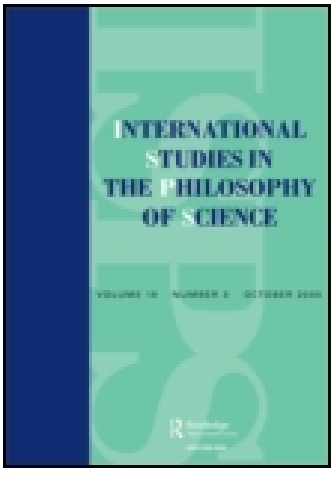

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Iconic Representations and Representative Practices

Chiara Ambrosio

I develop an account of scientific representations building on Charles S. Peirce's rich, and still underexplored, notion of iconicity. Iconic representations occupy a central place in Peirce's philosophy, in his innovative approach to logic and in his practice as a scientist. Starting from a discussion of Peirce's approach to diagrams, I claim that Peirce's own representations are in line with his formulation of iconicity, and that they are more broadly connected to the pragmatist philosophy he developed in parallel with his scientific work. I then defend the contemporary relevance of Peirce's approach to iconic representations, and specifically argue that Peirce offers a useful 'third way' between what Mauricio Suárez has recently described as the 'analytical' and 'practical' inquiries into the concept of representation. As a philosophically minded scientist and an experimentally inclined philosopher, Peirce never divorced the practice of representing from questions about what counts as a representation. I claim that his account of iconic representations shows that it is the very process of representing, construed as a practice which is coextensive with observing and experimenting, that casts light on the nature of representative relations.

1. Introduction

Charles S. Peirce's philosophy, and in particular his distinctive formulation of pragmatism, is gradually beginning to gain greater visibility in philosophy of science. Yet, his rich account of representations continues to raise a certain degree of scepticism, especially among analytical philosophers of science. Indeed, the current attitude towards Peirce still seems strongly affected by Bertrand Russell's metaphor of 'a volcano, spouting vast masses of rocks, of which some, on examination, turn out to be nuggets of pure gold' (Russell [1946] 1969, xvi). Alas, Russell never truly bothered

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to separate the gold from the debris, nor did, after him, a great portion of analytical philosophers (on the relations between Peirce and Russell, see Anellis 1995).

My primary aim in this paper is neither to rehabilitate Peirce nor to 'translate' his philosophy for an analytical audience (a move that has been occasionally made, but that I consider at least partly against the spirit of his work, for reasons that will be clearer later on). Instead, I hope to show that parts of his voluminous corpus of writings, if investigated accurately, have a great deal to offer to contemporary debates in philosophy of science. In particular, I want to suggest that Peirce's work on (and with) representations, which constitutes one of the pillars of his philosophy, anticipates—and potentially resolves—some of the tensions that characterize contemporary debates around the nature and role of representations in scientific practice. For this purpose, I focus on a class of representations that Peirce grouped under the category of iconicity. Peirce characterized iconic representations as the dynamic constituents of scientific inquiry. He clearly distinguished them from indexical and symbolic representations, and placed them at the very centre of his innovative approach to logic, his work in mathematics, and his practice as a scientist more broadly.

In emphasizing the iconic nature of scientific representations, Peirce seemed to suggest that a key characteristic of the representative tools and practices constructed and used by scientists is their fundamental fruitfulness, and indeed it is this fruitfulness that distinguishes iconic representations from indexical and symbolic ones. As I will show in greater detail later on, a distinctive feature of iconic representations is that they exhibit aspects or qualities of the objects they stand for, qualities they would possess 'whether any such Object actually exists or not' (EP 2, 291). This has been often interpreted as Peirce claiming that a relation of similarity or resemblance—or, as Peirce often labels it, a generic 'likeness'—ultimately governs all representations deemed to be iconic. In the rest of this article, I will attempt to spell out what kind of role similarity plays in Peirce's account of representation, and what this account has to offer to the contemporary debates around scientific representations. One important conclusion that emerges from Peirce's writings is that his account goes beyond a perceived or superficial resemblance between a particular representation and the states of affairs it stands for. Instead, Peirce's emphasis is on the inferential processes that are triggered by the very act of picking out qualities or aspects that are recognized *in some capacity or respect* to be shared between the representation and its object. Thus, the very process of constructing and inspecting an iconic representation (a process that for Peirce involves a dynamic act of interpretation) discloses novel features of the objects or states of affairs being investigated through the representation. As Christopher Hookway incisively explained:

> The key of iconicity is not perceived resemblance between the sign and what it signifies but rather the possibility of making new discoveries about the object of a sign through observing features of the sign itself. Thus a mathematical model of a physical system is an iconic representation because its use provides new information about the physical system. This is the distinctive feature and value of iconic representation: a sign resembles its object if, and only if, study of the sign can yield new information about the object. (Hookway 2000, 102)

What I hope to show is that Hookway's claim can be extended to incorporate not just the discovery of new aspects of the *object* of an iconic representation, but the *relation of representation* itself. Specifically, Peirce's account seems to suggest that the process and practice of representing entails a two-fold discovery.[1] An obvious feature of his definition of iconic signs is indeed that new properties of objects or states of affairs are discovered through the investigation and manipulation of the representation itself. On the other hand, the very process of *constructing* an icon matters for Peirce, as it reveals the very respects in which a particular sign stands for its object. What seems to emerge from Peirce's account is that the very relation of representation is itself the result of a process of discovery: 'constructing' an icon amounts to discovering, and selecting, relevant respects in which a representation captures salient features of the object it stands for.

My discussion will develop as follows. I begin with a brief overview of Peirce's own use of a particular kind of representations, his logical diagrams, which will serve as a case study to illustrate his views on iconicity. I claim that Peirce approached the question of representation first and foremost from the standpoint of his practice as a scientist and as a logician, and that this complicates the interpretation of 'iconicity as (perceived) resemblance' that appears to be dominant in the cursory references that philosophers of science have made to Peirce's work.

In the second part of this article, I defend the contemporary relevance of Peirce's approach to iconic representations. For one thing, Peirce offers a useful 'third way' between what Mauricio Suárez (2010) has described as the 'analytical' and 'practical' inquiries into the concept of representation. While the former focuses on the question of what *constitutes* representation, the latter implies abandoning constitutional questions to privilege the ways in which scientists *use* models and draw inferences from them. Whether the two approaches are as sharply distinguished and mutually exclusive as Suárez seems to suggest is, of course, in itself debatable. I rely on the distinction for eminently practical purposes and in setting out the context for my argument; however, I argue that Peirce's account of iconic representations challenges the very basis of this distinction, and that in his account constitutional questions cannot, and should not, be separated from questions of use. As a philosophically minded scientist and as an experimentally inclined philosopher, Peirce never divorced the practice of representing from questions about what counts as a representation in the first place. I claim that his account of iconic representations shows that it is the very process of representing, construed as a *practice* which is coextensive with observing and experimenting, that casts light on what counts as a representative relation in the first place.

2. Reasoning Through Icons

'I do not think I ever *reflect* in words: I employ visual diagrams, firstly, because this way of thinking is my language of self-communion, and secondly because I am convinced that it is the best system for the purpose' (MS 619, 8). Peirce often complained about his inability to cope with the limitations of language. But his preference for visual representations goes beyond a mere psychological effect: diagrams, in his view, are the *best*

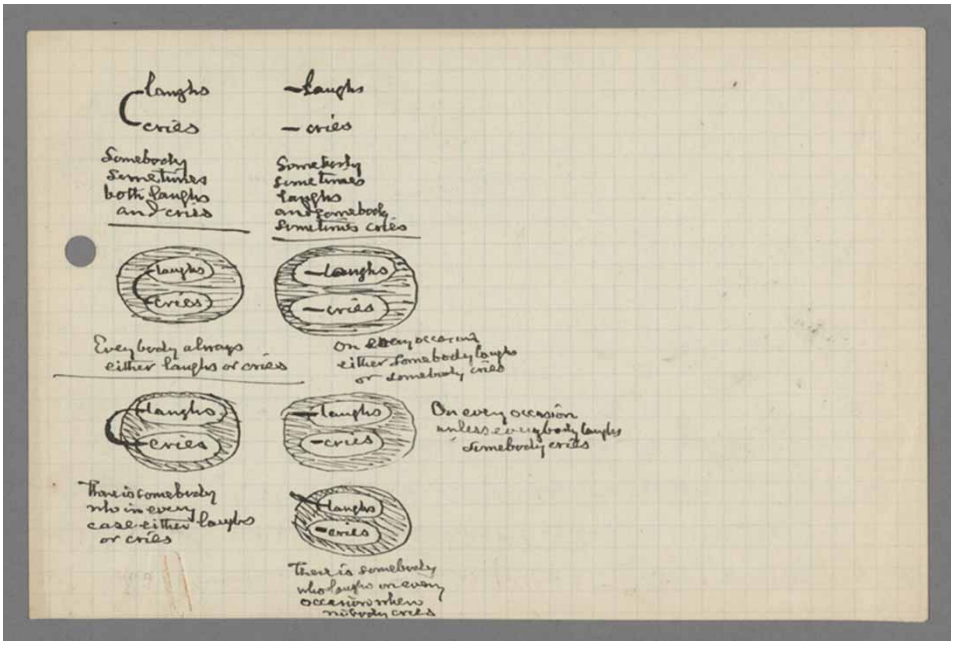

Figure 1 Charles S. Peirce, Existential Graphs. From MS Am 1632 (292), 'Prolegomena to an Apology of Pragmatism' (1906), unnumbered sheet. Houghton Library, Harvard University.

system to capture the process of reasoning in action. This normative judgement constitutes the philosophy at the basis of what Peirce defined as his 'Chef d'Oeuvre': a diagrammatic system of logic that he labelled his 'Existential Graphs' (Figure 1).

I want to use Peirce's iconic system of logic as a way to cast light on the problem of scientific representations more broadly. That Peirce's philosophy has a great deal to offer to the debate is occasionally acknowledged by philosophers of science; however very little has been done in exploring the extent and value of his contribution (for an exception, see Knuuttila 2010, who uses a Peirce-inspired notion of mediation in her discussion of models, without, however, explicitly invoking iconicity). For instance, in the entry on 'Models in Science' in the *Stanford Encyclopedia of Philosophy*, Roman Frigg and Stephan Hartmann suggest that the category of iconicity, construed in terms of resemblance, might contribute to explain the representative function of at least one particular category of models:

> Scale models seem to be a special case of a broader category of representations that Peirce dubbed icons: representations that stand for something because they resemble it . . . . This raises the question of what criteria a model has to satisfy to qualify as an icon. Although we seem to have strong intuitions about how to answer this question in particular cases, no theory of iconicity for models has been formulated yet. (Frigg and Hartman 2006)

The choice of scale models here—which reflects a suggestion first advanced by Max Black (1962)—reveals a common misunderstanding about the concept of iconicity: that it consists *exclusively* of a relation of resemblance or similarity between a

representational source and its target. While Peirce in several passages seems to reinforce this misunderstanding, his system of diagrammatic representations discloses a different perspective on the issue of iconicity. For Peirce, diagrams make *relations* visible, and their iconic nature is crucial in achieving this aim. It is this aspect of Peirce's work that can offer particularly useful insights into the broader question of representation in science.

Before turning to some of the key features of Peirce's system of diagrams, it might be useful to review the broader context surrounding iconicity. This requires a brief digression into Peirce's semiotics, which he described as 'the quasi-necessary, or formal, doctrine of signs' (CP 2.227, c. 1897). Peirce scholars have discussed extensively the complexity of Peirce's theory of signs,[2] and an exegetic study of the intricacies and technicalities of his approach, which comprises an extended system of classification of various types of signs, exceeds the scope and focus of this discussion. Nevertheless, two basic observations are here in place. First, semiotics for Peirce goes hand in hand with *logic*, construed as reasoning in its broadest possible sense:

> Logic, in its general sense, is, I believe I have shown, only another name for *semiotic* . . . , the quasi-necessary, or formal, doctrine of signs. By describing the doctrine as 'quasi-necessary', or formal, I mean that we observe the characters of such signs as we know, and from such an observation, by a process that I will not object to naming Abstraction, we are led to statements, eminently fallible, and therefore by no means necessary, as to what *must be* the characters of all signs used by a 'scientific' intelligence, that is to say, by an intelligence capable of learning by experience. (CP 2.227, c. 1897)

Semiotics thus is both tied to experience and at the same time has the constructive function of generating fallible abstractions, in the form of representations (Bergman 2009, 45ff). Necessity is not the hallmark of Peirce's identification of semiotics with logic; instead his emphasis is on the fallibility of principles, hypotheses, or concepts that undergo such a process of abstraction. This—rather than deriving necessary truths from strictly deductive principles—is the distinguishing feature of the way signs (and logic) are produced and used by a 'scientific intelligence'—that is, an intelligence 'capable of learning by experience' (CP 2.227, c. 1897).

Second, iconic representations are part and parcel of this broader logical project for Peirce. It is in the very context of an explanation of the kinds of representations that are indispensable in all reasoning that Peirce discusses iconicity alongside the two related contrast classes of indexical and symbolic signs:

> There are three kinds of signs which are indispensable in all reasoning; the first is the diagrammatic sign, or *icon*, which exhibits a similarity or analogy to the subject of discourse; the second is the *index*, which like a pronoun demonstrative or relative, forces the attention to the particular object intended without describing it; the third [or *symbol*] is the general name or description which signifies its object by means of an association of ideas or habitual connection between the name and the character signified. (CP 1.369, c. 1885)

In this passage, Peirce identifies icons with 'diagrammatic signs'.[3] He contrasts them to indexes, signs that 'force attention' to their objects by exhibiting a relation of

physical contiguity with them (such as demonstrative pronouns, or a barometer reading indicating atmospheric pressure) and symbols, signs that stand for their objects by virtue of a convention or habit (such as words in natural languages).[4] The passage above also well exemplifies the reasons of many misunderstandings about the category of iconicity: here, like in several other passages, Peirce refers to icons as exhibiting a similarity, or analogy (and in other places a resemblance, or likeness), with the objects they stand for. The reference to diagrams, in this case, is revealing. Surely a diagram does not literally 'resemble' the objects it stands for—be they concrete objects or logical relations. What Peirce was struggling with was something more profound, and epistemically more fruitful, than a mere superficial resemblance.

An insight into what Peirce is referring to comes from a passage in which he tries to spell out the meaning he attributes to 'likeness' via a number of illustrative examples:

> Another example of likeness is the design an artist draws of a statue, pictorial composition, architectural elevation, or piece of decoration, by the contemplation of which he can ascertain whether what he proposes will be beautiful and satisfactory. The question asked is thus answered almost with certainty because it relates to how the artist will himself be affected. The reasoning of mathematicians will be found to turn chiefly upon the use of likenesses, which are the very hinges of the gates of their science. The utility of likenesses to mathematicians consists in their suggesting, in a very precise way, new aspects of supposed states of things. (EP 2, 6)

The passage, included in an article originally entitled 'The Art of Reasoning' (1893–1895), was written to be part of Peirce's *Grand Logic*. This reinforces the idea that it is precisely in the context of logic—construed in the very broad sense I outlined above—that Peirce formulates his notion of iconicity. The first thing to notice is that Peirce groups under the class of 'likenesses' a broad range of representations—from preparatory drawings and plans for artistic and architectonic works to mathematical representations, where likenesses, Peirce claims, are ubiquitous and even constitute 'the hinges of the gates' of the whole discipline. What is common in all these cases is a combination of predictive power (the artist/architect can ascertain through the drawing whether what he or she proposes will be beautiful and satisfactory) and the possibility of discovering, through the practice of representing, new aspects of the phenomena under investigation.

How do iconic representations work? And why privilege iconic representations over predominantly indexical or symbolic ones? In the same paper, and immediately after his discussion of the role of likenesses in mathematical reasoning, Peirce suggests a very simple example:

> Suppose we have a winding curve, with continual points where the curvature changes from clockwise to counter-clockwise and conversely, as in Figure 1. Let us further suppose that this curve is continued so that it crosses itself at every such point of reversed bending in another such point. The result appears in Figure 2. It may be described as a number of ovals flattened together, as if by pressure. One would not perceive that the first description and the second were equivalent without the figures. (MS 404, 1893–1895, 36, reprinted in EP 2, 6; Figure 2)[5]

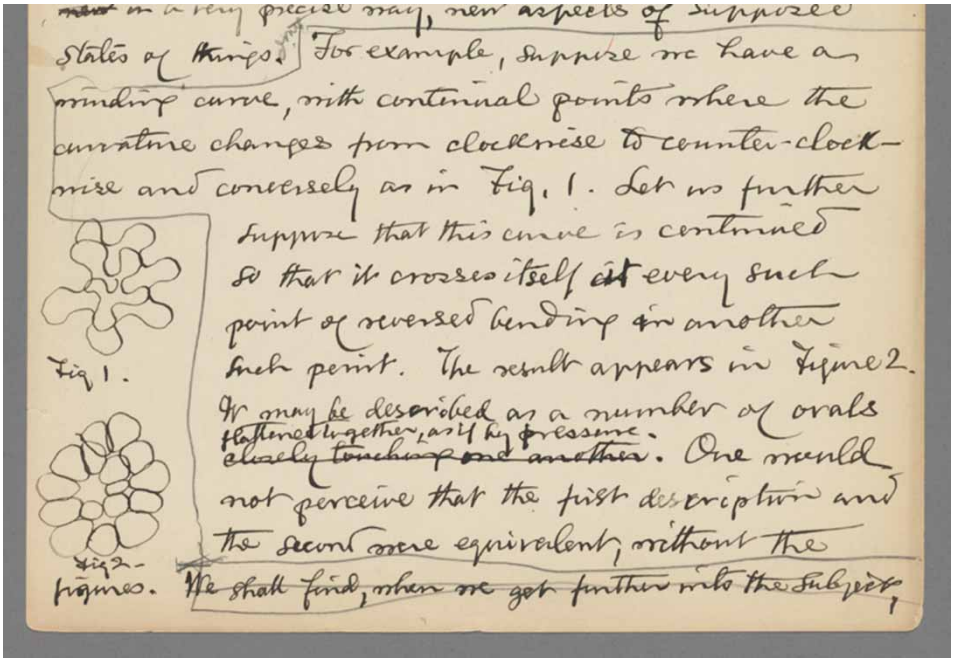

Figure 2 Charles S. Peirce, MS Am 1632 (404), 'The Art of Reasoning' (1893–1895), p. 36 (detail). Houghton Library, Harvard University.

In this particular case, the *relation* of equivalence between the two images is visually inferred—in a way that would not have been otherwise—through reference to the picture. This reflects more broadly Peirce's conviction that a distinctive feature of iconic representations consists of prompting what we would now call 'surrogative reasoning': the capacity to draw inferences (and he was particularly interested in inferring novel relations) from them (Swoyer 1991; Suárez 2004). I shall return to the issue of surrogative reasoning later on, but at the moment it is important to note that for Peirce the comparison between the two images invites a process of construction and experimentation upon the two winding curves. It is this very process that makes iconic representations especially fruitful, and it is this process that exemplifies the idea that Peirce's notion of representation entails a two-fold discovery. In order to discover the relation of equivalence, the reader/interpreter of the image needs to re-enact the process of drawing both curves and observe the consequences of that experimental process. In other words, the fruitfulness of icons partly consists in the fact that they naturally invite us to re-enact the process of *representing*, that is, the process of finding a suitable representative relation holding between particular signs and the states of affairs they stand for. It is in this way that the relation between the two images becomes 'evident'—and for Peirce this term is has a particular epistemic weight, as I will show later on. Alas, this very simple example condenses many of the features that Peirce attributed, in a slightly more methodical and systematic way, to his diagrammatic system of logic.

The years in which Peirce was completing 'The Art of Reasoning' were also the time in which he was most intensively working on his system of Existential Graphs, which were formally put forward in 1896. As Ahti-Veikko Pietarinen (2006, 109ff) notes, the system was rooted in Peirce's previous investigations in logical algebra. It is possible that the original motivation for the Existential Graphs dated as far back as 1882, and it was a clear effort on Peirce's part to improve on the perspicuity and readability of his logic of relatives. Indeed, in a letter to his student and then colleague at Johns Hopkins, Oscar Mitchell, Peirce noted that his 'notation of the logic of relatives can be somewhat simplified by spreading the formulae in two dimensions' (MS L294, 1882, quoted in Pietarinen 2006, 109). Peirce's aim was to build a system of logic that could capture the closest correspondence with the process of reasoning and exhibit this correspondence in the clearest and most perspicuous manner. The diagrams, in Peirce's own words, should function as 'moving pictures of thought' (CP 4.8, c. 1905; Pietarinen 2006), and in this respect they were supposed to break a trend that was dominant in the approaches to logic that were most popular in Peirce's time. Indeed, in a 1909 manuscript (MS 514; see Sowa 2001 for a detailed commentary), Peirce explicitly contrasts his own logical system to the drive towards symbolic formalism pursued by his contemporaries:

> So I will break off that and just give an illustration or two of how this Syntax of Existential Graphs works. But before doing that I wish to draw your attention, in the most emphatic way possible, to the purpose this Syntax is intended to subserve: since anybody who did not pay attention to that statement would be all but sure, not merely to mistake the intention of this syntax, but to think that intention as contrary to what is as well he could. *Namely he would suppose the object was to reach the conclusion from given premises with the utmost facility and speed, while the real purpose is to dissect the reasoning into the greatest possible number of distinct steps and so to force attention to every requisite of the reasoning.* The *supposed* purpose would be of little consequence, and it is the fussiness of the mathematicians to furnish inventions to attain it; but the *real purpose is to supply a real and crying need, although logicians are so stupid as not to recognize it and to put obstacles in the way of meeting it*. (MS 514, 20–21; emphasis mine)

The primary requirement of a good system of logic is to supply *a real and crying need to force attention to every requisite of reasoning*. In the passage, Peirce complains that logicians in his time are placing obstacles to the development of a transparent inquiry into the process of reasoning, by privileging facility and speed over perspicuity and clarity. On the contrary, logic should provide the clearest and most perspicuous way of dissecting reasoning in each of its steps. It is this requirement that Peirce's Existential Graphs were supposed to fulfil.

Peirce outlines an even clearer formulation of the iconic function of diagrams, applied to the Existential Graphs, in a manuscript (MS 293, c. 1906), which is probably a draft for what would become his *Prolegomena to an Apology for Pragmaticism* (CP 4.530ff, c. 1906). A diagram, in the manuscript, is defined as 'an Icon of a set of rationally related objects'. By 'rationally related' Peirce means 'that there is between them, not merely one of those relations which we know by experience, but know not how to comprehend, but one of those relations which anybody who reasons must

have an inward acquaintance with' (MS 293, 10–11). This is in line with Peirce's dictum that all necessary reasoning is ultimately diagrammatic (MS 293, 6), and in particular with his idea that necessary reasoning makes (or *should* make) its conclusions *evident*. Reasoning upon a diagram, Peirce explains, allows for the truth of the conclusion to be '*perceived*, in all its generality; and in the generality the how and why of the truth is perceived' (MS 293, 11, emphasis in the text). His claim here is that only iconic representations such as diagrams can provide just this kind of evidence:

> It is, therefore, a very extraordinary feature of diagrams that they *show*,—as literally *show* as a Percept shows the Perceptual Judgment to be true,—that a consequence does follow, and more marvellous yet, that it *would* follow under all varieties of circumstances accompanying the premises. (MS 293, 13)

A few preliminary conclusions can be drawn from this brief account of Peirce's approach to diagrams as a particularly illuminating kind of iconic representations. First—and more importantly—iconic representations should provide ways of forcing attention, observationally, on the necessary relations between premises and conclusions. It is for this reason that diagrams should be as iconic as possible.[6] Iconicity is what grants the perspicuity of diagrams, thus making surrogative reasoning possible in the first place. Indeed, in the years leading up to the development of the Existential Graphs, and perhaps with his system of diagrams in mind, Peirce placed the very concept of observability at the centre of his notion of iconicity:

> A great distinguishing property of the Icon is that by the direct observation of it other truths concerning its object can be discovered than those which suffice to determine its construction. (CP 2.279, c. 1895)

Clearly here Peirce is not advocating a crude form of empiricism, nor should he be seen as a precursor of the concept of observability that the Logical Positivists, later on, would associate with the meaning of 'observation statements'. Instead, observation in his account is the first step towards the discovery of 'new truths' that go beyond what is placed before an observer's eyes. Even more importantly, diagrams—and indirectly, iconic signs—for Peirce are an opportunity to reflect on the evidential status of logical relations. On the one hand, he claims, relations are *discovered* through the very process of constructing and inspecting a diagram. This process requires the diagram to be built in relation to an Interpretant—which for Peirce is the interpreting sign that a sign itself triggers in an interpreter's mind (or quasi-mind). Once a diagram has incorporated an intention to appeal to an Interpretant, its necessary conclusions become universally communicable and thus *evident*—that is, appealing to 'those relations which anybody who reasons must have an inward acquaintance with' (MS 293, 10–11). Incidentally, it is no wonder that, only a few lines later in the same paper, Peirce equates this formulation of diagrams with the Kantian concept of schema:

> Meantime, the Diagram remains in the field of perception or imagination; and so the Iconic Diagram and its Initial Symbolic Interpretant taken together constitute what we shall not too much wrench Kant's term in calling a *Schema*, which is on

> the one side an object capable of being observed, while on the other side it is a general. (MS 293, 13)

This is not the place for an in-depth evaluation of the relations between iconicity and Kantian schematism, which would require a long exegetic discussion on the relations between the two philosophers. Suffice to say that the comparison put forward by Peirce is particularly apt to illustrate, once more, the connection between diagrammatic reasoning and the possibility to discover novel relations between phenomena. Just like schemata, diagrams are at the same time observable objects and general rules that allow the synthesis of a manifold of experienced ideas into a unified representation (on icons and Kantian schematism, see Hookway 2002, 40ff).

3. Reconciling Analytical and Practical Inquiries

Peirce's account of iconic representations, and especially his work on diagrams, offers a fruitful ground to resolve a tension that has characterized—and still very strongly permeates—contemporary accounts of representation in philosophy of science. In what follows, I draw on the distinction, recently proposed by Suárez (2010), between 'analytical' and 'practical' accounts of representation. In Suárez's account, the 'analytical inquiry' draws together philosophical accounts that use the concept of representation to investigate the relation between theory and the world. These accounts, Suárez claims, concern themselves mainly with problems of meaning, reference and the metaphysics of relations. The 'practical inquiry', on the other hand, exemplifies the contemporary tendency to integrate history and philosophy of science in a unified account. Rather than focusing on the nature of the relation of representation, these accounts concern themselves with the practice of model building and with the ways in which scientists actually use models. The two approaches, in this crude formulation, seem mutually exclusive (or they are often depicted as such): if we are interested in representation as a *relation* we need to give up history and practice, while if we are interested in representation as a *practice* (and in the ways in which it unfolds historically) we should abandon analytical questions about what counts as a representation in the first place.

Let us consider the two positions outlined by Suárez slightly more in detail. The analytical inquiry formulates representation as a relation between a source (the vehicle of the representation) and a target (the object of the representation), which are considered as mere placeholders. The aim of these accounts is to provide an analysis of the relation holding between source and target—in other words they focus on what Suárez defines as the *constituents* of representation. In their simplest formulation, they assume that representation is a relation R such that 'X represents Y' is equivalent to 'R holds between X and Y'. A common answer to this question in philosophy of science has been that the relation holding between a source and a target should be formulated in terms of similarity or isomorphism.[7] Both accounts are problematic in several respects, and a number of criticisms have been raised against them. The most common argument is a logical one, and was proposed by Nelson Goodman

(1962). The central claim in Goodman's work is that representation is independent from similarity or resemblance: his argument is based on the assumption that resemblance is neither a necessary nor a sufficient condition for signification. Resemblance is reflexive, while representation is not: objects resemble themselves, but this does not mean that they represent themselves. Moreover, resemblance is symmetric: an object *A* resembles an object *B* as much as *B* resembles *A* (and vice versa). According to Goodman, the same does not hold for representation: it is possible to say that a portrait represents someone, but it is not possible to say that a person represents his or her portrait. The upshot is, in Goodman's words, 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. (Goodman 1962, 5)[8]

An analogous counterargument has been formulated against the notion of isomorphism, which is a mathematical formulation of structural identity. Isomorphism is a one-to-one, bijective mapping between two mathematical structures or sets, so that for each element in the source there is one and only one corresponding element in the target. It is pretty evident that Goodman's logical argument holds equally well in the case of isomorphism: like similarity, isomorphism is reflexive and symmetric, while representations are not. A further problem with a concept of representation as isomorphism is that source and target are not usually mathematical entities. So, the only way to use isomorphism as a representative relation is to appeal to instantiations of mathematical structures. But even in this case, instantiation remains 'underdetermined': as Suárez points out, 'the physical world underdetermines its mathematical structure—which may only be ascribed under a particular description' (Suárez 2010, 96).[9]

This brief overview of the major problems characterizing analytical accounts of representation does not do full justice to the broad range of arguments that have been presented in favour or against similarity and isomorphism.[10] Nevertheless, it contributes to explain the reasons that compelled some philosophers of science to shift towards practice-based accounts of representation. Such accounts mainly concentrate on various articulations of the concepts of use and means as opposed to the constituents of representations, and focus on model building (rather than theories or their structural features) as fundamental to scientific practice. Their starting assumption is that the relation of representation cannot be captured by appealing to mathematical or formal structures, and that the debate around representation should be shifted to a concrete investigation of the various uses of models and the particular contexts in which they are used.[11] It is within the context of the practical inquiry that Suárez puts forward his own account of representations, which has the advantage of focusing on surrogative reasoning—a feature of representation that, as we saw, was central in Peirce's account of diagrams.

Suárez claims that representation is best understood in a deflationary spirit, which implies abandoning constitutional questions, and with them relations such as

similarity or isomorphism. His account poses two minimal requirements at the basis of representation. On the one hand, the source must point to a target—that is, a source must be used as a representation to assert something novel about the target (he defines this as the requirement of directionality or representational force). Second, the representational source must allow a competent and informed agent to draw specific inferences regarding the target—in other words it must allow surrogative reasoning.

Despite its flexibility and appeal, the inferential view presents some limits. Suárez considers directionality as a requirement of representation and treats it as a precondition for representation. However, I would argue, one of the aims of an account of representation is to explain directionality, rather than treat it as a given prerequisite. Directionality—*how* we *construct* and use a source to represent a target—is fundamental to explain surrogative reasoning and the discovery of novel facts about the target. Take the case of Peirce's winding curves, which I discussed earlier on: it is only through the process of constructing the two curves *qua representations* of each other that we can infer the relation of equivalence between them. Even more fundamentally, the only way we have of fleshing out this relation is by tracing back, as carefully as possible, the process of representing both curves. This, of course, involves considering the 'intended uses' of representations, which is part of what Suárez considers as the representational force requirement. But 'use' in his account seems to imply that representations are ready-made entities, waiting for us to do something with them. In this, his deflationary account shares the same problem as the analytical inquiry: both seem to focus on the justification of the representative relation (in terms of necessary and sufficient conditions) or of the ways in which we use representations without explaining how we come up with them in the first place. What I want to stress, instead, is an aspect of the practical inquiry into representations that has remained only as a background assumption so far: what we do with representations depends on how we construct them. The question is, in some respects, still one of discovery versus justification: current accounts, even when focusing on practice, tend to privilege the latter, while the very issue of surrogative reasoning requires a shift of emphasis on the former. It is in this particular respect that Peirce's account of iconic signs becomes especially relevant.

The account of iconicity that I have presented in the previous sections shows that Peirce had a clear interest in constitutional questions, and that for him those questions were coextensive with practice and use. Interestingly, Suárez includes Peirce among the proponents of the analytical inquiry—a move that apparently seems to be in line with his broader point about the polarity that characterizes current accounts of representations. However, Peirce's interest in constitutional questions was not—strictly speaking—analytical. Instead, it was motivated by his broader interest in perspicuous representations—that is, in the type of representative relations that generate, via some form of experimentation involved in their construction, novel knowledge about their target. It is in this particular respect that Peirce's account offers an interesting 'third way' between analytical and practical inquiries. But this also implies that a more substantive account of representation is at the core of his definition of iconic signs.

I am going to put forward a suggestion that might (rather dangerously) expose my account to the charge of reproducing some of the weaknesses of structuralist/semantic accounts of representation, and so it might be crucial to specify that my interpretation of Peirce is not tied, at least theoretically, to any of those accounts.[12] My argument revolves around the idea of a common relational structure between a representational source and its target. But more importantly, I argue that this common relational structure should be construed and understood from the viewpoint of discovery, rather than as a justification of a representative relation that is somehow 'already there'. This claim is rooted in Peirce's own idea that what characterizes iconic representations is that they exhibit the *form* of a relation (CP 4.530).[13] True, similarity is neither necessary nor sufficient to representation. However, for a source to represent its target, the recognition (by a user or interpreter) of some common relational structure seems to be a minimal *necessary* condition. It is necessary especially for the purpose of producing surrogative reasoning: the discovery of a shared set of properties (which goes beyond a one-to-one correspondence, as I will show below) is what allows 'competent and informed users' to generate inferences about the target.

A similar intuition has been proposed in two recent philosophical accounts of representations. Both Ronald N. Giere (2004) and Bas C. van Fraassen (2008), animated by different motivations, have tried to reconnect a notion of similarity with scientific practice. Specifically, both suggest that the notion of 'use' is indispensable to continue to capitalize on some notion of similarity in representation. In response to Goodman-inspired criticisms stressing that similarity is symmetrical while representation is not, both Giere and van Fraassen respond that introducing the notion of use is just what breaks the symmetry in the case of models and representations.

Van Fraassen (2008, 23) explicitly claims that 'to understand representation we must . . . look to the practice of representing'. But 'the practice of representing' in his case, becomes an expedient to avoid, rather explicitly, the question of what constitutes a representation: 'There is no representation except in the sense that some things are used, made, or taken, to represent some things as thus and so' (van Fraassen 2008, 23). In putting forward this claim van Fraassen takes a minimalist approach towards the relation of representation, and indeed the very opening of his discussion contains an acknowledgement to the deflationist account proposed by Suárez (van Fraassen 2008, 7). As in the case of Suárez's account, the shortcoming of van Fraassen's is ultimately that it divorces 'use' from the question of what counts as a representation in the first place. The account of iconicity I have outlined so far, combined with the more explicit notion of morphism I will outline below, aims to suggest that this is not a necessary move, and that an emphasis on practice requires considering the question of what constitutes a representation as coextensive with the question of how certain things are 'used, made or taken' to represent others.

An alternative that is perhaps closer to Peirce's views has been proposed by Giere (2004), who tried more explicitly to reconcile a substantive account of representation with the practice of representing. His discussion on this issue is worth quoting in full, as it contains points that recapitulate part of my arguments and contribute to push them a step further:

> How do scientists use models to represent aspects of the world? What is about representational models that makes it possible to use them in this way? One way, perhaps the most important way, but probably not the only way, is by exploiting possible *similarities* between a model and that aspect of the world it is being used to represent. Note that I am not saying that the model itself represents an aspect of the world because it is similar to that aspect. There is no such simple representational relationship. Anything is similar to anything else in countless respects, but surely not everything by itself represents something else. It is not the model that is doing the representing; it is the scientist using the model who is doing the representing. One way scientists do this is by picking out some specific features of the model that are then claimed to be similar in some specific respect to features of the designated real system. It is the possibility of specifying such similarities that makes possible the use of the model to represent the system in this way. (Giere 2004, 64)

Giere's emphasis on scientists 'picking out some specific features ... that are then claimed to be similar' to the states of affairs represented by a certain model is in several respects compatible with the account of 'likeness' that Peirce proposed at the basis of iconic representations. For one thing, it places the epistemic burden of similarity on the scientist's recognition and selection of relevant features that are then 'claimed' to capture aspects of the world through the process of representing. But Peirce wanted a little more from iconicity: salient features are not chosen arbitrarily (which is what some conventionalist readings of similarity occasionally seem to hint at) and then 'claimed' to be similar to particular states of affairs. For Peirce, iconic representations entail the discovery of a common relational structure between representations and the objects they stand for, and this discovery happens through the process of representing. In his account, this is a minimal necessary requirement to explain the epistemic fruitfulness of iconic representations. It is in this sense that Peirce's account of representation counts as slightly more substantive than Giere's general appeal to similarity, at the same time maintaining, as I will stress below, a strong emphasis on practice.

I propose that the relation posed by Peirce at the basis of iconic representations is more accurately expressed in terms of a weak form of morphism. The idea in itself is not entirely new, and even before it was explored in defence of structuralist accounts of representation and in defence of the semantic view of theories (Da Costa and French 2003; Bartels 2006), it became a well consolidated account of the representative function of logical diagrams. So, for example, Jon Barwise and Eric Hammer (1996, 71–72) and Jesse A. Norman (1999, 21–22) place a relation of homomorphism at the basis of the functioning of logical diagrams, and more broadly of heterogeneous systems of logic. It is this *logical* definition that I intend to adopt and extend to iconic representations more generally. Homomorphism is a structure-preserving mapping between two structures or sets. Contrary to isomorphism, homomorphism is a non-bijective, many-to-one mapping. Thus a source domain can be mapped onto a target domain, so long as their relevant structure is preserved. Moreover, the structural relation between the source and target does not necessarily extend to all the elements

of the target domain: part of the elements in the target might not be included in the mapping. The conditions holding for homomorphism can be summarized as follows:

(1) Elements of a source domain *A* represent elements of 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′*;
    (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*.

Thus construed, homomorphism helps in clarifying the ambiguous notion of 'likeness' that Peirce placed at the basis of iconic representations. Indeed, his own Existential Graphs qualify as 'iconic' in this particular sense. 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. Iconic representations trigger the discovery of novel facts, and act as the prime prompts for surrogative reasoning, because of the structural relation that they exhibit with the states of affairs that they represent. A theory of iconic representations as homomorphic representations accounts for structure preservation as a relation which is itself *discovered* through the process of representing, rather than a mere similarity of appearance. One question is whether homomorphism is in fact *too weak* as a representative relation—which might render it subject to the objection that anything can in principle be homomorphic to anything else. This criticism is very much along the lines of Suárez's claim that structures can only enter representation as instantiations, and as such they are 'underdetermined'. A Peircean answer to this problem would be that this is not the case if we consider representations as partaking of a process of discovery. In that case, the fact that homomorphisms are 'underdetermined' is actually a virtue and a precondition for surrogative reasoning. Considered as a description of how we *discover* representative relations, homomorphisms needs to be 'filled in' with other particular kinds of mapping, depending on specific representational uses, purposes, and the particular 'context of discovery' in which users operate. In this particular sense, a view of iconicity as homomorphism is perhaps the account of representation that is closer to Suárez's deflationist account—except that it does not pay the price of giving up a substantive account of representation altogether.

One last aspect of iconicity as homomorphism needs to be stressed—and this is a programmatic point that I intend to leave as an open suggestion in concluding my discussion. Framing representations from the viewpoint of discovery reinforces their relation with the practical aspects of experimentation, without denying the importance of philosophical questions about what counts as a representation in the first place. In this particular sense, my proposal is to shift the focus from the concept of

representation exclusively framed in an analytical fashion to a (Peirce-inspired) concept of *representative practices*. Here 'representative' serves as a reminder that constitutional questions still matter, that the business of philosophy has been, and continues to be, one involving (among other things) epistemological questions about the nature of representation. 'Practices', on the other hand, aims to reconcile such epistemological questions with concrete contexts of application and with the experimental work that goes into the use of models, diagrams, and the multitude of representational formats and tools scientists rely on in their daily activities. This is very much in line with Peirce's idea that surrogative reasoning of the kind that features in diagrams is inextricably related to practical experimentation. In the final version of his *Prolegomena to an Apology for Pragmatism* (c. 1906), Peirce states this in the clearest and most incisive manner:

> One can make exact experiments upon uniform diagrams; and when one does so, one must keep a bright lookout for unintended and unexpected changes thereby brought about in the relations of different significant parts of the diagram to one another. Such operations upon diagrams, whether external or imaginary, take the place of the experiments upon real things that one performs in Chemical and Physical research. Chemists have, I need not say, described experimentation as the putting of questions to Nature. Just so, experiments upon diagrams are questions put to the Nature of the Relations concerned. (CP 4.530)

Construed from the viewpoint of discovery, representative practices account for the process of inquiry, both theoretical and practical, that informs the construction and use of models, diagrams and the various tools scientists use for the purpose of surrogative reasoning. As a practicing scientist and a scientifically informed philosopher, Peirce did not divorce practical use from the question of what counts as a representation in the first place: on the contrary, he made this complementarity a keystone of his philosophy. And so should contemporary philosophers of science.

4. Conclusions

I have suggested that the philosophy of Charles S. Peirce, and in particular his formulation of iconic representations, can offer a useful way of reconciling what Suárez (2010) has described as the 'analytical' and 'practical' inquiries into the concept of scientific representation. In the course of this paper I have shown that a crucial concern for Peirce, especially evident in his formulation of a diagrammatic system of logic, was what we would now define, following Chris Swoyer (1991) and Suárez (2004) as 'surrogative reasoning'. While Suárez suggests that a deflationary approach to representations might be more suitable for the purpose of accounting for surrogative reasoning, I have shown that for Peirce a substantive account of iconic representations, however loose, was pretty much necessary. Indeed, in Peirce's case, the question of what counts as a representation was never divorced from its uses, and in particular from the process of experimentation triggered by the very act of representing. Finally, I have tentatively suggested that the complementarity of theoretical concerns and practical experimentation in Peirce's account of representations might

be best captured by shifting the focus from a concept of representation construed in a purely analytical fashion to a concept of *representative practices*, which reconciles constitutional questions with the pressing need to account for the uses and contexts of application of concrete representations for particular goals and purposes. Whether the notion of representative practices stands the challenges posed by analytical and practice-based accounts alike remains to be seen. However, its emphasis on the *discovery* and *construction*—rather than justification—of representative relations, along with its connection with observation and experimentation, might offer at least an avenue of productive debate, if not a useful third way, to reconcile these two accounts.

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Notes

[1] I owe this insightful point to Margherita Benzi.

[2] The literature on Peirce's theory of signs is voluminous, and a comprehensive review of it is beyond the scope of this article. It is worth mentioning, however, at least two recent publications that explicitly reconnect Peirce's semiotics to broader philosophical themes. Short (2007) offers an illuminating discussion of the relevance of Peirce's theory of signs to contemporary debates in epistemology, while Bergman (2009) draws together Peirce's semiotics with his broader views on the nature of scientific inquiry, offering an account of Peirce's theory of signs as a whole philosophy of communication. Two useful introductions to Peirce's semiotics for the uninitiated are Atkin (2010) and De Waal (2013).

[3] This is not unusual, as for Peirce diagrammatic representations, exemplified by his own system of diagrammatic logic, are a prime example of iconicity. The passage was written more or less at the time in which Peirce was developing his Existential Graphs, so it is not surprising to find 'diagrams' and 'icons' in the same sentence. Iconicity is, however, not just restricted to diagrammatic representations. For Peirce it incorporates a much broader range of representational formats. In a subsequent passage, he sub-classifies icons in three further categories, which he dubs 'hypoicons':

> Hypoicons may roughly [be] divided according to the mode of Firstness which they partake. Those which partake the simple qualities, or First Firstness, are *images*; those which represent the relations, mainly dyadic or so regarded, of the parts of one thing by analogous relations in their own parts, are *diagrams*; those which represent the representative character of a representamen by representing a parallelism in something else, are *metaphors*. (EP 2.274)

[4] It is important to note that Peirce always stressed the continuity, rather than mutual exclusiveness, of his semiotic categories. In other words, he explicitly claimed that we never deal with 'pure' icons (or 'pure' indexes, or 'pure' symbols). The three classes of signs are always experienced and used in their mediated form. So, in the case of iconic signs, the participation of indexical and symbolic components is essential in experiencing and using icons as representations. This will become especially clear in Peirce's the discussion of diagrams, where both indexical and symbolic elements are recognized by Peirce as indispensable in supporting and performing the iconic process of *making relations visible*. This aspect of Peirce's discussion also reinforces the criticism against interpretations of iconicity as entailing *exclusively* a relation of similarity or resemblance between a representation and its object.

[5] Perhaps a bit confusingly here, Peirce labels his two versions of the winding curve respectively as 'Figure 1' for the upper part, and 'Figure 2' for the lower part where the curve bends over and crosses itself. For an insightful discussion of Peirce's image in terms of William Hogarth's concept of *Serpentine Line*, see Viola (2012).

[6] Here it may be useful to reiterate the idea that for Peirce iconicity in representation is not exclusively a matter of 'resemblance' or 'likeness', and that the representative function of diagrams is not, and cannot be, exclusively iconic (see note 4). The operation of 'forcing attention' in diagrams is performed by their indexical components, for instance. And their material representation depends on shared conventions, which are indispensable for their interpretation as diagrams in the first place.

[7] Defenders of similarity (and selective similarity) comprise, among others, the early van Fraassen (1980), van Fraassen (2008), Giere (1988, 2004), and Teller (2001). On the isomorphism (or partial isomorphism) side of the debate are Da Costa and French (2003). Van Fraassen's (2008) 'structural empiricism' hinges on a notion of selective similarity that ultimately is explained in terms of (structural) isomorphism, whereas Giere (2004) proposes a much weaker notion of similarity that refrains to appeal to 'structure'.

[8] Goodman's criticism is addressed to a view of representation considered and defined exclusively in terms of resemblance. It must be noticed, however, that no philosophical definition of visual representations focuses *exclusively* on a notion of resemblance to explain the relation between pictorial representations and the objects they represent. This argument is developed, with specific reference to the relation of resemblance or 'likeness' that seems to govern Peirce's notion of iconic representations, by Dipert (1996, 381) and Shin (2002, 25).

[9] This is a more general problem affecting what is usually known as the semantic view of theories, which originated with Suppes (1960) and sees among its supporters van Fraassen (1980), Giere (1988), and Da Costa and French (2003).

[10] Indeed, as I show below, there are at least two recent accounts of scientific representations (Giere 2004; van Fraassen 2008) that attempt to bring together similarity and 'use', at the same time accounting for the fact that similarity does not exclusively exhaust the relation of representation.

[11] Practice-based accounts are a result of the most general 'turn to practice' that has characterized philosophy of science starting from the 1980s. The forerunners of this approach are Black (1962), Hesse (1963), and Achinstein (1968). Cartwright (1983), Hacking (1983), and Morgan and Morrison (1999) pioneered the shift towards practice-based approaches to models, whereas De Chadarevian and Hopwood (2004) have recently examined the historical context surrounding the production and use of models. More recent accounts include Suárez (1999, 2003) and useful overviews of this debate are in Frigg and Hunter (2010) and Suárez (2010). Some proponents of the semantic view have tried to reconnect a view of representation in terms of selective similarity with scientific practice: see for example Giere (2004) and van Fraassen (2008). The turn to practice in philosophy of science has a sociological counterpart in the accounts of representation in practice presented in Lynch and Woolgar (1990), and its recent revisited edition by Coopmans et al. (2014).

[12] Indeed, interpreting Peirce in light of contemporary structuralist accounts would only amount to projecting contemporary philosophical categories upon his account of representation, which would not do justice to the historical context in which Peirce formulated his ideas, and the specific aims that his account of representation was supposed to fulfil. Incidentally, the tendency to 'project' or attribute some of the assumptions advanced by contemporary structuralism to historical actors (Poincaré is a particularly recurrent case) seems to be a practice contemporary structuralists are particularly fond of.

[13] The emphasis on *form* makes Peirce's account slightly more subtle, and at the same time weaker, than the structuralist's emphasis on relations construed as set-theoretic structures.

Abbreviations for the Works of C. S. Peirce

CP followed by volume and paragraph number: Peirce (1931–1938/1958)

EP followed by volume and page number: Peirce (1992–1998)

MS followed by manuscript number (and page number, where available): unpublished manuscripts keyed to Robin (1967)

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