Peter Weibel

Contours of a History of the Theory and Art of Perception in Austria

I. From Color Dominance to the Problematic of Movement and Perception

After painting had explored the phenomenon of color and its composition and effect on the eye in the nineteenth century,[1] at the beginning of the twentieth century its attention turned to the perception of motion and the mechanisms of the perception of form. The artistic movements of Cubism, Futurism, Suprematism, Constructivism, De Stijl, as well as the experimental photography and film of the 1920s bear witness to this. The study of motion and perception as isolated and absolute phenomena logically came into play through the investigation of color as an isolated and absolute element. The catalytic position that color had held for the evolution of art in the nineteenth century was held by the visualization of motion in the twentieth century.

This shift of attention and artistic focus towards the phenomenon of movement was necessitated by the emergence of machines, i.e., wheel technology. There were suddenly machines that could move faster than the human and animal body, and machines — namely photographic and cinematic — that could document movement more precisely than painting; therefore, the historic visual arts had to deal more intensely with the problem of the representation of motion, be it the representation of moving objects (Futurism) or the representation of observers in motion (Cubism). The task was: how can movement that occurs in four dimensions, in space and time, be represented on the two dimensions of the picture? Art began to face this problem of movement around 1900.[2]

From this task posed by the problem of movement — the two-dimensional representation of a four-dimensional event — arose the necessity of abstraction. As the motion was mostly carried out by wheel technology, or rather, was made by it, wheels or abstracted wheels such as circles and other visual symbols for motion, acceleration, and speed found their way into painting. An abstract representation of motion developed very quickly from the realistic representation of movement machines, since this corresponded more closely with the subjective sensation of seeing. Since the elements of the movement machines — wheels, pistons, and so on — were already geometric figures such as circles, lines, and rectangles, the abstraction followed geometrically. The "More geometrico," as a method of visual representation, had been predominant in the tradition of painting ever since the development of perspective in the Renaissance. Geometric abstraction was therefore the logical result of painting's search for a visual vocabulary that could represent four-dimensional movement (in space and time) two-dimensionally (on a flat surface). Parallel to that, technical image media such as photography and film also developed new approaches to the problem of the representation of motion that were somewhat more artistically advanced and more convincing than those in painting since film had three dimensions at its disposal (namely surface and time) with which it could better depict the changing of forms in time, the phenomenon of movement.

Film thus became the actual art of movement, the language of motion, cinematography. It was only in the course of its own artistic development that film became the language of vision: opseography.

In this confrontation with the problem of movement, answers to the questions of how the eye perceives motion and how perception functions became more urgent. The new problem of movement and the historical problem of color converged upon the common problem of perception. Thus, distinct branches of art that dealt explicitly with movement and optical processes developed from the motion and perception problematic: Kinetic Art and Op Art. The contribution of Hungary to these art forms, from Moholy-Nagy to Kepes and Vasarely to Schöffer, enjoys international renown, whereas the contribution of Austria (similar to almost everything modern in Austria) remains relatively unknown both domestically and abroad. Nonetheless, Austria has achieved a great deal in these areas, both scientifically and artistically.

II. The Picture between Manual Color Analyses and Machine-Supported Movement Studies

Under the influence of the performance of machines, not only was the phenomenon of motion analyzed but also the processes of perception. Experimental physiology, particularly that studying the eye, as well as experimental psychology developed in the nineteenth century out of the confrontation between human and machine.

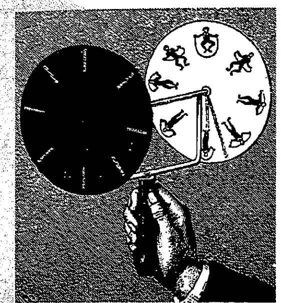
Around the middle of the nineteenth century, the progress of the machine-based Industrial Revolution had led to questions about the relationship between human and machine performance. One example was the measurement of the time the human organism required for its diverse activities compared with the machine's time (Taylorism). Human behavior was measured and recorded. This obsessive study of the functioning of the human body, which was now itself considered a machine, gave rise in the nineteenth century to experimental physiology, psychology, and medicine. Cinema and the technical arts would never have developed without this experimental physiology, psychophysiological research, and early physiochemical experiments. The conversion of technical knowledge from physics and physiological properties of vision — gained from

1. To remember how catalytic the scientific color theory of the nineteenth century was in the development of painting up to the beginning of the twentieth century, refer to the well-known enormous influence of the publications from: Michel Eugène Chevreul, *De la loi du Contraste Simultané des Couleurs* (Paris, 1839); Charles Henry, *Cercle Cromatique* (Paris, 1888); Charles Blanc, *Grammaire des arts du dessin* (Paris, 1867); Charles Ogden Nicholas Rood, *On the Relation between Our Perception of Distance and Color*, American Journal of Science, 2nd ser., 32, no. 95 (1861): 184, and *Modern Chromatics, with Applications to Art and Industry* (New York, 1879), as well as Impressionism, Pointillism, Divisionism, and so on. Also the related works of James Clerk Maxwell ("color top," 1855); Hermann von Helmholtz, *Handbuch der physiologischen Optik* (Leipzig, 1867); Gustav Theodor Fechner, *Elemente der Psychophysik* (Leipzig, 1860); Jakob Stilling, *Tafeln zur Bestimmung der Blau-Gelb-Blindheit* (Kassel, 1878); *Pseudo-isochromatische Tafeln zur Prüfung des Farbensinns* (1878); David Sutter, "Les Phénomènes de la vision," in L'Art 1 (1880), are mentioned in connection with this, as well as the influence which Ernst Brücke had with *Die Phänomenologie der Farben* (Leipzig, 1866) on Frantisek Kupka and Dr. H. Schoenmaeker's *Het Nieuwe Wereldbeeld* (1915) with his theory of the three primary colors (red, blue, yellow) on Mondrian. See also William J. Homer, *Seurat and the Science of Painting* (Cambridge, MA: MIT Press, 1964).

2. Ludwig Volkmann, *Das Bewegungsproblem in der bildenden Kunst* (Esslingen: Paul Neff, 1908).

comparison with machines — builds the historical basis for not only the art of film but also every art oriented on perception.

With the help of experimental perception psychology, the properties of vision and the mechanisms of perception were investigated methodically for the first time. In 1824, persistency of vision was discovered by Dr. Peter Mark Roget, whom we also thank for *Roget's Thesaurus*.



Simon Stampfer
Stroboscopic disks, 1833

James Clerk Maxwell with his *color disc*, 1855

The afterimage effect — the light impression that remains approximately 1/20 of a second after the influence of the light — and the stroboscopic effect caused by it — the apparent melting of a rapid succession of images on the retinal surface — were scientifically analyzed and used for the construction of so-called "optical toys" that produced illusions of motion. The discovery of the afterimage effect and, most importantly, the stroboscopic effect, build the physiological basis of cinematography: the art of the mechanical, visual simulation of motion.

Around 1830, the great physicist Michael Faraday constructed Faraday's disc, which, "with the help of a technically produced stroboscopic effect" gave rise to "illusory motion."[3] At the same time, the Belgian physicist Joseph Ferdinand Plateau made initial investigations into stroboscopic effects (Greek: *strobos* = whirl or spin, *skopein* = seeing), such as the flicker limit or the fusion effect of images.[4] In 1839 he formulated the law of the "stroboscopic effect."[5] The Austrian professor of geometry Simon Stampfer discovered stroboscopic discs independently in 1833. In these, a disc with perforated slits carrying sequential drawings is spun quickly similar to Plateau's *Phenakistiscope* (Greek for "deceitful vision") motion wheel. In order to observe movement, the observer looks through the slits onto a mirror that reflects the drawings in simulated motion. In order to do away with the mirror, the devices were improved so that two counter-rotating discs rotated on one wavelength.[6] In 1912, the gestalt psychologist Max Wertheimer formulated a further law of illusory movement, the "phi phenomenon."[7]

The nineteenth century was addicted to the analysis and synthesis of sequential movement. New forms of a technical art developed through the comparison of bodily and machine functions, primarily those that involved time sequences. With the help of a machine, static images could be moved so quickly that the eye experiences the illusion of naturally continuous motion. The machines used, so to speak, the eye's optical deficits as measured by physiologists to create a machine-supported art of optical illusion, especially the simulation of motion. Because this early mechanical phase of the industrial revolution was marked by wheel technologies, the first cinematographic devices were called *Lebensrad* [wheel of life] (Stampfer), *Faraday's wheels* (Faraday), *Scheiben* [discs] (Stampfer), *Zoetropes* (W. G. Horner), and *gyroscopes* (J. C. Maxwell).

The manual color wheels and color gyroscopes in the nineteenth century were supplemented by machine-produced optical discs (image and split discs), whose function was to call forth the illusion of motion. These discs merged the analysis of movement, the dissection of the motion into individual phase images, and movement synthesis; the fusion of the individual images to the creation of illusory motion. In the course of development, the picture camera and the film camera took over the task of motion analysis, while the film projector took on the task of movement synthesis.

All of these wheel, disc, and revolver apparatuses, which mirrored the movement apparatus of industrial wheel technologies, had the disadvantage of not collectively, but rather only individually, allowing access to

3. Michael Faraday, "On a Peculiar Class of Optical Deceptions," Journal of the Royal Institution of Great Britain, no. 1 (1831): 205–223, 333–336.

4. J. A. F. Plateau, "Sur un nouveau genre d'illusion optique," in Corresp. mathem. et pys. de l'observatoire de Bruxelles, no. 7 (1832): 365–368.

5. The stroboscopic effect determined the frequency at which the individual bits were sequentially perceived as continual image impressions, and through that, brought about an illusion of movement. To avoid the flittering or flickering of the light, twenty-four pictures per second are not enough. To achieve the necessary frequency of fifty impulses per second, each of the twenty-four images must be broken by the wings of a revolving mixer in two dark pauses during the projection time of 1/24th of a second.

6. Simon Stampfer, "Über die optischen Täuschungs-Phänomene, welche durch die stroboskopischen Scheiben (optischen Zauberscheiben) hervorgebracht werden," in Jahrbücher des k.u.k. polytechnischen Instituts in Wien [Yearbook of the Royal Polytechnic Institute of Vienna], vol. 18 (Vienna, 1834), p. 239. In 1833, this was already included in the second edition of the "Zauberscheiben" as a brochure.

7. Two stationary short light lines that are spatially separated are shown for a time one after the other. If the interval between the illumination of both of the lines is short (1/32nd of a second), both lines appear simultaneously. If the interval is long, the two lines are seen as one after the other. At a certain interval, markedly at the frequency of 1/16th of a second, the two lines are seen as the movement of one line.

the optical phenomena. Only the *Magic Lantern*, an early form of projection, allowed a group experience of machine-supported images. The first suggestion to combine the *Lebensrad* and the *Magic Lantern* came from T. W. Naylor in 1843. The Viennese magician Ludwig Döbler developed "a new Magic Lantern" in 1847, "which conjures up moving images on the wall." The Austrian Franz Uchatius delivered an improved version of the device from Naylor and Döbler in 1853.[8] In the nineteenth century, a mechanical device was created from the basic laws of the physiology of vision that would eventually lead in 1895 to the birth of film, to the *Cinématographe* of the brothers Lumière, which at that time was still described as "Cinétoscope de projection," which it actually was, as it combined the photo-cinematic series of shots with theatrical projection.

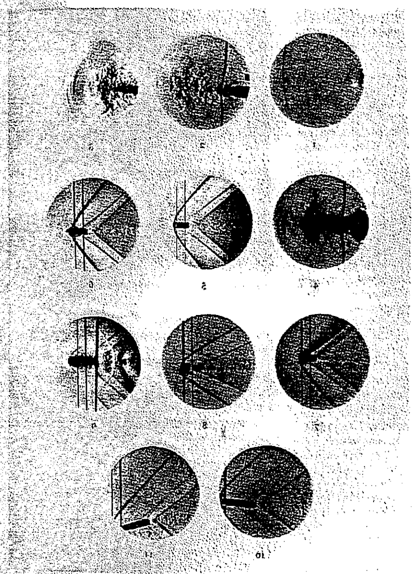
III. Marey, Muybridge, Mach

Painting and sculpture at the beginning of the twentieth century learned from the photographic and cinematographic experiments in movement analysis and synthesis of the nineteenth century. In tackling the problem of motion, painting relied on the results of photography, especially on the work of Etienne Jules Marey and Eadweard J. Muybridge. Also the physico-photographic experiments of Ernst Mach were helpful in creating a visual vocabulary for motion. The significance of the scientific study of movement through photography was the same for painting that confronted the problem of movement as the scientific color theory had been for abstract color painting.

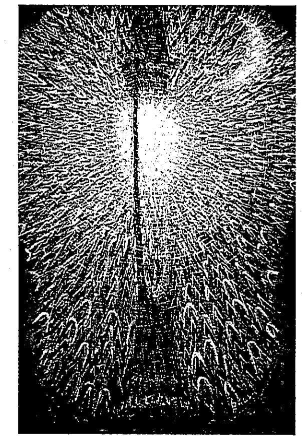
Marey's works offered painters more advantages than Muybridge's, as Marey placed the various phases of a movement together on a single two-dimensional photo, something that naturally fit with painting, limited to a two-dimensional surface. Marey developed the method of simultaneity. As a physiologist, he was primarily concerned with a graphic method for recording movement, as attested to by his article, "Moteurs Animés. Expériences de physiologie graphique" (1878).[9] Marey's procedure showed the different phases of movement side by side on a single plate; at first from a single perspective, but as of 1887 with three cameras simultaneously from above, from the side, and from below. The paintings of Cubism and Futurism found a solution to the movement problem in Marey's simultaneity of various movement phases and his synthesis of the multifold perspective. Through that, simultaneity and synthesis became central concepts of Cubism and Futurism.

The sequential method originates with the British-American photographer Eadweard J. Muybridge. Muybridge developed a method that was, in a way, opposite to Marey's: the method of (photo)graphic representation of movement. With Muybridge, every image showed only a single phase of movement. He set up as many as twenty-four cameras at a distance of half a meter apart, and received a series of twenty-four pictures that showed twenty-four phases of movement. Muybridge's decisive step was to distribute the photographic registration of movement from one image to many images and to represent consecutive movement phases through consecutively placed images in "An Electrophotographic Investigation of Consecutive Phases of Animal Movements," as the subtitle of his book *Animal Locomotion* (1887) explains. Muybridge paved the way for the art of film as cinematography, as a language of movement; Marey paved the way for art as opseography, as a language of vision. The experiments and theories of Mach were especially relevant for the art of observing vision when seeing, opseoscopy, as well as for the continued advancement of experimental perception psychology in the twentieth century.

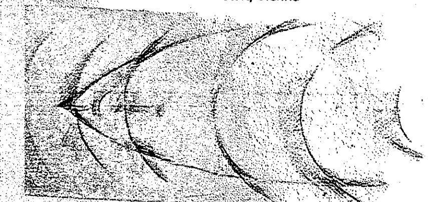
In addition to the photographic research of the French physiologist Marey and the British-American photographer Muybridge, the conclusions of the Austrian physicist Mach were of particular importance for the development of those pictorial arts that strove to depict movement two-dimensionally. Through contacts with the physiologists Ernst Brücke and Carl Ludwig, through studying the writings of Gustav Theodor Fechner and Hermann von Helmholtz, Mach tied together physics, physiology, and psychology. Thus in 1873 he published *Optisch-akustische Versuche* [Optical-acoustic experiments] and, in 1875, *Grundlinien der Lehre von den Bewegungsempfindungen* [Fundamentals of the theory of movement perception] and several additional fundamental research results on optic-acoustic sense perception.[10] He compiled all of his research results in his first major comprehensive work on this subject, *Beiträge zur Analyse der Empfindungen* [Contributions to the analysis of perception] (1886). His subsequent books, such as *Populärwissenschaftliche Vorlesungen* [Popular scientific lectures] (1896) and *Die Analyse der Empfindungen und das Verhältnis des Physischen zum Psychischen* [The analysis of the sensations and the relationship of the physical to the psychic] (1900), as well as his posthumous publication, *Die Principien der physikalischen Optik* [Principles of physical optics] (1921), not only made him a central intellectual figure at the turn of the century in Vienna but also assured his influence in the international avant-garde to the present day. It is, however, typical for the imbecilic and revisionist conservatism in Vienna that Mach was completely left out of an influential 1985 Viennese exhibition on the fin-de-siècle, *Traum und Wirklichkeit. Wien 1870–1930* [Dream and reality: Vienna 1870–1930). Mach contributed in various ways to the development of the optical arts. First, his work *Zur Analyse der Empfindungen* [On the analysis of sensations] (1886), where the terms "Tongestalt" (sound shape) and "Raumgestalt" (space shape) made their appearance, contributed to the founding of Gestalt theory. Second, his studies of spatial vision such as *Beobachtungen über monoculare Stereoskopie* [Observations on monocular stereoscopy] (1868), and his popular essay "Warum hat der Mensch zwei Augen?" [Why does man have two eyes?] advanced stereoscopic research — the fusion of two flat images into a picture with an apparent depth effect. Third, his work on the appearance of flying projectiles, snapshot photographs, and attempts at ballistic photography[11] in the years 1887–1895 delivered the basis for a vocabulary with which painters could visually express speed and movement, the three-cornered arrow form. His photos of flying projectiles show, namely, a waved head at the tip, the supersonic cone, also called a Mach cone, which became the sign (index, or symbol) for speed. This cone, or arrow form, cultivated by air resistance, has been visually appropriated by many painters since the beginning of the twentieth century, especially the Futurists, to visualize accelerated movement, speed, light rays, wave expansion, and so forth.



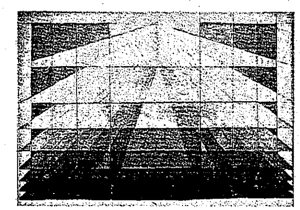
Ernst Mach, *Photographies of a flying bullet*, 1887
Graphische Lehr- und Versuchsanstalt, Vienna



Giacomo Balla
Lantern with Arcs, 1909
© VBK, Vienna, 2005



Giacomo Balla, *Study of a Flying Swallow*, 1913
Pencil on paper, 40 x 60 cm
© VBK, Vienna, 2005



Giacomo Balla
Study for *Iridescent Penetrations*, 1912
© VBK, Vienna, 2005

8. L. L. Döbler and T. W. Naylor, *Die verschwimmenden und die beweglichen Bilder. Zwei neue Anwendungen der Laterna Magica* (Leipzig, 1844); Franz Uchatius, "Apparat zur Darstellung bewegter Bilder an der Wand," in Department Report of the Mathematics-Science Class of the Kaiserliche Akademie der Wissenschaften [Imperial Academy of the Sciences], no. 4 (1853): pp. 482-485.

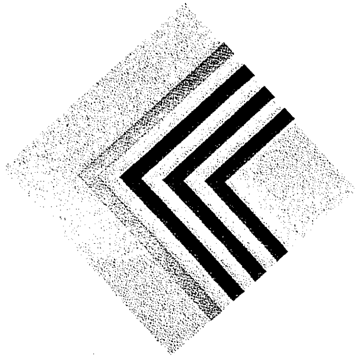
9. In *La Nature* 28.9 and 5.10 (Paris, 1875). See also E. J. Marey, "Dévelopement de la méthode graphique par l'emploi de la photographie," in *Supplément à la méthode graphique* (Paris, 1885). E. J. Marey, "Photography of Moving Objects and the Study of Animal Movement by Chrono-photography," Scientific American supplement (February 5, 1887): p. 12.

10. Ernst Mach, "Über die Änderung des Tones und der Farbe durch Bewegung," Sitzungsbericht der kaiserlichen Akademie der Wissenschaften, Mathematisch-naturwissenschaftliche Classe (hereafter SW) 41 (1860): 543–560; "Über das Sehen von Lagen und Winkeln durch die Bewegung des Auges," SW 43 (1861): 215–222; "Zur Theorie des Gehörgangs," SW 48 (1863): 283–300; "Vorträge über Psychophysik," Österreichische Zeitschrift für praktische Heilkunde 9 (1863); "Zwei populäre Vorlesungen über musikalische Akustik" (Graz, 1865); "Über den physiologischen Effect räumlicher vertheilter Lichtreize," part 2, SW 54 (1866): 131–144; part 3 and 4, SW 57 (1868): 11–19; "Bemerkungen zur Lehre vom räumlichen Sehen," Zeitschrift für Philosophie und philosophische Kritik, N.F. 46 (1865): 1–5; *Einleitung in die Helmholtzsche Musiktheorie, Populär für Musiker dargestellt,* (Graz, 1866); "Über wissenschaftliche Anwendungen der Photographie und Stereoskopie," SW 54 (1866): 123–126; "Beobachtungen über monoculare Stereoskopie," SW 58 (1868): 731–736; Ernst Mach, *Contributions to the Analysis of the Sensations* (Bristol, UK: Thoemmes Press, 2001); *Open Popular Scientific Lectures* (Chicago: Open Court, 1986); *Science of Mechanics* (Chicago: Open Court, 1988); L. R. Young, V. Henn, and H. Scherberger, eds., *Ernst Mach: Fundamentals of the Theory of Movement Perception*, book/CD-ROM (New York: Plenum Press, 2001; Ernst Mach, *Space and Geometry: In the Light of Physiological, Psychological, and Physical Inquiry* (Chicago: Open Court, 1988); *Knowledge and Error: Sketches on the Psychology of Enquiry* (Dordrecht: D. Reidel, 1976); *Principles of the Theory of Heat* (Dordrecht: D. Reidel, 1987); J. Blackmore, *Ernst Mach's Vienna 1895-1930, or Phenomenalism as Philosophy of Science* (New York: Kluwer Academic Publishers, 2001); J. Blackmore, *Ernst Mach – A Deeper Look: Documents and New Perspectives* (New York: Kluwer Academic Publishers, 1992).

11. E. Mach, Salcher, "Photographische Fixierung der durch Projectile in der Luft eingeleiteten Vorgänge," SW 95 (1887): 764–778; "Über die Fortpflanzungsgeschwindigkeit des durch scharfe Schüsse erregten Schalles," SW 97 (1888): 1045–1052; "Über eine Lichtquelle zum Photographieren nach der Schlierenmethode," in Jahrbuch für Photographie und Reproduktionstechnik 2, ed. J. M. Eder (1888): 284. E. Mach, Salcher, "Über die in Pola and Meppen angestellten ballistisch-photographischen Versuche," SW 98 (1889): 41–50; "Über die Schallgeschwindigkeit beim scharfen Schuß nach von dem Kruppschen Etablissement angestellten Versuchen," SW 98 (1889): 1257–1276. E. Mach, Salcher, "Optische Untersuchung der Luftstrahlen," in SW 98 (1889): 1303–1309; together with L. Mach, "Weitere ballistisch-photographische Versuche," in SW 98 (1889): 1310–1326.

Wolfgang Paalen, born in 1905 in Vienna. Joined the surrealist movement as a painter. Invented "fumage" (fire) painting. Many surrealist objects. Emigrated to Mexico in 1939, died there in 1959.

Wolfgang Paalen
The Discovery of Infraspace I, 1940
77,7 × 57,3 cm



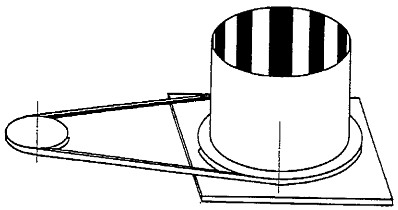
Kenneth Noland
Drive, 1964

As an experimental photographer, Mach therefore had an important position alongside Marey and Muybridge in the modeling of visual images for the representation of movement. In addition to Simon Stampfer (1833), Ludwig Döbler (1847), and Franz Uchatius (1853), among others, with Mach Austria not only had a technical pioneer of photography and cinematography to show for itself but also a philosopher who connected experimental physiology and physical experiments on the analysis of sense perception with experimental technical research into optical and acoustic laws. In 1873 he furnished the proof that special organs for the perception of movement sensations are found in the labyrinth of the inner ear.

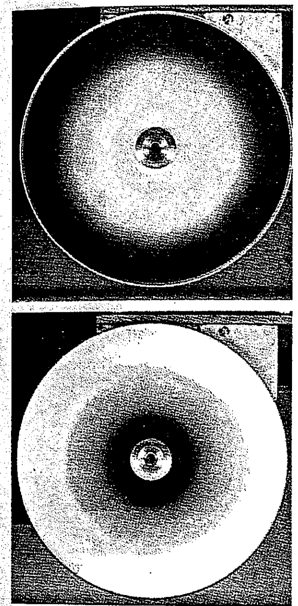
Apart from this, of Mach's numerous contributions to the physiology of sensory perception, Gestalt theory, and the psychology of perception, Mach banding is probably still the most well known today.[12] This effect of contrast perception discovered by Mach is a quite mysterious interaction between contrast and adjustment, a sensory illusion of the distribution of brightness. Contrasts or contours that deviate from the actual distribution of brightness appear before the eye. In the change from white fields to black the separator, for example, is accentuated. In the transition from the white to the black surface, a narrow ring of brightness in the white surface and a darker ring in the black surface is subjectively seen. This effect was already consciously employed by Paul Signac (see *Le Petit Dejeuner*, 1886/1887). Such effects of brightness contrasts and adjustments, which Mach himself described as neuronal inhibition procedures or sensory inhibition, are still employed today, for example by Mark Rothko. Rupprecht Matthaei, in *Das Gestaltproblem* (1929), expanded this lateral interaction of fields of vision, this interaction of the powers of contrast and adjustment.

The Mach drum is an example of induced movement of the observer. Observers who are in the middle of such a drum while it is moving feel themselves to be turning in the opposite direction. Mach developed sophisticated physical methods and experiments to mathematically grasp and document the objective reality of mental and sensory perceptions, particularly of movement. Thus in this way a physicist became the forerunner of Gestalt psychology.

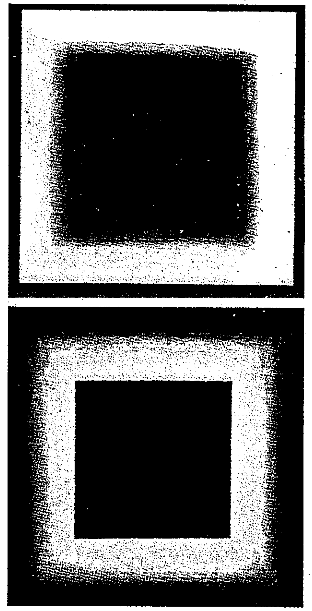
12. Floyd Ratliff, *Mach Bands: Quantitative Studies on Neural Networks in the Retina* (San Francisco: Holden Day, 1965); "Contour and Contrast," Proceedings of the American Philosophical Society 115 (1972): 150–216.



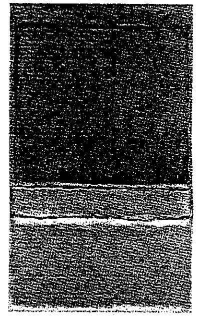
The Mach drum



Mach Bands (top dark, bottom light). Mach Bands (left: dark, right: bright) are created where two different, steep gradients of strong light meet.



Conditions for contrast and comparison: the actual color of the two interior squares is exactly the same. However, the square below looks much darker than the upper. The sharp edges are dominated by contrast; the fuzzy edges are compared to the bright frame (after R. Matthaei, *Das Gestaltproblem*, 1929).



Mark Rothko, *No. 18*, 1952

Notebook 11, (17 February 1877)

The I from ideas, which hold together more strongly. Borders of the I.
Transition of I in one-another. Dissolving of I in another expanded I. Distance.
Memory of grasping?
Holding the distance constant.
How do the three local sketch-series become one and the same?
Understanding the body.
The eye is a grasping instrument equipped with light sensitivity.
It feels before the position, the tactile instrument after the position.
The tactile space is a space for memory and imagination.
The visual space less so. The great distance of further removed points is perhaps no longer optical (perspective enlargement).
The eye moves without obstacles.
The arm doesn't always. One sees bodies.
One detaches form from them,
Herbart insufficiently*
... leads to physiological theory. Visual sensations bound to spatial sensations.
Which type are the spatial sensations? The mere impulse of movement shifts the object.
Natural reversal (time).
Grasping is associated with a sense of space and arises through the same.

* Johann Friedrich Herbart (1776-1841), German philosopher, psychologist and pedagogue. 1802-1809 private docent and professor in Göttingen, afterwards he held Kant's chair in Königsberg, 1833-1841 he was again professor at the university in Göttingen.

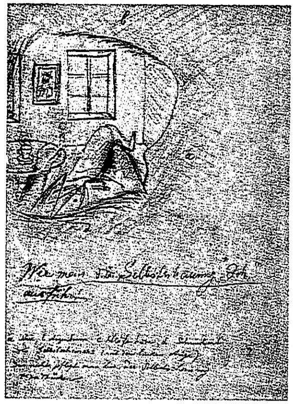


Fig. 1.

Excerpts from the note books (1871-1910) from Ernst Mach, probably drafted around 1871.

Mach can therefore be considered among the great nineteenth-century perception psychologists, who still exercise an enormous influence on art and philosophy to the present day. Mach was, incidentally, so influential in his time that Lenin found it necessary in 1909 to compose a polemic against Mach and his corrupting influence on Bolshevism, namely *Materialism and Empiriocriticism. Critical Remarks on a Reactionary Philosophy* (see Alexander Bogdanov's *Empiriomonism* [1904].) It is also interesting how the Hungarian psychiatrist Thomas S. Szasz takes up Mach's line of thought in order to criticize psychiatry and psychoanalysis.[13]

IV. Gestalt Psychology in Vienna and Graz

Franz Brentano

Among the most important forerunners of modern psychology was Franz Brentano (1839–1917), who lived in Vienna from 1874, and prior to that taught in Würzburg (where Carl Stumpf was his student). With his work *Psychologie vom empirischen Standpunkte* [Psychology from an empirical standpoint] (1874) and *Untersuchungen zur Sinnespsychologie* [Investigations on sensory psychology] (1907), he laid the foundation for phenomenology, the psychology of action (aktpsychology), and the Graz School of Psychology and the Würzburg School of Thought Psychology (Karl Bühler, Otto Selz). At the core of his teaching lay the concept of intentionality: all psychic acts are directed at objects. Every psychic phenomenon is characterized by its intentionality. Among his students in Vienna were Edmund Husserl, Alexius Meinong, and Sigmund Freud.

Christian von Ehrenfels

Building on Mach's analyses and Franz Brentano's teachings on intentionality, Christian von Ehrenfels (1859–1932), a student of Brentano, developed his thoughts on gestalt and published them in his famous article "Über Gestaltqualitäten" [On gestalt qualities], which founded Gestalt psychology.[14] Ehrenfels was professor of philosophy at the University of Vienna in 1888, and also from 1899-1929 in Prague. Mach, who held the chair for experimental physics at the University of Prague from 1867 to 1895, published the *Analyse der Empfindungen* (with the terms "tongestalt" and "raumgestalt") in 1886; Ehrenfels published his essay in 1890. In it, he defined gestalt: "a gestalt is that perceived something that is more than and something other than the simple summation of its constitutive parts, although these are essential for its existence."

Alexius Meinong

The founder of the Graz School of Theory of Objects, Alexius Meinong (1853–1920) became involved early on with the treatise of his friend Christian von Ehrenfels, who had graduated with him in Graz in 1885.[15] But Meinong wanted to present the concept of gestalt theoretically. He believed that a special psychic act was

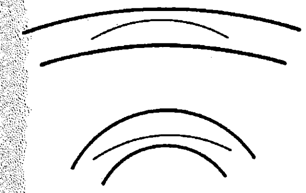
13. Thomas S. Szasz, introduction to E. Mach, *The Analysis of Sensation and the Relations of the Physical to the Psychical* (New York, 1959). Thomas S. Szazs, "Mach and Psychoanalysis," Journal of the Nervous and Mental Diseases 130 (1960): 6–15.

14. Christian von Ehrenfels, "Über Gestaltqualitäten," Vierteljahresschrift für Wissenschaftliche Philosophie 14 (1890): 242–292; B. Smith, ed. *Foundations of Gestalt Psychology* (Munich: Philosophia, 1988).

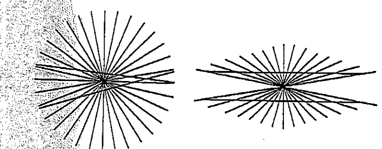
15. A. Meinong, "Zur Psychologie der Komplexionen und Relationen," Zeitschrift für Psych. und Physiolog. der Sinnesorgane 2 (1891): 245–265; A. Meinong, *On Emotional Representation* (Evanston, IL: Northwestern University Press, 1972); *On Assumption* (Berkeley and Los Angeles: University of California Press, 1985); D. F. Lindenfeld, *The Transformation of Positivism: Alexius Meinong and European Thought, 1880-1920* (Berkeley and Los Angeles: University of California Press, 1981).

16. M. Wertheimer, "Experimentelle Studien über das Sehen von Bewegung," Z. f. Psychol. 61 (1912): 161–265; English translation in T. Shipley, ed. *Classics in Psychology* (Philosophical Library, 1961); M. Wertheimer, *Productive Thinking* (New York: HarperCollins, 1945, 1959); K. Koffka, *Principles of Gestalt Psychology* (Lund Humphries, 1935).

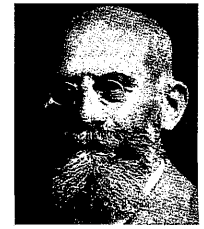
necessary so that from the professed elements of perception the corresponding gestalt impression followed. A gestalt idea is the result of a psychological procedure that should be understood as idea production. Therefore, he suggested replacing the label "gestalt quality" with "higher-order object." In his autobiography (published posthumously in 1921) Meinong admitted that Ehrenfels's treatise "Über Gestaltqualitäten" was the most important preliminary work for his theory of objects. Meinong, together with his students in Graz, Stephan Witasek and Vittorio Benussi, and his Viennese friend Alois Höfler, developed a "Substantiation and Production Theory" of gestalt that stood in contrast to the Berlin School, which believed that gestalts are primary. According to the substantiation theory, gestalts are higher-order ideas first added to the complex of sensations by the subject.



Curve contrasts according to Höfler. Between the flatter curves, the same arc appears stronger than it does between the more steeply graded curves.



Höfler's Deception: If the angles on both halves of the straight lines oppose each other, they must appear bent.



Christian von Ehrenfels

Alexius Meinong

Max Wertheimer and Wolfgang Köhler

Max Wertheimer, who came from Prague (where Christian von Ehrenfels taught), was considered the founder of the Berlin (and Frankfurt) School of gestalt psychology. At first Wertheimer worked with Wolfgang Köhler and Kurt Koffka, students of Carl Stumpf, from 1910 until 1914 in Frankfurt where, as of 1910, he investigated the phi phenomenon of illusory movement.[16] Following that he went to Berlin. Kurt Koffka (1886–1941) went to Giessen and, in 1924, to America.

Wolfgang Köhler (1887–1967) worked with chimpanzees from 1914 until 1920 on Tenerife,[17] and from 1922 to 1935 he worked in Berlin. In Frankfurt and Berlin, Wertheimer, Köhler, and Koffka developed the world-famous school of gestalt psychology.[18] There they joined with the psychologist Kurt Lewin. Wertheimer returned to Frankfurt between 1929 and 1933 as chair and institute director; Wolfgang Metzger,[19] previously assistant to Köhler in Berlin, became his assistant. In 1933, Wertheimer emigrated to the U.S.A. out of necessity; in 1935 Köhler went by choice. Leon Festinger (theory of cognitive dissonance) was Lewin's student there.

The immediate beginnings of gestalt psychological thought are bound with the names Franz Brentano, Ernst Mach, Christian von Ehrenfels, and Alexius Meinong, and the effects they had in Vienna, Würzburg, Prague, and Graz. Gestalt psychology developed in Berlin through Brentano's student, Carl Stumpf (1848–1936) of Würzburg, who went in 1894 by way of Prague, Halle, and Munich to Berlin, where his students were, among others, Köhler, Wertheimer, Koffka, Lewin, and Friedrich Schumann. Through Meinong, phenomenological holistic and gestalt theory developed in Graz, especially through his students Vittorio Benussi (1878–1924) and Stephan Witasek (1870–1915).

But these schools came to contrasting conceptions of gestalt, as can be shown through the example of the understanding of a melody. The Graz School said that the act of production by the subject makes the melody from the individual tones. In the Berlin School (Wertheimer, Koffka, Köhler) however, the gestalts are primary. When the notes C and G sound together, a quint is produced whose quality lies neither in the note C nor the note G, and is also independent of these two notes. Every pair of notes with the oscillation relation of 2:3 is recognized as a quint. The quint is a gestalt that is not only more than the sum of its parts, but rather,

17. W. Köhler, *Intelligenzprüfungen an Menschenaffen* (Berlin: Springer, 1921); W. Kohler, *The Mentality of Apes* (London: Routledge, 1999); R. Ley, *Whispers of Espionage: Wolfgang Kohler and the Apes of Tenerife* (Harmondsworth: Avery Penguin Putnam, 1990).

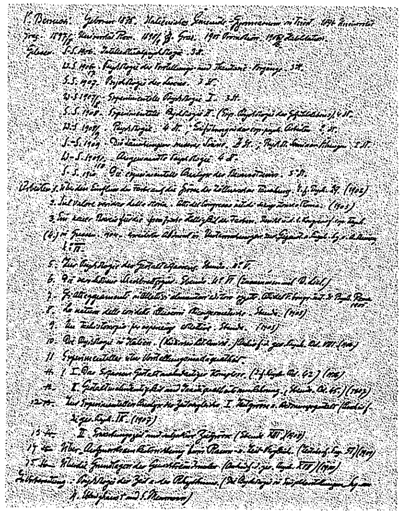
18. M. Wertheimer, "Untersuchungen zur Lehre von der Gestalt," Psychol. Forschung I (1922): 47–48; V (1923): 301–350; English translation in W. D. Ellis, ed. *A Source Book of Gestalt Psychology* (New York: Harcourt, Brace, 1938); M. Wertheimer, *Drei Abhandlungen zur Gestalttheorie* (Berlin, 1925). K. Koffka, "Zur Grundlegung der Wahrnehmungspsychologie," Z. f. Psychol. (1915); "Perception. An Introduction to Gestalttheorie," Psychol. Bulletin (1922); "Über Feldbegrenzung und Felderfüllung," Psychol. Forschung 4 (1923); *Principles of Gestalt Psychology* (New York, 1935). W. Köhler, *Die Physischen Gestalten in Ruhe und im stationären Zustand* (Braunschweig, 1920); "Komplextheorie und Gestalttheorie," Psychol. Forschung 6 (1925); *Gestalt Psychology* (New York, 1929). Viktor v. Weizsäcker, *Der Gestaltkreis. Theorie der Einheit von Wahrnehmen und Bewegung* (Stuttgart, 1950).

19. Wolfgang Metzger, *Gesetze des Sehens* (Frankfurt am Main, 1936).

above all, shows that the gestalt as a whole is different than the sum of its parts. Wertheimer and Köhler formulated the hypothesis from the psychophysical isomorphism: "psychological facts and causal brain processes are similar in all of their structural characteristics."[20]

Vittorio Benussi

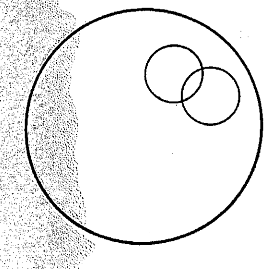
Playing a particularly central role in this discussion was Vittorio Benussi (1878–1924), born in Trieste, where he later completed his secondary education in 1896. In the 1896/ 1897 academic year he enrolled at the University of Graz. In 1899–1900 he attended Meinong's lectures and in 1901 wrote a dissertation, "Über die Zöllersche Figur. Eine Experimentalpsychologische Untersuchung" [On Zöller's figure: An experimental psychological investigation]. He had spent most of his time as a second assistant in Meinong's psychological laboratory, which Meinong had founded in 1894. Benussi became a close student and active colleague of Meinong. In 1904, Meinong published the festschrift *Untersuchungen zur Gegenstandstheorie und Psychologie* [Investigations on the theory of objects and psychology] for the ten-year anniversary of the psychological laboratory at the University of Graz, in which Benussi established himself as psychologist par excellence of the Graz School.[21] In 1905 Benussi made his home in Graz. In the following years he dedicated himself solely to his research on geometric-optical-illusion, the psychology of time perception, and especially gestalt perception.[22]

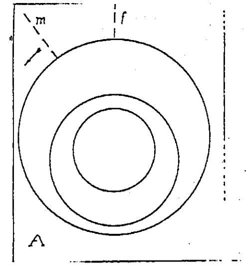

Facsimile of a handwritten page by Vittorio Benussi: summary of his courses and publications

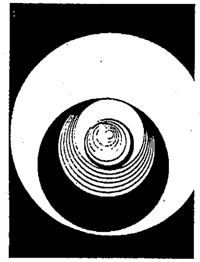
Despite his international renown as experimental psychologist, he was never named as a professor due to his Italian heritage. In December 1918, after the end of the war, he was dismissed. In 1919 he was awarded a chair for experimental psychology in Padua, where he founded the psychological school of Padua (1919–1927), whose most important (and initially only) student was Cesare L. Musatti, who later taught Gaetano Kanizsa and Fabio Metelli.[23] In the last years of his life Benussi drew closer to psychoanalysis, a move intensified through his friendship with Doctor Edoardo Weiss of Trieste. Benussi committed suicide on November 24, 1927 at the age of forty-nine. Particularly relevant for the position of gestalt psychology is the discussion between the Graz production theory and the Berlin Gestalt theory, or the Benussi-Koffka controversy. In 1912 Benussi published his work on stroboscopic illusory movement.[24] In the same year, Max Wertheimer published his essay "Experimentelle Studien über das Sehen von Bewegungen" [Experimental studies on the perception of movement], the manifesto of gestalt theory from which came the previously mentioned discovery of the phi phenomenon.[16] In 1913, on the other hand, Kurt Koffka and Friedrich Kenkel published a work about the same phenomenon, at the end of which they criticized Benussi,[25] who replied in a review.[26] Koffka reacted to that with a thorough critique of production theory.[27]

From today's perspective, Benussi's standpoint was closer to cognitive neurosciences because he extended the experimental analysis of perception to an analysis of consciousness and the latent subjective factors in the construction of the perceived world.[28] Benussi's students, the Italian successors of the Graz School of Gestalt Psychology (Cesare L. Musatti, Fabio Metelli, Gaetano Kanizsa, Renzo Canestrani) further crucially developed gestalt theory into cognitive psychology, as the following titles show: *Seeing and Thinking: Vittorio Benussi and the Graz School* (Natale Strucchi),[29] and *Seeing and Thinking* (Gaetano Kanizsa).[30] What we thank Benussi for, above all, is the discovery of stereokinetic phenomena, the seeing of illusory movements and illusory bodies. In 1912, through a relatively simple experiment, he researched the connection between movement and depth perception that had already been suggested by Helmholtz: Patterns of circles on rotating discs create moving cones and with that the illusion of spatial perception; the perception of a three-dimensional picture in motion.[31]

20. W. Köhler, *Die Aufgabe der Gestaltpsychologie* (Berlin: De Gruyter, 1971), p. 50; W. Kohler, *Gestalt Psychology: An Introduction to New Concepts in Modern Psychology* (1947; London: Liveright, 1992; W. Kohler, *The Task of Gestalt Psychology* (Princeton, NJ: Princeton University Press, 1969); M. Henle, ed. *The Selected Papers of Wolfgang Kohler* (London: Liveright, 1971). (Berkeley and Los Angeles: University of California Press, 1981).
21. V. Benussi, "Zur Psychologie des Gestalterfassens (Die Müller-Lyersche Figur)," in A. Meinong, ed., *Untersuchungen zur Gegenstandstheorie und Psychologie* (Leipzig: Barth, 1904), pp. 303–448.
22. V. Benussi, "Gesetze der inadäquaten Gestaltauffassung," Arch. f.d. ges. Psychol. 32 (1914): 396–419; "Versuche zur Analyse taktil erweckter Scheinbewegungen (kinematohaptischer Erscheinungen) nach ihren äußeren Bedingungen und ihren Beziehungen zu den parallelen optischen Phänomenon," Arch. f. d. ges. Psychol. 36 (1917); "Experimentelles über Vorstellungsinadäquatheit. I. Das Erfassen gestaltmehrdeutiger Komplexe," Z. f. Psychol. 42f, (1906); *Psychologie der Zeitauffassung* (Heidelberg, 1913); "Zur experimentellen Grundlegung hypnosuggestiver Methoden psychischer Analyse," Psychol. Forsch. 9 (1927).
23. C. L. Musatti, "La scuola di psicologia di Padova (1919–1927)," Rivista di psicologia 24, no. 1 (Bologna 1928).
24. V. Benussi, "Stroboskopische Scheinbewegungen und geometrisch-optische Gestalttäuschungen," Arch. f. ges. Psychol. 24 (1912): 31–62.
25. Kurt Koffka and Friedrich Kenkel, "Beiträge zur Psychologie der Gestalt- und Bewegungserlebnisse in Untersuchungen über den Zusammenhang zwischen Erscheinungsgröße und Erscheinungsbewegung bei einigen sog. optischen Täuschungen," Z. f. Psychol. 67 (1913): 353–449.
26. V. Benussi, "K. Koffka, F. Kenkel, Beiträge zur Psychologie der Gestalt- und Bewegungserlebnisse," Arch. f. ges. Psychol. 32 (1914): 50–57.


Vittorio Benussi, 1912; apparent transparency in stereokinetic phenomenon. If the circular pieces are glued or drawn in three colors on a card and then set to rotating slowly, it looks as if two circles, like sections of a cylinder, each of one color, are lying next to each other.

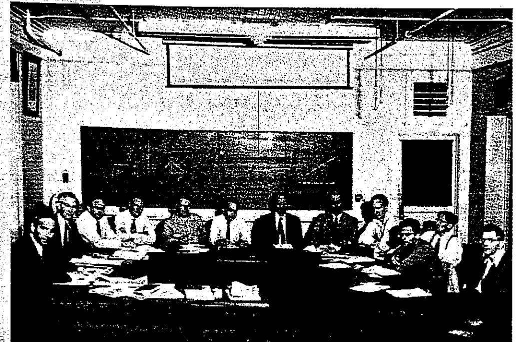

Cesare L. Musatti, 1924; circles that create stereokinetic effects when rotating.


Marcel Duchamp, 1925-26; optical disk from the film *Anémic Cinéma*
© VBK, Vienna, 2005

The unfinished stereo-films of Duchamp (1920), the optical disc of his film *Anémic Cinéma* (1925-1926), and the *Roto-Reliefs* from 1935 are based on these stereokinetic phenomena. Benussi's student, Musatti, refined and built on Benussi's discovery of the stereo-kinos in 1924.[32] He gave the phenomenon the lasting name, "stereokinetic effect." The discovery of stereokinetic spatial images and illusory bodies in motion was forgotten and first rediscovered by Metzger and Hans Wallach.[33] The results of Brentano's, Mach's, and Ehrenfels's research on gestalt theory and perception psychology continued not only in Berlin, Graz, and Würzburg (Carl Stumpf), but also in Vienna.

Karl Bühler

Bühler (1879–1963), a student of Stumpf, published an important work on gestalt perception in 1913. In 1922 he moved to Vienna, where he was professor of psychology at the university from 1922 until 1938. Together with his wife Charlotte he built a center for perception and developmental psychology,[34] the Institute for Psychology at the University of Vienna (1924–1938), which was supported by donations from the Rockefeller Foundation and had an amazing assembly of students: Peter R. Hofstätter, Ernest Dichter, Kurt Eissler, Paul F. Lazarsfelder, Konrad Lorenz, Heinz Hartmann, Lajos Kardos, Karl Popper, Else Frenkel-Brunswik, Emil H. Erikson, and Egon Brunswik.[35] By the end of his life Bühler had expanded gestalt theory to become gestalt philosophy, which also took into account new results from cybernetics, cognition theory, and automation theory.[36]


Cornell symposium on the "Effects of the Gestalt Revolution," 1957.
From left to right: Wolfgang Metzger, Fritz Heider, George Klein, James Drever, Robert B. Macleod, James J. Gibson, Hans Wallach, Egon Brunswik, Gunnar Johannson, Ivo Kohler, Julian E. Hochberg, and T.A. Ryan.

27. Kurt Koffka, "Beiträge zur Psychologie der Gestalt und Bewegungserlebnisse. III. Zur Grundlegung der Wahrnehmungspsychologie. Eine Auseinandersetzung mit V. Benussi," Z. f. Psychol. 73 (1915): 11–90. See also Fabio Metelli, "La polemica Benussi-Koffka," in *Vittorio Benussi nelle storia della psicologia italiana*, ed. G. Mucciarelli (Bologna, 1988), pp. 119–132.
28. See the excellent monograph from Mauro Antonelli, *Die experimentelle Analyse des Bewußtseins bei Vittorio Benussi* (Amsterdam, 1994), published in the series "Studien zur österreichischen Philosophie," ed. Rudolf Haller, vol. 21.
29. P. M. Simons, ed., *Essays on Meinong* (Munich: Philosophia, 1994).
30. In Acta Psychologica 59 (1985): 23–33.
31. V. Benussi, "Stroboskopische Scheinbewegungen und geometrisch-optische Gestalttäuschungen," Arch. f. ges. Psychol. 24 (1912): 31–62; "Kinematohaptische Scheinbewegungen und Auffassungsumformung," in Report on the VI Congress of experim. Psychol. in Göttingen, ed. F. Schumann (Leipzig: Barth, 1914), pp. 31–35. "Über Scheinbewegungskombinationen (Lissajoussche S-, M- u. E-Scheinbewegungsfiguren)," Arch. f. Psychol. 37 (1918): 233–282; see also J. Wittmann, *Über das Sehen von Scheinbewegungen und Scheinkörpern* (Leipzig, 1921); R. Renvall, "Zur Theorie des stereokinetischen Phänomenons," Ann. Univ. Aboensis Abt. B (1929). G. Tampieri, "Sulle condizioni del movimento stereocinetico," in Kanizsa Vicario, "Ricerche sperimentale sulla percezione," (Trieste, 1968).
32. C. L. Musatti, "Sui fenomeni strecientici," Archivo Italiano di Psicologia 3 (1924); "Sulla plasticita reale stereciinetica e cinematografica," Arch. Ital. Psicol 7 (1929).
33. W. Metzger, "Tiefenerscheinungen in optischen Bewegungsfeldern," Psychol. Forschung 20 (1934): 195–260. H. Wallach and D. W. O'Conell, "The Kinetic Depth Effect," Journal of Exp. Psychol. 45 (1953): 205–217; H. Wallach, "Über visuell wahrgenommene Bewegungsrichtung," Psychol. Forsch. 20 (1935).

34. Karl Bühler, *Die Gestaltwahrnehmungen. Experimentelle Untersuchungen zur psychologischen und äesthetischen Analyse der Raum- und Zeitanschauung* (Stuttgart, 1913); "Die Erscheinungsweise der Farben," *Handbuch der Psychologie: Die Struktur der Wahrnehmungen*, vol. 1 (Jena, 1922).

35. K. Bühler, *Die Krise der Psychologie* (1927); *Ausdruckspsychologie. Das System an der Geschichte aufgezeigt* (Jena, 1934); *Theorie der Sprache. Die Darstellfunktion der Sprache* (Jena: Fischer, 1924); K. Buhler, *The Representational Function of Language* (Amsterdam: John Benjamins, 1990); A. Eschenbach, ed., *Karl Buhler's Theory of Language* (Amsterdam: John Benjamins, 1988); R. E. Innis, ed., Karl Bühler: *Semiotic Foundations of Language* (New York: Plenum, 1981).

36. K. Bühler, *Das Gestaltprinzip im Leben der Menschen und Tiere* (Bern: Huber, 1960).

37. Fritz Heider, *Thing and Medium: On Perception, Event, Structure, and Psychological Environment: Selected Papers* (Guildford, CT: International Universities Press, 1959); *The Psychology of Interpersonal Relations* (New York: John Wiley & Sons, 1958); *The Life of a Psychoanalyst* (Lawrence: University of Kansas Press, 1983).

Meeting in Rostock, 1928. From left to right: Fritz Heider, Kurt Lewin, David Katz, Heinz Werner, Rose Katz, Wolfgang Köhler, A.E. Michotte, E. Rubin, Max Weimar

International congress for psychology, Bonn, 1960. From left to right: Ludwig Kardos, Philipp Lersch, Fritz Heider, Richard Meili

Fritz Heider

A further link between the gestalt schools in Graz and Berlin is Fritz Heider. He was born in 1896 in Vienna but after half a year moved with his family to Graz, where he completed secondary school in 1914. He studied psychology with Karl and Charlotte Bühler in Munich in 1918, and graduated with a Ph.D. in 1920 under Alexius Meinong and Hugo Spitzer in Graz. There, he also came into contact with Benussi, who awakened his interest in gestalt psychological problems, so that from 1921 to 1927 (except for short breaks in Florence and Naples) he was at the psychological institute in Berlin studying with Wertheimer, Köhler, and Lewin. In 1926 he published his most well-known article, "Ding und Medium," which appeared in English in 1959 as "Thing and Medium."[37] In this article, the difference between distal and proximate stimulation led to a perception-theoretical definition of mediation whereby mediation was understood as the negotiation of information on things to our sense organs.

It is insufficient to say that the distal object causes the proximate stimulation as the environmental conditions that make the perception of the distant object possible must also be taken into consideration. Things (or objects), therefore, are only perceived through mediation. Such concepts were later developed by information theorists and cybernetics experts. Heider developed these aspects further in his *Attitudes and Cognitive Organization* (1946). In 1927 he went to William Stein in Hamburg and in 1930 to the U.S., where he first worked as an assistant professor with Koffka at the Clarke School of Smith College in Northampton, Massachusetts, and later, in 1947, at the University of Kansas. In 1958, he published his standard work, *Psychology of Interpersonal Relations*, which investigates the influence of perception and cognition through subjective factors. In 1959, his autobiography, *The Life of a Psychologist*, was published.

V. Experimental Perception Psychology

Else Frenkel-Brunswik

Else Frenkel-Brunswik

Born in Lemberg, Frenkel-Brunswik (1908–1958) moved to Vienna in 1914. In 1926 she began her studies at the University of Vienna (mathematics, physics, psychology). In 1927 she studied with Karl Bühler, with whom she later wrote her dissertation in 1930. Until 1938 she worked at the psychological institute of the University of Vienna as Charlotte Bühler's assistant. In 1938 she emigrated and became a research associate at UC Berkeley. She became well known (together with Theodor W. Adorno, D. A. Levinson, and R. N. Sanford) in 1950 through the publication of *The Authoritarian Personality*,[40] which she had been working on since 1944. In 1954 she became a fellow at Stanford University; in 1956 she had a Fulbright scholarship in Oslo. She died in Berkeley, probably through suicide.

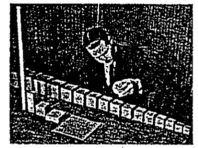
Egon Brunswik

Karl Bühler's assistant, Egon Brunswick (1903–1955), who also remained close to the positivism of the Vienna Circle and its successor in America, Unity of Science, developed the psychology of perception in Vienna.[38] Egon Brunswik's work, *Experimentelle Psychologie in Demonstrationen* [Experimental psychology in demonstrations), published in Vienna in 1935, contained the results from experiments that Brunswik conducted at the university alongside the general lectures on psychology from Karl Bühler. This book is a methodological masterpiece. He introduced probabilistic functionalism into psychology as he believed the pro-babilistic methodology of physics

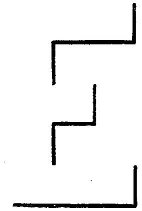
also suitable for psychology. Brunswik was born in Budapest in 1903 and finished his secondary education in Vienna in 1921. In 1923, after two years studying engineering , he began to study psychology, philosophy, mathematics, and physics at the University of Vienna. In 1927 he completed his dissertation; in 1929 he became an assistant to Bühler; in 1934 he completed his Habilitation; and in 1935–1936 he held a Rockefeller fellowship at the psychological laboratory of the University of California at Berkeley under the direction of Edward Chase Tolman. He emigrated to the U.S. in 1937, and from 1937 was an assistant professor at Berkeley. The renowned neo-behaviorist Tolman (1886–1959), who brought cognitive concepts into learning theories ("cognitive maps"), was in Vienna in 1934 and worked together with Brunswik at Karl Bühler's institute.[39] In 1938 Brunswik married Else Frenkel, whom he had known since 1928. In 1955 he committed suicide in Stanford.

After his emigration Egon Brunswik became an important methodologist and science theoretician of psychology. In his final work in 1952 he referred to the newer results of cybernetic and mathematical communications theory (from Warren McCulloch to Gregory Bateson up to Claude Shannon).[41] His colleagues, Bühler's students, also provided important contributions to the study of color, depth perception, volume estimation, and the study of perception in general.[42] Friedrich Kainz from the University of Vienna wrote an interesting art historical work in 1927 on gestalt regulation and ornament development.[43]

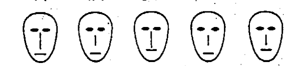
Egon Brunswik



Comparing the volume of different-shaped bodies, taken from E. Brunswik, *Experimentelle Psychologie in Demonstrationen*, Vienna: Springer, 1935, p. 101.



Supplementing lines. Instead of three black, interrupted lines, experience leads us to easily discern a white E. In this case, exactly half of the entire outline has been supplemented (after Brunswik).



	T7	W7	D7	W4	G7
Sad	1st				
Old	1st				
Bad	6th	5th			
Unlikeable	3rd	1st	7th		
Ugly	6th	2nd	1st		
Unintelligent		3rd	7th	1st	
Unenergetic					1st

Schematic heads after Brunswik and Reiter, 1937

In the 1930s, the Austrian art historian **Ernst H. Gombrich** began his research into the problematic of perception in art. With his friend and teacher, the psychoanalytically oriented art historian Ernst Kris (1900–1957) — to whom, in addition to Emanuel Loewy and Julius von Schlosser, the book *Art and Illusion*[44] is dedicated — he conducted several experiments on the understanding of expressions of pictures for a study on the history of caricature.[45] For this, also Brunswik volunteered as a test subject. He had conducted perception experiments in 1936 together with L. Reiter using schematic heads. These experiments had confirmed the sensitivity of our physiognomic perception to minor changes. He defined the face as a field of face variables, as a thick bundle of countless variables. Tiny shifts within these facial variables (such as eye distance, nose length, distance of mouth to nose, etc.) radically change the facial expression.[46] Gombrich's world-renowned work on art and optical illusion is the product of a milieu, which Gombrich mentions in the foreword to his book.[47] In it, he points out the concurrence of his views with those of Brunswik as expressed in the well known collaborative work of Tolman and Brunswik, *The Organism and the Causal Texture of Environment* (1935), which emphasizes the hypothetical character of all perception processes.[39] Gombrich is therefore the convergence and culmination point of Austrian Gestalt psychology and art history methodology.

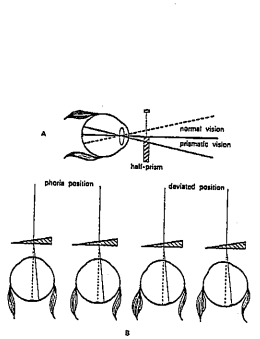
Through the forced migration of these academics in the 1930s, this style of thought spread abroad, but in Austria itself broke off.

VI. Vision Machines: Perception of Illusory Bodies and Illusory Movements

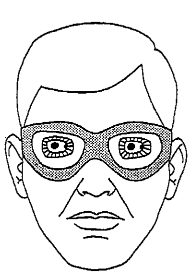
By the end of the nineteenth century Helmholtz had worked with prismatic distortion and George Stratton (1865–1957) had used inversion lenses on one eye for eight days. Theodor Erismann, head of the Psychological Institute at the University of Innsbruck, updated and carried these experiments further. Beginning in 1928, through his experiments with inversion glasses and mirrors, in part in collaboration with Hubert Rohracher, he recognized the inversion of the retinal image as an illusion problem.

Ivo Kohler (1915–1985) first studied theology, then philosophy, and finally psychology. He was Erismann's assistant at the Psychological Institute of the University of Innsbruck for eighteen years before he became its head. His experiments, carried out at the same university in 1947, have shown that in the field of vision the body's senses alone determine what is above or below, what is left or right. Kohler experimented with

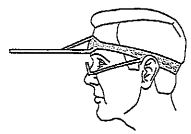
38. K. R. Hammond, *The Psychology of Egon Brunswik* (New York, 1966); K. R. Hammond, *The Essential Brunswik: Beginnings, Explications, Applications* (Oxford: Oxford University Press, 2001); E. Brunswik, "Prinzipienfragen der Gestalttheorie," in *Beiträge zur Problemgeschichte der Psychologie, Festschrift for Karl Bühler's 50th Birthday* (Jena, 1929); E. Brunswik et al., eds. "Die Zugänglichkeit von Gegenständen für die Wahrnehmung und deren quantitative Bestimmung in Untersuchungen über Wahrnehmungsgegenstände," Arch. f. die ges. Psychologie 88 (1932): 377–418; *Psychologie vom Gegenstand her* (Leipzig/Vienna, 1934); *Experimentelle Psychologie in Demonstrationen* (Vienna, 1935); "Die Eingliederung der Psychologie in die exakten Wissenschaften," Einheitswissenschaft 6 (1938): 17–34. "The Conceptual Focus of Some Psychological Systems," Journal of Unified Science (Erkenntnis) 8 (1939); "Points of View," in *Encyclopedia of Psychology*, ed. P. L. Harriman (New York, 1946); *Systematic and Representative Design of Psychological Experiments, With Results in Physical and Social Perception* (Berkeley, 1947).



The optical arrangement of Kohler's "half prisms":
A. Side view of the upper and lower sections of the half prism.
B. If the upper section of the image falls on the fovea, the lower section is displaced; if the lower section of the image falls on the fovea, the upper section is displaced.



Kohler's prism glasses, which allows right-left inversion of vision.



Reverse mirror; Kohler's mirror headdress, which produces top-bottom inversion of vision.

technological twists, distortions, and inversions of the visual field: he and his test subjects wore special glasses, prisms, and mirrors.[48] Erismann helped Kohler build the optical instruments with which the visionary field was turned from left to right and upside-down. They also built devices that allowed the user to only look up or over his shoulder while at the same time navigating his surroundings.

We know that the eye receives images of the world in reverse and that the brain compensates for this inversion. The brain "repairs" the false, inverted pictures that the eye brings to us. We see the world of objects right side up and upright, although the eye does not. The brain adjusts the received images with the help of mental mechanisms to fit the experience of other bodily senses. In these experiments, the rotations and shifts of the field of vision were again distorted through the inversion glasses, so subjects moved in an inverted world until they became used to it and once again saw "correctly." These prism glasses were worn between six and ten days, or even as long as twenty-four to thirty-seven days, during which subjects were artificially returned back to an early stage of the development of visual powers. After putting on the glasses the perceived world, at first upside-down, righted itself in four to nine days, depending on the subject. Eventually it worked so perfectly that subjects could ski or ride a bike in city traffic unimpeded by the glasses. After taking off the glasses, the world, as expected, looked upside-down once again but returned to normal much more rapidly.

Through this, the process of perceptual development could be observed, as it was assumed that the mechanisms that led to the adjustment to a disorienting situation were the same as those that define normal perceptual development. During the adjustment time to the inversion, objects were seen again "correctly," but not letters — for example, writing on the sides of buildings — which appeared as in a mirror. Several subjects broke off the tests because they became dizzy and depressed. At first the subjects needed assistants to help them navigate daily life. Kohler's experiments on adjusting to inversion glasses, published at the beginning of the 1950s, showed that internal models of the environment can be modified through experience. The organization of data is changeable. It does not appear necessary to theoretically presume a constructive organizational process between stimulation and perception, as gestalt theory does, but rather, perception processes could be explained through mechanisms of adaptation, conditioned reflexes and learning.[49] Beyond that, the experiments showed that no insurmountable barriers exist between the diverse sense modalities, for example, perception and movement; on the contrary, they can be synchronized. There is an interesting film by Erismann and Kohler that shows these experiments.[50] Incidentally, Kohler, together with Erika Kohler and Marina Grover, translated the classic work of James J. Gibson, *The Senses Considered as Perceptual Systems* (1966), into German [as Die Sinne und der Prozess der Wahrnehmung (Bern, 1973)].

Also in the 1950s, Theo Hermann analyzed and summarized in a methodological treatise the radical change from the elementary and association psychology of the nineteenth century to the holistic and gestalt psychology of the twentieth century.[51] He discusses the gestalt principles of biology, the gestalt perception of animals, the holistic moments in purposeful behavior, and the value of meaning in social relations of animals as investigated by Lorenz, Tinbergen, and Uexküll.[52] The economist Friedrich von Hayek also made an attempt as a perception psychologist when he published *The Sensory Order* (Chicago, 1952).

Kurt R. Fischer, *Wahrnehmung und Gegenstandswelt. Zum Lebenswerk von Egon Brunswik* (Vienna/New York: Springer, 1997).

39. E. C. Tolman and E. Brunswik, "The Organism and the Causal Texture of Environment," Psychol. Rev. 42 (1935). E. C. Tolman, *Purposive Behavior in Animals and Men* (Berkeley, 1949).
E. Brunswik, "Representative Design and Probabilistic Theory in a Functional Psychology," in Psychol. Rev. 62 (1955); *Perception and the Representative Design of Psychological Experiments* (Berkeley and Los Angeles; University of California Press, 1956).

40. T. Adorno, E. Frenkel-Brunswik, D. A. Levinson, and R. N. Sanford, *The Authoritarian Personality* (New York: W.W. Norton, 1993); J. Grant, ed. *Else Frenkel-Brunswik: Selected Papers* (Springfield, IL: Charles C. Thomas, 1974).

41. E. Brunswik, *The Conceptual Framework of Psychology* (Chicago, 1952).

42. E. Haschek, *Quantitative Beziehungen in der Farbenlehre* (Vienna, 1927). L. Kardos, "Die Konstanz phänomenaler Dingmomente. Problemgeschichtliche Darstellung," in *Bühler-Festschrift* (Jena, 1929); "Ding und Schatten," additional vol. 23, Z. f. Psychol. (Leipzig, 1934).

43. Friedrich Kainz, "Gestaltgesetzlichkeit und Ornamententwicklung," Z. f. angew. Psychol. 28 (1927): 267–327.

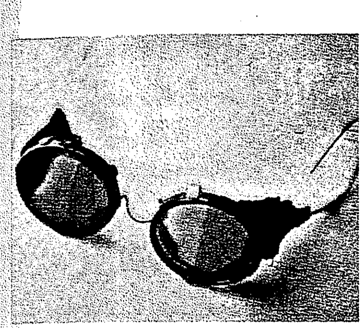
44. E. H. Gombrich, *Art and Illusion*, rev. ed. (Princeton, NJ: Princeton University Press, 1961).

45. E. H. Gombrich and E. Kris, "The Principles of Caricature," 1938. Second edition in E. Kris, *Psychoanalytic Exploration in Art* (New York, 1952). See also E. H. Gombrich and E. Kris, *Caricature* (Harmondsworth: Penguin, 1940).

46. E. Brunswik and L. Reiter, "Eindruckscharaktere schematisierter Gesichter," Z. f. Psychol. 142 (1937): 67–134; E. Brunswik, *Perception and the Representative Design of Psychological Experiments*, 2nd ed. (Berkeley: University of California Press, 1956), p. 115.

47. Gombrich, *Art and Illusion*, see note 44.

48. T. Erismann, "Wesen und Entstehung der Scheinbewegung," Arch. f. ges. Psychol. 100 (1938); *Allgemeine Psychologie III* (Göttingen, 1962). Ivo Kohler, "Über Aufbau und Wandlungen

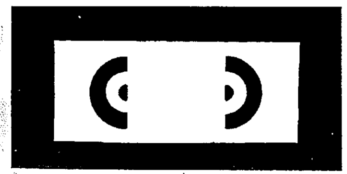


Glasses with "colored half-discs," after I. Kohler. On both sides, the left half is blue; the right half, yellow.

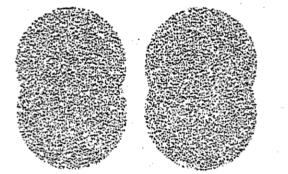
Brimmed cap with mirror, which turns everything upside-down (after I. Kohler)

Gaetano Kanizsa

From Trieste and of Hungarian origin, Gaetano Kanisza (1913–1992) continued the scientific investigation of the subjective – that is, illusory contours of apparent edges, borders, and contours that are not real but are perceived by our sense of sight. Schumann first determined the existence of illusory contours in 1900.[53] Kanizsa put forward as explanation the hypothesis of completion or the inclination of the sense of sight to complete incomplete elements and open figures in the visual field. At the end of his well-known article from 1976,54 he refers to a further example for the perception of contours in insufficient levels of brightness, namely to the scattered dot pattern developed by Béla Julesz in 1960,55 the so-called random-dot stereogram.



The first published "pseudo contour," 1900 (after F. Schumann)



B.N. Kompaneysky, *Random-dot-stereogram*, 1939

Béla Julesz

A random-dot stereogram (RDS) shows three-dimensional forms and contours under a stereoscope. The RDS produces an illusory depth perception that creates three-dimensional pictures hidden in a field of dots. This stereogram from randomly distributed dots has no depth if looked at with the naked eye but under a stereoscope, three-dimensional forms and contours are visible. Benussi had already pointed out the stereokinetic effect, the connection between movement and depth perception, in 1912. Stanley Coren, in 1972, formulated the hypothesis that the perception mechanism that brings forth subjective contours and forms is the same as the one that makes three-dimensional depth perception possible.[56] The work from Julesz on spatial perception go back to that of Charles Wheatstone[57] (1838) and Boris Kompaneysky, who, in 1939, published two fields of randomly distributed dots[58] in which faces of Venus were hidden. Julesz needed computers for the production of his clever stereograms of imperfectly corresponding dots. His student and assistant, Christopher W. Tyler, produced the first automatic stereogram in 1979 with an Apple II computer and the BASIC programming language. Auto-stereograms are computer-generated stereograms that can be seen without gadgets, in which only one picture instead of two are necessary for the production of stereo vision.[59] The Japanese graphics designer Masayuki Ito, in the wake of Julesz, developed a single-image stereogram in 1970. These single-image stereograms became more and more popular in the 1990s as "magic images."

Alfons Schilling, originally from Switzerland, moved to Vienna at the end of the 1950s, and was associated with the initial phases of Viennese Actionism as an "informal" painter. From 1962–1986 he lived

der Wahrnehmungswelt insbesondere über bedingte Empfindungen," Gest. Akad. Wiss. Phil. Hist. Klasse. Sitzungsber 1 (1951): 22; "Warum stehen wir aufrecht?," Die Pyramide 2 (1951): 30–33; "Umgewöhnung im Wahrnehmungsbereich," Die Pyramide 3 (1953); "Experiments with Prolonged Optical Distortion," Acta Psychol. 2 (1955): 176ff; "Experiments with Goggles," Scientific American 206 (May 1962): 65–72; "Anpassung der Wahrnehmung an fehlerhafte Gläser," 14, special printing of the Wiss.-Vereinigung der Augenoptiker (Mainz, 1964); "Die Zusammenarbeit der Sinne und das allgemeine Adaptationsproblem," in *Handbuch der Psychol., vol. 1*, 1st half (Göttingen, 1966).

49. H. Werner and S. Wapner, "The Innsbruck Studies on Distorted Visual Fields in Relation to an Organismic Theory of Perception," Psychol. Rev. 62 (1955): 130–138. L. Spillman and B. Wooten, eds., *Sensory Experience, Adaptation and Reception, Book in honor of Professor Ivo Kohler* (Hillsdale, NJ: Erlbaum, 1984).

50. T. Erismann andI. Kohler, "Upright Vision through Inverting Spectacles," Psychol. Cinema Reg. No. Penn. State College (1953): 2070.

51. Theo Herrmann, "Problem und Begriff der Ganzheit in der Psychologie" Österreich Akad. d. Wiss. Phil. hist. Kl. Sitzb. 3. Abh. (1957): 231; "Der Methodendualismus in der Psychologie," Jahrbuch f. Psychol. u. Psychother. (1958).

52. Konrad Lorenz, "Ganzheit und Teil in der tierischen und menschlichen Gemeinschaft," Studium Generale 3 (1950); "Gestaltwahrnehmungen als Quelle wissenschaftlicher Erkenntnis," Z. f. exp. und ang. Psych. 6 (1959); *Studies in Animal and Human Behavior* (Cambridge: Harvard University Press, 1974). N. Tinberger, *The Study of Instinct* (Oxford: Oxford University Press, 1951). J. von Uexküll, *Streifzüge durch die Umwelt von Tieren und Menschen* (Hamburg, 1955).

53. F. Schumann, "Beiträge zur Analyse der Gesichtswahrnehmungen," Z. für Psychol. I, 23 (1900): 1–32, II, 24 (1900): 1–33, III, 30 (1902): 241–291, IV, 36 (1904): 161–185.

Leopold Szondi, *Experimental Pyschology Test*, 1947

Kurt Kren, *2/60 48 Köpfe aus dem Szondi-Test (2/60 48 Heads, from the Szondi Test)*

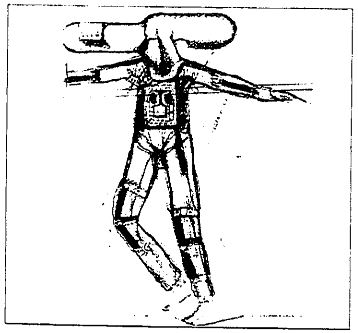
in New York and experimented quite early with different lenses, self-constructed cameras, and instruments to create 3-D stereo systems – all with the goal of artificially expanding the field of perception. He occasionally worked as a cameraman for the video artist Woody Vasulka. Unlike to Julesz, he decided to develop his own method for 3-D stereogram by painting directly on the canvas without the help of a computer. In 1973 he drew pictures for the left and right eye that consisted of dots and spots to produce stereoscopic effects of illusory depth perception. In 1974 he produced a handmade single-image stereogram (from C. W. Tyler). He also went on to produce vision machines with prisms with which color and black and white pictures on the wall created an amazing appearance of depth in color and black and white (figures, geometric shapes) and stereokinetic effects.

This meeting between the Hungarian Julesz and the Austrian Schilling also had an amazing counterpart from ten years earlier: the Austrian film maker Kurt Kren used optical test material from 1947 from the Hungarian experimental psychologist **Lipót (Leopold) Szondi**[60] to create a moving film from still shots, the famous *Szondi-Test* (1964). With this film, Kren completed the transformation from cinematography as the language of movement to opseography as the language of vision, and with that transformed the art of movement into the art of perception. A perception test, an experimental perception situation, became a work of art.

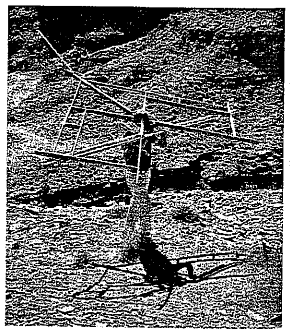
At the beginning of the 1940s, **Friedrich Kiesler** drafted his *Vision Machine*. In 1927 he had also sketched a telematically networked telemuseum in which pictures could be seen in other museums. Kiesler also propagated machine-supported perception similar to that which Schilling later took up.

My drawing shows the two ways in which painting and sculpture will contribute to future interior design: 1. Light-sensitive plates will serve as receiving screens for sent pictures. 2. Original masterpieces will be kept in built-in "shrines" sunk into the walls and will be only occasionally revealed. The use of pictures as permanent wall decorations will cease.[61]
The Telemuseum
Just as operas are transmitted by wireless, this will also happen with picture galleries. From the Louvre, the Prado to you, from everywhere to you. You will enjoy the privilege of choosing any picture which fits your mood or the needs of a certain situation. With the help of the dial on your teleset you will be a partner in the greatest treasures of the world.[62]

This area of research has been historically established, from Kiesler right up to the Innsbruck studies on distorted fields of vision – that is, changing perception using analog devices (prisms, inversion glasses, mirrors) and digital machines, and exploiting the laws of perception to create two- and three-dimensional illusions. The linking of experiments with illusory movement and illusory forms on the one hand and inversion glasses and vision machines on the other led directly to the ideas of cyberspace. Oswald Wiener's essay on the cybernetic *Bioadapter*,[63] a first explicit model of the data-suit, Walter Pichler's TV-helmets and radio-vests, and Peter Weibel's imaginary spaces of perspective-oriented, closed-circuit video installations, are clear precursors to cyberspace.



Walter Pichler, *Man on a Leash with TV Helmet, Radio Vest, Standard Suit, and Fingers Spread*, 1967



Alfons Schilling with his vision machine, *Excavated Bird*, 1986

54. G. Kanizsa, "Subjective Contours," Scientific American 234 (1976): 48–52; "Margini quasi - percettivi in campi con stimulazione omogenca," Rivista di Psicol. 49 (1955); "Randform und Erscheinungsweise von Oberflächen," Psychol. Beiträge 5 (1960); "Amodale Ergänzung und Erwartungsfehler des Gestaltpsychologen," Psychol. Forsch. 33 (1970); *Organization in Vision: Essays on Gestalt Perception* (New York: Prager, 1979).
55. B. Julesz, "Binocular depth perception of computer-generated patterns," Bell Technical Journal 39 (1960); "Binocular depth perception without familiarity cues," Science 145 (1964); *Foundations of Cyclopean Perception* (Chicago, 1971).
56. S. Coren, "Subjective Contours and Apparent Depth," Psych. Review 79 (1972): 359–367.
57. Charles Wheatstone, "Contributions to the Physiology of Vision. 1. On Some Remarkable, and Hitherto Unobserved Phenomena of Binocular Vision," in *Philosophical Transactions* (London: Royal Society of London, 1838). David Brewster, *The Stereoscope. Its History, Theory and Construction* (London, 1856).

VII. Neuropsychology and Cognitive Science

In 1894, in the spiritual tradition of Mach and psychophysical parallelism, the Viennese physiologist **Sigmund Exner** delivered decisive models of thought and vision in that he led psychic manifestations back to the framework and networking of the nerve center, thereby anticipating the later analyses of the perception process done by Donald Hebb in *The Organization of Behavior* (1948) and thus anticipated the cognitive neurosciences.[64]

The first explicit representation of a neural network is found in the text *Untersuchungen zu einer physiologischen Erklärung der psychischen Erscheinungen* [Investigations on a physiological explanation of psychic manifestations] (1894) by Exner (pp. 3 and 225):

I view it as my duty to lead the most important psychic manifestations back to the levels of excited states of the nerves and nerve centers, according to which everything that appears as diverse in our consciousness can be traced back to quantitative relationships and the diversity of the central connections of otherwise very similar nerves and centers.

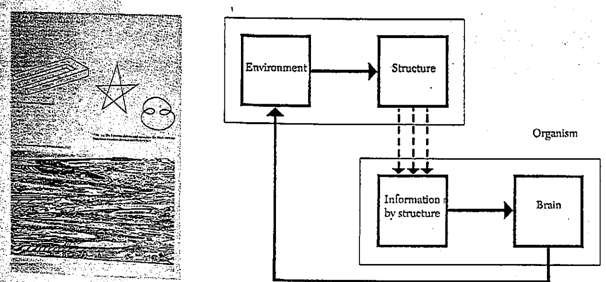
The activation of certain nerve tracts and neuron populations forms the sensations.

All manifestations of the qualities and quantities of conscious sensations, perceptions, and ideas can be traced back to quantitatively variable portions of the totals of these tracts. Two sensations are the same for consciousness when the same cortical tracts are stimulated to the same degree. Two sensations are similar when at least a part of the stimulated cortical tracts is identical in both cases.

Olaf Breidbach wrote in *Die Materialisierung des Ichs. Zur Geschichte der Hirnforschung im 19. und 20. Jahrhundert* [The materialization of the self: On the history of brain research in the nineteenth and twentieth centuries] (1997, pp. 28–29):

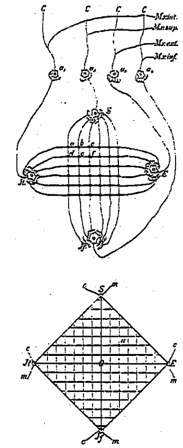
In connection with this, Exner sketched in detail the internal representation of spatial coordinates of visual perception. Starting from a detailed description of this perception situation, he formalized his idea of the overlapping of stimulation phases in a topologically strictly defined neuron structure and thereby succeeded in formulating the concept of a neuronal network.

In this complexly bound architecture of neuronal contacts, there are also self-references and reflexive systems and the phenomena of "modulation" and "pathing," whereby cascades of associational processes arise as functions of interneuronal contacts.



Heinz von Foerster, "Vom Reiz zum Symbol," *Zeichen, Bild, Symbol, sehen + werten*, György Kepes, ed., Brussels: La Connaissance, 1972, pp. 55, 57

The shift from gestalt theory through perception psychology to cognitive psychology — thus the shift in research interests from the physiological and psychological factors to the cognitive, from factors achieved by the brain in perception — cannot be more clearly shown than it was by **Heinz von Foerster**. After the publication of a quantum mechanics model of thought, he moved to the U.S. in 1948, where he became a cofounder of cybernetics and editor of the protocols of the Macy Foundation, *Cybernetics: Circular Causal and Feedback Mechanisms* (5 volumes, 1949–1953). In 1958, he founded the Biological Computer Laboratory



Representation of a neural network (Exner, 1894, p. 193)

58. B. N. Kompaneysky, "Depth sensations. Analysis of the theory of simulation by non exactly corresponding points," Bulletin of Ophthalmology (USSR) 14 (1939): 90–105 (in Russian).
59. C. W. Tyler, "Sensory processing of binocular disparity," in *Vergence Eye Movements. Basic and Clinical Aspects*, ed. L. M. Schor and K. J. Ciuffreda (London, 1983).
60. L. Szondi, *Lehrbuch der experimentellen Triebdiagnostik*, 3 vols. (Bern: Huber, 1972); *Szondi Test: In Diagnosis, Prognosis, and Treatment* (Philadelphia: Lippincott, 1959).
61. F. Kiesler, *Contemporary Art Applied to the Store and its Display* (New York, 1930), p. 110.
62. F. Kiesler, *Contemporary Art Applied to the Store and its Display*, op.cit., p. 121.
63. O. Wiener, *die verbesserung von mitteleuropa. roman* (Hamburg, 1969).
64. Sigmund Exner, *Untersuchungen über Localization der Functionen in der Grosshirnrinde des Menschen* (Vienna, 1881); *Untersuchungen zu einer physiologischen Erklärung der psychischen Erscheinungen* (Leipzig/Vienna, 1894); D. Hebb, *The Organization of Behavior: A Neuropsychological Theory* (New York: John Wiley & Sons, 1949).

65. Lynn Segal, *The Dream of Reality: Heinz von Foerster's Constructivism* (Vienna/New York: Springer, 2001).
66. H. v. Foerster, "Kybernetik einer Erkenntnistheorie," in *Kybernetik und Bionik* (Oldenburg, 1974); "Circuitry of Clues to Platonic Ideation," in *Aspects of the Theory of Artificial Intelligence* (New York: Plenum, 1960); *Understanding Systems: Conversations in Epistemology and Ethics* (New York: Plenum, 2002); *Understanding Understanding: Essays on Cybernetics and Cognition* (New York: Springer, 2002).
67. E. v. Glasersfeld and J. Richards, "The Control of Perception and the Construction of Reality," Dialectica 33, no.1 (1979): 37–38; E. v. Glaserfeld, *Radical Constructivism: A Way of Learning* (London: Routledge/Falmer, 1996); P. W. Thompson, *Radical Constructivism in Action: Building on the Pioneering Works of Ernst von Glasersfeld* (London: Routledge/Falmer, 2000); P. Watzlawick, *Invented Reality. How Do We Know What We Believe We Know?* (New York: W.W. Norton, 1984); *How Real Is Real? Confusion, Disinformation, Communication* (New York: Random House, 1977).
68. L. v. Bertalanffy, *General System Theory: Foundations, Development, Applications* (New York: George Braziller, 1976); *Robots, Men, and Minds: Psychology in the Modern World* (New York: George Braziller, 1969).
69. M.A. Arbib, P. Érdi, and J. Szentágothai, *Neural Organization: Structure, Function, and Dynamics* (Cambridge, MA: MIT Press, 1997).
70. G. Guttman, *Einführung in die Neuropsychologie* (Bern: Huber, 1972).
71. P. Baumgartner and S. Payr, *Speaking Minds. Interview with Twenty Eminent Cognitive Scientists* (Princeton, NJ: Princeton University Press, 1995).
72. O. Wiener, *Schriften zur Erkenntnistheorie. 1965-95* (Vienna/New York: Springer, 1996).

at Illinois State University. As a continuation of his psychophysical program, he published a series of writings about the construction of realities, self-organizing systems, observed systems, and cognitive processes in perception. In this series he developed an operative theory of knowledge put together from elements of physiology, information theory, perception theory, technology, and epistemology. This system he called Constructivism,[65] and he defined it as "an epistemology of the observed, signifying that the observer and observed are inseparably connected" (Von Foerster). Von Foerster transferred the cybernetic theory of cyclical causal chains to the epistemology: "knowledge or the process of the expansion of knowledge as a recursive calculation."[66]

In the essay "From Stimulus to Symbol: The Economy of Biological Computation," which appeared in *Sign, Image, Symbol* (1966) in the series *Vision and Value* (George Braziller, New York 1966), edited by György Kepes, Von Foerster explained the function of perception in cognitive processes by analyzing, for example, precisely those neuronal procedures that change signals into visual meanings, thus the course of information between an organism and its surroundings.

Ernst von Glasersfeld, an Austrian born in Munich in 1917, who later went to the U.S. in 1966 and became professor of cognitive psychology in 1970, is acknowledged as the second founder of "radical constructivism," according to which cognition is the creation or invention of reality.

The title of a 1979 essay by John Richards and Ernst von Glasersfeld, "The Control of Perception and the Construction of Reality," shows pointedly that in the theory of Constructivism, there is a great amount of perception in the construction of reality because as Von Foerster states, "an observing organism is itself part, partner, and participant of the observed world." Therefore, the whole appearance and illusion potential of perception is brought into reality. It is thus that reality is separated into real or fictive elements, as expressed in the title of two books by the third Austrian founder of Constructivism, **Paul Watzlawick**: *How Real Is Real?* (1976) and *Invented Reality* (1981).[67]

The Austrian founder of biological systems theory, **Ludwig von Bertalanffy**, worked at the University of Vienna from 1934 to 1948; he was de-Nazified and became active in Ottawa, Canada from 1949 and from 1955 in the U.S. (from 1969 as professor at the State University of New York in Buffalo). He also wrote (in the same volume of the Kepes series) about symbol systems, *The Tree of Knowledge*. In one of his later works, *Robots, Men and Minds* (1967), Bertalanffy also expanded psychology with cybernetic and thermodynamic concepts (from N. Wiener to I. Prigogine).[68]

Perception physiology, which Mach had furthered through his work on the ear (the discovery of the balance functions in the inner ear), was carried further by **György von Békésy**, who developed Mach's discovery of the inhibiting sense phenomenon as demonstrated by the example of the Mach bands. Békésy expanded the function of the Mach bands to other sensory areas and in 1928 discovered inhibiting effects in the inner ear for which he received the Nobel Prize in 1961. Over the years he applied his inhibition theory to all of the senses. In 1961 he published the book *Experiments in Hearing* and in 1967, *Sensory Inhibition*. Another Hungarian, **János Szentágothai**, made significant contributions to experimental brain research and with that, contributed to the definition of the brain as a neuronal machine.[69]

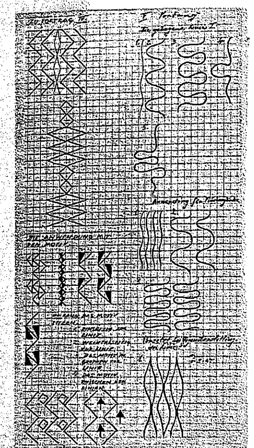
In Austria, **Giselherr Guttman** drafted a neuropsychology of perception,[70] an area of research which flourished abroad as cognitive science. Two Austrians, Peter Baumgartner and Sabine Payr, are responsible for keeping track of the success of this Austrian export in the U.S. and for remembering the Austrian forerunners to cognition theory.[71]

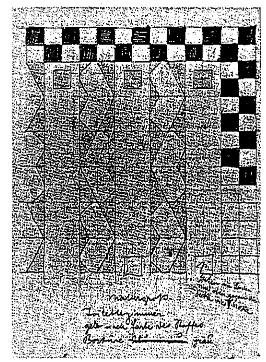
The previously mentioned author, **Oswald Wiener**, also delivered contributions to cognitive research over the past thirty years, in that he laid out a theory of the creation and function of imaginary images.[72]

Perception and motion are distinguished as problem areas in the art of the twentieth century. Hungary and Austria have offered outstanding contributions to these areas. The Hungarian contributions by the golden foursome: Moholy-Nagy, Kepes, Vasarely, and Schöffer are well known throughout the world. The contribution of Austria has remained relatively unknown (apart from Kiesler, although it is not well known that he is actually an Austrian since he lived in New York from 1927 to 1965).

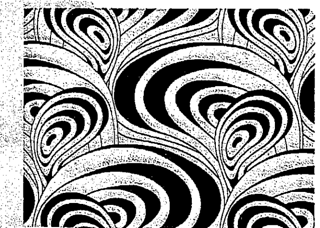
The following is a step-by-step attempt to present, for the first time, a coherent picture of the development of perceptual and motion art in Austria and Hungary.

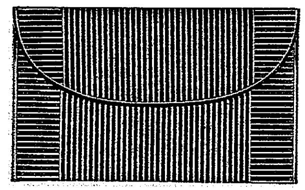
The Abstract Ornament and the Quadratic World of the Wiener Werkstätte around 1900

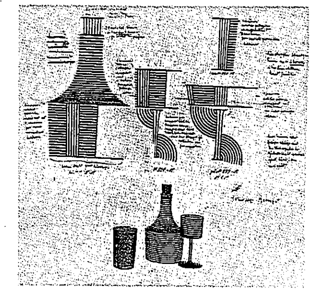

Formenlehre IV (teaching of forms), c. 1900


Josef Hoffmann
Sketch for a curtain


Felicien Freiherr von Myrbach among his students, 1902

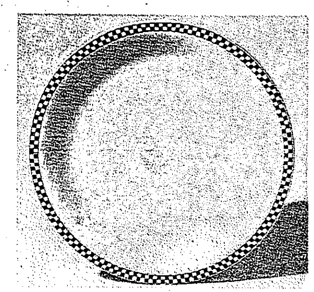

Koloman Moser, *Foehn*, 1899


Josef Hoffmann, *Purse*, c. 1910


Josef Hoffmann
Service of glasses with carafe
(design and product)


Adolf Hölzel
Abstract Ornament, c. 1900


Adolf Hölzel, *Composition*, 1911


School Koloman Moser
Plate, c. 1902