The Optical Machine's Asynchronic Progress[1]

The research that led to this paper began with the acquisition of a curious artefact (Figure 1). It is a card designed for use in a stereoscope; but its maker has ignored the scientific principles by which the stereoscope was meant to produce an illusion of depth. Charles Wheatstone's whole purpose in designing the stereoscope had been to demonstrate that binocular disparity, that is, two slightly different retinal images from two different perspectives, could, indeed regularly did, combine to produce our experiential sense of three-dimensionality.[2] Yet this maker, long after the superiority of stereoscopic spatial effects had been widely acknowledged, produced two images for that platform that were identical – a non-disparity image which should not, but somehow strangely does nonetheless create a 3D effect.[3] My initial question was, what was he/she thinking? In other words, what alternative optical principles informed his/her design choice?

[1] I would like to thank Ana David Mendes for organizing the workshop on *The Optical Machine*; the Museu da Imagem em Movimento (m|i|mo, Leiria, Portugal), for hosting the workshop; and students and faculty from the Escola Superior de Artes e Design (Caldas da Rainha, Portugal), for their participation and comments. I would also like to thank Maureen Moynagh for her constructive comments on an earlier draft of the paper, as well as the two anonymous reviewers for their kind comments and suggestions.

[2] Charles Wheatstone, "Contributions to the Physiology of Vision – Part the First."

[3] The images are identical, but the prints are cropped slightly differently on the left and right borders. The effect, when freeviewed cross-eyed, is to locate the scene well behind the border. Oddly, in the stereoscope the tendency will be to locate the border behind the scene.

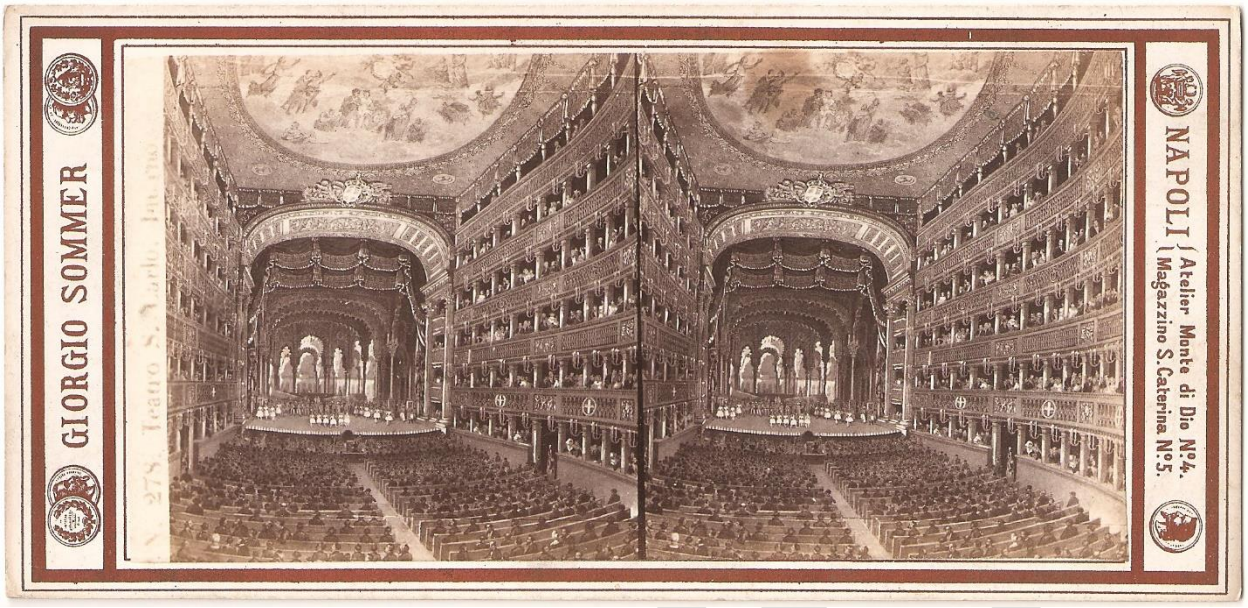

Figure 1 – Giorgio Sommer, c. 1870, *Teatro della Scala Milano*, albumen on paper, 8.5 cm x 17.6 cm, collection of the author.

There is an entire constellation of apparatuses that were thought to produce a depth effect from single images by the mediation of a biconvex lens (or its artefactual inversion, a concave mirror). The lenticular stereoscope with non-disparity images is a variation on that theme. This theme and its variations is distributed across a wide range of devices and a long sweep of time: the eighteenth-century optical machine, peep show, zograscope, concave mirror, kulissentheater; the nineteenth-century *boîte d'optique*; polyrama panoptique, stereoscope, megalethoscope, graphoscope; the twentieth-century shomescope, snapscope and reflectoscope. There have been numerous attempts to explain the principles by which these devices work, by reference to classical optics and binocular convergence in the eighteenth century and by more psychological principles such as cue consistency in recent times.[4] While plausible when applied to one or two devices, none of the explanations can encompass the full range of device variations.

[4] A. Ames, "The Illusion of Depth from Single Pictures;" Neil Arnott, *Elements of* Physics; Erin C. Blake, "Topographical Prints through the Zograscope;" Barry G. Blundell, "On Alternative Approaches to 3D Image

I arrived at this conclusion in part through experimental analysis of period devices in order to expose their physical and optical properties. In addition, I designed controlled experiments to test the physiology of the devices against the phenomenology of the observer experience. These material investigations took me only so far in understanding the peculiarities of peoples' perceptual experiences. The textual record both of design intent and user experience of these devices is quite thin; however, there is artisanal knowledge embedded in the artefacts. To get at it, I have resorted to a further methodological tactic and that is to read artefactual themes and variations across the full constellation of artefacts. If we think of each device or cluster of devices as a note, or a musical phrase, then the full constellation can be imagined as a complete orchestral work from which patterns of melody and form emerge. In addition to the biconvex lens /concave mirror, three themes emerge across the complex: 1) images rendered in a hybrid of linear and curvilinear perspective (hybrid projection); 2) images that are layered transparencies and 3) devices and/or images that invoke the performativity of the theatre (see Figure 1). I argue that these features point to an affinity with a new, constructivist paradigm for understanding perception. If I am correct, then my answer to the question "what were they thinking?" points to just how asynchronic the connections between the histories of perceptual theory, technological innovation and "new media" are.

Perception: Monoscopic 3d Techniques;" E. Claparede, "Stéréoscopie Monoculaire Paradoxale;" J. T. Enright, "Paradoxical Monocular Stereopsis and Perspective Vergence;" Atsuki Higashiyama and Koichi Shimono, "Apparent Depth of Pictures Reflected by a Mirror: The Plastic Effect;" Kees Kaldenbach, "Perspective Views;" Jan Koenderink, Maarten Wijntjes, and Andrea van Doorn, "Zograscopic Viewing;" Jan Koenderink, A. J. van Doorn, and A. M. L. Kappers. "On So-Called Paradoxical Monocular Stereoscopy;" William Molyneux, and Edmond Halley *Dioptrica Nova*; Harold Schlosberg, "Stereoscopic Depth from Single Pictures;" Dhanraj Vishwanath, "Toward a New Theory of Stereopsis;" Dhanraj Vishwanath, and Paul B. Hibbard. "Seeing in 3-D with Just One Eye: Stereopsis without Binocular Vision."

When the optical machine was new in the eighteenth century it embodied a set of theoretical assumptions that were at odds with what is often thought to be the dominant empiricist, realist paradigm of perception that Jonathan Crary associates with the figure of the *camera obscura*.[5] When it, or its descendants, were "old" (and perhaps by some accounts should have been obsolete) in the twentieth century, the theoretical assumptions that it embodied were not so much new as newly dominant. That newness in the old might offer hints as to how to answer a further question which is how this eighteenth-century visual technology survived well into the age of cinema. It has roots in the same constructivist paradigm that inspired modernist innovations in painting such as cubism (Figure 2) and avant-garde cinematic experiments such as Vertov's *Man with a Movie Camera*.[6]

[5] Jonathan Crary, *Techniques of the Observer*, 38.
[6] For a thumbnail sketch of the film and its innovations, see Lev Manovich, *The Language of New Media*, xiv-xxxvi.

Figure 2 – Roger de la Fresnaye, 1913, *Still Life* [with Zograscope], 92.5 x 73.5 cm, oil on canvas, Statens Museum for Kunst, Copenhagen.

SPATIAL DEPTH FROM SINGLE IMAGES

Linear perspective was in the eighteenth century the dominant technique, both in theory and in painterly practice, for invoking an illusion of depth from a two-dimensional surface. Painting was the standard for verisimilitude in representation and also the defining metaphor for clear and accurate perception. Exquisite miniature representations of the world were painted in linear

perspective on the retinae by rays of light just as they could be seen to be painted on the screen of a *camera obscura*. This conflation of perception, epistemology and optical device Crary calls the "figure" of the *camera obscura*. It is an empiricist ideal that promises truth by passive intromission.

However, the problem of how you deduce space, that defining structure of the world itself, from the flat retinal image was raised as early as 1637 by Descartes.[7] George Berkeley, in 1709 launched a powerful attack on the idea that we can either "see" or deduce space from retinal images (visual representations).[8] His skepticism was the inspiration for a counter-paradigm the premise of which is that we *impute* space, and thereby construct the basic frame of the world, using inconclusive and uncertain data. Most philosophers of the eighteenth century, in order to address Berkeley's problem, had to accept that perception was not passive, that it involved the action of the mind to make sense of external representations.[9] Berkeley's opponents sought, however, to show that these mental operations were reliable, indeed perhaps forced upon us by the ineluctable claims of reason.[10]

Geometrical reasoning could, they argued, rebuild world-space if binocularity were added to their perceptual model. An additional machine metaphor was invoked such that the two eyes became *camera obscuras* mounted on surveyor's transits, precisely triangulating the location of objects within their sights.[11] This elaboration caused difficulties for perspective which, many

[7] René Descartes, 'Discourse and Essays: Optics,' 165-173.
[8] George Berkeley, *An Essay towards a New Theory of Vision*.
[9] David Hume, *A Treatise of Human Nature*, 161, 241-2, 423.
[10] On the debate, see for example Thomas Reid, *An Inquiry into the Human Mind*, 146-154.
[11] On the surveyor's metaphor see Descartes, "Optics," 170.

recognized, is undermined by binocularity. When the spectator views the painting of a distant mountain, her two eyes converge on the peak and her pre-conscious reason measures the angle of convergence and tells her that the represented object is located not at the purported vast distance away, but at the very proximity of the canvas, inches from her nose. The problem inspired proposals for mediating apparatuses to correct the newly evident failings of perspective. One was to view the canvas with one eye though a hollow tube – artificially re-asserting the monocularity of perspective and at the same time masking out the frame and gallery spaces that contradict the purported space of representation.[12]

Another mediating apparatus was the biconvex lens, large enough to be looked through with both eyes. Incoming light from the painted peak of the mountain is refracted and bent inwards as it passes through the lens to each eye. The eyes converge less, the mind calculates a greater distance and the represented object appears further away. This is the account of the effect of the biconvex lens in creating an illusion of depth that has been widely accepted since it was first proposed by William Molyneux in 1692 and up until the present.[13] However, Molyneux and his followers may be claiming too much for the biconvex lens. He asserts that "these Glasses making Objects appear further off than really they are, must consequently make the Parts of the Perspective seem really *Hollow'd* or sunk in, the *French* term it *Renfoncè.*"[14] If the eyes measure with the surveyors' precision, then they will locate the entire canvas at a greater distance, and no parts of it will be "sunk in" relative to others. The foreground will be at the

[12] Thomas Reid, *An Inquiry into the Human Mind*, 315.
[13] William Molyneux, *Dioptrica Nova*, 117; Joseph Harris, *A Treatise on Optics*, 232; Neil Arnott, *Elements of Physics*, 200; Kees Kaldenbach, "Perspective Views," 86; Erin C. Blake, "Topographical Prints through the Zograscope," 120-124.
[14] Molyneux, *Dioptrica Nova*, 117.

same distance as the background. In short the lens will do nothing to construct the purported space that defines the relative positions of objects within the view.

Nor will the lenses make the image-objects appear farther off in the example I opened this paper with. In the Brewster-style lenticular stereoscope the biconvex lens is split and the two halves rotated so that the central thickness is now on the outside edge, reversing the direction of refraction. By this means the eyes become more convergent when viewing the representational surface, not less as in Molyneux's theory, yet the enhanced 3D effect is perceptible nonetheless. The effect is also evident without a lens if one views a non-disparity stereogram by cross-eyed free-fusion. The freeviewing effect was what first intrigued me about the *Teatro della Scala* view.

These are important problems for realists, who insist that there is a determinate and mimetic relation between the outside world and inner representations in perception and that visual, representational artefacts can and should be constructed on that same determinate logic. However the new paradigm that was inspired by Berkeley and that I will argue also informs the design of optical machines, was not realist in this sense.

THE THEATRE AS WORLD-CONSTRUCTION

The lead empiricists, Locke, Berkeley, and Hume, were far less sanguine about sense perception than is popularly assumed. Hume was troubled by Berkeley's problem of how the inner representations of sensation (e.g. little paintings inside the perceiver's head or mind) could be a

reliable basis for deducing the external world. He uses the metaphor of the theatre, another representational apparatus understood in the eighteenth century as a form of machine, to think about the predicament. "The mind is a kind of theatre," he writes,

> where several perceptions successively make their appearance; pass, re-pass, glide away, and mingle in an infinite variety of postures and situations. There is properly no *simplicity* in it at one time, nor *identity* in different; whatever natural propension we may have to imagine that simplicity and identity.[15]

He uses the terms "simplicity" and "identity" to refer to the problem of the temporal coherence of successive impressions, let us say the multiple perspectives of an object that signal for us its spatial volume. The unity which we like to think of as underlying the successive impressions is not available to us in sensation – we imaginatively impose it. Hume makes the same point with respect to the containing space, which in his metaphor is the theatre stage: "The comparison of the theatre must not mislead us. They are the successive perceptions only, that constitute the mind; nor have we the most distant notion of the place, where these scenes are represented, or of the materials, of which it is composed."[16]

The empiricist predicament threatened objectivity because if the object is not given in perception but rather imposed by the perceiver, then it is subjective. Immanuel Kant attempted to solve this problem by arguing that the mind imposes both the volumetric forms of individual objects ('schemas') and the containing space (plus time), but it does so objectively, in only one possible way and according to the logic of Euclidean geometry. This "unity of apperception" is imposed at two levels: the personal or "empirical" and the universal or "transcendental."[17] The metaphor

[15] David Hume, *A Treatise of Human Nature*, 301. For a similar use of the theatre metaphor see Reid, *An Inquiry into the Human Mind*, 306.
[16] Hume, *Human Nature*, 310.
[17] Immanuel Kant, *Critique of Pure Reason*.

of the theatre, which I suggest becomes crucial to the coherence of this line of thought, is helpful for understanding Kant's two levels. The empirical unity of apperception is the theatre-goer's synthesis of the scenography into a coherent world seen from a particular location in the seats. The transcendental unity of apperception is the work of the scenographer – painting the sets in linear perspective, arranging the coulisses, scenes, lighting and making the scenes move in a coherent world-story that anchors each of the individual observer's version of it.

The influence of Kant's model of world-construction was enormous, but his attempt to secure objectivity for it was less successful. For many who followed, what for Kant was meant to be an objectivity resistant to will becomes a power subject to will and indeed to fancy. Kant himself used yet another optical device, the magic lantern, to develop the idea of projection – that we project the external world from internal representations.[18] Arthur Schopenhauer reads Kantian world-projection as "dream-like" and, equally taken with the magic lantern metaphor, suggests that Kant had revealed the workings of projection by "taking to pieces the whole machinery of our intellect by means of which the phantasmagoria of the objective world is brought about."[19] He also, as many tended to do, collapsed Kant's two levels in a way that landed him back in Hume's predicament. He writes,

> …space itself is a form of our faculty of perception, i.e., a function of our brain. Therefore that externality to us to which we refer objects, on the occasion of sensations of sight, is itself really within our heads; for that is its whole sphere of activity. Much as in the theatre we see the mountains, the woods, and the sea, but yet everything is inside the house.[20]

[18] Stefan Andriopoulos, "Kant's Magic Lantern."
[19] Arthur Schopenhauer, *The World as Will and Idea*, 9.
[20] Ibid., 179.

While certainly troubling to epistemologists, this idea, that the supposedly objective world was the theatrical projection of a fantastic dream was, I suspect, deeply appealing to many of the artists and artisans engaged in the production of optical machines and the images for them.

THE CHALLENGE TO LINEAR PERSPECTIVE AND EUCLIDEAN SPACE

Kant's play for objectivity relied upon the universality of Euclidean space and on Euclidean geometry as a kind of objective science of its internal structure. Metaphorically he imagines the scenographer of the world-stage painting his coulisses and stage flats in linear perspective. But the artisans of the stage had already moved beyond Euclid. Baroque stage set designers were already employing hybrid projections meant to invoke vast sweeps of space.[21] One of the devices that produced the wide-angle view was the convex mirror that features often in Dutch paintings of the Golden age where they produce curvilinear projections within a linear perspective frame. Another device was the rotating *camera obscura* which produced successive images that were sutured together much in the same way that a modern cellphone panorama is created. A well-known example is Carel Fabritius's *A View of Delft*, of 1652.

This mobile use of the *camera obscura* belongs to a perceptual and representational paradigm radically different from Crary's static figure of the *camera obscura*. It constructs its object by synthesizing successive appearances and folding time into space. It bends the floor-plan of space such that right angles intersect at angles wider than 90°. In other words it produces a non-Euclidean space where the rules of Euclidean geometry do not apply. When representing

[21] Oscar Brockett, et. al., *Making the Scene*, 147; see also Marguerite Yourcenar, "The Dark Brain of Piranesi."

architecture, as it was frequently used to do in stage sets, it renders straight lines as curved. Artists and set designers, not willing to offend our pre-notions of the structure of architecture, straightened edges to produce Euclidean-looking architecture within non-Euclidean spaces. This was hybrid projection.[22] It was self-consciously constructivist in two senses: 1) in constructing a unity across time and 2) in then imposing pseudo-Kantian "schemas" upon the synthesized sense data.

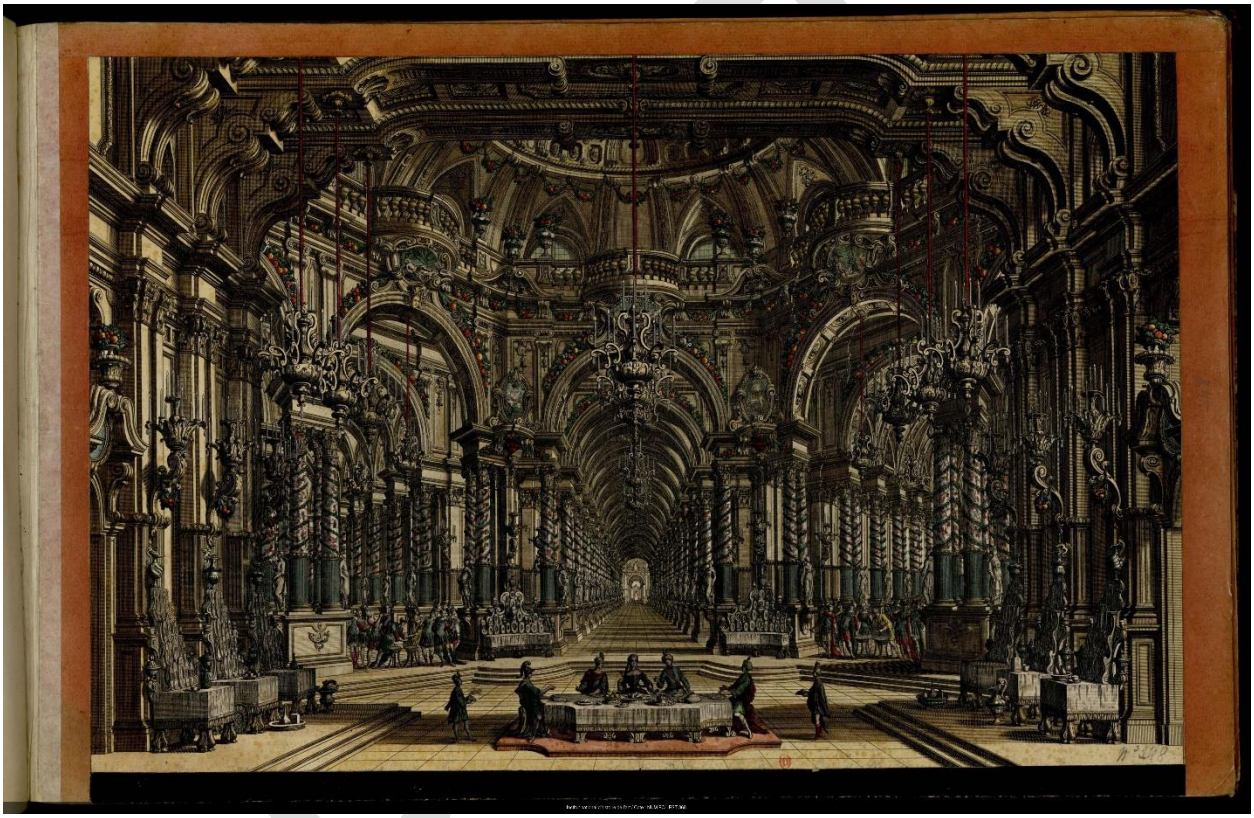

Figure 3 – Bibiena, Giuseppe Galli, and Johann Andreas Pfeffel. 1740. *Architetture e prospettive dedicate alla maesta di Carlo sesto imperador de' Romani da Giuseppe Galli Bibiena, suo primo ingegner teatrale ed architetto, inventore delle medesime*. Paris: Apud Basan.

[22] See Bantjes, "Hybrid Projection."

Figure 4 – Unknown Artist, c.1750, *Vue des trois Galeries du Palais des Arts et des Sciences à Rome*, copperplate engraving, 44 x 29.7 cm (plate), collection of the author.

The *vue d'optique*, the standard image for all eighteenth-century optical machines, was typically rendered in hybrid projection, almost universally in the case of depictions of interiors. These were copperplate engravings often inspired by, or else direct copies of, Baroque set designs. The hybrid projection is one of the artefactual themes that recurs across variations in our constellation of apparatuses. The ubiquity and persistence of hybrid projection is key evidence that these artefacts were conceived within the emergent constructivist paradigm.

Practitioners, new media artists in particular, were often in advance of theorists in departing from the old *camera obscura* model of perception and representation, but their challenges were embedded in practice and rarely written about. Perspective theorists remained impervious to the

development of hybrid projection until the perspective crisis of the 1850s.[23] Kant was relying on Euclidean space after some artists had abandoned it and even after reading the work of philosopher Thomas Reid who in 1876 had proposed a non-Euclidean geometry to account for the way that "great circles" curve in a panoramic view or in the curved grids of global navigation.[24] Non-Euclidean geometries were formalized by Carl Friedrich Gauss, Nikolai Lobachevsky and others in the 1820s and 30s and popularized by Henri Poincaré in the early twentieth century when artists (the cubists) become enamored with them anew.[25]

Optical Machines as Mobile Stages, Mechanically Reproduced

The theatre of the eighteenth century functioned as a kind of philosophical toy. It was a concrete experiential metaphor for thinking about mind, perception and world-creation – how hidden machinery might play upon the senses to produce a mental construct of a world. Its power to "cheat the senses" was considered to be superior to any other medium. William Porterfield in 1749 argued that it was the only medium that could exploit the newly important principle of binocular convergence. In sets using coulisses, the different depths of a scene could be painted "on different Planes, obliquely placed, and a little removed from each other" (see Figure 5).[26] The eyes, converging at different angles for each coulisse would corroborate the conceit of a space "sunk in" and of objects differentially ordered in space. Figure 5 is a maquette used to design such a set. The maquette is a miniature, portable theatre. It almost certainly inspired

[23] Bantjes, "Vertical Perspective Does Not Exist."
[24] Reid, *Inquiry*, 168-174; Norman Daniels, "Thomas Reid's Discovery of a Non-Euclidean Geometry."
[25] Leonard Mlodinow, *Euclid's Window*, 117; Henri Poincaré, *Science and Hypothesis*; Albert Gleizes, and Jean Metzinger, *Cubism*.
[26] William Porterfield, *A Treatise on the Eye*, 410.

designs for the optical box. While Bonifazio's coulisses are hand-drawn originals, artists like Martin Engelbrecht produced them as engravings exhibited in lensed viewing boxes called kulissentheaters.[27] All optical machines relied on mechanically reproduced content.

Figure 5 – Piero Bonifazio Algieri, *Palais de Cérès*, maquette of scenography for Act I of Proserpine de Lully, 1758, gouache with gold highlights, La BnF de l'Opéra, Paris, photographed in stereo.

Illusion in the theatre-optical box complex was understood to be generated mechanically and physiologically. Binocular convergence was understood to be signaled by sensations of muscular movement.[28] Focus, or the "accommodation of the eye," was understood by Porterfield to be a further index of depth only exploited by the theatre. It was similarly mechanical and tactile. *Camera obscuras* had lenses that could be focused either by a sliding mechanism or by rack and pinion. And as the gears turned, the image became an artefact of this motion with

[27] Georg Füsslin, *Der Guckkasten*, 46-52.
[28] Descartes, "Optics," 169.

different planes becoming confused or crisp depending on the depth of focus. Porterfield writes that coulisses placed at different depths on the stage (or in Kulissentheaters) "occasion that Change in the Conformation of our Eyes, by which we likewise judge of Distances."[29]

Artisans, in search of improved illusions, pursued inspiration from the physiology of machines. Consider the following theme across variations. The *boîte d'optique* is an artefactual reversal of the *camera*.[30] The structures are similar but light travels in the opposite direction. Where, in the *camera*, external light entered from nature, now in the miniature show-boxes the viewer peers, receiving light from an artificial scene within. The flap, originally for viewing, now becomes an aperture for the admission of stage-lighting. All of the boxes have a backdrop image that can be illuminated. The *boîte*, like many eighteenth-century optical boxes, contained framing coulisses as well. A front flap enabled these to be illuminated separately from the backdrop which has its own lighting aperture. All three exhibition boxes were fitted with either an oiled paper diffuser or a ground glass for back-illumination that produced transparency effects in the image. They incorporated a technology that, according to Porterfield, "contribute[d] yet further to the Perfection of the Cheat [of the senses]" which was "the false Light wherewith these Decorations are always illuminated."[31] The stereoscope's position within a lineage of binocular devices with theatrical roots is clearly evident.

[29] Porterfield, *Treatise*, 410.
[30] Füsslin, *Der Guckkasten*, 13; Joseph Harris, *A Treatise of Optics*, 278.
[31] Porterfield, *Treatise*, 410.

Figure 6 – Box-type Camera Obscura, English, 1795-1805, overall (open): 20.5 cm x 14.5 cm x 25.5 cm, Science Museum Group Collection, © The Board of Trustees of the Science Museum, photo credit Thomas Henry Court.

Figure 6 – Boîte d’optique, French 1830, 49 cm x 28.5 cm x 20 cm, 2 lenses, 6 cm diameter. La Cinémathèque française Collection, N° Inventaire : AP-95-1207, photo credit: Stéphane Dabrowski.

Figure 8 – Pierre Lefort, French, c. 1850, Polyrama Panoptique, ©Antiq-Photo, Paris.

Figure 9 – Antoine Claudet, English, c. 1850, Lenticular Stereoscope, Science Museum Group © The Board of Trustees of the Science Museum, London. Photo credit: Thomas Henry Court.

A technology whose purpose in the theatre was to make its illusory world dynamic – to invoke changes of time or shifts in space – was the fly-tower from which alternate stage flats could be raised and lowered on rigging. These were common in eighteenth-century touring boxes – shew-boxes, peepshows and raree shows.[32] One of the best surviving examples is an Italian *mondo nuovo* pictured here. Fly-towers also appear as a variant in nineteenth-century French *boîtes d'optique*.[33] Alternate scene-changing devices can be found in the slide-in slot used in the polyrama panoptique, stereoscope and megelethoscope, as well as the continuous roll of images found in show-boxes,[34] French optical tables,[35] toy theatres and cabinet stereoscopes.[36]

Figure 10 – Mondo Nuovo, c. 1780, Italy, collection of François Binétruy.

In addition to a fly-tower, and illumination flaps, front and back, the *nuovo mondo* makes numerous visual references to the theatre. It has a decorated foyer that precedes an illusionistic

[32] The fly-tower is present wherever the showman is depicted pulling strings, see Füsslin, *Der Guckkasten*, 39-45.
[33] La Cinémathèque française Collection, N° Inventaire: AP-95-1630; AP-95-1629; personal communication, Sébastien Lemagnen, Antiq-Photo Gallery, Paris, 30 June, 2019.
[34] There are two examples in the collection of François Binétruy, www.collection-binetruy.com: Boites d'Optique XVIII ème : *Boite Optique vers 1700* / *Boite Optique XVIII ème a Rouleau*.
[35] A zograscope affixed over a table across whose surface a hand-cranked roll moves (Lemagnen, Antiq-Photo Gallery).
[36] Paul Wing, *Stereoscopes*, 61-74. The image-roll also has theatrical origins, although there it was typically used for the repetitive motion of water.

rendering of the auditorium, opera-boxes, proscenium arch and grand drape – all on a stage flat that serves as a curtain to the "actual" stage inside. Proscenium arches and grand drapes, both framing devices that announce theatricality, can be found painted onto actual boxes, and are also common as frames for images in *vues d'optique* and stereoviews – claiming for stereoscopic space the status of performance (see also Figure 13).

IMAGES: TRANSPARENCY, PERFORMATIVITY, PHANTASMAGORIA

In this section I consider image-forms that migrate across platforms and in so doing claim equivalencies across the full constellation of optical artefacts. With respect to their form, I am interested in two themes: 1) hybrid projection and 2) the illuminated transparency. Both originate from the stage. The transparency derives from an old form of stage flat or coulisse that has piercings lit from behind by candlelight diffused through coloured tissue.[37] Eighteenth-century *vues d'optique*, such as those used for the *mondo nuovo*, were often hand-pierced to produce lighting effects in this way.[38]

In nineteenth-century optical-box transparencies the entire image-surface is translucent in a way that allows underlying layers of tissue or paint to be used to create a wider range of effects (see Figure 11). Stage techniques for creating fleeting atmospheric effects – the fall of evening light, the dark moods of a storm, the alarming glow of a building bursting into flame – can be traced to the seventeenth century.[39] However, the scenographer Philippe de Loutherbourg developed them

[37] Brockett, *Making the Scene*, 97-8.
[38] William Hooper (*Rational Recreations*, 191) in 1774 gave do-it-yourself instructions for how to create optical-box transparencies that invoked changing atmospheric effects.
[39] Viktoria Tkaczyk, "Which Cannot Be Sufficiently Described by My Pen," 99.

to a degree of perfection that astonished his contemporaries in the late 1700s.[40] In 1781 he migrated these atmospheric stage effects to a large immersive optical theatre that he called an eidophusikon dedicated entirely, like an optical box, to visual spectacle. In Paris, in 1822, Louis Daguerre and Charles Bouton created a similar immersive spectacle called a diorama, notable for its use of transparencies. A proliferation of optical-box transparencies can be dated to this period.

Figure 11 – Unknown artist, c. 1830, *Salle de l'Opéra à Paris*, hand-coloured lithograph on paper with coloured tissue layers, 20 x 14.4 cm, collection of the author.

The transparency, like the hybrid projection, stands in opposition to the *camera obscura* paradigm. It is a non-realist, non-empiricist form of the image. It is no longer merely a surface, a sense-impression on a retinal screen; but rather a layered construction from which the viewer can unfold time, mood and imagination. The very subjectivity of this dynamic, layered image-form may have appealed to Romantic sentiments of the early nineteenth century.[41] The moonlit

[40] Christopher Baugh, "Philippe De Loutherbourg."

[41] Romantic painters like Caspar David Friedrich used the medium (Füsslin, *Der Guckkasten*, 81-85) as did Thomas Gainsborough who built his own optical box to exhibit his transparencies. The medium was tainted as machinic, but these artists saw in it less the mechanical deception of the senses and more the liberation of the imagination (Ann Bermingham, "Gainsborough's Show Box," 204).

scene that emerges onstage in *Salle de l'Opéra à Paris*, as the front lighting is dimmed and the backlighting increased, is typical of the gothic mystery that pervades many of the images produced in this medium.

Salle de l'Opéra à Paris, an example both of hybrid projection and of transparency, was designed for the polyrama panoptique. Strikingly, almost this very image, the wide sweep of the interior of an opera house, recurs across platforms, linking a theatrical paradigm of perception and representation and an actual image of the theatre to all of these artefacts: eighteenth-century showboxes, nineteenth-century *boîtes d'optique*, the megalethoscope, stereoscope, graphoscope and shomescope.[42] The stereoscope, as a product of advances in perceptual theory, should stand apart from these other devices; still, there is a considerable archive of images that are in hybrid projection (and therefore, necessarily hand-drawn rather than photographic)[43] and non-disparity manufactured as stereo-cards. These are miniature *vues d'optique* for the stereoscope. Transparent stereoviews, or tissue views, were produced in the tens or even hundreds of thousands.[44]

In the tissue view, the illuminated transparency makes claims against photography's purported realism. Carlo Ponti's *Grand Canal* (Figure 12) is an example of a tissue view created for the megalethoscope.[45] The top layer, the surface impression on the retina, is a photographic print.

[42] For an image of a megalethoscope, see La Cinémathèque française collection, N° Inventaire : AP-95-1613.
[43] The original images are typically hand-drawn and reproduced for the stereoscope by photography rather than by engraving.
[44] In David Brewster's earliest designs for the lenticular stereoscope, he imagines the device being used for hand-drawn transparencies, Brewster, "Description of Several New and Simple Stereoscopes,"
[45] La Cinémathèque française collection, N° Inventaire : AP-94-905. The print and layers are stretched on a wooden frame curved in the horizontal plane. The idea that curvature enhanced depth is proposed by Harris (*Treatise*, 232), and revived again by the Keystone stereoview company whose stereo-cards curved away in the vertical plane.

The deeper layers of coloured tissue and piercings allow the user to transition from daylight appearance to a particular mood of evening revelry on the Venetian canal. There is yet more than meets the eye: gondolas filled with ghostly figures crowd the canal. Such figures, common in tissue views for the stereoscope, suggest a reality that the camera cannot capture. These reveals are often vaguely ominous – a dark silhouette carrying a mysterious package through the streets of Paris, a pastoral scene into which a fiery steam engine intrudes, a fire that bursts from the windows of a quiet building. They invoke spirits from the past or anticipated futures, wish fulfilment, nightmares.

Figure 12 – Carlo Ponti, 1862, *Grand Canal: Palaces Cavalli and Barbaro, Salute Church, Venice*, albumen print with hand-coloured layers, 43.7 cm x 31.2 cm, La Cinémathèque française collection.

Viewers who manipulated the lighting mechanisms in these boxes, and thereby changed the atmospheric mood of the scene, were controlling the constructive theatre of representation as though they were Kantian world-making impresarios. The artists, in their choice of imagery, seem to have felt, like Schopenhauer, that Kantian world-making was suited to bringing about, not a dull, obligatory objectivity, but rather a "phantasmagoria of the objective world."

ARTEFACTUAL ACKNOWLEDGMENT OF EQUIVALENCE AND CONTINUITY

Promiscuous assemblages that threw together the *vue d'optique* and the stereoscope, photography and phantasmagoria, the theatrical and the real, were common in the nineteenth century, a period when realism and technological progress were commonly thought to have reigned. French stereoviews in particular – the diableries[46] as well as thousands of theatre maquettes of popular operas are further evidence of this counter-trend. Adolphe Block's tissue view of *L'Africaine*, like all of the *Theatres de Paris* series, playfully mixes conventions of spatial representation. At one level it is a truly stereoscopic photograph rendering a reality in full stereoscopic volume. That reality is a miniature maquette of an opera stage – that is, an illusionistic representation of an illusionistic device (actual theatre stages). On the stage are little clay sculptures representing actors (who represent real people).

Figure 13 – Adolphe Block, c. 1870, *L'Africaine, Act 2, Scene 2*, albumen on paper, coloured tissue, 17.5 x 8.8 cm, Collection of the author.

[46] See May, et al., *Diableries*.

The embossed, cutout frames of the card are designed to read as a proscenium arch, and are positioned so as to enhance the illusion of the stereoscopic space of the maquette stage opening out behind it. With the front lights up the proscenium arch is dramatically lit and the coulisses and painted backdrop convey their spatial claims convincingly. These claims rely not just on perspective but also on the power of the stereoscope's lenses. They are non-disparity images invoking space using the eighteenth-century optical-box principle yet on the same platform as stereoscopic space-making. The stereoscope has become a kind of virtual kulissentheater. When the front lights are dimmed, the clarity of stereoscopic space is dulled. The *trompe d'oeil* of the scene painter's work and the stereoscopic spaces take on similar epistemic values rendering the on-stage world less navigable and slightly more fantastic as though one could (like the hapless Wile E. Coyote) never be sure if one were going to step through or run into a stage flat.

The implied equivalence of eighteenth- and nineteenth-century technologies of spatial construction is also built into the devices themselves. The graphoscope, popular in the 1890s and early twentieth century, combines stereoscopic lenses and an eighteenth-century style viewing lens wide enough to view through with both eyes. The graphoscope was intended for viewing either stereoviews or single images. While the latter are mostly photographic, many, including the one depicted here (Figure 14), were photographically reproduced hand-drawings. Here again is the opera-house interior rendered in hybrid projection, a point of evidence that plots the *vue d'optique* /stereoscope association through to the end of the nineteenth century.

Figure 14 – Graphoscope with hybrid projection. Image: Unknown artist, c. 1890, *Salle de l'Opera*, albumen on paper, 16.4 x 10.9 cm, collection of the author.

Evidence of the long-term persistence of the eighteenth-century spatial technology extends furthest for its concave mirror variation. Eighteenth-century writers mention the concave mirror almost as often as the biconvex lens.[47] It is a further example of an artefactual reversal: the "glass" flips from being convex to concave, the action of light switches from refraction (going through) to reflection (being repelled). Concave mirrors were also used as a means of image-projection, a form of the device that Kant takes up as another metaphor for world-projection. Harris gives directions for the construction of an optical box using a concave mirror and argues

[47] Anon. "Correspondence," 534-5; Anon. "Directions to the Binder," 584; Harris, *Treatise*, 207; Jacques Lacombe, *Dictionnaire Encyclopedique des Amusements*, 756.

that the mirror version is superior to the lens.[48] However, no surviving examples of the eighteenth-century concave-mirror optical-box have come to light.

The technology re-emerges in the twentieth century in numerous variants including the Shomescope (depicted in Figure 14), the Reflectoscope[49] and the Snapscope.[50] These devices were designed to enhance the 3D effect of popular hand-held images of the period including postcards and home-made photographs taken perhaps with the mass-produced Brownie box camera. I have pictured it here, merely suggestively, with a late-nineteenth-century miniature of the opera-house interior in hybrid projection.

Figure 15 – Shomescope with Hybrid Projection. Image: J. Carlo, *Naples Théatre*, hand-painted albumen print, 6.7 cm x 11.4 cm, collection of the author.

[48] Harris, *Treatise*, 207.
[49] Arthur Judge, *Stereoscopic Photography*, 137.
[50] Antiq-Photo Gallery, Paris, 30 June, 2019.

Discussion and Conclusion

In earlier stages of this research I conducted tests and experiments upon these artefacts to try to answer questions that the period literature was largely silent on. My idea was that there would be a design intent that artisans had built into their devices perhaps at odds with or in addition to the knowledge of the theorists, in the same way that seventeenth-century painters experimented with curvilinear perspective despite the silence or opposition of perspective theorists. I measured focal lengths and distances between lenses and images. I considered the ways in which devices did or did not (e.g. the zograscope) mask out cues at counter-purpose to the purported illusion. I considered the ways in which the devices either fixed the point of sight or, conversely allowed for movement and a striking space-box effect with pseudo-parallax.[51] I tested the binocular divergence effect on a Wheatstone-style stereoscope with moveable arms able to change the angle of convergence of the eyes.

While I found numerous candidates for design features enhancing a 3D effect, none applied across all devices, and many were not only not present but worked at counter-purpose to the way that they operated in other devices. So, for example the space-box effect was reversed in the zograscope, or binocular divergence was decreased in the stereoscope. Even my assumption that stereography was technically superior was challenged. I conducted a workshop for professors and students at an art and design school in which they were asked to evaluate their experience of the 3D effects of most of the devices I have discussed in this paper.[52]

[51] See Bantjes, Rod. "Strange Persistence."
[52] *The Optical Machine*, collaborative workshop with Ana David Mendes, m|i|mo (museu da imagem em movimento), Leiria, Portugal, 19 February, 2019.

Each device exhibited the same *vue d'optique* image, in hybrid projection, of the interior of a cathedral. I asked people to score the strength of the spatial illusion on a scale of -2 to +12 with the benchmark for 0 being the unmediated *vue d'optique* and 10 a photographic stereoview, using binocular disparity, of the interior of a similar cathedral. To my perceptual eye, the force of the stereoscopic 3D illusion was of a different order of magnitude than any of the non-disparity views. So I was astonished that some people gave devices operating on eighteenth-century principles equal or higher scores than the stereoscope. A simple biconvex lens was awarded 11: "The image becomes more enveloping, but the sense of depth is not so great, although the first planes have more depth of field." Half of my audience thought the megalethoscope produced a 3D illusion equal to or better than the stereoscope. One who gave it a 12 writes, "I loved this one. I felt as if I had been completely enveloped, from light to immersive box format, everything worked in perfect tune creating a completely inclusive and immersive experience." Another, who gave it a 10 says simply, "It felt like I was within a cinema."[53]

Here people are asserting a phenomenological equivalence between the eighteenth-century optical box principle and the technically superior nineteenth-century stereoscopic principle. There is no material explanation of this result that appeals to optics or what we know of the perceptual mechanism of stereopsis. Perhaps I was not sufficiently clear to my participants about how I wanted them to abstract just the qualities of volume and spatial separation from the other attractions of each experience. I think, rather, the point is that people do not normally

[53] Translation from the Portuguese by Ana David Mendes.

abstract "objective relations" from the charms of an immersive experience. They can feel seduced and drawn in by a whole range of qualities that have little to do with the mechanical operations of optics. The comment "It felt like I was within a cinema" is the most telling. The person is reading the device in terms of its cultural associations with familiar illusion-invoking experiences.

For eighteenth- and nineteenth-century users the defining cultural association was not the cinema but the theatre. Let me elaborate on what I think was actually going on, and what I also think the makers of these devices understood to be going on, by using the example of the Necker cube. This is the transparent figure discovered by Louis Necker in 1832 that can be flipped between two contradictory spatial configurations – one an inside-out version of the other.[54] It was a discovery consistent with the constructivist paradigm of perception and confirmed by some of Wheatstone's own experiments with inverting spatial objects.[55] It demonstrates the extent to which the projection of spatial hypotheses is subject to will and intention. Schopenhauer's *World as Will and Representation* resonates here. In the case of the Necker cube, the spatial hypotheses are both prompted and constrained by the optical "input" – a parallel projection of a cube. In the same way, there is an optical, physiological basis for the spatial promptings that each of the devices we have discussed offers the viewer. Such promptings are present, if not uniform across all devices. However the making of space in these contexts is always in some measure willed.

[54] Louis Necker, "Observations on Some Remarkable Optical Phenomena."
[55] Wheatstone, "Contributions to the Physiology of Vision – Part the First," 302 (on his interpretation of Necker); Wheatstone, Charles. "Contributions to the Physiology of Vision – Part the Second," 14 (on his experiments with inverting volumes).

Modern psychologists have demonstrated that a lens-enhanced 3D effect for non-disparity images does exist.[56] However they have not so far offered a persuasive explanation for why it does. They are implicitly engaged in the debate aroused by Berkeley and are generally committed to the idea that through some mechanism, whether geometric or physiological, spatial representations are imprinted in the mind in some obligatory, "objective" fashion. I have been arguing that eighteenth- and nineteenth-century artisans sided rather with Berkeley and the constuctivists in the conviction that we project spatial constructs on the world, sometimes willfully and at times when the sensory input is incomplete or even contradictory.

I have shown that this paradigm for thinking about perception and representation was available in the eighteenth century and was perhaps inspired by and certainly metaphorically expressed through examples of optical and theatrical devices. I have surveyed a constellation of artefacts that share the same core technology, looking for artefactual themes and variations that give insight into the design intent of the makers of these devices. I argue that hybrid projection, which recurs in images across this constellation, is implicit recognition that in perception we synthesize a temporal sequence of sense impressions and impose upon them Kantian schemas where they fail to conform to our spatial preconceptions. Layered transparencies, present across most, but not all devices, have embedded within them the idea that what we see cannot be reduced to what is imprinted on the surface of the retina, but rather is coloured by the imagination. Finally, both artefacts and the images produced for them make frequent references to the experience of the theatre and the plays on space, the techniques of spatial construction, that the theatre puts on display.

[56] Koenderink, "Zograscopic Viewing."

The constructivist paradigm was designed to explain perceptual anomalies that could not be accounted for in the simple *camera obscura* model. It applied, in other words, to how we actually see the world. The makers of optical boxes were applying it to how we see images. The question here, one that modern writers seem sometimes to forget, is not so much how people perceive space, but rather, how they read the spatial claims of pictures, while remaining fully aware that they are pictures. How is it that we are willingly seduced into the conceit of an illusory world? Perhaps we love what eighteenth-century writers called "pleasing deception."

In a final note, I want to turn to a remarkable image of the collision of the eighteenth-century technology with the twentieth-century avant-garde (Figure 2). How do we read this and other quotational and metaphoric references to the optical device in philosophy, literature and visual art? My work acknowledges a precise material diversity among optical artefacts, while tracing a logic of theme and variation that hints at a unifying paradigmatic coherence. The meanings of the zograscope and stereoscope are often framed in terms of the veridical seeing of Crary's *camera obscura* or else nineteenth-century immersive realism. Until now writers have tended to miss the parallel, dissenting discourse that situates these devices as instruments of a world-making, constructive imagination. This frame makes perfect sense of the idea that the zograscope should be the focus of a cubist painting.

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