HEAD-MOUNTED DISPLAY SCREENS: 
A (DE)CONSTRUCTION OF SENSE-CERTAINTY?

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1. Introduction

*Birdly* and *Eyesect* are head-mounted display (HMD) installations that take two very different approaches to the construction of virtual space and user immersion within it. As a flight simulator, *Birdly* incorporates a rotating chair with mobile panels attached to either side, as can be seen in Fig. 1(a). Users lie on their stomachs with their arms spread out and strapped to the panels while wearing an HMD. Now they are ready to “fly” over San Francisco or New York City, beating their “wings” by using both panels while images on the HMD screen synchronize to the chair’s motion. With these combined features, a *Birdly* user experiences what flying might feel like, if only for a few moments.

The *Eyesect* installation, by contrast, attempts to simulate moving and seeing like an insect. Two external mobile camera modules are attached to an HMD headset—a first-generation *Oculus Rift* as video images are transmitted to two screens installed inside the headset, one for each eye, as seen in Fig. 1(b). Both moving cameras are attached by extension cords allowing users to easily move them around; in this way users are granted an unfamiliar view of the world, e.g., when positioned above or below eye level. Such manoeuvring—especially when it induces a constant change of perspective—twists vision and perception alike. Spatial perception is thrown into a state of flux as the brain

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1 *Birdly* was designed at the Zurich University of the Arts beginning in 2013. Max Rheiner, Fabian Troxler, and Thomas Tobler finished the first *Birdly* prototype in 2014. First introduced at several exhibitions and festivals (e.g., the Sundance Film Festival 2015 and the SXSW [South by Southwest] Festival 2015), a version of this device is now commercially available to private consumers. See also Section 2.2 and http://www.somniacs.co/.


3 The *Oculus Rift* is a virtual reality headset developed by Oculus VR to be released commercially in 2016.
struggles to reconcile the input of images that do not necessarily merge to form a coherent single image. Unlike *Birdly*, which seeks to immerse users in a virtual reality, *Eyesect* inspires a sense of bodily “disintegration” as users confront a constantly changing field of vision. Despite these obvious differences in immersive experience, however, I argue that both devices nevertheless uncover a shared and indeed fundamental feature of HMD architecture as it concerns the construction of space and spatial perception.

Arguing that the installation “externalizes” the senses, I examine the ways that *Birdly* deploys a Cartesian-Euclidean framework in which vision, geometry, and the mechanical apparatus itself are connected. Central here is the point of vision, both constructed and ostensibly guaranteed by the HMD. In this respect, *Birdly* operates as a “typical” VR device that promises sensory immersion and mediation without interference. Certainly, the potential for motion-sickness or latency threatens to destabilize the immersive construction of a fixed, stable space. However, taking René Descartes’s thought experiment as a guide, I problematize the role of the apparatus itself as both mediating and space-constructing. The famous Cartesian doubt of the senses does not necessarily manifest with *Birdly*; indeed, to the extent that *Birdly* succeeds as an immersive experience, the sensation of simulated flight is ideally rendered as “real.” However, I argue below that a theoretical doubt nevertheless haunts the *Birdly* experience—a doubt which stems from the manner in which the senses are “externalized” into the device. That is, because perception ultimately relies

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on a material device, the possibility of doubt creeps in as a discrepancy between
the immersed body and the construction of immersive space tied to and
mediated by the apparatus itself.

In contrast to Birdly, however, Eyesect does not hold out the immersive
promise of mediating fixed space. Rather, Eyesect purposely subverts the user’s
visual orientation and the geometry of perceived space. But while Birdly and
Eyesect appear to offer two very distinct experiences of space, both
nevertheless point to a fundamental characteristic that applies to HMDs in
general, namely, that the construction of space via HMD is always unstable,
even when the apparatus promises stability in the form of a “perfect” mediation.

My argument proceeds in Section 2 by turning to Descartes’s
understanding of vision based on the integration of geometry and the physical
apparatus, an amalgamation that would ostensibly anchor the senses (vision in
particular) and prevent the doubt of the senses. Descartes’s “externalized”
conception of vision aligns well with the visual experience of Birdly. Descartes
argued, for example, that blind individuals may “see” using two sticks—i.e.,
using an external apparatus that functions according to the rules of “natural
geometry.”6 My critical reading theorizes Birdly in the same manner: as a
mechanical apparatus by which individuals might “see,” it functions according
to the laws of mathematics and as a way to avoid the doubt of the senses. This
is how VR developers tend to understand the HMD, architecturally and as an
experience. The current commercial version of Birdly bills itself as causing
hardly any latency or motion sickness—technical improvements by VR
developers who conceive doubt and the problem of sense-certainty in relatively
narrow terms. This paper offers a very different conceptualization of doubt. I
argue that because Birdly mediates experience and produces space through the
use of an external, material device, theoretical doubt is woven into the
architecture of the HMD itself—a doubt, in other words, which might prompt a
discrepant experience. Even if the user experiences no immediate doubt in the
context of a short “flight,” it is precisely because the experience of immersive
space is produced that the user is free to doubt this production, to doubt the
immersion itself, or to doubt the conditions of possibility for immersive
experience more generally, whether bodily or architecturally or both. If such
doubt is “theoretical,” it not exclusively so: doubt is always potentially
experiential, since a user’s expectations and reflexivity may influence—even if

retroactively—the experience, the manner in which one sees and is self-reflexively positioned within spatial coordinates.

In Section 3, I develop my reading of doubt by turning to an analysis of Eyesect using Paul Klee’s understanding of the “point” as a conceptual frame. I read Klee alongside Gilles Deleuze’s notion of “nomadic science” in relation to the HMD’s externalization of the senses; in contrast to Birdly’s alleged sense-certainty, Eyesect not only withholds sense-certainty but purposely subverts the coordinates of the user’s visual field. Rather than a “state science,” which bases itself on an axiomatic approach—such as Descartes’s “natural geometry”—Deleuze proposes a conception of space that is always “becoming,” an event that does not seek a stable basis. A Deleuzian form of doubt, I argue, suggests that the HMD deconstructs space rather than (re)constructs it.

Finally, in Section 4, I argue that this deconstruction of vision and space compels users to re-learn how to see. At the same time, however, complete visual adaptation is destined to fail, whether through a “theoretical” doubt of the HMD architecture that constructs space (as with Birdly) or through the deconstruction of space in and by the HMD (as with Eyesect). In this light, HMDs offer a new epistemology of vision and space in which the facilitating apparatus that mediates between the user and constructed space ultimately subverts the very experience it intends to convey.

2. Descartes and Birdly: Ensuring the Irreducible Point of Vision

Birdly extends the scope of user sensory experience by virtually fulfilling the perennial dream of flying. Users lie on their stomachs on a specially designed chair complete with panels to direct movement and a ventilation system directed towards the head. Once the user’s arms are strapped to the panels, the headphones and the Oculus Rift complete the immersive effect of flying as an eagle over San Francisco or New York. While in operation, the entire device responds to the user’s movements, affording a genuine sense that one is flying.

Birdly purports to offer the assurance that what is experienced is indeed flying, even if Birdly does not exactly imitate avian flight. In this section, I argue that Birdly attempts to affirm sense-certainty according to Descartes’s theory of vision by placing emphasis on his insight that the sensory world could—and indeed should—be (re)constituted through scientific apparatuses in order to overcome the doubt of the senses. Birdly hopes to offer the certainty that Descartes sought by positioning the user in a well-constructed geometric space. However, as I will point out towards the end of this section, although Birdly’s construction of space may well minimize the user’s experiential doubt
of the senses, theoretical doubt as an ever-present possibility is embedded in the functionality and architecture of the HMD itself.

2.1. Euclid and Descartes: Geometric Vision

To frame my discussion concerning the origins of the geometric-axiomatic approach to vision, I begin with Euclid. Relating the domains of geometry and vision, Euclid conceptualizes the ‘point,’ in its mathematical sense, according to the notion of the ‘line.’ These two foundational elements are conceived as absolute idealities, generating all possible forms either on the plane or in space. “A point,” Euclid argues in the first definition of Book I of *Elements*, “is that which has no part.” The Euclidean point has no visible property: no length, width, or position. As an abstract entity without parts, it is ideally indivisible.

Euclid’s theory of vision is linked to this hollowed mathematical point in the *Optica*. Following Lejeune,7 I understand Euclid’s theory as purely mathematical and divorced from either the physical or physiological properties of vision. Instead, Euclid’s approach to vision is axiomatic in nature, structured similarly to the *Elements*. Indeed, as Lindberg argues, “Euclid intended to formulate a theory of vision restricted to geometry.”8 Thus, the first three postulates of the *Optica* may be read as axioms9 from which it is clear that (1) the eye, positioned at the vertex of a cone, is an irreducible point; (2) light travels in straight lines; and (3) vision is restricted to cones made up of rays emanating from the eye so as to hit the object. An object’s size and dimensions are perceived according to the angles subtended by the rays issued from the eye. Hence, for example, Euclid’s statement that equally sized objects located at unequal distances appear unequal in size is proven mathematically by using the properties of these angles. What proves especially illuminating, found in Euclid’s drawings that accompany his manuscript, is that both eyes are reduced to a single eye: a geometric point. Euclid reduces vision to theoretical geometry itself, which is forced to follow the rules of mathematics.

9 “Let it be assumed:
1. That the rectilinear rays proceeding from the eye diverge indefinitely;
2. That the figure contained by a set of visual rays is a cone of which the vertex is at the eye and the base at the surface of the objects seen;
3. That those things are seen upon which visual rays fall and those things are not seen upon which visual rays do not fall.”
For Euclid, geometry (re)constructs the seen space for the user. Descartes presents a more ambivalent approach. In his theory of vision, a mechanical apparatus—which only operates according to “natural” geometry but is not reduced to it—offers a way to ensure sense-certainty (particularly vision). For Descartes, geometry functions as both a part of mathematics—a science that cannot be doubted—and as that which provides devices independent of the human being. In this respect, the geometrical apparatus itself promises sense-certainty. However, as I argue below, since the apparatus mediates between space constructed by the laws of geometry and the user, we might say that a theoretical doubt is implicit the apparatus itself—a doubt over whether (or not) there is discrepancy between the immersion into this constructed space and one’s bodily experience of that space. This theoretical doubt is architectural, as it might prompt potential discrepancy in the immersion—doubt or discrepancies concerning how the HMD produces the experience. To elaborate this further I turn to Descartes’s integration of geometry and the physical apparatus as the means by which he sought to guarantee sense-certainty.

It is well known that by doubting his senses Descartes aims to find a unique point of certainty in the cogito. With respect to vision, however, Descartes suggests that this point of certainty may be found in the scientific apparatus itself. On the one hand, he emphasizes the medium—the mediating apparatus—through which we see, and which reduces vision to a point; and, on the other hand, he understands visual space as geometric—a space in which no matter what one sees, or whether one sees at all, the same geometric methods apply. It is in La Géométrie (1637) that Descartes relates the apparatus to certainty, a foundational manuscript that virtually reinvents geometry and scientific scrutiny.

Descartes is considered one of the fathers of analytic geometry—and one of the first, together with Fermat, to understand that equations that define curves in space are central to an analytic treatment of geometry. Starting from two axes, X and Y, setting the point of origin, and commencing with an equation expressed in terms of X and Y, one can produce a geometric interpretation of that equation. As Timothy Lenoir notes, “the equation is the essential datum, and it has an ontological priority over the geometrical construction.”¹⁰ It is in La Géométrie that Descartes first presents his analytical geometry, a translation of lines and their physicality (i.e., their continuous,

analogue character) into letters (discrete, “digital” elements), which suggests a rupture between geometry and algebra and a reduction of geometry to algebra.

However, Descartes also suggests another approach to the relations between geometry and algebra. Throughout the first book of La Géométrie he offers several examples for how pure algebraic equations might be solved geometrically. Rather than reconcile the alleged rupture between algebra and geometry, he attempts to extend the class of objects and apparatuses included in geometry. For example, according to Descartes the ancients distinguished between three classes of curves in problems involving constructions. The first class, known as “plane” curves, included Euclidean constructions involving straightedge and compass. The second class, known as the class of “solids,” was made up of conic sections. For the ancients geometry exclusively comprised the study of just these two classes: the third class, which includes objects that could only be constructed by imagined mechanical artifices or mechanisms, was excluded. From Descartes’s perspective, omitting this third classification excludes too much. The problem is that the ancients “did not wish to make more than two postulates.”

"Postulates" refers to two devices: ruler and compass. Given a section of length $a$, one can construct a section of length $\sqrt{a}$ using the two together, but the problem of constructing a section of length $\sqrt[3]{a}$ with these two remained open for the Greeks. Descartes’s critique is not directed at the geometry of the ancient world as such—i.e., not being able to construct the third root of two ($\sqrt[3]{2}$), unlike the square root of two ($\sqrt{2}$). Rather, Descartes’s is critical of the axiomatic exclusion of too many instruments and devices, where stability was preferred over the plurality of mechanical instruments. One of these devices is Descartes’s Mesolabium (Fig. 2).

Figure 2: Descartes’s Mesolabium. Denote: $YB = e, YC = x, YD = y$ and $YE = a$. Hence, $e : x = x : y = y : a$. If $a = 2$ and $e = 1$, then $x^2 = y, y^2 = 2x$ and, hence, $x^3 = 2xy$ or $xy = 2$, which is equivalent to $x = 2/y$. Therefore, $x^3 = x^2x = y^2/y = 2$, i.e. $x = \sqrt[3]{2}$.

12 Ibid., 370.
This device was already known to antiquity. The Mesolabium consists of hinged and flat-lying two-legged compasses. Six rulers are integrated at right angles to the legs of the compass, all of which move together when the compass is stretched open. Essential to this device, apart from the fact that it solves one of the Delian problems (constructing a section whose length is the third root of a number) is that the moving geometric instrument operates by itself. Although one requires a limb to move the instrument, a donkey’s hoof would suffice. Therefore, “geometrical propositions [are] effected by mechanical means.”

Descartes’s understanding of geometry is directly applied to vision in a now famous passage regarding “natural geometry,” where Descartes describes in “Optics” how a blind individual may also see (see Fig. 3):

We know distance by the relation of the eyes to one another. Our blind man holding the two sticks AE and CE (whose length I assume he does not know) and knowing only the distance between his two hands A and C and the size of the angles ACE and CAE, can tell from this knowledge, as if by a natural geometry, where the point E is. And similarly, when our two eyes A and B are turned towards point X, the length of the line AB and the size of the two angles XAB and XBA enable us to know where the point X is. We can do the same thing also with the aid of only one eye, by changing its position.

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13 The Mesolabium refers back to the Greek tradition. Indeed, this device is far from new; Eratosthenes had already reported it.
14 Descartes also emphasizes that the points on the moving Mesolabium trace curves which are neither lines not conic sections. Thus, for example, the point D in Fig. 2 traces the curve $x^4 = a^2(x^2+y^2)$.
16 Descartes, “Optics,” 170. Obviously, Descartes was neither the first nor the last to discuss the harmony or discord between touch and vision. Berkeley, Locke, and Condillac, among others, debated whether or not there was a concordance between the two senses. Locke is well known for formulating the problem of what happens when an individual born blind is suddenly able to see (e.g., see Locke’s An Essay Concerning Human Understanding). For an overview, see Jonathan Crary, Techniques of the Observer: On Vision and Modernity in the Nineteenth Century (Cambridge: MIT Press, 1992), Chapter 2.
Descartes’s method is geometric: although insisting on the need for two eyes (or two sticks), in contrast to a Euclidean analysis he reduces vision to the fixed focal point, the point X. There is, as Celia Wolf-Devine highlights, a “unification of the input from the senses.” In Descartes’s analysis this unification is based on geometric, mechanical considerations akin to the Euclidean approach. It is as if human observers and, with them, the senses, could not be trusted but mathematics could be.

This well-known account can be found in the first book of *Meditations on First Philosophy*, which comprises an attack on the principle of the reliability of the senses. Indeed, by maintaining mathematical certainty to be the highest criterion for knowledge, Descartes ultimately questions whether one can know anything at all. This move leads him to find a singular point that cannot be doubted: the act of thinking itself with its famous dictum *cogito ergo sum*. That which cannot be doubted, from which every other aspect of human experience disappears, is the *cogito*. From this perspective, Descartes’s *Meditations* reconstitutes the whole world, now taking this irreducible guarantor as the reference point.

Correspondingly, Descartes argues that geometry and its devices may also function as this irreducible anchor from which the senses—especially vision—are constituted. One might couple this irreducible element to the point of origin in the Cartesian coordinate system as well. I would like to note that Descartes did not necessarily use perpendicular axes in *La Géométrie*: The main quintessence of any coordinate system is the element (called the point of origin) by which all other points, lines, and curves are positioned.

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space and subjectivity. Such an anchor is to be found in mechanical apparatuses—such as sticks and Mesolabiums. The Mesolabiums, as well as the sticks, work without any connection to the observer and hence eliminate the doubt of the senses. By analogy, they could have been considered as this irreducible anchor, and Descartes does point in this direction. However, another problem arises in the form of the apparatus itself. My suggestion is that we must distinguish between Descartes’s “natural geometry,” which may indeed guarantee sense-certainty, and the scientific apparatuses themselves. As Gary Hatfield suggests regarding the above quotation from Descartes’s “Optics,” “[t]he lines and angles involving the two eyes and retinal locations are useful theoretical constructions for understanding how the system works.”\(^{20}\) However—and this must be emphasized—the sticks and Mesolabiums, in contrast to the “lines and the angles,” are not theoretical constructions but rather physical apparatuses, which, I suggest, open the possibility of theoretical doubt. These apparatuses, in contrast to natural geometry, may deceive because they are material and mediating. As I will argue in the following section, a theoretical doubt is implicit in the architecture of the HMD itself through a potential discrepancy between the geometrical space and the user in it.

2.2. Birdly: The Reconstitution of Cartesian Space

Birdly, as I have mentioned, attempts to fulfill the old human dream of flying.\(^ {22}\) By embedding users into a full-body flight simulator utilizing two HMDs.

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\(^ {20}\) Hatfield, “On Natural Geometry and Seeing Distance Directly in Descartes,” 185 (italics in original).

screens to project a virtual recreation of San Francisco or New York City (see Fig. 5). *Birdly* is designed to evoke a genuine sensation of flight while the user is tied to a (mobile) chair. The chair’s movement corresponds to the movement of the arms while imitating flying and is synchronized to the sound of flapping wings filling the air through a ventilator. The complete assemblage of actions occurs via a feedback system.

![Figure 5: Flying over New York: a Birdly image.](image_url)

My own experience with the device, despite the fact that I was only allowed to use it for two minutes, was mesmerizing. Even before using *Birdly* I believed it was possible to separate sensations generated by virtual experiences (such as flying over San Francisco) from technological contrivances (like the chair, headphones, the ventilation system, and, of course, the HMD). But these two minutes felt completely immersive. Apart from the city, seen from above, a constant flow of air hit my body. Turning my head from side to side allowed me to see my “wings” as I heard them flap. Only two minutes into the experience and I could not have agreed more with the accolades written at the beginning of 2015: “Immersive and exciting, *Birdly* is the kind of VR experience that turns skeptics into true believers.”

In an interview, Rheiner admitted that “the first versions made everyone [in the team] super sick, because [it has to be done] super perfectly,” where “it” refers to the correspondence between what is seen and represented,

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22 The Software Studies group at the excellence cluster *Bild Wissen Gestaltung*, Berlin, visited the Zurich University of the Arts on May 4, 2015. We would like to thank Max Rheiner for hosting us.


and what is physically felt. In more recent versions, the feeling of nausea has been rendered negligible. Rheiner describes team members flying for over 20 minutes without stopping, with only a small percentage of users experiencing motion sickness during exhibitions. With this description, Rheiner expresses his opinion that his product can overcome the feeling of latency and motion sickness, and thus provide a stable experience of VR space. Indeed, companies developing VR headsets do promise to eradicate latency. They have a particular—and narrow—conception of doubt and sense-certainty in mind.

This immersive experience suggests that the doubt of the senses hardly plays any role here. If there is latency, it is not felt, and when the bird-user hits a wall the simulation simply stops, amounting to a pause in gameplay and therefore rendering no doubt whatsoever in the user. However, my claim is that while Birdly offers an experience of stable space, it theoretically and continuously destabilizes it.

As I’ve argued above, the Birdly scenario is only possible if the senses are externalized. Similar to the Cartesian move, the reconstitution of the world is enabled only through the trust one places in devices that operate according to the rules of mathematics: the Mesolabium, or the two sticks of the blind person. Birdly therefore re-locates the observer (vision and body) within the apparatus, which operates according to “natural geometry” and mathematics. However, the difference between “natural geometry” and its apparatuses and devices results in a theoretical doubt of external devices.

My claim, then, is that Cartesian space is indeed reconstituted once more, only now not through a reduction performed by the power of contemplation but by mapping the anchoring point onto the device itself. Following Euclid’s and Descartes’s accounts of vision, Birdly embeds the body in a unified space: a body whose characteristics (i.e., what it experiences) regain certainty only with respect to the apparatus. This, I claim, is how Birdly conceptualizes the user in relation to the device. The feeling of sense-certainty and immersion is founded on the idea that the users and their bodies are externalized and measured according to the operation of a mechanical device.

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26 Latency in general means a time delay between the cause and the effect of a physical change in the system. In Birdly this refers, for example, to a movement of the chair or of the panels performed by the user, where the image shown on the screen changes only after several seconds, i.e., after an interval of time that the user can detect and hence that can cause discrepancy between movement and vision, and thus confusion and discomfort to the user.

and the synchronization of mechanics and imaging. This is similar to the procedure done with the Mesolabium. While the experience with Birdly is meant to be immersive and meant to eradicate the doubt of the senses, and while the apparatus tends to vanish in the experience (if there is no experience of latency, etc.), the possibility of discrepancy nevertheless looms precisely because the immersive space is being produced. If there is sense-certainty in some respects, there is the potential uncertainty in the ways that the senses—and this “certainty” itself—are produced by the mediating device.

Whereas for Euclid the treatment of perceptual space is reduced completely to the laws of mathematics, with Descartes, the perceptual space is produced via apparatuses that aim to follow these laws. In this respect, for Descartes the senses are externalized. As a producing-mediating apparatus, Birdly produces the possibility of a discrepancy in the immersion, since space is produced according to the laws of geometry, but neither the laws nor the device—however integrated—can guarantee the validity of their own production. Whereas the Euclidean-axiomatic approach does indeed validate itself and guarantees its own certainty (as every geometrical proposition is derived from a set of basic objects and the axioms between them), this validity does not apply to the Cartesian apparatus, precisely because it is a production-via-mediation, an assemblage that prompts theoretical doubt in the form of a potential discrepancy. Doubt is implicit in the HMD because it produces space, i.e., because space is not presumed as given (as it is with Euclid). In the context of a brief “flight,” the user may not feel any discrepancy whatsoever, but the production of immersion produces at the same time the potential that this production might not be immersive, it casts doubt on the experience of immersion itself, the manner in which one sees and is self-reflexively positioned within spatial coordinates controlled by the apparatus. Therefore, epistemological instability is inherent to the construction of space, whether it consists of two sticks or an HMD, precisely because that construction is fashioned by an external apparatus.

Yet, another conceptualization may be proposed which goes beyond the externalized anchor that would seek to guarantee sense-certainty. This conceptualization is needed since a Cartesian framework leads VR developers to develop better apparatuses and to deliver “sense-certainty” by eradicating latency and motion sickness, for example. Yet, this is a narrow understanding of doubt and sense-certainty. In the next section, I explore doubt as something more than a matter of sense-certainty, and more than a question of a device that would finally “anchor” or “guarantee” it.
3. Klee, Deleuze, Eyesect: HMD as a Subversion of the Point of Vision

Against the conception that Birdly offers as a mechanical device that aims to give mathematical sense-certainty to vision, I argue that Eyesect offers a more subversive conception, showing how the mechanical apparatus constantly splits and distorts the foundation of visual perception. Eyesect is an HMD set incorporating an Oculus Rift headset consisting of video glasses inside a helmet positioned in front of the user’s eyes with two camera modules. These modules can be attached anywhere on the helmet with magnets, but might also be held by the user. As we shall see, this design induces a new perception of space that no longer coincides with everyday physical space.

To think through Eyesect’s subversion of space, I would like to turn not to a geometric but rather a philosophico-theoretical conception of the point and of its mathematics as expressed by Klee and Deleuze. Both thinkers call for a non-Euclidean understanding of the point in particular, and the mathematical event in general, not as the end result of reduction or as what constitutes an apparatus that serves as a basis for certainty but rather as a dynamic, unstable process. As I will argue, Eyesect is an example of an apparatus that undermines the very concept of the indivisible geometric point.

3.1. Klee: The Non-Dimensional Point

I begin with Paul Klee’s approach arguing against indivisibility. My aim in doing so is to offer a different perspective on the notion of the “point,” one which may appear at first glance to be unrelated to vision and mathematization but will serve to illustrate the subversion of the axiomatic understanding of space (see Section 3.2).

Klee argues that the point is not at all an irreducible Euclidean one but instead has internal structure. With this argument, Klee gestures to the rupture of the point and space itself. In a lecture delivered on the occasion of an exhibition at the Jena Kunstverein in 1924, Klee makes reference to a “grey point,” calling it “dimensionless”:

Chaos as an antithesis is not complete and utter chaos, but a locally determined concept relating to the concept of the cosmos. […] The pictorial symbol [for chaos.] for this ‘non-concept’ [Unbegriff], is the point that is really not a point, the mathematical point. The nowhere-existent something or the somewhere-existent nothing is a non-conceptual concept of freedom from opposition.
If we express it in terms of the perceptible […] we arrive at the concept grey, at the fateful point between coming-into-being and passing-away: the grey point [Graupunkt]. The point is grey because it is neither white nor black or because it is white and black at the same time. […] It is grey because it is a non-dimensional point, a point between the dimensions.28

The grey point is the place between black and white, between one colour and its opposite. It is clear that Klee is not operating on a logical-mathematical plane: this point is both $W$ (white) and not-$W$ (black). Klee suggests that we should think of the point not only in mathematical or artistic terms but also in cosmological terms. Once this (grey) point is established, the cosmos, as the order of the universe, may emerge. However, this is not the creation of a universe by way of order. This eruption of space and the universe is also not what Euclid proposed. Indeed, when Euclid presents his axiomatic method all the fundamental elements of geometry are ascribed a dimension, which is to say an integer number.29 What Klee proposes with his grey point is to subvert not only the notion of dimension but also the “point” itself. The point (even the mathematical point) is an Unbegriff, a non-concept that does not a priori assume a dimension but rather constitutes space and the cosmos as such, hence emerges as that which is “between the dimensions.” The mathematical point has the same status as the grey point: an event in becoming that has almost already passed away. Rather than conceptualizing the mathematical point as that which has zero dimensionality, Klee problematizes the very concept of dimension; on the one hand, the grey point is an “undimensionaler Punkt,” a “non-dimensional point.” On the other hand,

The point is not dimensionless but an infinitely small planar element […]. The point is cosmic, a primordial element. Things on earth are obstructed in their movement; they require an impetus. The primordial movement, the agent, is a point that sets itself in motion (genesis of form). A line comes into being.30

29 The dimension of the point is 0, the dimension of the line is 1, and the dimensions of the plane and of space are 2 and 3, respectively. What do not exist in Euclid’s treatment are forms or elements whose dimension is between 0 and 1 or between 1 and 2, i.e., having, for example, a fractal dimension.
Here the movement of the point as an event creates the space (what is to be seen) but is not a movement derived from an external guarantee of sense-certainty, as I demonstrated with Descartes.

How does Klee’s conception of a point that resists categorization as a basic element of space (but that nevertheless creates it) stand in relation to the mathematization of space, in general, and to the conception of space through an HMD, and Eyesect in particular? To answer this question I turn to Deleuze, who examines two types of mathematics and mathematizations: the axiomatic versus the nomadic, or the problematic. For him, Klee’s point serves as the quintessence of the mathematical event that opposes an axiomatic system or a point of reference.

3.2 Deleuze: The Point as an Event

Following Klee, Deleuze states:

the point, as a ‘nonconceptual concept of noncontradiction,’ moves along an inflection. […] Bernard Cache defines inflection—or the point of inflection—as an intrinsic singularity. Contrary to ‘extrema’ (extrinsic singularities, maximum and minimum), it does not refer to coordinates: it is neither high nor low, neither right nor left, neither regression nor progression […]. Thus, inflection is the pure Event of the line or of the point, the Virtual, ideality par excellence. It will take place following the axes of the coordinates, but, for now, it is not yet in the world: it is the World itself, or rather its beginning, as Klee used to say, ‘a site of cosmogenesis,’ ‘a nondimensional point,’ ‘between dimensions.’

It is clear that Deleuze posits the point not as an origin that functions as a reference but rather as a point of becoming. To parse this out I will consider how Deleuze understands the two axes of the history of mathematics.

Deleuze in Difference and Repetition, and Deleuze and Guattari in A Thousand Plateaus, delineated two types of science, describing the interrelations between “state science” and “nomad” or “minor science.” State mathematicians—among them Euclid and Descartes—endorse the axiomatization of mathematics where a sound and static basis is required. With “state science,” also termed “axiomatics,” a set of theorems is derived from a

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set of axioms. By contrast, in “nomadic science” (also termed “problematics”) deduction “moves from the problem to the ideal accidents and events that condition the problem and form the cases that resolve it.”33 “State science” treats the objects of mathematics as static, their properties derived from their essence. As Deleuze and Guattari explain,

the model [of the nomadic sciences] is problematic, rather than theorematic: figures are considered only from the viewpoint of the affections that befall them: sections, ablations, adjunctions, projections. One does not go by specific differences from a genus to its species or by deduction from a stable essence to the properties deriving from it, but rather from a problem to the accidents that condition and resolve it. This involves all kinds of deformations, transmutations, passages to the limit, operations in which each figure designates an ‘event’ much more than an essence; the square no longer exists independently of a quadrature, the cube of a cubature […]. Whereas the theorem belongs to the rational order, the problem is affective and is inseparable from the metamorphoses […].34

Deleuze explicitly remarks, “Theorems seem to express and to develop properties of simple essences, whereas problems concern only events and affections.”35 State scientists put an end to dynamic, nomadic sciences and mathematics of flow by imposing “civil, static, and ordinal rules” on concepts such as “becoming, heterogeneity, infinitesimal, passage to the limit, [and] continuous variation.”36 Nomadic mathematics, therefore, emphasizes the ‘event’ nature of mathematics, while the axiomatic deals with the deduction of properties from an essence, a set of foundational sentences, or a fundamental origin.37

34 Deleuze and Guattari, A Thousand Plateaus, 362.
36 Deleuze and Guattari, A Thousand Plateaus, 363.
37 As an example, Deleuze and Guattari address Desargues’s attempt to develop the mathematics of problem-event. But Desargues “was condemned by the parliament of Paris, opposed by the king’s secretary; his practices of perspective were banned,” and his geometry was marginalized by the rise of analytic geometry. Indeed, “[r]oyal, or State, science only tolerates and appropriates stone cutting by means of templates (the opposite of squaring), under
Taking the above distinction under consideration, I follow Deleuze’s remarks on Klee to argue that the point itself becomes an event in mathematics. The point is not conceptualized: in Klee’s writings, the point is a non-concept because, if it were a concept, it would serve as a basis for axiomatics. As Klee’s point is dimensionless it is always in the process of being-a-point (as the square is always in the process of quadrature) and is not to be considered under any coordinate system. This means there is no point of reference, no point of origin, no certainty, and, in Descartes’s terms, not even the sense-certainty that hands or devices can provide. This might explain the following remark by Deleuze and Guattari: “It becomes impossible to understand the relations between science and technology [...] because nomad science is not a simple technology or practice, but a scientific field in which the problem of these relations is brought out and resolved in an entirely different way than from the point of view of royal science.”

Whereas Descartes placed an emphasis on technical, even tactile, apparatuses that support geometric vision (the blind person’s sticks or the Mesolabium), Deleuze offers another perspective. With Deleuze we can understand the construction of space via HMD as a construction in-becoming, and hence conceptualize the HMD not as a technical instrument (such as the Mesolabium) whose functioning, constructions, and results are already known in advance. With the Cartesian approach, one already knows how devices will function because vision is subordinated to the mechanical apparatus. With Deleuze, however, the HMD must be understood as that which problematizes this subordination, calling into question the relation between the geometrical eye and its supporting tactile apparatuses. Deleuze’s discussion on painting and art offers some clue here: “to describe the relationship of the eye and the hand, and the values through which this relation passes, it is obviously not enough to say that the eye judges and the hands execute. The relationship between the hand and the eye is infinitely richer, passing through dynamic tensions, logical reversals, and organic exchanges and substitutions.” Significantly, there is no subordination of vision to touch, or vice versa. While “[t]he digital seems to mark the maximum subordination of the hand to the eye,” developing the ideal, geometric state-space “we will speak of the haptic whenever there is no

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40 Ibid.

longer a strict subordination in either direction […] [that is to] be recreated [also] in the ‘modern’ eye, through violence and manual insubordination.”

Given that the royal sciences take, in part, the form of the analytic geometry of Descartes and Fermat, and of Euclid’s axiomatic method, Sections 2.1 and 2.2 offered a discussion of royal science’s relationship to technology as manifested in the apparatuses that express them: the sticks of the blind person, the Mesolabium, and in my reading, Birdly. The “royal” apparatuses conceive of geometry as supplying a point of reference, shaping vision by giving it a static frame. HMD devices, under this framework, are apparatuses that serve as the basis for a “royal” or “state” mathematization of space. However, as I argued, they also prompt the possibility of doubt in the apparatuses themselves, and so a never-ending process of change in technology itself, as VR developers race to find the perfect, most stable, most immersive technology or HMD installation. This already indicates a problematic relation between vision and technology, but HMDs also enable the appearance of nomad sciences that problematize this relation via the deconstruction of space. The apparatus of nomad sciences establishes itself as that which undermines and subverts. These apparatuses act through “manual insubordination,” they cut “the contents of royal science loose.” Moreover, they resist any conceptualization via basic concepts; they no longer provide sense-certainty, visual or otherwise. Rather, they bring vision to a state of “passage to the limit.” HMD installations may offer the possibility of (coming to and) crossing the limit of the stable relationship between technology and vision, between the externalization of vision into the HMD and the space in which the user is supposedly immersed. To this end, I turn now to Eyesect.

3.3 Eyesect: A Nomadic Apparatus

Eyesect was designed by Constitute: The Centre for Applied Future, a Berlin-based group of artists who emerged out of VR/Urban, a public media collective that deals, among other things, with bionic effects and virtual realities. Designer Christian Zöllner, together with Sebastian Piatza and engineer Julian Adenauer, conceived Eyesect.

Eyesect is a wearable interactive installation that reflects an Out-of-Bodiment in an immersive way. By this, it allows users

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41 Ibid., 155. See also ibid., 189, footnote 2 and Deleuze and Guattari, A Thousand Plateaus, 382, where nomad space and the haptic space of visibility are treated together: “The variability, the polyvocality of directions [of haptic space], is an essential feature of smooth spaces of the rhizome type, and it alters their cartography. The nomad, nomad space, is localized and not delimited.”

42 Deleuze and Guattari, A Thousand Plateaus, 367.
to experience their environments from new points of view. The world, as we perceive in reality and through media, is aligned to binocular and stereoscopic vision of human beings. These omnipresent human-centric perspectives and the critical debate about contemporary 3D Technology that only simulates real space [...] Two hand-held cameras capture the surroundings and stream the image data straight to the single eyes. The spatial perception is then constructed inside the human sensory system. Arms and fingers become eye-muscles and create impossible human-biological perspectives [...]. [The users] experience space in a complete new visual manner.43

My own experience with Eyesect was perplexing.44 In contrast to my experience with Birdly, I did, indeed, feel doubt of the senses. While I found it relatively easy to accustom myself to the cameras, as they were attached to the helmet in angles of varying degrees, once I held them in my hands the experience was hard to make sense of. As I continued moving the cameras I saw an image but found it difficult to understand what I was seeing. Other responses from those who have experimented with the device have ranged from bafflement to astonishment.45 One such visitor to the exhibition Cynet Art (Dresden, 2012) who walked around with the Eyesect on remarked “this is a bit too much for me.”46

What is it, exactly, that is “a bit too much”? As Piatza describes in his Master’s thesis on the Eyesect project in its development stages,47 the device enables one to see in a completely new way.48 Piatza parallels this “new way of seeing” to (yet another one of) Descartes’s famous quotes regarding blind persons, this time in reference to using the hands to see:

But consider it [a stick, used to aid people walking in the darkness] in those born blind, who have made use of it all their lives: with them, you will find, it is so perfect and so exact that one might almost say that they see with their hands, or that their

43 “Eyesect”.
44 The Software Studies group visited the Constitute and experimented with Eyesect on 22 April 2015. I would like to thank Christian Zöllner for the visit and the hospitality.
46 “EYEsect vs USER.”
47 I would like to thank Christian Zöllner for sending me Sebastian Piatza’s thesis.
The parallel lines of thinking found in Descartes might be deceiving. Here, one might claim, is a new way of seeing, as with individuals blind from birth that have suddenly gained sight. Instead, I suggest that *Eyesect* subverts the constituting point of seeing. Indeed, for Descartes, blind persons act geometrically and seeing ultimately has a point of origin: if a blind individual can use two sticks that function as eyes, there is no need for a real eye, only for an imaginary mathematical ‘point’ that would consciously or unconsciously calculate and integrate the two distances (or images) received from the sticks or the eyes. With *Eyesect*, this point is either in a state of never-ending becoming—an event, to follow Deleuze—or never-ending splitting: The user’s hands are no longer acting as the source of stability, nor are they yet another organ that implies “natural geometry.” Instead, they subvert it. It is not only that “[t]he eyes are not where they are supposed to be” but rather that there is no single place where the eyes are supposed to be. This contrasts sharply with the Cartesian-Euclidean model in which the eyes are considered as a single unit. With *Eyesect* the always-moving eyes undermine the Cartesian-Euclidean model.

The two cameras of *Eyesect* transmit two images, and constantly move, “stream[ing] the image data straight to the single eyes.” The two images are supposed to be integrated into a single coherent image seen by the user. Nonetheless, this single image, in Klee’s terms, is an *Unbegriff*, a non-concept or non-image. It may constitute a different space but this space may also always change and does not permit sensory cohesion. In *Eyesect*, hands control seeing, and there is no correlation between what users see and the spaces they inhabit and touch. Acting as two eyes, the cameras are in constant motion—a constant state of becoming. As such, *Eyesect* is not akin to seeing with insect vision since the eye-cameras may be positioned at unconventional points on the helmet. The HMD is, instead, a nomadic apparatus enabling the disintegration and dissolution of any point of reference with respect to vision or space. Any sense-certainty and the constructed three-dimensional space itself—allegedly established through various apparatuses—are fractured.

We find that the apparatus does not (re)construct a point of origin, but rather subverts or splits it perpetually, and “acts violently” against it and

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50 “Eyesect.”
51 As when the cameras are placed stably on the helmet in different angles.
52 Since insect eyes are fixed.
beckons toward its rupture. This subversion and rupture cannot be thought in a Euclidean-Cartesian framework that promises sense-certainty. The user therefore finds the experience “a bit too much” not because vision is unstable, but because the apparatus that was supposed to provide sense-certainty in its construction of space ultimately undermines its own premises. This is the flip side of Cartesian doubt of the apparatus, which emerges in the VR experience even with the most immersive HMD installations, such as *Birdly*.

### 4. Two Sides of the Same HMD: Alleged Sense-Certainty and Subordination

*Birdly* and *Eyesect* suggest two aspects of spatial construction through HMDs, but, in a way, they are two sides of the same coin. By positing itself as an apparatus that provides certainty and stability, *Birdly* constructs an immersive space with the apparatus itself serving as the guarantee of certainty. I have argued that *Birdly’s* understanding of space should be conceptualized as a Euclidean-Cartesian space, where the point of reference is fixed and “has no parts.” The user’s sense of security and spatial immersion originates from it. HMD-constructed space is, ostensibly, constant and aspires to remain undisrupted by motion sickness or latency, the eradication of which is the main goal of VR developers. As such, one may consider *Birdly* as a “royal” apparatus. However, the very same apparatus gives rise to doubt of its measurements and resulting displays. While users do not necessarily doubt their senses, the very fact that the device is external suggests a possibility of discrepancy between what is immersed (the moving body) and the immersion itself (the immersed space). This possibility destabilizes the conception of a stable space, a space where there is a self-reflexive correspondence between the user and his or her self-relation within these spatial coordinates.

*Eyesect*, by contrast, purposely subverts the conception of a fixed, well-behaved space from another direction. Instead of trying to overcome the possibility of discrepancy, which might spur new, improved technologies, my analysis of *Eyesect* suggests a “problematic,” to borrow Deleuze’s terminology, or a “non-conceptual point,” to borrow Klee’s. *Eyesect*’s user is no longer held in check by the apparatus. Rather, the apparatus enables the user to undermine this firm hold that is all too typical of screen-based practices that surround us by making the theoretical discrepancy apparent. The space in which the user is located is always in a state of becoming. It has no fixed point and offers no integration of body or vision within the external apparatus. As such, I have argued that *Eyesect* uncovers what lies hidden in other HMD installations.
installations: these installations not only (re)construct vision but also deconstruct it.

While *Birdly* and similar VR games based on HMD technology go to great lengths to conceal visual and spatial deconstruction, *Eyesect* demonstrates that complete concealment is impossible. And this impossibility of concealing the instability in the (re)construction of space applies also to *Birdly*. The apparatus itself reveals that a doubt of the way the apparatus functions is inherent to its (re)construction of space despite incessant efforts to eradicate any discrepancies, and regardless of whether users doubt their senses in this context. Even as HMD developers look to design better devices that would (re)construct a stable space without interruption or doubt, this space, I argue, remains an essentially unstable (re)construction.

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