

Spaces That Perform Themselves

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Abstract

As we generally experience on earth, there is no space without sound and there is no sound without space. Spaces That Perform Themselves proposes to expand the way we relate to sound and space by presenting a multi-sensory kinetic environment that morphs along with a musical piece and creates a dynamic space in constant flux. This augments our sonic perception through a cross-modal spatial choreography that combines sound, physical movement, light, color, and vibration. This project builds up a scenario to study the possible relationships between a human body and a robotic architectural body, throughout a dance/exchange of perception and matter. The objective is to challenge our static structures and by doing that, stimulate our own plasticity.

Introduction

The study of the relationship between sound and space, or music and architecture has been fundamental to the opening of new explorations towards the expansion and merger of both fields. In the second half of the 20th century, many creators explored this in experimental ways. Contributions such as Stockhausen's sound spatialization, La Monte Young and Marian Zazeela's Dream House, and Bernhard Leitner's sound architectures, to name a few, revealed expressiveness and malleable capacities of spatial sonic experience, as well as opening an extensive discourse around musical spaces and plastic architectures.

Cedric Price's Fun Palace proposed a cybernetic architectural system that could adapt depending on the varying necessities of individuals and its context. Today this vision is no longer considered to be a utopia, as shown in the work of researchers like Behnaz Farahi, Ruairi Glynn, Skylar Tibbits and Michael Fox, which have opened engaging possibilities to augment the interaction between

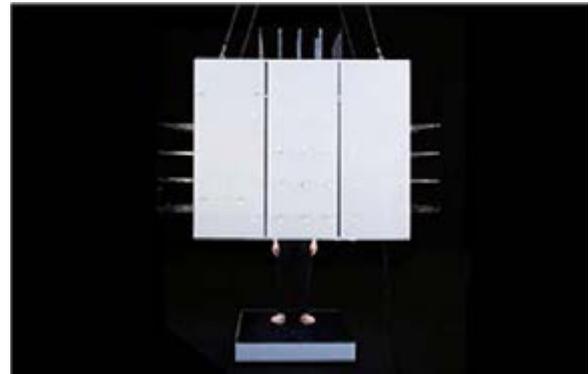


Fig 1. *The cube*, multisensory kinetic environment with human in its inside.

humans and dynamic forms of the built environment.

Spaces That Perform Themselves continues and extends the discussion from a sonic-spatial perspective; it poses the question: how does a kinetic architectural system change the way we think about and perceive sound? One of this project's objective is to create an augmented relationship between sound and space. Currently, we generally build *static* spaces to contain *dynamic* sounds. What if we start building *dynamic* spaces to contain *dynamic* sounds? By integrating kinetic behavior as part of the performance of a space, one is able to give life to a container that morphs along with a musical piece: bringing to life an emerging aesthetic form of expression, augmenting the field of exploration that combines architecture, music, science and technology. This project seeks to explore the plasticity of the spaces we inhabit and the plasticity of our own minds. The perceptual plasticity of a room is not only related to its capacity to move, change, and evolve, but it also has to do with conquering and pushing the limits of how we relate to the environment and other non-human agents on it.

In the exploration of spatial experience and its relationship to the phenomenon of sound, it is imperative to understand how sound and space are linked: as we generally experience

on earth, there is no space without sound and sound carries the essence of the space it is embodied in. To be able to explore this further, it is necessary to have in mind notions of acoustics and acoustemology. These fields of study are essential for an optimal achievement of a sonic-spatial composition, because both reflect the constitutional relationship between sound, space, and experience. They define how the characteristics of a space will affect the way we perceive sound, derive meaning therefrom, and in turn, how the characteristics of sound will affect the perception of a space and its experience.

This project presents an environment that re-configures itself and presents a multi-sensory scenario to perceive sound. *Spaces That Perform Themselves* is a project that will allow music to give shape to a dynamic room that is both alive and in constant flux: it moves, changes its geometry and size, breathes, feels and responds. It is what Bruno Latour would call an Actant or an enhanced body of “Vibrant Matter”, referencing Jane Bennett’s vital materialistic theories. This room will take the shape of a cube that can host one individual at a time, presenting an intimate and personal experience. By creating the perception of a single space that morphs along a progression of sonic situations, this room will have the ability to become “many rooms” within the same structure. A synchronous choreography of sound, motion, vibration, light, and color will shape this perceptual experience, confounding the senses and giving the possibility of inducing different physical and psychological scenarios.

In order to understand the mediation that connects spaces to bodies, we must explore the body-and-space relationship. The notion of space that this paper will address is the uniform boundless medium where things are organized in three dimensions, thus enabling encounters between animated and in-animated bodies. A scenario that represents a regular body-and-space relationship can be typified by imagining an individual inside an architectural body, for example, a person standing inside a container composed of static walls. Due to the simplicity and familiarity of static architectural bodies, an individual in this specific situation can easily understand and predict his or her interaction within this scenario. In other words, it is not a challenging situation for her or him to experience due to our accustomed quotidian action of encountering rooms with fixed structures.

However, the individual’s ability to understand and predict the body-and-space relationship becomes increasingly more

complex if, in the previously mentioned scenario, the architectural body is replaced by a natural body. A natural body is an organic container that is dynamic in its essence and presents an unpredictable and ever-morphing self. When a room is constantly changing or evolving, it demands more of our attention and cognitive action to be able to understand our relationship to it and how to act/be. By encountering a dynamic room that morphs and reacts to sounds, it is possible to reconstruct the way we relate with our environment, it is possible to think about a hybridization or viscosity of the self; allowing the possibility of being natural, mechanical, fictional, real, material, and immaterial at the same time. This way, indeterminacy and uncertainty are presented as a key factor for constructing narratives of coexistence and the de-territorialization of thought. This way, this cube creates a platform for new imaginaries to defy and replace stereotypes.

The human body is placed at the inside of a body that teaches us about plasticity, resilience, adaptability, and vulnerability. And by doing this, we can understand the fragile alien condition in which we experience and relate to the world. By encountering this body, we might discover a less hierarchical and more transversal ecology, where situations of control are constantly shifting, where things can gain control and guide us on the performance of a narrative that unfolds on time; understanding this as a constant exchange between two bodies that are subjects of emergence. *Spaces That Perform Themselves* presents a body that is in a constant act of becoming, a body that reconfigures not only its shape, but also structures of power, and by so doing, proposing alternative forms of being. As a result, unusual possibilities are triggered challenging systems of thinking, making us aware of our bodies in an emotional relationship with space, sound and time. Critically challenging the way humans relate to other agents, as well as challenging the role of a space, which tends to be static, utilitarian, and functional, which tends to be in service of anthropocentric structures.

1. Body

1.1. Shell

The shell of this project is its architectural structure, what contains the body and also what contains the experience. The shell in this case takes the shape of a 180 x 180 cm cube that hangs from the ceiling and has no bottom, leaving an opening beneath so that a human can enter it by kneeling

down and emerging into it. The five faces of the cube feature a motorized mechanical system of rack and pinion, which engages clear acrylic rods to actuate flexible fabric walls on its inside. These walls will adopt different shapes and positions creating a malleable room. The fabric not only is the dynamic enclosure of the inside walls, but also acts as a screen to diffuse the light and color of LEDs behind it. The cube floats over a platform that vibrates, this creates a sense of physical sound that goes from your feet to your whole body.

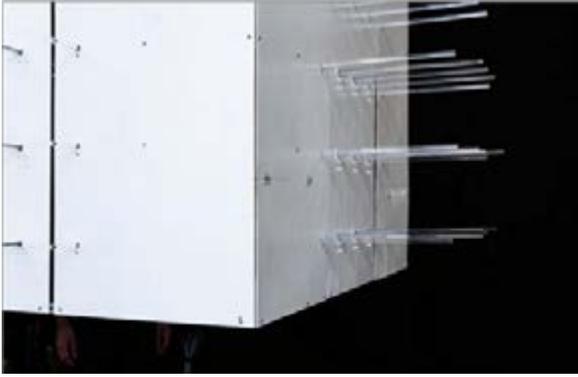


Fig 2. *Cube exterior detail, shell and rods.*

1.2. Guts

The guts of this body are constituted by four Systems that give life to this dynamic environment. First of all, the Motion/ Mechanical System that consists of all the parts that generate physical movement of the walls. There are 45 simultaneous stepper motors to actuate the fabric walls. Every motor is conceived as an individual module with its own microcontroller and address tag. They are all interconnected and controlled via I2C communication. This modular networked platform allows all the motors to act independently or simultaneously. The Sound/Vibratory System provides 5.1 high fidelity spatialized audio system. All four walls have a speaker embedded in the structure, and a fifth low frequency transducer is placed beneath the platform. This creates a controlled scenario for an embodied perception of air vibrations. The Light/Optical System consists on an array of LEDs in every wall to add the dimension of light, color, and brightness. Finally, the Sensory/Reactive System is what gives the room its interactive ability and opens the possibility of improvisation; it gives the chance of triggering changes and

making every performance unique. Every wall has a capacitive touch sensor, which creates a system of 5 triggers that changes color and adds sounds.

1.3. Brain

The computational structure that brings this system to life is an interconnected set of elements that receive musical data and create different synchronized outputs. A graphical user interface (GUI) control platform is designed to present a tool primed for movement composition alongside the other aspects of the spatial choreography. This control platform communicates software - a DAW (Digital Audio Workstation) with Processing - to send synchronized data (MIDI) via serial communication. This enables the mapping of different sound/musical parameters to pre-programmed output patterns for controlling the motors and lights. The system can be either entirely reactive to the music, or controlled in real time. This opens the possibility of a mixed use, promoting further experimentation, creative processes, and customized outputs. The four Systems that determine the cube's functionality are triggered from the same software. This allows an organized and easy way for the mapping of all the elements, which facilitates the composition and creative processes.

2. Expression

2.1. Personality

Even if the cube's body is a concrete and rigid object, what constitutes its personality is light and ethereal. Donna Haraway wrote: "Our best machines are made of sunshine; they are all light and clean because they are nothing but signals, electromagnetic waves, a section of a spectrum, and these machines are eminently portable, mobile..." [1]

The cube requires the capability of being expressive to communicate, connect and engage. The musical parameters are carefully mapped to the electronic elements of the system. This opens an extensive exploration of cross-modal perception, ranging from sound and color perception, light awareness to vibrations, acoustics and space modulation. The personality of the cube is given by each one of its parts working together. To unveil this character, it is fundamental to understand the phenomenological objectives of each one of its Systems. This will give clarity of the creative possibilities and set up the context for composing.

1. Motion / Mechanical System: architectural spaces are containers of experiences and different levels of

interactions. Interactions between bodies inside of a space and bodies interacting with a space. When a room changes and is unpredictable, we need to re-map how we relate to it. This modifies our own spatial presence in a new dialectic manner. This means that the movement of the room triggers new perceptual associations and perceptual dispositions towards the room itself.

The cube embodies a dance that alters its geometry, dimensions, volume, and proximity to the human on its inside. The motion carries a direct connection with the kinesthetic sense of the cube and visual sense of the user. Humans are visual beings, often trying to understand things from a distance and observe remotely before involving touch and a state of vulnerability. “Our vision of the world is far more complex than the mere activation of the visual part of the brain. Vision is multimodal; it encompasses somatosensory, emotion-related, and motor brain networks, and this activation plays out in endocrine systems and more. (Images can make you sweat.) The observation of touch triggers the somatosensory cortex. The observation



Fig 3. *Interior detail*, flexible fabric wall with capacitive touch sensor.

of the expression of emotions and feelings activate limbic and emotional-related brain regions. Motor neurons not only cause movements and actions but they also respond to body-related visual, tactile, and auditory stimuli, mapping the space around us, the objects at hand in that very same space, and the actions of others. Cortical motor networks thus define in motor terms the representational content of space, objects, and actions.” [2]

Though, spatial experience is never a fragmented phenomenon; everything that rises from it comes from the

combination of the diverse sensory elements around us. The human brain will react to the movement of the cube and will re-wire the way we understand and relate with spaces, creating a new perceptual model of dynamic behavior, instead of taking for granted its initial configuration as a permanent static state. Spatial recognition is usually done immediately; our brains know how to understand a space and its dimensionality; this way our bodies can be there at ease without even thinking about it. As Marvin Minsky said: “We are less aware of what our minds do best.” [3]

By challenging this way of thinking, our minds will expand to include the dimension of time as part of a room’s configuration. Having a room changing in a dynamic way opens the encounter of an architectural system that is designed not to accomplish a purpose, but to create an effect.

2. Sound/Vibratory System: usually, for human beings the sense of audition is less fundamental than the sense of vision or touch. Even though the sonic phenomenon is an important tool for understanding our context, dimensions, materials, and distances. Sound places us in the world. There are many theories of how sound is physical and creates a link between the material and immaterial world. This is what ties sound to an extensive discourse as a creator of material affective memory.

Sound is actually the resonance and vibration of matter, of particles of air or other materials. Within Husserlian phenomenological thinking, the material aspects of sound makes it a valuable tool of auto-affection, because it involves touch. Thus sonic phenomena is material and has spatial presence. “The most important sense in our body is touch... Hearing is linked to touch from a phylogenetic perspective (inside of the lateral line organs of a fish, destined to the reception of pressure stimuli of ultrasound, then evolved into amphibian’s auditory organs, and later into our ears) and from a ontogenetic perspective (the vibrations of sound reach the fetus through the capture of the amniotic liquid’s pressure over the epidermis; during the prenatal phase we can talk about a “global ear”, an approach of hearing with all the skin). Thus, drawing a “haptocentric” vision of human sensitivity, where the tactile contact is the source of synesthetic associations and human being’s affective associations.” [4]

Sound breaks down boundaries between material spaces and immaterial spaces, between the visible and the invisible. Sound carries dynamism and empowers the cube to guide the conversation. Organized sounds, or music carries in its

essence the elements of time, space, and matter. And most important, it deploys them in a viscous relationship with the listener, "... music reveals the dynamic depth of the space, not at a distance, how vision does, but at the inside of the most intimate proximity, as living depth." [5]

3. **Light/Optical System:** the possibility of controlling color is an essential characteristic for the multi-sensory composition of the cube, since it comprises one of the primary sensory stimuli human beings have: the distinction of colors. This ability came with evolution, where humans developed a deeper sense of the visual by adding the layer of color.

There is a strong tradition of color and sound association. Even though these are very appealing relationships, they are not totally consistent; thus color vision is not entirely consistent either. It changes and varies through different individuals. A standard human viewer has a trichromatic vision, though a few alterations can occur and alter the perception of color by having partial blindness, color blindness or tetrachromacy (a genetic modification presented only in women). This is why color-to-sound models are subjective and not very consistent.

Even though color and sound correlation models are subjective, they still give us a tool or an extra layer to convey information and materiality. Other than color, visual stimuli can be achieved with light, like in Bryon Gysin's *Dream Machines*, achieve varying mental states through calibrating particular frequencies of sound and flickering light.

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4. **Sensory/Reactive System:** the tactile dimension implies proximity; it opens the possibility of physicality and a more direct relation. Touch is an action that takes place in the most personal sphere: touching something always implies being touched in return. It conveys closeness and at the same time vulnerability; it conceives sensuality as well as danger, among other emotions. The cube's Sensory System is reactive to touch at five distinct points. Though it can touch the user with all of its rods, this empowers the cube, being sometimes scary, sometimes intimidating. This is why inviting the user to touch it is also a way of breaking down this notion of control, making the cube also vulnerable to the human body inside. This provides a relationship

between action and reaction, it presents a dialogue, and it sets a dance.

It is important to refer to the concept of haptocentrism. This notion comes from Derrida's logocentric action of deconstructing the sense of vision (heliocentric or optocentric) as the primordial human sense and exalting touch as the main sense. The haptocentric paradigm establishes that "touch is the sense par excellence of autoaffection. Wherever there is flesh, Derrida seems to imply, there is auto-affection... Just as in *The Voice and the Phenomenon* three decades earlier, Derrida had outlined why Husserl's notion of the voice led to auto-affection ("speaking is hearing oneself speak"), in *On Touching - Jean-Luc Nancy*, carnal auto-affection of touch completes the picture ("touching is touching oneself")." [6]

Following Derrida's ideas, a better relational body is constructed by heightening the sense of touch. This allows us to create tighter relationships since through physical contact, humans can create meaningful embodied affective memories. Human beings are physical three-dimensional bodies that are expressed through the exchange of matter, using material interaction to build immaterial experiences.



Fig 5. *Interior view*, human touching the cube during performance, installation.

3. Relationship

"How could movements of deterritorialization and processes of reterritorialization not be relative, always connected, caught up in one another?" [7]

The concept of Rhizome presented by Deleuze and Guattari sets up the relational aspects of the dance between

the cube and the person inside of it. The cube becomes a symbiotic environment, which gives and receives, that changes, that affects, that is changed and is affected, giving place to a transversal relationship; like a dance, an embodied dialogue. This way of communicating with an architectural space evolves from an exercise of embodied cognition. The environment plays a formative role in the development of cognitive processes of the human inside of it. This person relates to a new type of room, one that is constantly changing, always demanding his attention, telling a story and guiding an interaction.

The interesting thing about a relationship like this one is that it has no beginning or end. It takes place in the middle, on the encounter of the cube and the person. The aesthetic interaction goes from one to the other, feeding the system and transforming both of them (the cube and the individual) as limitless bodies of continuous transference.



Fig 6. *Interior view*, multisensory kinetic environment with human in its inside.

The cube presents a set of territories that can create assemblages, uniting and articulating among them. All the sensory modalities are territories that can be presented and explored. So the performance or the relationship is constructed upon the idea of a constant territorialization and deterritorialization. This is given by the constant variation of situations and state changes, creating a loop of cycles ceding and gaining control. These territories provide the aesthetic material for this experience to be able to construct meaning.

The Cube is a room, a stage, a performer, a dancer, an instrument, and a reactive feeling body all at the same time.

It can build a symbiotic relationship of giving and receiving. Essentially initiating a dance that reorganizes our relationship with our environment by allowing an individual to step into the center of the construction and deconstruction of a space that performs itself.

How can an expressive environment like this one effect and change the way we compose music, spaces, and aesthetic experiences? How can the relationship with this room modify the way we interact with and understand the built environment? How much attention do we pay to the bodies we inhabit and other non-human agents around us?

3.1. Choreography

“Choreography is tied to Biology. Choreography gets its start from something about our nature. It is grounded in our biology.” [8]

The composition of the sensory choreography will unite three main parts: the human body, the cube, and the proposed sensory stimuli. This creates a relationship between the three of them by combining them on a single unified construct. This composition will combine different sensory stimuli that will transform the cube into a synesthetic synthesizer. Synesthesia has been a vastly studied topic among scientific and aesthetic research. Though, even if similar, the notion of kine-synesthesia has been less explored. As the researcher Francesco Spampinato [9] establishes, this concept applies to psycho-sensory-motor characteristics of sensory association, in other words, adding embodied motion. It brings the notion of kinetic to the conversation, and also adds the concept of physicality to the original synesthesia model.

The formulation of the sensory choreography implies the composition and disposition of situational elements on time, thus also on space. Time is never an isolated phenomenon, but it is the element that configures the dialog between the content. Time appears at the moment of mediating the dialog of the parts. Time is the element that denotes the different material and affective aspects of the composition. This capacity of time gives it the particularity of providing a dynamic order, re-configuring static and flat elements into a set of physical and three-dimensional elements. This way, time transforms itself into a spatial factor.

“So we can formulate this law: perception is master of space in the exact measure in which action is master of time.” [10]

Conclusions

When spaces move, they not only transform what we understand as a building, but they also change our presence in it. Their movement makes us aware of our body's relation to change and time. Interactive or kinetic architectures have the power to mutate our physical and psychological milieu. In addition to this, the polymorphism of the cube is given not only by its flexible fabric walls, but also by sounds, lights, colors, and vibrations. The objective is to achieve an organized whole, where the sum of its parts reveals the expressiveness of a system where no isolated element is predominant and all the parts exist in a fluent dialogue between each other. One way to approach making a composition for the cube is to create a series of situations that guide the user seamlessly through diverse scenarios. This fluent arrangement of sensory elements will construct a sensory mass, an amalgamated atmosphere that envelops the user and transports the human inside to a physical world of sound.

Although the cube has many limitations, it is a great tool for programmable spaces, for diverse perceptual studies and sensory mapping. An important lesson was the relational aspects of the project that opened up a deep study of body-and-space interaction and the elements that construct emotional relationships via material memory. The outcome allowed this project to present a first prototypical model that proposes architecture as a medium not only for a purpose, but also for an effect. Other very important conclusion from building and experimenting with the cube is to understand that the machine is finite, however the person who interacts with it is not. This project exposes the encounter between an artificial object and an organic creature. This project bridges the interaction between finite and infinite, it frames the setup for a poetic relationship between things and beings.

References

- [1] Donna Haraway, *A Cyborg Manifesto: Science, Technology, and Social-Feminism in the Late Twentieth Century*, in *Simians, Cyborgs and Women: The Reinvention of Nature*, 153.
- [2] Vittorio Gallese, *Bodily Framing*, in *Experience, Culture, Cognition, and the Common Sense*, edited by Carlonie Jones, David Mather and Rebecca Uchill, 240.
- [3] Marvin Minsky, *The Society of Mind*, 29.

- [4] Francesco Spampinato, *Les Métamorphoses du son, Matérialité imaginative de l'écoute musicale*, 174. Translation by the author.

“Le sens le plus important de notre corp, c'est le toucher... L'ouïe se lie au toucher d'un point de vue phylogénétique (dans les organes de la ligne latérale du poisson, consacrés à- la fois à- la réception de stimuli pressifs et d'ultrasons, puis évolués en organes auditifs chez les amphibiens, jusqu'à- nos oreilles) et d'un point de vue ontogénétique (les vibrations sonores sont saisies par le fœtus à- travers le captage de pressions du liquide amniotique sur l'épiderme; au cours de la phase prénatale on peut parler d'une "oreille globale", à- savoir de toute la peau "à- l'écoute"). Ainsi, se dessine une vision "haptocentrique" de la sensibilité humaine, où- le contact tactile est la source des associations synesthésiques et des associations affectives de l'homme.”

- [5] Brandon LaBelle, *Background Noise, Perspectives on sound art*, Introduction xi.
- [6] Emmanuel Alloa, *Getting in Touch: Aristotelian Diagnostics, in Carnal Hermeneutics, Perspectives in Continental Philosophy*, edited by Richard Kearney and Brian Treanor, 205.
- [7] Gilles Deleuze and Felix Guattari, *Rhizome*, in *A Thousand Plateaus, Capitalism and Schizophrenia*, 10.
- [8] Alva Noë, *Strange Tools, Art and Human Nature*, 15.
- [9] Francesco Spampinato, *Les Métamorphoses du son, Matérialité imaginative de l'écoute musicale*, 142. Translation by the author.

“Le corps devient lecteur de l'expérience parce que l'écoute s'accompagne d'une micro-reproduction empathique des configurations tensives de la musique, à travers l'adoption de certains patterns de tonus musculaire: une "micro-danse imitative”.

- [10] Henri Bergson, *Matter and Memory*, 32.

Bibliography

- Bennett, Jane. 2010. *Vibrant Matter, A political ecology of things*. Durham and London: Duke University Press.
- Bergson, Henri, translated by N.M. Paul and W.S. Palmer. 1996. *Matter and Memory*. 5th ed. New York. Zone Books.
- Blessner, Barry, Salter, Linda-Ruth. 2009. *Spaces Speak, Are you listening? Experiencing aural architecture*. Cambridge: MIT Press.

- Born, Georgina. 2017. *Music, Sound and Space, Transformations of Public and Private Experience*. Cambridge, UK: Cambridge University Press.
- Chouvel, Jean-Marc, Solomos, Makis. 1998. *L'espace: Musique/ Philosophie*. Paris: L'Harmattan.
- Deleuze, Gilles, Guattari, Felix. 2016 (16th edition). *A Thousand Plateaus, Capitalism and Schizophrenia*. Translation by: Brian Massumi. Minneapolis: University of Minnesota Press.
- Feld, Steven. 2015. "Acoustemology". In *Keywords in Sound*, edited by David Novak & Matt Sakakeeny. Duke University Press. 12-21.
- Fox, Michael. 2016. *Interactive Architecture, Adaptive World*. New York: Princeton Architectural Press.
- Haraway, Donna. 1991. "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century," in *Simians, Cyborgs and Women: The Reinvention of Nature*. New York: Routledge. 149-181.
- Jones, Caroline, Mather, David, Uchill, Rebecca. 2016. *Experience, Culture, Cognition, and the Common Sense*. Cambridge: MIT Press.
- Kearney, Richard, Treanor, Brian. 2015. *Carnal Hermeneutics, Perspectives in Continental Philosophy*. New York: Fordham University Press.
- LaBelle, Brandon. 2013. *Background Noise, Perspectives on sound art*. New York: Bloomsbury Academic.
- Latour, Bruno. 2004. *Politics of Nature, How to Bring the Sciences into Democracy*. Cambridge, MA and London, England: Harvard University Press.
- Latour, Bruno, Yaneva, Albena. 2008. "Give me a Gun and I will Make All Buildings Move : An ANT's View of Architecture." *Explorations in Architecture: Teaching, Design, Research*. edited by Reto Geiser. Basel: Birkhäuser. 80-89.
- Leitner, Bernhard. 1978. *Ton : Raum, Sound : Space*. New York: New York University Press.
- Merleau-Ponty, Maurice. 2012. *Phenomenology of Perception*. Trans. Donald A. Landes. New York: Routledge.
- Minsky, Marvin. 1986. *The Society of Mind*. New York: Simon and Schuster.
- Noë, Alva. 2016. *Strange Tools, Art and Human Nature*. New York: Hill and Wang.
- Pallasmaa, Juhani. 2012. *The eyes of the skin, Architecture and the senses*. John Willey & Sons Ltd.
- Spampinato, Francesco. 2008. *Les Métamorphoses du son, Matérialité imaginative de l'écoute musicale*. Paris: L'Harmattan.
- Tibbits, Skylar. 2016. *Self-Assembly Lab: Experiments in programming matter*. Routledge.
- Torpey, Peter A. 2009. *Disembodied Performance: Abstraction of Representation in Live Theater*. S.M. Thesis: Massachusetts Institute of Technology, Media Arts and Sciences.
- Varela, Francisco, Thompson, Evan, Rosch, Eleanor. 1991. *The Embodied Mind: Cognitive Science and Human Experience*. Cambridge: MIT Press.
- Yaneva, Albena. 2008. "How Buildings 'Surprise': The Renovation of the Alte Aula in Vienna," in *Science Studies: An Interdisciplinary Journal of Science and Technology Studies*, special issue "Understanding Architecture, Accounting Society".21(1).
- Young, La Monte, Zazeela, Marian. 2004. "Dream House". In *Selected Writings La Monte Young & Marian Zazeela*, edited by M. H. Tencer. Ubuclassics. 10-16.