

# Vibratory Modernism

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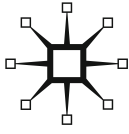
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## Ether Machines: Raoul Hausmann's Optophonetic Media

*Arndt Niebisch*

In one of the last texts that the Berlin Dadaist Raoul Hausmann published before he left Germany in 1933, 'Trommelfeuer der Wissenschaft'/'Drumfire of Science', he strongly rejected Albert Einstein's theory of relativity and promoted the cosmological model of the Austrian engineer Hanns Hörbiger who, in his *Glacial Cosmogony*, explained cosmic processes based on an interaction of ice and fire in the universe.<sup>1</sup> Hausmann's polemic shows that the artistic avant-garde of the Weimar period was not always in tandem with the scientific avant-garde of the time. In fact, Hausmann's main aesthetic project, which he called *Optophonetics*, also stood in stark contrast to Einstein's revolutionary insights, because it was connected to a theory of the ether.<sup>2</sup> In the nineteenth century, ether was assumed as the medium in which light and electromagnetic waves would propagate – a hypothesis that was rejected by the theory of relativity.<sup>3</sup> However, the ether and its connection to electromagnetic fields, X-rays, and notions of multi-dimensional spaces fuelled the imagination of many modernist artists. Linda Henderson showed that painters such as Boccioni, Kupka and Kandinsky were inspired by the ether as a phenomenon that stood at the intersection of scientific and occult understandings of mediality. For these artists, aesthetic expression had the task to display the ethereal, electromagnetic, and multidimensional structure of the world that was not yet accessible to human perception. Hausmann also believed in the ether and was convinced that there was a structural identity between light and mechanical waves. The relatively new technology of the photo cell, with its capacity to transform light input into analog electrical signals, was for him the proof that there was a physical basis for a synaesthetic art.<sup>4</sup> In the following, I will outline how Hausmann became fascinated with the idea of an 'eccentric form of perception' – a

concept developed by the German neo-Kantian thinker Ernst Marcus, who described perception as an interaction with the ether. Hausmann recognised in this theory a connection to modern media technology such as the radio and the photo cell. In the second part of this essay I will show that Hausmann's project to design an optophonetic device was geared towards building 'ether machines' that would simulate the stipulated functioning of the human sensorium.

### **Sense perception and the ether**

Fundamental for an understanding of Hausmann's work from the early 1920s onwards is the fact that he developed his model of sense perception based on the ideas of the philosopher Ernst Marcus. Marcus lived on the periphery of Germany, namely in the industrial city of Essen (Westphalia), where he held a position as judge. He intensely studied the works of Kant and was closely connected to the Berlin scene surrounding the philosopher Salomo Friedländer. Especially important to Hausmann is Marcus's book *Das Problem der exzentrischen Empfindung und seine Lösung/ The Problem of Eccentric Perception and its Solution*, published in 1918. Marcus develops in this text a theory of perception in which the subject constructs its experience in a reciprocal operation. In his opinion the perception of the outside world functions as follows: Objects emit a certain undulation, which travels through the ether. These undulations affect through the retina the nerve of the eye. This irritation does not produce the sensation of light, but the stimulus is transmitted through the nerve to the brain or, as Marcus calls it, the central organ. Triggered by the stimulus, the central organ itself produces ethereal undulations, which project the sensation of the object outside the body (Marcus 1918: 23).

Sensations of outside objects occur for Marcus not inside the body as internal mental processes, but outside the body as projections of a central organ. Through this theory, Marcus tries to solve the problem of 'eccentric perception', that is, the problem that our perception is generated by the sensory organs although we experience objects as external to our organs, outside of our body (Marcus 1918: 7–8); as Marcus explains it, experience (especially optical and acoustical) appears largely as transsomatic and the only form of experience, which is seemingly somatic and therefore immediate to the body is tactile sensation (Marcus 1918: 7). Only the sense of touch is able to convey immediate data about an object in the world. The eccentric perception in seeing or hearing, which has no immediate contact to the body or nerves,

is problematic, and Marcus tries to solve the problem by assuming a reciprocal construction of experience: undulations are sent out from the object and in return subjective undulations are projected as a reaction by the subject. The brain, or rather the 'central organ', becomes a constructive device that not only examines but also creates its environment. Marcus develops the concept that the radius of the sensorium is not limited by physiological restrictions but is extended through the connection of the central organ to the cosmic ether:

Wir nehmen [...] an, daß das Zentralorgan nicht nur aus einer festen anatomischen Masse besteht, sondern daß mit dieser organisch eine ätherische stets im Flusse befindliche Materie verbunden ist, und daß diese Materie einen ebenso integrierenden Bestandteil des Zentralorgans bildet, wie die feste Masse derart, daß beide Bestandteile in ihren Zuständen wechselseitig von einander abhängig sind. (Marcus 1918: 68)

We assume that the central organ does not only consist of a solid anatomical matter, but that it is also connected to an ethereal matter constantly in flux. This matter is in the same way an integral part of the central organ, just as the solid matter is. Both components are dependent on each other substantially.

Marcus makes it explicit that the central organ is not simply a physiological substratum, but is rather an extended perceptual system that is attached but not limited to the organic unity of the body. The ethereal structure of the central organ stands in a dynamic exchange with the ether and thereby creates experience. Perception constructs its environment by sending out rays, which let the objects emerge in perception outside of the body. The immediacy of touch, which constitutes for Marcus the most reliable access to the objective world, is in this way part of every 'sense emanation'. All senses are, due to their constructive nature, immediately connected through the ether to the objects they perceive.<sup>5</sup> Marcus thus claims that experience is dependent on the ether and not on the sensory organs: 'Die Sinngebilde haften also nicht, wie man bisher annahm, an den leiblichen Organen, an den Nerven, an den Nervenzentren (Gehirn), sondern am organischen Primäräther.'/'Thus, the phenomena of the senses are not, as one assumed until now, attached to the bodily organs, located in the nerves, in the center of the nervous system (brain), but are connected to the organic prime ether' (Marcus 1981: 572). The subjectivity of experience, which is fundamental for the Kantian philosopher Marcus, does not lead to the conclusion

that the world constitutes itself in the perceiving subject, but rather the process of perception projects the perceived objects outside of the body. The decisive point is that this idea gives Marcus the possibility to claim an immediate contact between the object of the outside world and the perceiving subject.<sup>6</sup>

It is critical that for Marcus the most important part of the construction of experience is not undertaken by the sensory organs but through the response of the central organ to a certain stimulus.<sup>7</sup> Only in this way can Marcus claim the absolute immediacy of perception, as there is then no difference between tactile (somatic) and optical (transsomatic) perception. This is what makes Marcus's theory so attractive to Hausmann. The Dadaist found in Marcus a theorist who based the immediacy of experience on a constructive operation of the subject and also presupposed one central form of sense perception that constructs a common basis for auditory, visual and tactile sensations (Blom 2001: 211–12). Therefore, when Hausmann is speaking about haptic perception he does not mean literally the sense of touch, but a central operation that is common to all senses and constructs an immediate contact with the perceived world through the medium of ether (Hausmann 1982: I, 183). This form of ether-based perception represents the mode of all sense experience.

In general, Marcus' theory implies an externalisation of sense perception and subjectivity. The inner self is no longer an internal system, but a dynamic system both receiving information from and sending it to the ether (Marcus 1967: 572). Hausmann recognises that this theory has a media-historical marker, and he compares it to radio technology:

Dabei misst Marcus den Zäpfchen des Sehcentrums noch haptische Emanationen bei; es ist aber anzunehmen, dass die Tätigkeit der Stäbchen darin beruht, den concentrischen Strahl zu modificieren und teilweise zu absorbieren, und die Tätigkeit der Zäpfchen darin, den excentrischen Strahl in den Raum hinauszuschleudern, gewissermassen wie bei einer Marconistation, die nach Ladung mit einer gewissen Menge Strom denselben in kurzen Intervallen als abgedämpfte Wellen aussendet – (BG-RHA 1757, 28)

In this process Marcus still ascribes haptic emanations to the cones of the visual centre, but it has to be assumed that the activity of the cones consists in a modification and partially in an absorption of the concentric beam. The activity of the rods consists in projecting the excentric beam into space, similar to a 'Marconi Station', which



after being charged with a certain amount of electricity emits the same charge in short intervals as diminished waves.

Hausmann criticises Marcus's theory for the absence of a discussion regarding the transformative capacity of the perceptual organs. Hausmann suggests that the central organ receives energy from the environment and processes it to generate a subjective reality of the world. The technological model Hausmann uses is the electric medium of the radio ('Marconistation') that transmits electromagnetic waves.<sup>8</sup> Here Hausmann shifts from Marcus' understanding of the ether, which resembles occult notions of telepathy, to an understanding of the ether that is supported by the radio engineers of his time. Marcus' mysterious 'central organ' becomes in Hausmann's interpretation a radio station – he fuses human organisms and media technology. Technology is not understood as a mechanical prosthesis, but rather as an innate organic function that is connected through electromagnetic waves to the environment. The connection between electricity and human perception is central to Hausmann's ideas about art, technology and sensation, because electricity is for Hausmann's adaptation of Marcus' theory the force that enables a projection of subjectivity onto the outside world. The media of radio imitates in this respect the process of human sensibility. This is an idea that brings Hausmann close to the media theoretical thinking of Marshall McLuhan:<sup>9</sup> 'With the arrival of electric technology, man extended, or set outside himself, a live model of the central nervous system itself' (McLuhan 1999: 43). McLuhan sees in the dawn of electric media an inversion of human subjectivity. Perception, communication, and any other contact with the outside world are no longer internal processes that draw clear distinctions between the inner self and the outside world. Rather, they are externalised through media that reach out and connect the body to its environment. The expansion of electric networks is understood as the expansion of nervous systems into the world. Hausmann differs from this model only in the sense that although he recognises media technology as an extension of man, he implies that these machines are only crutches which could be replaced eventually through the trained organic functions of the human sensory system.

Electricity as undulation of the ether corresponds to the undulations that create the immediacy of human perception. For McLuhan as well as for Hausmann electricity becomes the emblematic structure for all human extensions or interactions with the world. It also constitutes the central interface through which different sensory sensations can

be translated into one another. Electricity stands at the basis of both synaesthesia and modern data processing that transfer different kinds of input into a universal structure: 'Durch die Elektrizität sind wir instande gesetzt, all unsere haptischen Emanationen umzuformen in mobile Farben, Geräusche, in eine neuartige Musik.'/'Electricity enables us to transform all our haptic emanations into mobile colors, noise, into a new kind of music' (Hausmann 1982: II, 28). The linking of technology and sense perception explains the growing hegemony of technology in Hausmann's thinking starting from the early 1920s. The assumption of an eccentric/tactile form of perception enables the consideration of a common basis for all forms of sense perception since every sense perception depends on the undulation of the ether. Therefore, Hausmann and Marcus postulate the existence of an interface that can transform one form of sense perception into another (Hausmann 1982: II, 55). Hausmann attempts such transformations of sensory data through special electric devices: he tries to construct an *optophone* that has the capacity to translate acoustic into visual data and vice versa. He thereby mimics the data processing of the human sensorium as described by Marcus.

### The synaesthetic apparatus

Hausmann became quite serious with his involvement with technology from 1920 onwards. He did not only study technologies such as the photo cell, but also designed several devices. In his estate one can find the plan for an improved sound-pick-up system for gramophones,<sup>10</sup> he patented an endoscope,<sup>11</sup> and designed together with Daniel Broido, the brother of his lover Vera, a calculating machine.<sup>12</sup> All these constructions have in common that they tried to process light and/or acoustical frequencies. However, Hausmann was not entirely original with his constructions and technological ideas. The machines he planned were already built by engineers or discussed in periodicals such as *Der Mechaniker*. For example, Alexander Graham Bell developed a 'photophone', a device that enabled telephony based on the transmission of light rays, and the British engineer E. E. Fournier d'Albe invented in 1912 a so-called 'optophone' that transformed light intensities with the help of photo cells into sounds, and was intended to help the blind. Hausmann had probably at least a rudimentary knowledge about these technologies, and in one of his first reports about an attempt to build a synaesthetic apparatus, he refers to an established practice of the early film industry. This text 'Vom sprechenden Film zur

Optophonetik'/'From the Speaking Film to Optophonetics' deals with the construction of a 'sound-film' or sound-on-film system:

Auch bei dem neuen Sprech- und Singfilm werden wie bei Ruhmer, Schallschwingungen in Lichtschwingungen verwandelt, diese werden vermittels Photographie auf dem Filmstreifen festgehalten und wieder in Töne überführt. (Hausmann 1982: II, 72)

In a way similar to Ruhmer's construction, the new speaking and singing film transforms acoustic vibrations into light frequencies, which are stored through photography on a film strip and can be reproduced as sound.

The optical medium of film is used for storing acoustical data. A light-sensitive film is used for storing and reproducing sound. This 'sound film' was attached to a film carrying optical data, so that the simultaneous reproduction of sound and visual data was possible. In this so-called 'sound-on-film system' a 'kathodophone' transforms sound into electrical impulses; these impulses are transferred to a high-frequency lamp, which represents the different impulses by changing light intensity. The lamp is filmed and in this way, the film stores the optical signals, which correlate to the acoustic data. The reproduction functions this way: the film is projected onto a potassium cell<sup>13</sup> that transforms the light input into electrical currents, which go to the 'statophone' which retranslates the currents into acoustic signals (Hausmann 1982: II, 71–2).

This technology had a great and lasting impact on Hausmann,<sup>14</sup> and the most pivotal source for construction plans of synaesthetic machines was Ernst Ruhmer's book *Das Selen und seine Bedeutung für die Elektrotechnik /Selenium and its Importance for Electrical Engineering* (1902). The photo cell represents the central technology for all of Hausmann's synaesthetic experiments, because the photo cell brings light and sound intensity in an analog relationship to one another.<sup>15</sup> In 'Über Farbklaviere'/'About Color Pianos' Hausmann gives a concise account of this data transformation:

Farbenklaviere sind technische Einrichtungen zur Umwandlung von Tonwerten in Farbwerte und umgekehrt. Zu einem optisch akustischen Gestaltungsmittel wird die technische Einrichtung erst, wenn die beabsichtigte Wirkung einwandfrei wird ... (Hausmann 1982: II, 173)

Colour pianos are technical devices for the transformation of sound into colour values and vice versa. This technical device

becomes only a means for optical acoustical composition, when the intended effect can be evoked without problems.

Indeed, the colour pianos already constitute a form of Hausmann's 'optophone', an instrument that is specifically designed for converting acoustical into optical data and vice versa:

Das Optophon verwandelt die induzierten Lichterscheinungen wieder mit Hilfe der Selenzelle, durch das in die Leitung eingeschaltete Mikrophon in Töne, also was in der Aufnahme-Station als Bild erscheint, ist in dem zwischenliegenden Stellen bereits Ton, und wenn die bei der Quelle vorgehenden Prozesse aufgenommen werden, werden diese im Telephon Ton erzeugen und umgekehrt. Die Reihe der optischen Erscheinungen verwandeln sich in eine Symphonie, die Symphonie ihrerseits in ein lebendiges Panorama. (Hausmann 1982: II, 54)

The optophone transforms induced light phenomena into sound again with the help of the selenium cell and through the microphone that is connected to the circuit. What appears in the recording station as a picture is in the transmitter already sound and, when the processes at the source are being recorded, they will produce sounds in the telephone and vice versa. The series of optical phenomena is transformed into a symphony, the symphony is for its part a living panorama.

Although Hausmann exhibits these ideas as new discoveries, they actually represent a well-established knowledge of electrical engineering in the early 1920s. Devices that transformed data with the help of photo cells were already used in the beginning of the twentieth century, and Ernst Ruhmer's book from 1902 contains an entire collection of inventions that use photo cells for a variety of applications from the transmission of visual data to the selection of coffee beans.

Hausmann's optophone displays one form of data simultaneously in an acoustic and in an optic form. Hausmann's gadget is relatively simple and relies on the capacity of the photo cell to conduct a current with the exact proportional ratio of the light that is projected onto the photo cell (Rieger 2003: 68). The input thus corresponds to an output on the same level. The 'singende Bogenlampe'/'the singing arc lamp' as mentioned by Ruhmer (Ruhmer 1902: 38–45), functions according to

this principle and Hausmann recognises this device as analogous to the function of his optophone:

Wird ein Telefon in den Lichtkreis der Bogenlampe eingeschaltet, verwandelt sich der Lichtbogen infolge der akustischen Wellen, die von dem Mikrophon weitergeführt werden, in Schwingungen, die den akustischen Schwingungen genau entsprechen, d.h. der Lichtstrahl, was seine Form betrifft, modifiziert sich im Verhältnis zu den akustischen Wellen. (Hausmann 1982: II, 53)

Were a telephone connected to the circuit of an arc lamp, the light arc transforms in response to the acoustic vibrations, which are transmitted through the microphone and correspond exactly to the acoustical vibrations. This means the ray of light modifies itself in relation to the acoustical vibrations.

The proportionality of the light input and the electrical output is important not only because of an equivalent translation from the one into the other, but also because the photo cell is able to process the entire range of possible data. The optophone should process the entire spectrum of the light input and represent it by electrical currents that are displayed in the form of sound. The sound-on-film system was already an example of this strategy: analog sound data are transformed into light data, these data are stored, and reproduced in an analog way. Moreover, the optophone is nothing more than a colour piano that is constructed for generating simultaneously a light and sound performance.<sup>16</sup> Thus it is not so much the construction of the apparatus that appears to be innovative – the technology is already well known – rather, the physical preconditions that Hausmann postulates imply the problematic and innovative potential of his machines. In fact, Hausmann's texts underlines this impression, because they speak often to the idea that the frequencies of light and sound have in principle the same structure and can therefore be translated into one another:

Unsere Töne, von Gesang angefangen, schwingen von 32 ungefähr bis 41.000 in den musikalischen Tönen, das Licht schwingt von 400 Billionen pro Sekunde des langsamsten Rot bis zu den 800 Billionen des Violett, in den von unseren Augen erfaßbaren Farbskalen Rot, Orange, Gelb, Blau, Grün und Violett. Aber in der Abnahme der Schwingungen unter dem Infrarot muß es eine mögliche Transformation in der Richtung zum Ton, zur Akustik geben, ... (Hausmann 1982: II, 53)

Our sounds, starting from singing, vibrate in the spectrum of 32 to 41,000 [vibrations per second]. Light vibrates from 400 billion [vibrations] per second for the slowest red up to 800 billion for violet within the colour range of red, orange, yellow, blue, green, and violet visible to us. In the reduction of the vibrations slower than the infrared, however, has to be a possible transformation towards the sound, towards acoustics.

Hausmann understands the frequencies of light and sound merely as part of one continuous spectrum: frequencies fluctuate in a medium. Although electric and mechanical waves have in common that they are waves, they differ in the fact that sound waves need a medium in which they can propagate, whereas light also travels through a vacuum. Hausmann's entire concept is based on the idea that light waves, similar to sound waves, travel through a medium. Hausmann, in accordance with nineteenth-century physics, postulates the existence of an ether in order to explain the propagation of light waves. Twentieth-century physics, in the vein of Einstein, abolishes the ether as a medium and claims that both frequency patterns are fundamentally different in respect to the medium in which they propagate. Walter Brinkmann, the student of the Bauhaus artists Lazlo Moholy-Nagy – after studying Hausmann's optophonetics – provides a more careful suggestion of how mechanical and electromagnetic waves can be correlated to each other. He agrees with the observation that these types of waves are fundamentally different from each other, since 'sounds are "vibrations of air"' (Moholy-Nagy 1969: 23) and 'light is "vibrations of ether"' (Moholy-Nagy 1969: 23). Nonetheless, he argues that optics – with light perceived as an electromagnetic phenomenon – represents a part of the theory of electricity and thus he suggests that electro-dynamics may serve as a unified theory that incorporates the study of mechanical as well as electromagnetic waves (Moholy-Nagy 1969: 23).

Also for Hausmann the correspondence between different physical wave structures is based on the theory of ether, the old form of electro-dynamics. Hausmann is in his assumption more radical than Brinkmann because – in accordance with Marcus's theory of perception – all physical wave phenomena are fundamentally based on the ether. Hausmann believes that undulations of the ether generate the sensation of sound (mechanical waves) as well as light (electromagnetic waves). Hausmann's synaesthetic apparatus tries to simulate a central cognitive ability of mankind that makes no difference between mechanics and electro-dynamics. The optophone is for Hausmann not

simply a synaesthetic apparatus, but also the description of a sensory organ that is capable of such a transformation:<sup>17</sup> 'Andere Lebewesen verfügen offensichtlich über keine isolierten Hör- und Sehapparate, so zum Beispiel die Bienen haben beide in einem, also haben sie ein wunderbares Optophon.'/'Apparently, other living beings don't have separate organs for seeing and hearing. For example, bees have both in one organ, they have a wonderful optophone' (Hausmann 1982: II, 55).

### **Ether machines**

It is important to understand that Hausmann's optophone is not simply an interesting kind of media engineering that fits into a historical series of similar apparatuses such as, for example, Thomas Wilfried's *Clavilux*. Certainly, Hausmann's project builds upon such predecessors. His goal, however, is to simulate human sensory functions.<sup>18</sup> In this sense, the optophone becomes a device that reproduces and mimics human systems of converting data input.

Marcus and Hausmann formulate their ideas within a technological and scientific imaginary. They correlate ideas drawn from the technological realm with concepts of human perception. This short-cut generates hybrid theories in which subjects navigate on the border between man and machine. Hausmann is intent on blurring the distinction between art and engineering: 'Die Mechanik als Wissenschaft, Technik und Maschine ist keine blosse Ökonomisierung der Arbeitsleistung, sie führt letzten Endes wie die sinnesphysiologische Leistung der Künste zur Steigerung der organischen Funktionalitätsform des Menschen.'/'Mechanics as science, technology, and machine is not simply an increased economy of work, but leads in the end – similar to the sensory achievements of art – to the heightening of the organic functionality of mankind' (BG-RHA 1757: 2). The organic function of human beings and the technological capacities of machines engage in a phantasmagoric exchange. To transcend the organic status quo and to develop a new man that can be integrated into an emerging media ecology becomes the function of art. Art is a pedagogical tool that through synaesthetic or optophonetic media demonstrates the physiological potentials of the human senses. The idea that there is a uniform type of data in the world – the vibrations of the ether – brings Hausmann to an understanding of the human sensorium as a multimedia interface, which leads him to construct or at least design machines that may prove or may process the postulated physical reality of the ether. Here media art and engineering fuse into another. Hausmann's inventions,

from the gramophone sound-pick-up and endoscope to the optophone, exemplify this connection between media art and engineering. These technological experiments galvanised in his cooperation with the engineer Daniel Broido.

From 1930 onwards, they worked together on the construction of a calculating machine. In this machine Hausmann and Broido used a photo cell to switch the numerical wheel to the next position. This device was in its construction very simple, it was not much more than a simple multiplication table that was able to represent its result with the help of a relatively complex mechanical system – it did not calculate with light rays.<sup>19</sup> This device constitutes the end point of Hausmann's ether machines, because it was no longer supposed to simulate modes of sense perception, that is, it was no optophonetic device. This becomes apparent by the fact that in the extensive correspondence between Broido and Hausmann there was no mentioning of the ether or optophonetics. The 'calculating' machine also does not point to a shift towards a new computer age, as Hausmann suggested in a letter from 1966 (Hausmann 1982: II, 214). This apparatus had no ability to compute digitally, but simply summed up Hausmann's understanding of photoelectric systems, which is based on the analog transformation of light and sound waves as it can be found in the sound-on-film system.

Even if Hausmann's optophonetic world view failed, because it was based on an outdated model of the ether, his work represents an especially close and inspiring connection between media art and engineering. Although Dadaism was in general very sensitive to its mass media environment – the photocollage documents this sensitivity impressively – the intense interest in the deeper technological mechanics of media, however, was particular to Hausmann. He belongs in this regard to artists such as the Futurist noise composer Luigi Russolo or the Bauhaus professor Moholy-Nagy, who explored the deeper technical and psychophysical side of new media developments.

## Notes

1. The text 'Trommelfeuer der Wissenschaft' represents a sharp polemic against the public media in the Weimar Republic. For Hausmann, Albert Einstein becomes in this text a mere media image that is constantly reproduced in the press. In the typescript version of the text that is accessible in the Raoul Hausmann Archive (BG-RHA 1354), the critique against Einstein's relativity is more explicit. For a discussion of the polemical character of the text see my article 'Polemik des Wissen' (Niebisch 2006).



2. Hausmann developed this idea of a synesthetic re-education of mankind in texts such as 'Présentismus' (Hausmann 1982: II, 24–30), 'Optophonetik' (Hausmann 1982: II, 50–7), and 'Die überzüchteten Künste' (Hausmann 1982: II, 133–44).
3. However, the ether still remained in the discourse as a practical model in radio engineering. For example, the radio engineer Artur Fürst emphasised in 1922 that the ether is still indispensable as an auxiliary hypothesis (Fürst 1922: 14).
4. A major influence on Hausmann was the book *Das spierelige Wesen der Wellen in Anwendung auf Licht und Farben* by the artillery lieutenant Karl Koelsch, who developed his own understanding of light, in which light is ejected from the sun and propagates in form of a spiral through the ether.
5. This immediacy of perception, which Marcus at first assigns to tactility, is not an exception but rather the standard form of contact to the objects. More precisely, Marcus elaborates why the sense of touch is not different from 'transomatic' forms of perception. 'Es ist zunächst ein vollkommener Irrtum, daß [das] Tastgebilde im Gegensatz zum optischen ein intrasomatisches, am Nervenende lokalisiertes Gebilde sei. Es wird vielmehr ursprünglich transomatisch außerhalb oder unterhalb des tastenden Fingers, daher als Oberfläche eines Fremdkörpers empfunden (die gegenteilige Behauptung widerstreitet der Erfahrung)' (Marcus 1918: 70).
6. The reliance on the ether for explaining eccentric sensations follows the same logic as the explanation of the propagation of electromagnetic waves through the medium of ether. In both cases, a medium is presupposed because in the scientific opinion it is not possible to think about perception or waves without a medium. For Marcus, in accordance to the ether theory of the nineteenth century — ether is the matrix in which absolute relations between objects and absolute inertia become possible. 'Das Äthermeer ist in wirklicher Ruhe in Relation zum absolut ruhenden geometrischen Raume, daher in wirklicher Ruhe in Relation zur Allheit der bewegten Körper' (Marcus 1981: 562).
7. Marcus sees in the 'phantom pain' a proof for his idea. He claims that the pain in a missing limb is caused by the response of the eccentric undulation, which still responds to the prior shape of the body (Marcus 1918: 70).
8. The abilities of electric media to construct an immediate contact over long distances are for Hausmann not only a model for explaining human communication or perception. Hausmann believes that human perception itself will become capable of immediate communication: 'Für diesen Weg der Erweiterung der Organfunktionalität ist auch der Ausspruch Professor Ayrtons nur eine Andeutung; er sagte 1906: "Einst wird kommen der Tag, wenn wir alle vergessen sind, wenn Kupferdrähte, Guttaperchahüllen und Eisenband nur noch im Museum ruhen, dann wird der Mensch, der mit dem Freunde zu sprechen wünscht und nicht weiss, wo er sich befindet, mit elektrischer Stimme rufen, welche allein jener hört, der das gleichgestimmte elektrische Ohr besitzt"' (Hausmann 1998: 176).
9. Marcella Lista also points out the proximity between McLuhan and Hausmann (Lista 2005: 96).
10. The archival signature of the construction plan for the gramophone sound-pick-up ('Schalldose') is BG-RHA 1755.

11. The patent number for the endoscope is H112633 IX/30a.
12. This construction was finally patented in 1935 in Britain. The patent number is GB 446338.
13. The inventors Massolle, Vogt, and Engl optimised the sound-on-film system by developing a photo cell covered with potassium, which was much more responsive than the selenium cell. For a detailed description of this system see Engl (1927).
14. In a letter to Broido Hausmann mentions that he was in close contact to Tri-Ergon (BG-RHA 1073).
15. Stefan Rieger also acknowledges that the discovery of the selenium enabled an important transformation in scanning technology from scanning based on immediate contact towards a scanning based on light sensitivity (Rieger 2003: 69).
16. In his text 'Die überzüchteten Künste' Hausmann gives a detailed description of this machine (Hausmann, 1982: II, 143–4), another detailed description of the machine can be found in Erlhoff (1982: 142–5).
17. Current research, especially the work of Matthew Biro and Cornelius Borck, relate Hausmann's technological experiments to a notion of the cyborg and assert that Hausmann recognised in modern man a hybrid merging human nature and technology. This interpretation is in accordance with the Dadaist method of collage that also assembles heterogeneous material. However, this interpretation does not factor in Hausmann's reflections that see an analogy between technology and the organic system and try to formulate a new holistic concept of man (Borck 2005; Biro 2007, 2009).
18. For a discussion of light organs and its relationship to Hausmann's optophonetics see Elder (2008: 44–81).
19. Hausmann's work on this calculation machine is documented in my edition of Hausmann's scientific and technical writings *Dada-Wissenschaft. Raoul Hausmanns wissenschaftliche und technische Schriften*.

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Texts from the Hausmann Archive from the Berlinische Galerie are indicated with their archival signature BG-RHA.