term, which describes broader sense of bodily perception including tactile and inner-body perception.

The term "haptic sense" is now commonly understood as a combination of the tactile perception and kinaesthetic perception, which derived from mechanoreceptors embedded in muscles, tendons and joints. Therefore I'd like to suggest calling the type of works, which we are arguing here "audio-haptic" works.

Work examples

Typically audio-haptic works integrate the both sensory modalities in various ways. First work example is *Sonic Bed* by Kaffe Mathews. There are several different versions and all based on the original piece *Sonic Bed London* (2005). It utilises subwoofers for haptic sonic perception. Audience lying on the bed feels powerful pressure and vibration of the sound through 6 subwoofers under the mattress, while 8 loudspeakers on side framework of the bed create tree-dimensional sound field. The sound system of *Sonic Bed London* controls 12 channel sound compositions.

Second example of audio-haptic work is *STiMULiNE* by Lynn Pook, which I mentioned before (fig.1). The work involves only vibrotactile transducers, which are directly attached on audiences' body parts. Audience is required to use earplugs, in order to eliminate air-borne sound mediation. Technically vibrotactile stimuli are firstly mediated on the skin, and the "tangible" sound is re-mediated directly to inner ear via bone conduction. The extraordinary aspect of this work is that you feel the sound source inside of the body. My personal experience was that I heard the sound IN my feet, for instance. This work has peen presented as concert by Lynn Pook and Julien Clauss.

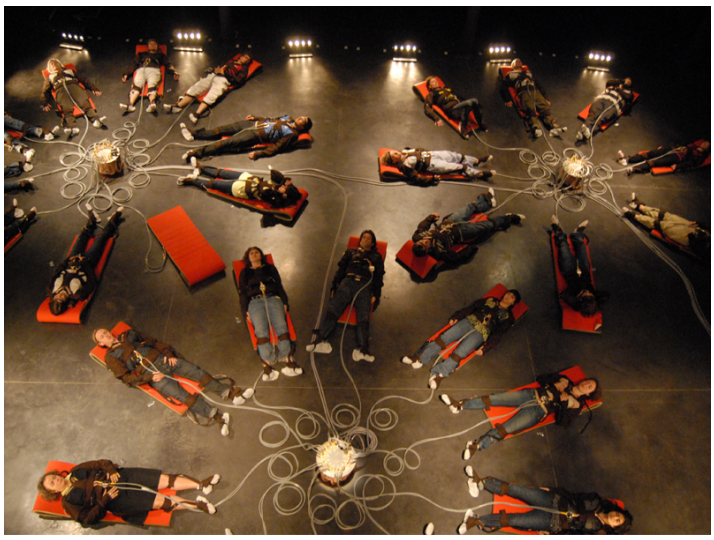

Figure 1: *STiMULiNE* by Lynn Pook

Third work example is *Sound Capsule* by this paper's author (fig.2). One person lies in the capsule and experience very intimate audio-haptic environment. Two coaxial loudspeakers beside the ears generate stereo sound field, while vibratory signal moves between the head and the feet with 6 vibro-tactile transducers. The consciousness of the relationship between auditory image and haptic sensation is very divers from each individual. Some audience are much more sensitive to haptic feeling than what they hear, and others are much more into the audible sound and feels less vibration. Each audience integrates the both sensory modalities in very personal level, and the degree of the integration is always unique.

These works suggest a new means of sound transmission and hence new notion of sonic space, which extend our understanding of listening. In the next chapter, I would like to address the issue of musical space, comparing with other types of expressions using electro acoustic sound material, regarding the mediation of sound.

Figure 2: *Sound Capsule* by this paper's author

Musical space

The notion of musical space in the electro acoustic music and related artistic expression has been an important issue. Here I would like to suggest a simplified categorization of musical space, which was inspired by the approaches by Denis Smalley and Jonty Harrison (fig. 3).

1) composed space (named by Denis Smalley);
2) sounding space (comparable to the "listening space" by Denis Smalley);
3) imaginary space (related to Jonty Harrison's approach).

They are interdependent and have intentionality towards each other. The interdependency and intentionality derive from the awareness and attitude of a subject, who generates each of the space.

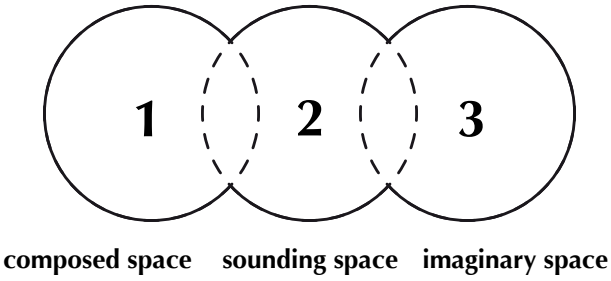

Figure 3: musical space

As the term itself tells clearly, the composed space (fig. 4) is constructed with musical intension of the composer. Therefore the composer's awareness is the foundation of the composed space and it has intentionality toward the creation of imaginary space via sounding space. The sounding space (fig. 5) can be considered as physical medium, which transmits the composer's intention represented with real sound. It underlies the following imaginary space, which is re-constructed intention of the composer in listener's musical imagination. Listener's auditory imagination is the foundation of the imaginary space (fig. 6). As this explanation here tells persistently, each space is interdependent.

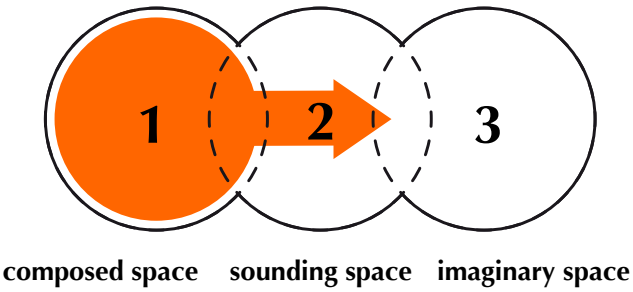

Figure 4: composed space

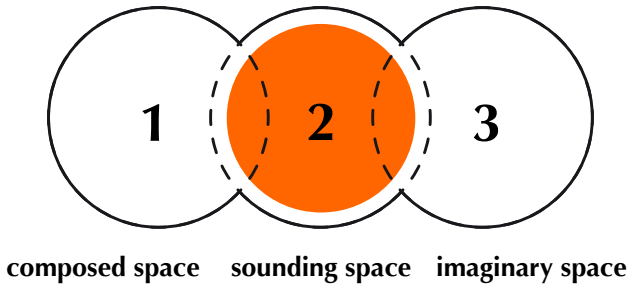

Figure 5: sounding space

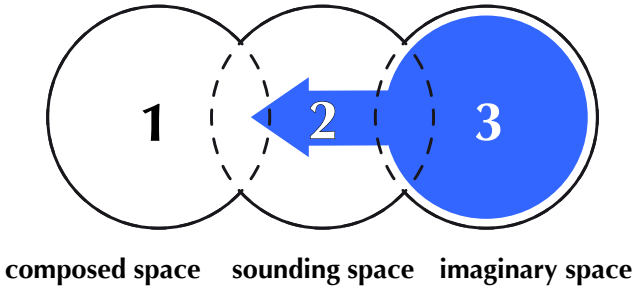

Figure 6: imaginary space

1) Composed space

The relationship between the composed space and the sounding space differs in each electro acoustic music and sound art practices.

For acousmatic music, the composed space is "frozen" in storage medium and the creative process competes temporarily with the assumption of being heard by listener (fig. 7). Needless to say, the frozen composed space is intended to be heard. It becomes "alive" again,

when it is played in a sounding space. In this case, the inherent properties of the composed space, which become audible again in the sounding space, are obviously never as same as in the one in the audio production environment, because of the specific acoustic properties and the characteristics of playback system.

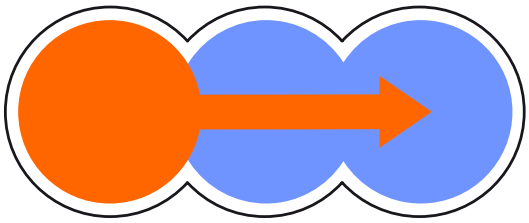

Figure 7: composed space acousmatic

In an electroacoustic concert situation, the composed space becomes a part of sounding space in real time operation (fig. 8). Performer, who is often composer herself/himself, completes the musical intention and in the sounding space in real time, by sharing it with audience. Here the performer reacts the acoustics and other related factors at the concert location immediately and sculpt the space with sound.

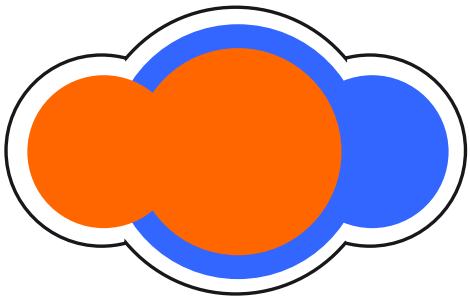

Figure 8: composed space electroacoustic concert

Composed space for sound installation embraces strong connection to the sounding space (fig. 9). During conceptualisation process of a sound installation, not only physical characteristics, such as acoustics of the location, but also historical, cultural and social context of the site may be an essential part of the concept of a sound installation work.

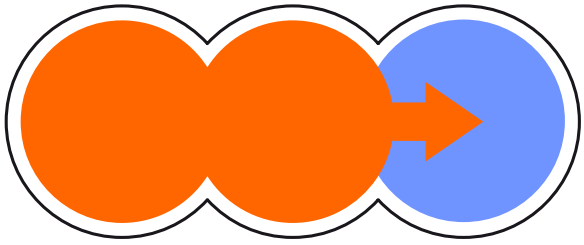

Figure 9: composed space sound installation

2) Sounding space

As mentioned before, sounding space is the medium, which represents composer's intention with real sound and raise the auditory imagination, namely imaginary space by audience (fig. 10). Acoustic properties and the specification of audio playback system have influence, in order to construct the actual sounding space in any case. In reality, it is not always the case that composer is familiar enough with the characteristics of the sounding space before the work is performed. Complex matter in the reality in the sounding space can cause unwanted effects, which might interrupt the precise transmission of the inherent properties of the composed space. In other words, the sounding space is dominated by real issues, including not only the acoustic matters but also even cultural and social context. Therefore it is crucial for artists, musicians and composers to consider well about the inherent properties of sounding space form a wide perspective during creative process.

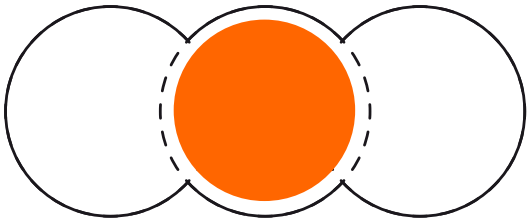

Figure 10: sounding space

3) Imaginary space

This space derives from the composed space and occurs in the listener's musical imagination via sounding space (fig. 11). The investigation of the origin and component of the imaginary space seems to be highly complex and I recommend to read papers about this issue, for instance by Jonty Harrison.

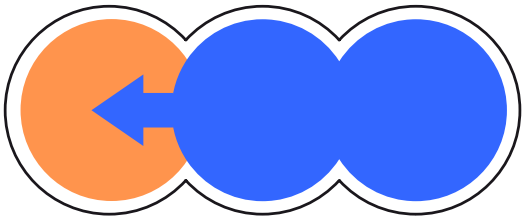

Figure 11: imaginary space

Integration of the bodily space into the context of musical space

I suggest considering inner-body space as one type of the sounding space. I described the sounding space as the physical medium, which transmits composed space to the listener's auditory imagination. In normal listening situation, air is the mediator of the musical content. For the audio-haptic works, body becomes the mediator of the sound. Hence our inner-bodily space, where we receive the vibrotactile stimuli, becomes a new type of sounding space.

The impression of the vibrotactile stimuli can be diverse, by controlling its frequencies and amplitude. Technically subwoofer is applied to create vibratory stimuli or even feeling of powerful pressure in larger area on the body. Its receptive field is diffuse. This can be typically experienced with *Sonic Bed*. Receptive field with vibro-tactile transducer is small. By controlling the frequency and amplitude, the stimuli can be very delicate, as it touches directly to the skin. Depending on the body location, the sensitivity of the precise localisation for multiple vibratory points varies. Therefore, one can have an illusion, comparable to panning by audible sound, when vibratory stimulation moves between two or multiple transducers with some distance. If you attach the transducer on a sheet of plastic, for instance, the whole surface generates the vibration and thus one can create larger receptive field for more delicate vibrotactile stimuli than with subwoofer. By combining these techniques and methods, one can create variety of haptic stimuli for a musical piece. It is also crucial to control the vibrotactile stimuli in the relationship to the imaginary space via aural modality, in order to enhance aesthetical intersensory audio-haptic listening experience.

Conclusion

The interaction between auditory and haptic perception suggests a new ground of musical space for electro acoustic music. Bodily awareness through sonic vibro-tactile stimuli is directed to intimate physical space, while aural component evokes auditory imagination. Thus our musical imaginary space coexists with the corporeal awareness.

Integration of audio-haptic works with electro acoustic music has been practiced over 10 years. The work examples proved the advantages of use of electro acoustic music for that the manipulation of parameter for vibratory stimuli.

- Access to the multi-channel sound production for diffusing vibratory stimuli around the body;
- The characteristics of the vibratory stimuli can be manipulated by the parameters such as frequencies and amplitude, which are already familiar method for electro acoustic music composers.

Further application of this type of works can extend the diversity of the audio-haptic sonic experience: For instance, for live performance of electro acoustic music, integration of the emotional response of the audience by means of psychophysiology and biofeedback, or compositional collaboration with electro acoustic musicians.

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