FROM SIMILARITY TO HOMOMORPHISM: TOWARD A PRAGMATIC ACCOUNT OF REPRESENTATION IN ART AND SCIENCE, 1880-1914[1]

Chiara Ambrosio
Department of Science and Technology Studies
University College London
c.ambrosio@ucl.ac.uk

Abstract

This paper explores the interplay between artistic and scientific representative practices between 1880 and 1914. I argue that science and technology challenged the concept of resemblance in art and that the rhythm of scientific and technological discoveries at the turn of the 20th century paralleled a shift from a notion of similarity to one of homomorphism in the conceptualization of artistic representation. Homomorphism denotes representations which dispense with a point-to-point correspondence between depicted objects and perceptual data. I developed the concept from a study of Charles S. Peirce's pragmatic account of representation, and in particular his theory of iconicity. Drawing on two case-studies – the photographer Alfred Stieglitz and the painter Pablo Picasso – I claim that, between 1880 and 1914, representative practices in art were strongly informed by scientific experimental practices and that the shift from figurative to conceptual representations in art was triggered by a more significant shift involving representation as a general philosophical notion. Ultimately, by combining the relative merits of historical and philosophical accounts of representations, I argue for the advantages and desirability of a philosophically informed history of representative practices.

Keywords: Representative practices; art and science; iconicity; homomorphism.

"Representative practices" between 1880 and 1914: An overview

The years between 1880 and 1914 were a time of intense experimentation in art and science, with no clear-cut separation between the "two cultures".[2] Representative conventions became variable in the visual arts, and artists deliberately departed from a concept of depiction considered as physical resemblance or photographic similarity. Pictorial considerations on form and space progressed toward a conceptualization of figures and objects that transcended perceptual data, and the rendering of pictorial objects turned into an experiment involving complex visualization processes. This paper explores the shift from figurative to conceptual representations in the visual arts in light of the developments that characterized scientific representative practices at the turn of the 20th century.

Recent interdisciplinary studies on the relations between art and science offer compelling evidence of an open dialogue between these two fields.[3] Building on the insights emerging from the existing literature on the relations between art and science, I will contribute to the field with an innovative, pragmatically grounded evaluation of the shift that characterized artistic representative practices between 1880 and 1914.

By referring to "representative practices", I intend to emphasize the pragmatic aspects of what philosophers, in a somehow restricting fashion, call

[1] This paper summarizes the main lines of inquiry of a research project which is still at its earliest stages, and which I intend to pursue in the coming years. I am grateful to Hasok Chang, Grant Fisher and Arthur I. Miller for their encouragement and their useful comments on earlier versions of this paper. I am especially grateful to Catherine M. Jackson for her help and guidance with references on Hofmann's and Liebig's laboratory.

[2] Knight (1986); Kern (1987); Miller (2001).

[3] Henderson (1983); Miller (2000) and Miller (2001); Parkinson (2008).

"representations".[4] Hence, rather than focusing on a normative quest for the necessary and sufficient conditions for representation (a quest that seems to occupy a central place in the philosopher's agenda nowadays), I propose a pragmatic evaluation of the means and strategies through which artists and scientists devise fruitful and perspicuous representations of the world. In doing so, I address two fundamental gaps in the literature on representation. Historians of art and historians of science fail to capture the philosophical import of the contemporary tendency toward conceptual representations. A historical evaluation of the representational shift in the years 1880-1914 needs to be substantiated by an epistemological account of how such a change affected styles of knowing and experimental practices in art and science. Philosophers, on the other hand, often neglect the history of representative practice, and the ways in which it was made by artists in their studios and scientists in their laboratories. Philosophical accounts of representation lack a fundamental connection with the history of artistic and scientific experimentation. This paper will inquire into the experimental aspects of representative practices considered as ways of exploring natural phenomena and intervening upon them.

A well established philosophical tradition dating back to the 1960s frames the problem of visual representations in terms of a critique of a notion of resemblance between representing facts and represented objects.[5] The core tenet of this position is well summarized in Nelson Goodman's 1962 classic work *Languages of Art*:

> "The plain fact is that a picture, to represent an object, must be a symbol for it, stand for it, refer to it; and that no degree of resemblance is sufficient to establish the requisite relationship of reference. Nor is resemblance *necessary* for reference; almost anything may stand for almost anything else. A picture that represents –like a passage that describes– refers to and, more particularly, *denotes* it. Denotation is the core of representation and is independent of resemblance". [6]

I claim that artists reached the conclusion that resemblance is neither necessary nor sufficient for representation much earlier than philosophers. And they did so through practice, a practice which was dramatically affected by the scientific and technological trends that characterized the turn of the 20th century. Contrary to Goodman, however, artists did not resort to a concept of denotation to explain visual representation. The story of their quest for a satisfactory representative relation can provide a useful, practice-based, and historically grounded corrective to Goodman's (and Goodman-inspired) arguments against resemblance.

An overview of the *fin-de-siècle* scientific and technological trends will help the reader contextualize my discussion of the changes that dramatically affected representative practices in the visual arts.[7] The climate of experimentalism that

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[4] See for example Bartels (2006); French (2003); Frigg (2006); Suárez (2002) and Suárez (2003). All these studies address scientific representations in comparison with artistic representations. Yet, as I will argue in the course of this paper, all seem to lack a fundamental connection with the experimental character of representational practices and their historical development.

[5] See for example Bierman (1963); Goodman (1962) and more recently Frigg (2006) and Suárez (2003).

[6] Goodman (1962), p. 5.

[7] What follows has by no means the pretence of providing an exhaustive historical treatment of the revolutionary changes that characterized the turn of the 19th century and their impact on the visual arts. For more extensive discussions see Alexis (1994); Behrens (2002); Didi-Huberman (1986); Everdell (1999); Galison, Holton and Schweber (2008), Henderson (1983); Kern (1987); Knight (1986); Jones

characterized 19th century science laid the foundations for the great changes that swept Europe in the years 1880-1914 and paved the way to the reception of such changes by the wide public. Throughout the 19th century, science had progressively shifted toward a practical and social dimension. Scientific societies, demonstration-lectures open to the public and the diffusion of popular science magazines are just some of the most glaring examples of how scientific knowledge gradually turned into an inclusive and public activity. Yet, the years between 1880 and 1914 were also a phase of transition and tension between opposite tendencies. The intellectual certainties and the trust in science as a truth-conducive pursuit that characterized the early 19th century became progressively eroded at the turn of the century. Discoveries such as X-rays (1895), radioactivity (1896) and the electron (1897) challenged the positivists' emphasis on observable data and suggested the possibility of unobservable phenomena behind them. The popularization of non-Euclidean and *n*-dimensional geometries brought about novel conceptions of space that exceeded sense perception. Automobiles, airplanes and the development of transports transformed the perception of geographical boundaries, while wireless telegraphy and telephones granted rapid transmission of information in real time, independently of physical distances. The invention of war camouflage defied the rules of perception and reshaped notions of form and space in novel and disorienting ways. Photography challenged scientific and artistic representative practices alike, while the scientific and technological roots of cinema offered the possibility of capturing the temporal sequence of action in space.

A climate of change and uncertainty permeated intellectual life at the turn of the 20th century. In this context, a concept of representation as a faithful correspondence to perceptual data was no longer possible. Both in art and in science fundamental concepts such as observation, space, time and the very nature of reality were questioned. This compelled artists and scientists to shift dramatically from perceptually accurate representations to conceptual ones.

The story of this transition is a fascinating and complex one, which is better tackled through case-studies. In the following sections I will look into the representative practices of the photographer Alfred Stieglitz and the painter Pablo Picasso, whose production triggered a genuine revolution in the way artists conceived representations at the beginning of the 20th century. Both of them were actively engaged in scientific debates that shaped their art. Both of them turned explicitly to science in their revolutionary effort to reformulate the relation at the basis of visual representations. Their works can tell us a great deal about the relations between representation and practice – indeed, their works show that representing is a form of experimenting.

Alfred Stieglitz: chemistry, experimentalism and the shaping of photography as art

Alfred Stieglitz (1864-1946) is widely recognized by art historians as the pioneer of modernist photography and the key impresario of American avant-garde. A visionary intellectual, patron and promoter of European modernist movements in America, Stiegliz played a key role in defining the theoretical and practical foundations of photography as a form of art. What art historians often tend to neglect,

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and Galison (1998); Miller (2001); Parkinson (1996); Parkinson (2008); Peat (2002); Robbin (2006); Wilder (2009).

however, is that the foundations of his practice as a photographer lay in the climate of experimentalism that characterized German science in the 1880s.[8]

Stieglitz was born in Hoboken (New Jersey) in 1864, from a relatively wealthy German family. His father, Edward Stieglitz, was a pragmatically oriented man who worked as a craftsman of mathematical instruments. His mother, Hedwig Stieglitz, was a cultivated woman whose interests laid primarily in literature, art and music. In 1881, the Stieglitz moved to Berlin, where Alfred enrolled at the Karlshrue Realgymnasium to enter the Charlottenburg Polytechnic. The following academic year, after his father's suggestion, he began a degree in mechanical engineering.

Stieglitz's biographers have usually regarded his student years as an initial obstacle to the development of his artistic career.[9] Yet, the impact that his engineering and chemical training had on his subsequent artistic production tells a different story. In the 1880s, a number of illustrious scientists were based at the University of Berlin and Stieglitz did not miss the opportunity to enrich his curriculum at the Polytechnic by auditing their lectures and laboratory practices. Among them were the physicists Hermann Von Helmholtz and Heinrich Hertz, who worked with Helmholtz in Berlin between 1881 and 1883; the physiologist Emil DuBois- Reymond and the anthropologist and pathologist Rudolf Virchow. But the two figures who influenced Stieglitz in the most dramatic way were the chemists August von Hofmann and Hermann Wilhelm Vogel.

Hofmann is especially known for his work on coal tar and his contribution to the development of aniline dyes, which laid the foundations of the German dye industry. A student of Justus Liebig at the University of Giessen, he had been, under his teacher's guidance, a pioneer in the transition from analytical to synthetic organic chemistry. In the 1880s, Hofmann was at the peak of his academic career. By the time Stieglitz attended his lectures, he had inherited and improved Liebig's successful methodology based on a harmonious combination of teaching and research.[10] Hofmann's laboratory was a proper research community, in which knowledge was conveyed through practice. Most of the daily learning under his guidance happened by observing and doing, whereas lectures fulfilled the purpose of providing a theoretical background for students who lacked prior chemical training.[11] Indeed, one of the most important methodological points that Hofmann adopted from Liebig was a systematic philosophy of chemical practice, whereby "experimental skill as well as theoretical convictions guided the analyst along a highly uncertain path from experiment to formula".[12]

The concept that practice, far from being subordinate to theory, was constitutive of it[13] became especially important to Stieglitz. In 1882, he switched from engineering to chemistry, and at the same time he began experimenting with photography. The scientific aesthetics underpinning his practice as a photographer revolved around the idea that photography and science shared the same experimental basis and that in both cases theoretical considerations emerged as generalizations from practical experience. When, in 1905, he established the Little Galleries at 291-

[8] The only exception so far is Kiefer (1990), whose excellent study is an invaluable source on Stieglitz and science.

[9] Kiefer (1990), p. 59; Lowe (2002), p. 74.

[10] On Liebig's laboratory see Fruton (1988); Holmes (1989); Morrell (1972); and Jackson (2008); on the relations between Liebig and Hofmann's laboratory practices see Jackson (2006) and Jackson (2009).

[11] Bentley (1970), p. 168.

[12] Jackson (2009), p. 16.

[13] Ibid., p. 13.

293 Fifth Avenue, New York, he characterised them as his "experimental stations",[14] and modeled them on a Liebig-inspired laboratory. And just as a scientific research community, Stieglitz and his laboratory group disseminated their findings through the journal *Camera Work*, which became one of the most important instruments for the promotion of experimental avant-garde in the 20th century.[15] As his friend Herbert Seligmann recalled several years later, "Stieglitz said of himself that at heart he was a scientist".[16]

Along with Hofmann, another influential teacher for Stieglitz was the chemist Hermann Wilhelm Vogel, whose classes and laboratory practice he attended at the Charlottenburg Polytechnic. Vogel's work in photochemistry was well known in the 1880s. His discovery of "optical" or "color" sensitizers resulted in the introduction of orthochromatic film, which was sensitive to all colors, except the notoriously problematic red end of the spectrum.[17] Under Vogel's guidance, Stieglitz developed indispensable technical skills and knowledge of the chemical process behind photography and its technological applications. At the same time, his laboratory practice focused on "training the eye"[18] by performing and documenting repeated photographic experiments.

Stieglitz's enthusiasm in Vogel's teaching was not only limited to his discoveries in photochemistry. In an article for the magazine *The Amateur Photographer* dated 1887, for which he was asked to write a report on amateur photography in Germany, he decided to focus on his teacher's laboratory. After a description of Vogel's use of the latest technological innovations for the purposes of laboratory practice and a discussion of the theoretical foundations of his approach to photochemistry, Stieglitz suggested that Vogel's laboratory, just like Hofmann's, was modeled on Justus Liebig's.[19]

Throughout his chemical training with Hofmann and Vogel, Stieglitz developed indispensable critical tools to approach the emerging and still greatly controversial field of photography. Since 1839, when the first daguerreotype was publicly announced at the Paris Académie des Sciences, the status of photography had been the subject of animated discussions. Scientists initially regarded it as the ultimate tool to obtain objectivity in observation and measurement. Its mechanical, reproducible and reliable nature was a reason to believe that it would function as "an artificial retina…at the disposal of the physicists",[20] as Jean Baptiste Biot enthusiastically announced to the assembled members of the Académie des Sciences. By the end of the 19th century, photography was widely used by scientists as an instrument of observation of phenomena which were considered otherwise unobservable and it was widely employed as a form of measurement and as a means of obtaining experimental evidence.[21]

Contrary to scientists, artists looked at photography as a creative medium which was complementary and comparable to painting. Pictorialism, a movement that became dominant in the 1890s, explicitly aimed to differentiate artistic photography from scientific photography by treating the former as painting. Pictorialist

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[14] Kiefer (1990), pp. 326 and 454.
[15] See Eversole (2005), pp. 5-18.
[16] Seligmann (1966), quoted in Kiefer (1990), p. 377.
[17] Kiefer (1990), p. 100, Wilder (2009), p. 69.
[18] Vogel (1875), p. 299.
[19] Stieglitz (1887), p. 96. See also Kiefer (1990), p. 104.
[20] Arago (1839), quoted in Wilder (2009), p. 9.
[21] See Didi-Hubermann (1986), pp. 71-76 and Wilder (1990), pp. 52-78.

photographers accomplished this by selecting carefully the content and the perspective from which photographs were taken and by intervening on the pictures by retouching them. This practice aimed to bring the artist's subjectivity right at the core of technical photography.

Stieglitz's scientific background, coupled with his involvement in modernist movements, progressively made him feel dissatisfied with the naïve subjectivity professed by the proponents of Pictorialism. Contrary to their claims, he conceived experimental photography as a practice in which artistic subjectivity could be used for the purpose of achieving objectivity through experimental inquiry. His 1907 photograph, *The Steerage*, condensed the artistic outcomes of his evolving views on scientific experimentalism and marked the culminating point of his synthesis of art and science.

The story of *The Steerage* is well known to art historians. Stieglitz was traveling to Europe on board the prestigious liner *SS Wilhelm II*. Despite having a place on the first class deck, he wondered with his camera in the vicinities of the steerage, with the purpose of taking pictures. In his memoirs, he recalls the taking of *The Steerage* as follows:

> "A round straw hat, the funnel leaning left, the stairway leaning right, the white draw-bridge with its railings made of circular chains—white suspenders crossing on the back of a man in the steerage below, round shapes of iron machinery, a mast cutting into the ski, making a triangular shape. I stood spellbound for a while, looking and looking and looking. Could I photograph what I felt, looking, looking and still looking? I saw shapes related to each other. I saw a picture of shapes and underlying that the feeling I had about life".[22]

By concentrating on the inner relations between forms, Stieglitz obtained a photographic representation that verged on the conceptual. Far from exhibiting a faithful, point-to point correspondence to a concrete event, *The Steerage* condenses Stieglitz's awareness that photography entails a process of abstraction and generalization from visual experience. His artistic quest for structure and form beyond immediate sense perception, which found its ultimate realization in *The Steerage,* was modeled on his chemical laboratory practice.

Under Hofmann's guidance, Stieglitz had come to appreciate that chemical knowledge proceeds from experiment to general formulae. As results of practical experimentation, chemical formulae are condensed abstractions of the objects they stand for. At the same time, however, they are richer and more informative than their objects, for they capture structural properties of the experimental processes from which they arise. Moreover, by practicing chemistry in Hofmann's laboratory, Stieglitz had become familiar with the view that practice and process are constitutive components of theoretical knowledge. In approaching photography as a scientific problem to be solved experimentally, he devised a novel form of representation which dispensed with exact resemblance, just like chemical formulae do.

With *The Steerage,* Stieglitz found a satisfactory balance between his photographic practice and his experimental philosophy. All his subsequent production is informed by his experimental quest for conceptual representations. By challenging naïve photographic realism and the simplistic subjectivity of Pictorialism, he devised an entirely novel relation at the basis of photographic representations. Stieglitz was well aware that photography, as every act of observation, is theory-dependent. And

[22] Stieglitz (1942-43), p. 128.

the theory that informs photography is in turn shaped by the needs and goals of the photographer, along with his tools and laboratory practice. Stieglitz's scientific training provided him with a renewed awareness of this aspect of photography and of the experimental process that guides the photographer from "looking, looking and still looking"[23] to the final image.

By concentrating on the inner relations between forms, Stieglitz brought photography at the centre of avant-garde experimentation, in a fashion that anticipated the multiple perspectives of Cubist paintings. Indeed, when shown *The Steerage* by art critic and caricaturist Marius de Zayas in 1910, Pablo Picasso is said to have promptly answered: "This photographer is working in the same spirit as I am".[24]

Cubism, science and representation beyond resemblance

In 1907 – the same year in which Stieglitz photographed *The Steerage* – Pablo Picasso (1881-1973) completed *Les Demoiselles d'Avignon*, the painting which would pave the way to Cubism. Recent interdisciplinary studies[25] reveal a fresh interest in the relations between Cubism and the scientific and technological discoveries that marked the beginning of the 20th century. Unlike Stieglitz, Picasso never received any formal scientific training. His initiation into the realm of science was unorthodox and unconventional, and took place in the lively setting of Parisian intellectual life.

Paris was at the centre of the cultural and scientific changes that shook Europe at the beginning of the 20th century. A manifold of sources that popularized the latest scientific developments in an accessible language were available to the public. French newspapers and magazines such as *L'Intransigeant, Le Temps, Le Matin* and *Paris-Journal* and the *Mercure de France* recurrently presented quasi-scientific articles publicizing the latest discoveries.[26] The popularization of non-Euclidean and *n*-dimensional geometries especially interested Picasso, as it implied a radically novel conception of space that turned out to be crucial for the development of Cubism.

Within the atmosphere of change and expectations that characterized Parisian life at the turn of the century, Picasso and his circle, comprising the poet Guillaume Apollinaire and the writers Max Jacob and André Salmon, embarked on a creative enterprise that compelled them to explore diverse realms of knowledge and confront the traditional separation between art, science, philosophy, technology and literature.

A central character in the story of the relation between Cubism and science is Maurice Princet. Princet was an insurance actuary with an interest in advanced mathematics; his mistress Alice Géry introduced him to Picasso in 1905. From that date onwards, Princet's presence among artists in Montmartre is recorded by a number of primary sources.[27] Because of his contribution in shaping the theoretical bases of Cubism, Princet earned the prestigious title of *"*le mathématicien du Cubisme*"*.[28]

Among the primary sources attesting to the presence of Princet within Picasso's circle there was the Cubist painter Jean Metzinger, who wrote in 1912:

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[23] Stieglitz (1942-43), p. 128.
[24] Kiefer (1990), p. 394.
[25] Henderson (1983); Henderson (2004); Miller (2000); Miller (2001); Robbin (2006).
[26] Henderson (1983), pp. 10-41; Miller (2001), pp. 26-28.
[27] Salmon (1912) in Miller (2001), p.102; Gleizes and Metzinger, (1912), p. 43; Salmon (1955), p. 187; Vauxcelles, (1918) in Henderson, (1983), pp. 71-72.
[28] See Salmon (1955), p. 187.

> "Often Maurice Princet joined us…He conceived mathematics like an artist and evoked continua of n dimensions like an aesthetician. He liked to interest painters in the new views of space opened by Victor Schlegel and succeeded in doing this".[29]

A first-hand account of Princet's role among Picasso's circle is found also in Salmon's writings. In a column of the *Paris Journal,* Salmon reports the forthcoming publication of "a curious book on aesthetics"[30] by Princet. He describes Princet as a mathematician who was inspired by the latest developments in contemporary art and who praised the disdain for ancient perspective expressed by modern painting.[31] Princet's book was never published, but his name recurs in Salmon's writings in concomitance with his description of the birth of Cubism.[32]

Another primary source testifying the presence of Princet within Picasso's circle was the French art critic Louis Vauxcelles, who related Princet to Henri Poincaré and his popularization of non-Euclidean geometries in an entertaining account of the birth of Cubism:

> "It is willingly believed in the studios of Montparnasse…that the inventor of Cubism was M. Max Jacob. We believed it ourselves. But, it is necessary to restore to Caesar his honor and Caesar, in this case, is named M. Princet. This is the first time, we think, that this name is printed in the annals of Cubism. M. Princet is an "insurance man" and very strong in mathematics. M. Princet calculates like Inaudi. M. Poincet [sic] read Henri Poincaré in the text. M. Princet has studied at length non-Euclidean geometries and the theorems of Riemann, of which Gleizes and Metzinger speak rather carelessly. Now, then, M. Princet one day met M. Max Jacob and confided to him one or two of his discoveries relating to the fourth dimension. M. Jacob informed the ingenious M. Picasso of it, explained his intentions to M. Apollinaire, who hastened to write them up in formularies and codify them. The thing spread and propagated…Cubism, child of M. Princet, was born".[33]

Through Princet, Poincaré's discussion of non-Euclidean geometries gradually entered the Cubists' imagination. It is highly improbable that Picasso read any of the scientific or philosophical papers on non-Euclidean geometries and fourth dimension circulating in Paris at the beginning of the 20th century. It was mainly through Princet that he elaborated a new concept of space as an expressive possibility that demanded pictorial exploration.[34]

Another source Princet might have referred to was Esprit Pascal Jouffret's vividly illustrated *Traité Élémentaire de Géométrie à Quatre Dimensions* (Elementary Treatise on Four-dimensional Geometry).[35] In his treatise, Jouffret summarized the current literature on fourth dimension; he repeatedly cited Poincaré's work and provided his readers with detailed illustrations of projections of four-dimensional polyhedra onto two-dimensional surfaces. A characteristic of Jouffret's projections

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[29] Metzinger (1912), p. 43.
[30] Salmon (1910), quoted in Miller (2002), p. 102.
[31] See Miller (2002), p. 102.
[32] See Salmon (1919), p. 485.
[33] Vauxcelles (1918), quoted in Henderson (1983), pp. 71-72.
[34] See Henderson (1983), pp. 67ff and Miller (2001), pp. 100-104 and pp. 114-115.
[35] See Henderson (1983), pp. 57ff; Miller (2001), pp. 108-110 and Robbins (2006), pp. 28-40.

was their extreme faceting, an effect which could be obtained through a new method known by mathematicians as “perspective cavalière”.[36]

Poincaré’s discussions on non-Euclidean geometries and Jouffret’s projections of four dimensional solids offered a basis for the geometric developments that characterize Picasso’s cubist canvases. He elaborated these elements at a crucial point of his artistic career, in which Princet’s lectures on geometry provided him with a radically novel way to reformulate visual representations. In 1907, while Picasso was completing *Les Demoiselles d’Avignon,* geometry would lead him to the discovery of Cubism.

Les Demoiselles d’Avignon represents five oddly shaped female figures gazing at a point in space outside the canvas. Progressing from left to right, a dominant feature of the painting is the gradual geometrization of the female bodies that reaches its highest point in the squatting demoiselle at the bottom-right corner of the painting. *Les Demoiselles d’Avignon* deliberately clashed with previous definitions of visual representation in art. The preparatory sketches contained in Picasso’s *cahiers* reveal that the completion of the canvas required him to break out of the boundaries of art and visually narrate the story of his “research on the frontiers of knowledge”.[37]

Notions from non-Euclidean geometry and the fourth dimension were at the core of Picasso’s revolutionary cubist aesthetics, which consisted of the reduction of forms to their conceptual geometric properties. The new geometries furthered his research of novel ways to explore the nature of space. This culminated in a reformulation of the very concept of spatial relations on the picture plane that verged on the possibility of conceiving geometrical relations that cannot actually be perceived.

Historical studies of Picasso’s 1907 conceptual turn[38] tend to underestimate its philosophical import for a general theory of representation. By challenging the relation of resemblance that had governed figurative painting since the Renaissance, Cubism offered artists a means to represent structural properties of objects in space. Figurative art exhibited a natural resemblance with the entities it referred to. This implied an immediate recognition of depicted objects and a clearly identifiable narrative structure, with a consequently lesser amount of conceptual effort for the viewer. *Les Demoiselles d’Avignon* radically clashed with this representative tradition. Picasso mapped figures and objects, their constitutive properties and the relations among them into a different spatial frame. Like non-Euclidean geometric visualization, *Les Demoiselles* requires a considerable conceptual effort, which consists of grasping a structural relation between representations and the states of affairs they stand for. This feature of Cubism shares a number of important features with Stieglitz’s original approach to photography, and that both exemplify the revolutionary shift that led artists from a notion of similarity to one of homomorphism in their conceptualization of representative relations.

Iconicity as Homomorphism: Representative Practices and Theories of Representation

Between 1880 and 1914, artists achieved through practice and through careful observation of scientific and technological developments what philosophers of science began exploring and questioning only recently: a critique of resemblance at the basis of representation. My discussion of Stieglitz’s and Picasso’s quest for a

[36] See Jouffret (1903), p. 154.
[37] Miller (2001), p. 106.
[38] Steinberg (1972); Bois (1987); Rubin (1994); Green (2001); Miller (2001).

novel relation governing visual representations aimed to produce reasonable evidence that representative practices at the turn of the century were strongly informed by experimental scientific practices and that the shift from figurative to conceptual representation in art was triggered by a more significant theoretical shift involving representation as a general philosophical notion.

A historical study of representative practices can provide a novel, practice-based interpretative framework to reconsider the philosophical problem of representation. I argue that it is desirable, and indeed possible, to do away with notions such as similarity or resemblance in favor of a more fundamental concept of "structural relation". Specifically, I claim that the conceptual turn that characterized visual representations in the years 1880-1914 is better understood through the concept of homomorphism. Homomorphism is a structure-preserving mapping between two algebraic structures or sets in which elements, properties and relations between elements are preserved. I developed the concept of homomorphic representations from Charles S. Peirce's theory of signs, and specifically from his controversial formulation of iconic signs.

For over four decades, Peirce's formulation of iconicity has been the object of animated philosophical debates. Classical conventionalist and nominalist arguments regarded iconicity as a weak representative relation based upon similarity or likeness.[39] This is due to some fundamental misunderstandings deriving from Peirce's own writings, which reflect the complex philosophical architecture of his semiotic theory. Peirce claimed that all thinking is by signs[40] and all knowledge is representational activity.[41] Hence, any effort toward a classification of signs describes the organizing principles of our cognitive activity.[42]

Peirce spent most of his life elaborating typologies of signs that he never brought to completion.[43] For the purposes of this article, I will focus exclusively on a portion of Peirce's division of signs, that is, the trichotomy comprising symbols, indices and icons.[44]

Symbols are signs that signify by a habit or a convention and exhibit neither a natural nor a logical connection with the objects they represent. Verbal language is an example of symbolic system based upon conventional signs. Words in verbal languages do not exhibit any resemblance with the objects they stand for and they are associated with certain general meanings by means of a set of rules stipulated by the speakers of a language.

Indices are signs that stand for their object in an ostensive manner or exhibit a causal connection with what they represent. Peirce maintained that somehow they "force"[45] us to recognize their causal relationship with the phenomena they stand for. Lightning before thunder, smoke indicating fire or the connection between a low barometer and the possibility of rain are examples of indices.[46] In these cases, the relation of signification is not based exclusively upon a convention.

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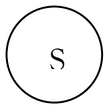
[39] Bierman (1963); Goodman (1962); Eco (1975); Eco (1997).
[40] CP 8.332.
[41] CP 5.283.
[42] CP 2.227ff.
[43] See for example CP 8.343 and CP 8.345.
[44] The trichotomy symbol-index-icon is relative to the relations between a sign and its Dynamic Object. The Dynamic Object for Peirce is the object considered as a real external entity, and it is opposed to the Immediate Object, that is the object as it is represented by the sign (or the object as it is represented in the process of thinking).
[45] Peirce states that indices "direct the attention to their objects by blind compulsion". See CP 2.306.
[46] CP 2.286

Lastly, Peirce defined icons as signs "partaking in the character of the object",[47] that is, signs that preserve the relational structure governing their objects. In several instances, Peirce seemed to stress that the representative relation at the basis of iconic signs is characterized by a similarity or likeness with the objects they represent. The definitions below illustrate this point:

> "[An] icon…exhibits a similarity or analogy to the subject of discourse".[48]

> "[An icon is a] sign which stands for something because it resembles it".[49]

The similarity that apparently governs iconic signs in Peirce's account has been at the core of the misunderstandings that still characterize certain philosophical critiques of iconicity.[50] I suggest that an alternative relation should be considered as the basis of iconicity. An example from set theory will clarify this point.[51] In Euler's diagrams, circles are employed to represent sets. Suppose that we want to represent the expression "Socrates is a mortal". A strictly symbolic or conventional representation of this expression is "$S \in M$", where "S" denotes Socrates, "M" denotes the set of mortals and "$\in$" denotes membership. In Euler's diagrams this relation is represented in an immediate, visual fashion, by inscribing S inside a circle which stands for the set of mortals:



A comparison of Euler's diagram and the notation "$S \in M$" shows that the diagram represents the relation of membership between an object and a set in a more natural and immediately observable way. Strictly speaking, however, no physical resemblance is noticed between the diagram and the states of affairs that it stands for. Additionally, the signs forming the diagram are conventional: they follow a stipulation by which S stands for Socrates and the circle stands for the set of mortal beings. Nevertheless, the way in which the relation of inclusion of an object (in this case Socrates) in a set (the set of mortals) is expressed through the diagram (S being inscribed in a circle) is not conventional: the diagram preserves the relations of the states of affairs that it represents. Such a structural relation allows one to associate the representation of S inside a circle to the relation of membership or inclusion in a set. Despite the conventional nature of the representing facts, the relation between the elements forming the diagrammatic representation of the statement "Socrates is a mortal" is an instance of semiotic iconicity.

It is not a coincidence that Peirce included diagrams and diagrammatic reasoning among the most fruitful kinds of iconic signs. The visual directness of diagrams depends on the iconic component that characterizes them and that is at the basis of their efficacy in the attainment of novel conclusions.[52] Such an iconic component should not be identified with a superficial similarity of appearance. Peirce explicitly stressed this aspect of structural relations:

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[47] Peirce, CP 4.531.
[48] Peirce, CP 1.369.
[49] Peirce, CP 3.362.
[50] See Dipert (1996).
[51] The example that follows is adapted from Shin (2002), p.26.
[52] See Shin (2002), p. 27ff and Pietarinen (2006), p. 113.

> "Many diagrams resemble their objects not at all in looks; it is only in respect to the relations of their parts that their likeness consists. Thus, we may show the relation between different kinds of signs by a brace, thus:
>
> Signs { Icons,
Indices,
Symbols
>
> This is an icon. But the only respect in which it resembles its object is that the brace shows the classes of *icons, indices* and *symbols* to be related to one another and to the general class of signs, as they really are, in a general way".[53]

The representational nature of diagrams is particularly effective for a clarification of Peirce's notion of iconicity. Peirce specified that diagrams, as all iconic signs, rarely function as pure icons:[54] symbolic elements intervene in the representation and background knowledge of such conventions is indispensable to attain the desired information. In Peirce's terms:

> "A *Diagram* is a representamen which is predominantly an icon of relations and is aided to be so by conventions. Indices are also more or less used. It should be carried out upon a perfectly consistent system of representation, one founded upon a simple and easily intelligible idea".[55]

Like diagrams, other examples of iconic signs participate in semiotic processes in a mediated form –that is, in the form of signs that are produced in order to be interpreted by a mind. Considered in a mediated form, iconic signs include conventional and indexical elements, which are indispensable for their construction.

The utmost value of icons consists of instantiating a cognitive rule that allows the mind to establish new relations between previously unconnected representations. Evidently, Peirce's formulation of iconicity is not limited to a superficial resemblance between a sign and the object it stands for. On the contrary, it is a semiotic category that directly concerns the role of representations in the progress toward novel and fruitful results. The efficacy of iconic signs consists of the process that they trigger in the interpreter's mind. As a result, icons are cognitively treated as real objects rather than representations.

Peirce explained this feature of iconic signs in one of his most illuminating passages:

> "A diagram, indeed, so far as it has a general signification, is not a pure Icon; but in the middle part of our reasoning we forget the

[53] CP 2.282

[54] Peirce clarifies that in most cases a sign displays features that belong simultaneously to the class of symbols, indices and icons. He stressed that iconic representations partly consist of symbolic components and considered diagrams as examples of iconicity in mediation. See, for instance, CP 2.276ff.

[55] MS 492:1, quoted in Pietarinen (2006), p.111.

> abstractness in great measure, and the diagram is for us the very thing. So, in contemplating a painting, there is a moment when we lose the consciousness that it is not the thing, the distinction of the real and the copy disappears, and it is for the moment a pure dream –not any particular existence and yet not general. At that moment we are contemplating an *Icon*”.[56]

In these terms, iconicity is a constitutive feature of thought processes that culminate in genuine discoveries. If conventional and/or indexical components are temporarily left aside, iconic representations participate of reasoning processes as if they were real entities. Peirce maintained that, in this process, the interpreter deals with "pure dreams", that is, representations which are neither general nor particular. Icons enter thought processes in the form of "a composite photograph of images"[57] of the objects they represent. As such, they are to be interpreted as "average images"[58] of real objects, that is, as generalizations deriving from experience. The function of iconic signs, (which are asserted icons, or icons as they appear in communicative processes) consists of evoking mental icons ("pure dreams", in Peirce's terms). The fundamental connection between asserted icons and mental icons is at the basis of the perspicuous and fertile character of certain visual representations.

I claim that the structural relation posed by Peirce at the basis of iconic representations is more accurately expressed in terms of the mathematical relation of homomorphism. Homomorphism is a structure-preserving mapping between two algebraic structures or sets. Contrary to isomorphism, homomorphism is not a one-to-one (bijective) mapping. A set A (source domain) can be mapped onto a smaller set B (target domain), so long as their relevant structure is preserved. This requires a correspondence between properties (symmetry/asymmetry; reflexivity/irreflexivity etc.) and operations (relations between elements) of both sets. Notice that, in abstract algebra, homomorphisms do not have to map between sets that have the same operations (for instance, addition can be mapped onto multiplication). Moreover, the structural relation between the sets A and B does not necessarily extend to all the elements of the target domain: part of the elements in the target domain might not be included in the mapping. In mathematical terms, the target domain thus obtained is said to be a homomorphic image of the source domain.

It is possible to summarize the conditions for a homomorphic relation to hold between a representational source and a target domain as follows:

1. Elements of a source domain A represent elements in a target domain B, with different elements of B represented by different elements of A;
2. *f* is a mapping or function between A and B such that:
    a) If elements in A stand in some relevant relation R, then there is a relevant relation R´ among elements of B to which they are assigned by *f*;
    b) If an element in A has a relevant property P, then there is an element in B with the corresponding property P´.

[56] CP 3.362.
[57] CP 2.317.
[58] I owe this successful expression to Mats Bergman (personal communication). On Peirce's definition of icons as "composite photographs" see also Hookway (2007).

c) If a relation R in A has some structural property (symmetry/asymmetry, reflexivity/irreflexivity, transitivity etc.), then the same property holds for R´ in B.[59]

The concept of homomorphism casts new light on the ambiguous notion of similarity or likeness that Peirce considered at the basis of iconic representations. A representational source is an icon of its target if it preserves relevant properties and relations that hold between the elements of the range of phenomena that it stands for. A theory of iconicity as homomorphism accounts for structure preservation as a relation which is established by an act of cognition, and as such has epistemic and practical consequences.

Conclusions: homomorphism and representative practices, 1880-1914

The conceptual turn that characterized representative practices between 1880 and 1914 revolved around the possibility of reformulating the concept of representation in terms of structure preservation. Stieglitz's and Picasso's works are examples of homomorphic representations in which elements, properties and relations between elements are preserved, independently of a faithful, point-to-point similarity with concrete states of affairs.

Stieglitz's conceptual approach to photography incorporated the interplay between experimental skills and theoretical knowledge which was at the basis of Hofmann's (and Liebig's) teaching. Modeled on the chemical practice of proceeding from experiment to formula, Stieglitz's photography became a way of capturing structural relations that are generalizations from visual experience. Similarly, in Picasso's Cubist experimentation, representations preserve properties and relations as they are present in the objects they stand for. Considered as iconic signs, such representations approach the ways in which objects are mentally conceived – they are, in Peirce's terms, "composite photographs of images".[60] Geometry, in particular the novel concept of space introduced by popularizations of non-Euclidean geometries, allowed Picasso to represent objects in space as abstractions from experience, in which fundamental elements, properties and relations were preserved.

From a purely formal viewpoint, Stieglitz's and Picasso's works are asserted icons –that is, representations that stand for certain states of affairs by virtue of a structural, homomorphic relation. Iconic representations such as *The Steerage or Les Demoiselles d'Avignon* are by their own nature cognitively fertile, as they evoke in a direct and immediate manner mental icons, or what Peirce called "pure dreams"[61] – mental representations that are neither particular nor general and that ultimately amount to generalizations from experience.

The study of the shift from similarity to homomorphism that characterized representative practices at the turn of the 20th century opens novel interdisciplinary paths of inquiry into the nature of representations in general. A philosophical study of representation needs to incorporate processes and practices that are constitutive components of specific representative modes of production. With this aim in mind, in this paper I have proposed a practice-based evaluation of the means and strategies that compelled artists to turn to science in their quest for a representative relation that dispenses with similarity. As a result, I hope to have presented a reasonable case for

[59] Allwein and Barwise (1996), pp.71-72.
[60] CP 2.317.
[61] CP 3.362.

adopting a novel approach to the study of representations, which I shall characterize as a "philosophical history of representative practices". This involves shifting the emphasis from a quest for the necessary and sufficient conditions for representation – which are in themselves rather uninformative – to a historically grounded and interdisciplinary understanding of representations considered as ways of exploring natural phenomena and intervening upon them.

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