Heartbeats and the Arts: A Historical Connection

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GENERAL ARTICLE

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ABSTRACT

This article traces the historical relation of heartbeats, science and art. It begins with an outline of historical ideas and science concerning the heart and the arterial pulse that will give better understanding of the intimate relation and differences between both and how early studies of the heart led to the discovery of the pulse and to the early relationship between heartbeats and art. Secondly, it tracks through history the particular interest of artists in making the pulse visible. Devices linked to bodies serve as mediators in artworks that project body mechanisms beyond corporeal limits. The works discussed project heartbeats as metaphors of emotions and life in installations that involve multiple senses.

THE VISUALIZATION OF PULSE

The heart has been conceived in history both as a metaphor (of emotions and sensations) and as a physical part of the body. In the fourth century BCE, Aristotle (384–322 BCE) thought that the heart was the core of vitality. He conceived the location of the heart in the body as intimately related with its key role in its functionality believing that as a heat organ it affected emotions, in opposition to the cold brain, by its nature immune to feeling [1]. Although Aristotle mentioned pulse in some writings, Praxagoras of Kos (340 BCE) was the first Greek physician to examine and write about the pulse. Like his predecessors, he attributed the origin of pulse to *pneuma* [2]—a "vital air" that traveled along arterial layers, while veins contained blood. Another important scholar, Erasistratus (304–250 BCE), stated that the activity of the heart and arteries was not synchronized, because the motion of arteries follows the contraction of the heart [3].

Later, Herophilus (335–280 BCE) found that pulsation was a physiological reaction caused by the contraction and dilation of the arteries drawing *pneuma*, corresponding to an impulse received from the heart. Before any other physician, Herophilus distinguished between veins and arteries and measured the pulse rate with an aesthetic and innovative apparatus: a *clepsydra* or portable water clock that contained a specific amount of water and was calibrated according the age of the patient (Fig. 1). As Shigehisa Kuriyama states, in Herophilus's greatest achievement, "by separating blood vessels from nerves, and among blood vessels, arteries from veins, anatomy thus helped forge the object of sphygmological study" [4]. Furthermore, he was the first thinker to compare pulsation to an art form: music. He thought that the pulse had upbeat and downbeat units that could connect metrical-musical rhythms with pulse rhythms [5]. This theory had considerable impact on the creation of music during the Middle Ages and the Renaissance, when music was believed to be inherent in the throbbing of pulse [6]. For instance, Boethius (480–524 CE) developed influential theories in which he distinguished three types of music: The first, *musica mundana*, was the music of the celestial spheres. The second, *musica humana*, connected *musica mundana* to the body and was determined by rhythms of the human pulse, hormonal cycles and patterns of breath and heartbeat. The third type was the *musica instrumentis*—the only type of music that humans could hear. Leonardo da Vinci also discussed the temporal nature of music using the term *tempo armonico* to denote a beat of music in his famous *Paragone*, a comparison of poetry, music and painting. He thought that *the interval between two beats of the pulse was a half of a musical tempo*. That said, Herophilus's analogies of music and pulse rhythms resulted in one of the first connections between arterial pulse, science and art.

Fig. 1. A clepsydra of the type used by Herophilus is at the top of this painting by Doeve. (Image courtesy of the Texas Medical Center Library's McGovern Historical Center, MS# 94, Texas Medical Arts Publishing Foundation records.)

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On the heels of Herophilus's work, Galen of Pergamon (129–200 CE), a prominent Roman physician and philosopher, added understanding of the heart and arterial pulse. Galen thought of the heart as an enclosed structure that by its "innate heat" dilated when drawing blood from the liver into its right chamber, converting it into a more refined type of blood. This arterial blood traveled through pores to nourish the lungs, continuing its circulation into the left heart chamber, which was a *pneuma* pump that sent the vital substance into the arteries, causing pulse [7]. Galen incorrectly stated diastole—the period of relaxation of the heart muscle when the chambers are filled with blood—and not systole—the period of contraction of the ventricles of the heart—as the true movement of the heart, but correctly found different kinds of pulses, based on the degree of arterial dilation, usable for diagnosis. The Persian polymath Avicenna (981–1037 CE), who correctly conceived pulse for the first time as a wave rather than a straight impact, extended Galen's studies about the arterial pulse rhythms. The discoveries of Galen and Avicenna about the different pulse rhythms strengthened the metric relation of pulse with music. Avicenna explicitly conjectured that the nature of music was found in pulse.

In an important step in the understanding of pulse, English physician William Harvey (1578–1657) correctly attributed the generation of the arterial pulse to the contraction of the left ventricle and located the source of heartbeats in the right atrium of the heart. Harvey elucidated that it was in systole and not diastole that the heart drew blood into its chambers and conducted the blood out into the arteries, producing the arterial pulse [8]. Despite Harvey's explanation, he did not provide significant instruments for assessing and visualizing the frequency of the arterial pulse; his studies were based on tactile methods (Fig. 2).

It was during the seventeenth and eighteenth centuries that additional instruments for measuring and visualizing pulse were created. Sanctorio Sanctorius (1561–1636) invented the *pulsilogy,* consisting of a graduated scale and a pendulum-like weight that measured the pulse rate as number of inches. John Floyer (1649–1734) examined pulse rate with a watch

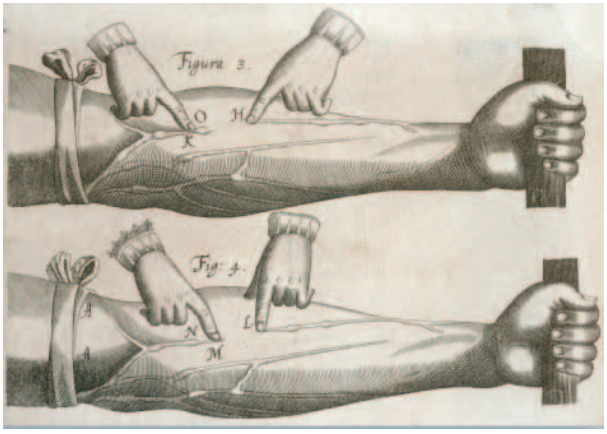

Fig. 2. William Harvey, *Exercitatio anatomica de motu cordis et sanguinis in animalibus* (Frankfurt: Fitzer, 1628). (Creative Commons Attribution CC BY 4.0)

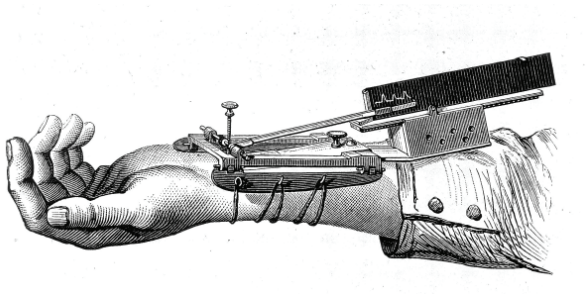

Fig. 3. Etienne Jules Marey, *La méthode graphique dans les sciences expérimentales et principalement en physiologie et en medicine* (Paris: G. Masson, 1885). (Creative Commons Attribution CC BY 4.0)

as done today, in beats per minute. During the nineteenth century more technical equipment was developed, such as the *sphygmomanometer,* consisting of a rubber bulb filled with water, connected to a glass tube with mercury, which when placed over the artery measured pulse. The *stethoscope*, invented in 1816, consisted of a monaural wooden acoustic device for listening to the internal bodily sounds such as heartbeats or blood flow. Another apparatus, the *kymograph*, was capable of recording hemodynamic measures on a rotating cylinder with a stylus [9]. Further detail is beyond the limits of this article, but it is important to mention that the first device that permitted studying arterial pulse as a wave was the *sphygmograph*, created in 1854 by German Karl von Vierordt (1818–1884). It consisted of a system of weights and levers that permitted the user to estimate blood pressure. In 1863, French physiologist and photographer Étienne-Jules Marey (1830–1904) improved the sphygmograph by making it portable and capable of generating a graphical record of the pulse wave in patients with diverse diseases (Fig. 3). The apparatus was simple but innovative for the time, consisting of a lever with one end rested on the pulse point of the wrist and the other connected to a stylus. A clockwork mechanism moved a strip of blackened paper under the stylus at the rhythm of the pulsation, converting it into an inscription [10].

Marey was fascinated with movement, considering it the most important characteristic of life [11]. The sphygmograph was one of multiple inventions he used to reveal and record barely perceptible physiological motions. For instance, in 1882 Marey invented a method of producing on the same negative a series of successive images of bodies in motion (e.g. blood transmission, flying birds and flexing muscles) to study a body's exact position in space and time. Marey called this technique, which anticipated cinematography, *chronophotography*. He developed it with an electric photographic gun using 35 mm film, capable of producing 12 images per second on a turning plate.

Marey's pulse graphic method was the forerunner of other graphing machines developed in the twentieth century, such as the *plethysmograph* and the *electrocardiogram.* The plethysmograph registered variations in the volume of body organs caused by alterations in the blood pressure. Created by Dutch doctor and physiologist Willem Einthoven in 1902, the electrocardiogram delivered for the first time accurate measurements of the heart's electrical currents, making visible the heart as an electric and magnetic field. These ma-

chines were developed using twentieth-century technologies such as crystal microphones, sensors and computers to determine the electrical activity and the configuration of the waveform of pulse [12]. These electric signals recorded from the skin provide relevant information about the state of a person's heart and health. Thus, in the twenty-first century, technological devices that measure pulse have crossed the boundaries that separate the medical and scientific fields. Many professional and consumer applications have emerged in the area of personal health, fitness, art and entertainment requiring sophisticated yet uncomplicated devices that measure and even allow users to share their heart rates.

ARTERIAL PULSE AND ART

The heart has been a recurrent motif of representation in paintings, drawings and sculptures, from the depiction of the Sacred Heart of Jesus in baroque *retablos* [13] and paintings in the seventeenth and eighteenth centuries to more contemporary artworks such as Jeff Koons's gigantic, shiny sculpture *Hanging Heart* (1994–2006). While heartbeats are a sign of the heart, the works that use cardiac activity are of a very different nature because they don't depict the heart but use the heartbeat itself as input for creating works.

The 1960s saw digital works created using cardiac activity as an interface enabling the uncanny possibility of seeing our vital functions as though from outside. Digital technologies have played an active role in the development of artworks that use heart rates: Speakers, stethoscopes, electrocardiograms, recorders and sensors are tools for creating works using heartbeats as input. These devices have gone beyond the visualization of the body to critically extend its limits to previously unimaginable spaces, challenging the conception of the body as a unity bounded by the skin.

In her "Cyborg Manifesto," Donna Haraway questioned the skin as a border of the body: "Why should our bodies end at the skin, or include at best other beings encapsulated by skin?" [14]. Following also the ideas of Steve Connor, the skin "is the vulnerable, unreliable boundary between inner and outer conditions and the proof of their frightening, fascinating intimate contiguity" [15]. In this manner, it is only through the skin, the outer main entrance to the inner body universe, that pulse, as an inner condition of the body, can be perceived from the outside through tactility. Therefore, in works that use pulse, the skin serves as a medium of passage for a participant's heartbeats. The skin connects the pulse to a speaker or a sensor that reads the pulse as data that later is translated via computers into light, sound or vibrations. This process results in the reterritorialization or disembodiment of the body to an exterior space. Thus, digital technologies open the possibility of the fragmentation of the body, allowing the creation of new body configurations created by artists in a variety of forms and spaces.

AMPLIFYING SENSATION

The condition of pulse as a rhythmical vital sign and its intimate connection to the heart, where it is usually believed that feelings are housed, has made it a fascinating element for artists to explore in art installations and performances appealing to the amplification of emotions or physical feelings. Take for example *Son et Lumière: Bodily Fluids and Functions* (1966) by Mark Boyle and Joan Hills, a performance wherein a couple had intercourse while connected to an ECG (electrocardiogram) and EEG (electroencephalogram). The oscilloscopes were on closed-circuit television and projected onto a large screen behind the couple. The performers made visible and hearable their heart and brain waves with the help of a microprojector, microphones and sound amplifiers. Ingrained in the aesthetics of expanded cinema and real-time processes, this performance innovatively deploys an electronic screen for extending the limits of the human body and to explore stimuli and sensations through physical phenomena such as heartbeats.

The intention of making visible and audible heart pulse wave sounds for making an investigation of physiology of emotions and endurance can be found in Ulay and Marina Abramovic's performance *Rest Energy* (1980), in which over a period of four minutes Abramovic held a bow while her partner at that time, Ulay, held the string of the bow and an arrow that was pointed directly at Abramovic's heart. They stood across from each other, looking into each other's eyes, and gradually leaned away, increasing the tension of the bowstring. Small microphones attached to both hearts recorded their pulsations, which as the seconds passed became more intense, making of their sensations a sonic and spatial presence in the exhibition space.

There is a body of musical work derived from cardiac activity, which is a natural connection, given the aforementioned relationship of the heartbeat to meter and rhythm. Pauline Oliveros, in her *Sonic Meditations* (1974), invites practitioners to listen to the environment as a drone, establishing a mental contact between the external sounds of the environment and the internal sounds of their own bodies, including the sounds of their own heartbeats and blood pressure. These connections of sounds create awareness of internal and external worlds, expanding sensations and consciousness. Another example is the Heart Chamber Orchestra's (2006–2012) algorithmic and audiovisual compositions using heartbeats. The performances consisted of a group of 12 musicians equipped with ECG sensors that detected their heart rates; with that data a computer created both a real-time score played by the same musicians and a graphic visualization projected on a screen behind the orchestra. These interactive performances imply that the improvisation of music that literally comes from the heart reflects the entanglement of the inside and the outside in the foundation of creativity, communication and emotions.

Some works also explore possibilities for technological communication by participants via the simulation of heartbeats, which creates the tactile impression and sensory lifelike experience of holding vital signs. *Charged Hearts* (1997) was created by Catherine Richards in collaboration with a group of scientists and engineers (Fig. 4). This installation consists of two glass hearts located inside bell jars, both charged with plasma gas. A terrella, placed between them,

Fig. 4. Catherine Richards, *L'intrus (after Charged Hearts)*, 1997–2012. (© C. Richards)

Fig. 5. Christa Sommerer and Laurent Mignonneau, *Mobile Feelings II*, 2001–2004. (© Sommerer & Mignonneau. Photo: Laurent Mignonneau.)

contains gases that became phosphorescent when visitors lift the bell jars. This contact produced the excitement of electrons that in turn made the glow pulsate as if it were connected to each participant's heartbeats. The glass objects became an interface that blurred the boundaries of the body, giving the virtual sensation of connection between persons via corporeal electromagnetic signals.

Another interactive work that connects to Richards's in relation to sense and simulated heartthrobs is *Mobile Feelings II* (2001–2004) by Christa Sommerer and Laurent Mignonneau, which explores different ambivalent possibilities of communicating and sharing personal body sensations with strangers via mobile "phones" (Fig. 5). Two egg-shaped "phones" need to be held, ideally by two strangers, in a room to be activated. Once they are touched, the mobiles—equipped with biosensors, ventilators, vibrators and electrochemical systems—simulate the pulse, sweat and smell of the stranger. The devices work on a standard mobile network so they can be used anytime or anywhere. *Mobile Feelings II*, in addition to bringing into question the frontiers of the public and private notions in our technological societies, explores the possibilities of expanding the body to unexpected spaces via digital technologies that use heartbeats as a paradigm of communication.

BLINKING SPACES

In addition to the aforementioned exploration of the relation of heartbeats to sensations, a number of artists have used light, space and time to create works that use heartbeats as input for the reconfiguration of spaces. One of the first to experiment with the use of art, light and digital technology in the 1960s was French artist Jean Dupuy, who collaborated with engineer Ralph Martel on one of the earliest works to engage pulse, light and technology. *Heart Beats Dust: Cone Pyramid* (1968) consists of a 60-cm plywood box with a glass window at eye level (Color Plate C). Inside the cube, an infrared light located in the ceiling illuminates a pile of Lithol Rubine—a bright red dust of low density that can remain suspended in the air for long periods of time—that pulsates according to the rhythm of the participant's heartbeats. The body's pulse is measured by a stethoscope and played on a speaker mounted directly under a rubber membrane upon which the blood-red dust rests. The sound activates the dust, which, once in contact with the light, creates a temporal red pulsing pyramid-shaped sculpture.

A very different perspective can be found in Christian Möller's architectural installation *Light Blaster: Immaterial Membrane* (1993), which consists of a 5-meter wall that faces the participant (Fig. 6). The visitor is invited to activate the work by using an electronic pulse sensor and an oxygen monitor that communicates to a computer system that rates the heart activity of the participant. A fiber-optic cable projects a blue-green light surface into the space from a water-cooled 4 W argon laser onto a spinning mirror. The light in the wall moves in correspondence with the heartbeats of participants, creating a beautiful display of light. Besides this optical effect, a loudspeaker system also transmits the sounds of the beating

heart synchronized with the pulsating motion of the membrane of light in space. Möller's biofeedback environment uses heartbeats as a medium to expand the boundaries of the body into new technological architectural spaces. There is an exteriorization of the inside when the body merges with architecture. In the case of Möller's installation the body expands its limits; the blue-green-light wall becomes the body itself, and the glass surface acts as skin.

Heartbeats inhabit a space in Christian Boltanski's *Les Archives du Coeur* (The Heart Archive). The artist initiated the project in 2005. Consisting of a collection of thousands of human pulses permanently located since 2010 in a special purpose-built house-museum located on a remote beach on the Japanese island of Teshima, the work, far from being a statement about life, is a reflection on death and (im)permanence (Fig. 7). When a participant enters the space, a computer screen provides information on the heartbeats that can be heard in the adjoining Heart Room. There, a single light bulb hanging from the ceiling illuminates the space, pulsating to the rhythm of someone's heartbeat. Visitors can consult the database that holds all the audio files and can record their own heartbeats to be part of the archive. By creating a collection of heartbeat recordings that could repeat over time, Boltanski intends to create a form of immortalization using digital sensors, computers and recording technologies, a chimeric memorial island that offers a notion of posterity: a palliative to mortality.

In contrast, artist Rafael Lozano-Hemmer avoids notions of immortality in more than eight works that use an interface that requires the input of heartbeats from participants, which are later projected as pulsing lights. His first "heartbeat work," *Pulse Room* (2006), consists of a darkroom full of bulbs blinking to the rhythm of participants' heart rates. The latest, *Pulse Corniche* (2015), uses a matrix of robotic searchlights, a DMX controller, a computer, custom software and a metal structure with a sensor (Fig. 8). When a passerby makes contact with the device, his or her heart rates are recorded, translated and projected as pulses of narrow-beam light in the sky, pushing one step forward the last heartbeats recorded, obliterating the oldest register. While the installation works as a memento mori reminding us of the inevitability of our disappearance, it also exalts the collective nature of life, as in these pieces the individual disappears to merge into the community of pulses. Furthermore, the work aims to invert the controlling and intimidating uses of biometric and searchlight surveillance technologies, creating instead a lighting environment of social interaction.

Undoubtedly, biometric works that use heartbeats and light share a formal structure in which heart rates are translated and projected as pulses of light when a participant makes contact with a sensor. As a result, the projection of these light rays of the installations is a process of reembodiment of the participant's body through vision and pulsation. This is now a triple process that reflects light as paradoxical wave or material, joining the biological with the technological. The pulse inside the body is rendered through the skin to the outside of the body, which enters new media and returns to the body via light and the eyes. Light enters through the participant's cornea, the transparent covering of the eye. The cornea bends or refracts the light rays that pass through the pupil. The iris, the colored part of the eye, contains muscles that allow the pupil to dilate or contract—a kind of pulsation effect—to regulate the amount of light that

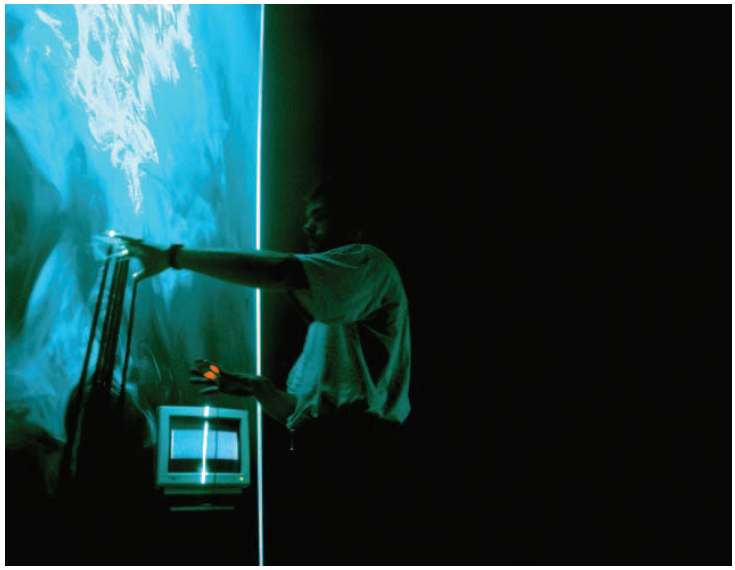

Fig. 6. Christian Möller, *Light Blaster: Immaterial Membrane*, interactive light and sound installation, 1993. (© Christian Möller. Photo: Dieter Schwer.)

Fig. 7. Christian Boltanski, *Les Archives du Coeur*, 2010. (Courtesy of Fukutake Foundation. Photo: Kuge Yasuhide.)

Fig. 8. Rafael Lozano-Hemmer, *Pulse Corniche*, 2015. Commissioned by Guggenheim Abu Dhabi. (Photo: Antimodular Research. Creative Commons Attribution 3.0 License.)

passes through. Then the light rays travel through the lens, which further focuses light onto the retina. The retina is a thin delicate layer that is located at the back of the eye and contains special "photoreceptor" cells called rods and cones. These cells in the retina convert the light into electrical impulses. Then the optic nerve sends these electrical signals to the brain, where images are produced or captured.

ENERGY FLOW

In all works using or simulating heartbeats, there is a flow of energy through different systems. The aforementioned artists transform or translate between various forms of energy by deploying electronic media. Electromagnetic waves are sourced naturally from the biological realm and translated into different kinds of waves (such as light and sound beats) that enable ecology or flow through a process of embodiment. The term "ecology" in this context is used because, as pointed out by Matthew Fuller, the concept comprises the interrelations and interactions of the parts or processes of a system [16]. Some pulse-based works are complex dynamic ecosystems of which each ecological cycle has as its starting point participants' hearts—one of the body parts better known for its electrical fields—that through their diastolic and systolic movements generates blood circulation through the arteries, creating pulse.

Clearly, pulse-based works such as those of the aforementioned artists involve a total corporal engagement with the artwork, involving heart, arteries, blood, pulse, hands, skin, eyes, brain, sound and hence the entire body as a collection of pulsing, sensing, energy organs. These senses are interconnected thanks to the interactivity of a user that activates the artwork simply by touching a sensor. Following Marshall McLuhan, "Tactility is the interplay of the senses, rather than the isolated contact of skin and object" [17]. This merging of flesh, organs and senses filtered through a system enables the artwork to destabilize the boundaries of the body.

At the core of all the works mentioned is the use of technological elements in which the machine meets the body to create a conscious experience of life via the heart and the pulse. Interactivity helps to involve the user in an intimate process that leads to the transformation and creation of new meanings within the works. All pulse-based biometric works remind us of our vitality because they are the result of a temporal wave—a periodic oscillation or disturbance—that is emitted and received, constant but inhomogeneous, and travels through space accompanied always by a transfer of energy. Pulse-based works use body energy as an interface that is transformed into data to then acquire a variety of forms manifesting the forcefulness of a system outside of the realm of the body, giving it a visual and aesthetic form, filtered and renewed through the lens of art.

CONCLUSION

Heartbeat works are connected to long traditions of art experimentation that explore ways of expanding the body beyond its limits through technology. The experiments and

historical devices of scientists are key historical precursors to the work of contemporary digital artists. Both reveal and record invisible biological processes, demonstrating the dialectic between the seen and the unseen. As a result, an essential characteristic of life, such as pulsation, movement and time, is not only visible but also recorded and shared beyond its ephemerality. The visualization of pulse aims to share what is naturally private, internal and invisible: the beating of a heart. Clearly, as science and technology develop and connect with art, the limits of pulse expand, creating communication vessels between the body and the environment. Digital artworks using pulse are part of a long trajectory of visualization and interdisciplinarity that at its core aims to share and reveal the inner nature of the human body beyond its natural confines.

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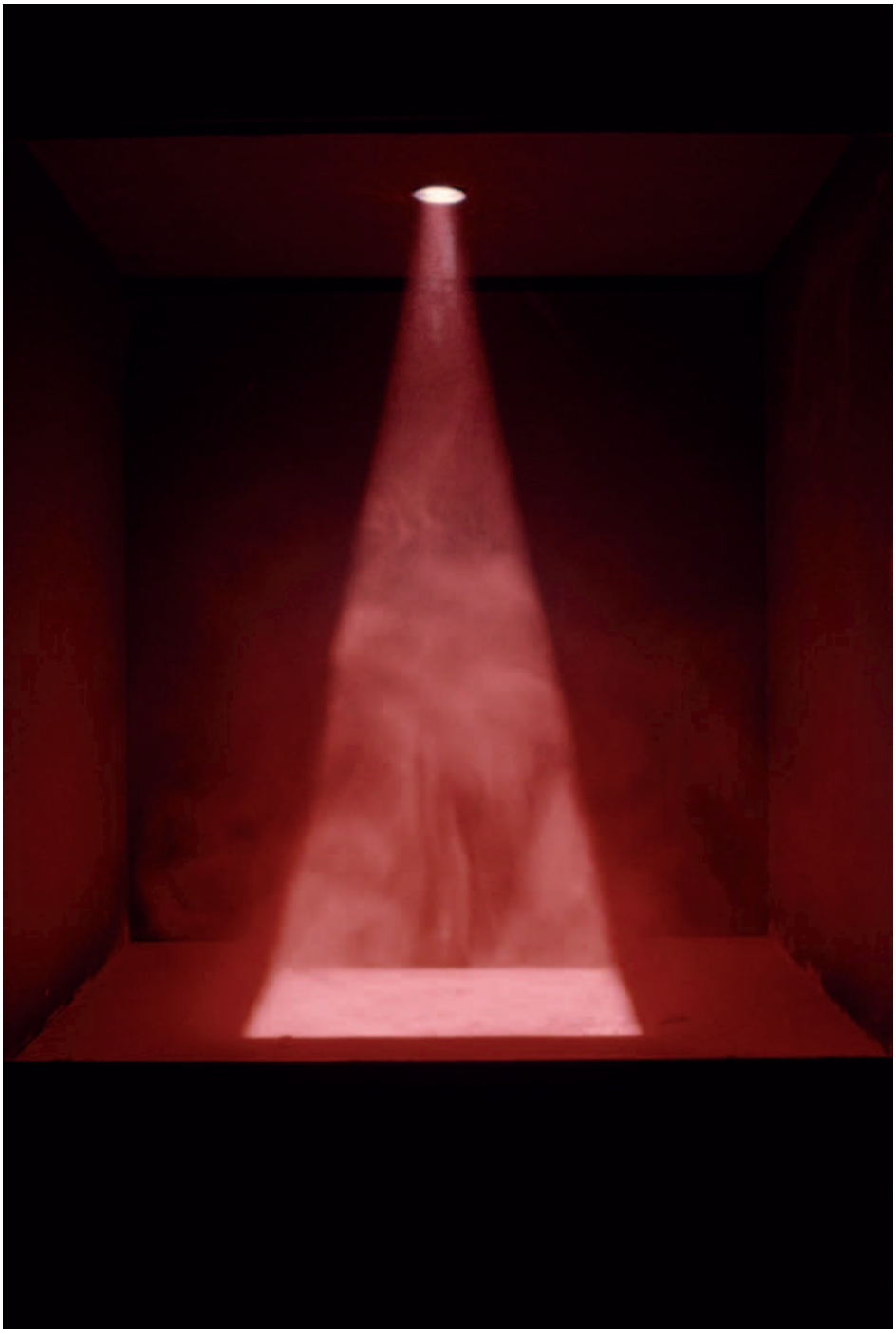
COLOR PLATE C: **HEARTBEATS AND THE ARTS: A HISTORICAL CONNECTION**



Jean Dupuy, *Cone Pyramid: Heart Beats Dust*, 1968. (© ADAGP, Paris/Courtesy of Loevenbruck, Paris. Photo: Terry Stevenson.) (See article in this issue by Claudia Arozqueta.)