Abduction or the logic of surprise*

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> For the methods of thinking that are living activities in men are not objects of reflective consciousness.
>
> —Charles S. Peirce (1892, *CP* 3.404)

In the obituary of Jon Barwise, one of the greatest logicians of the second half of the twentieth century, Jon Dorbolo recalls how Barwise used to remark that 'logic is not playing games with symbols,' but it 'is the science of valid reasoning' (Dorbolo 2000: 179). Everyone who has taught logic at any level has noticed how difficult is — contrary to what might, in principle, be expected — to combine pure thought with real life in their pedagogy, in order to help the students to discover that what is taught in the classroom has some relation with their ordinary way of thinking.

The causes of this phenomenon are very complex, and are not reducible to a fear of psychologism or to the mathematization of modern logic since Frege. As is well known, the humanists of the fifteenth century were already very critical of the later medieval logicians, accusing them of having lost contact with the real problems in the middle of the obscure scholastic debates. For instance, according to Juan Luis Vives it is necessary 'to transform logic into a useful and practical tool, because the disciplines that deal with language are necessarily linked with vital and concrete experience' (Muñoz Delgado 1986: 119; Ashworth 1982; Cerezo 1996). In fact, much of the great interest in philosophy of language in the second half of the twentieth century has had a direct relation with this question of providing context for logic. Nevertheless, it is not enough to bring life back to logic by paying more attention to language. It will be also necessary to pay attention to the real processes through which human beings, professors of logic or lay people, acquire new ideas and discover new knowledge.

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In this wide framework, my attention will be focused on the American logician, scientist and philosopher, Charles S. Peirce (1839–1914). Peirce made relevant contributions to deductive logic, but he was primarily interested in the logic of science, and more especially in what he called *abduction* (as opposed to *deduction* and *induction*), which is the process whereby hypotheses are generated in order to explain surprising facts. Indeed, Peirce considered abduction to be at the heart not only of scientific research, but of all ordinary human activities. Nevertheless, in spite of Peirce's work and writings in the field of methodology of research, scarce attention has been paid to the logic of discovery over the last hundred years, despite an impressive development not only of scientific research but also of logic.

Having this in mind, the exposition is divided into five parts: 1) a brief presentation of Peirce, focusing on his work as a professional scientist; 2) an exposition of the classification of inferences by the young Peirce: deduction, induction and hypothesis; 3) a sketch of the notion of abduction in the mature Peirce; 4) an exposition of the logic of surprise; and finally, by way of conclusion, 5) a discussion of this peculiar ability of guessing understood as a rational instinct.

1. Peirce, scientist and philosopher

The figure and thought of Charles S. Peirce have remained neglected for decades, but since the late seventies there has been a general renewal of interest in his work. The late American novelist Walker Percy wrote on Peirce that 'most people have never heard of him, but they will' (Percy 1989: 80), and it seems that this prophetic statement is becoming a reality. In recent times the figure of Peirce has been gaining an ever-increasing relevance in very different areas of knowledge: in astronomy, meteorology, geodesy, mathematics, logic, philosophy, theory and history of science, semiotics, linguistics, econometrics, and psychology (Fisch 1980). In all of these fields, Peirce has been considered a pioneer, a forerunner or even a 'father' or 'founder' (in the cases of semiotics and pragmatism). Bertrand Russell's comment is representative: 'beyond doubt ... he was one of the most original minds of the later nineteenth century, and certainly the greatest American thinker ever' (Russell 1959: 276). Umberto Eco echoes this thought: 'Peirce was ... the greatest American philosopher of the turn of the century and beyond doubt one the greatest thinkers of his time' (Eco 1989: x–xi). Even among academic philosophers it has become a commonplace to say that Peirce is the most original philosophical mind that the United States has yet produced (Nagel 1982:

303), and his seminal role in a wide range of philosophical problems has been alluded to by many philosophers: Popper described Peirce as 'one of the greatest philosophers of all times' (Popper 1972: 212) and Putnam called him 'a towering giant among American philosophers' (Putnam 1990: 252).

Some factors which have increased the growing interest in Peirce's thought are his personal participation in the scientific community of his time, his valuable contribution to the logic of relatives, and his sound knowledge of the philosophy of Kant as well as of the Scholastic tradition, in particular Duns Scotus (Boler 1963; Beuchot 2002). For many years, the interpretation of Peirce's thought and its evolution from his early writings in 1865 until his death provoked wide disagreement amongst Peirce scholars. This was due in part to the fragmentary presentation of his work in the *Collected Papers*, and in part to his going against the grain. In recent years, however, a deeper understanding of the architectonic nature of his thought and of his whole evolution has been gaining general acceptance (Hausman 1993: xiv–xv; Houser 1992: xxix). In the last decade the major Peircean scholars have all clearly acknowledged the basic coherence and undeniable systematic unity of his thought (Santaella-Braga 1993: 401; Hausman 1993; Parker 1998).

Following Hookway to some extent (1985: 1–3), I think that the most accurate understanding of Peirce is to see him as a traditional and systematic philosopher, but one dealing with the modern problems of science, truth and knowledge from a very valuable personal experience as a logician and as an experimental researcher in the bosom of an international community of scientists and thinkers. In addition to his personal experience of scientific practice, his sound knowledge of the history of science and of the history of philosophy helped him to establish a general cartography of scientific methodology. Peirce's personal participation in the scientific community of his time buttresses whatever he has to say about science from a philosophical point of view. Having done research in astronomy, mathematics, logic and philosophy and in the history of all these sciences, Peirce tried all his life to disclose the logic of scientific inquiry.

Peirce was first and foremost a real practitioner of science. Not only was he trained as a chemist at Harvard, but for thirty years (1861–91) he worked regularly for the U.S. Coast Survey as a meteorologist and as an observer in astronomy and geodesy. His reports to the Coast Survey are an outstanding testimony to his personal experience in the hard work of measuring and obtaining empirical evidence. As Max Fisch points out: 'Peirce was not merely a philosopher or a logician who had read up on science. He was a full-fledged professional scientist, who carried into all

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his work the concerns of the philosopher and logician' (Fisch 1993: xxviii–xxix).

2. Deduction, induction, and hypothesis

From the time of his early works in logic, Peirce had been interested in the classification of arguments (Peirce 1867), in particular the several modes of inference, that is, of the different ways in which a true conclusion follows necessarily or probably from two premises. In 1878, in the series *Illustrations of the Logic of Science*, Peirce published in *Popular Science Monthly* his paper 'Deduction, Induction and Hypothesis,' which contains a classic exposition of the three modes of inference. According to Peirce, all deduction is nothing more than the application of a rule to a case in order to state a result:

> The so-called major premiss lays down this rule; as, for example, *All men are mortal*. The other or minor premiss states a case under the rule; as, *Enoch was a man*. The conclusion applies the rule to the case and states the result: Enoch is mortal. All deduction is of this character; it is merely the application of general rules to particular cases. (*CP* 2.620, 1878)

As it is obvious, not all forms of reasoning are reducible to deduction and can not be expressed by a syllogism of this type. Moreover, inductive reasoning never can be reduced to this form, because it is 'something more than the mere application of a general rule to a particular case' (*CP* 2.620, 1878). In order to illustrate the contrast between the different kinds of reasoning, Peirce employs the well-known example of the bag of beans, which has not been always well explained and well understood (see *CP* 2.621–623, 1878).

Let's imagine that we enter a room in which there are several bags of beans. If, from a bag of beans (of which we know that all are white), we take a handful, we can assert before looking at them that the handful of beans is white (if the rule is true). This has been a necessary deduction, the application of a rule to a case to state a result. We have, in effect, the following syllogism:

Rule: All the beans in the bag were white
Case: These beans were in the bag
Result: These beans are white

Let's imagine now that without knowing the color of the beans of the bag, we take a handful at random and, finding that all of the beans in the

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handful are white, we conclude that all the beans in the bag are white. The induction then is the inference of the rule from the case and result:

Case: These beans were in this bag
Result: These beans are white
Rule: All the beans in the bag were white

In this case the inference is not necessary and it is an inversion of the deductive syllogism. Deductive reasoning is analytic, since the conclusion does not add anything to what it is already in the premises. On the contrary, the inductive reasoning is synthetic or ampliative, since what is asserted in the conclusion was not in the premises.

But there is a second way of inverting a deductive syllogism to produce a synthetic inference. Let us suppose a new situation in which we enter in a room in which there are a number of bags, containing different kinds of beans. We find on the table a handful of white beans, and after some searching we find that one of the bags contains only white beans. Then we infer that very likely the handful on the table was taken out of that bag. 'This sort of inference is called *making an hypothesis*. It is the inference of a case from a rule and a result.' (*CP* 2.623, 1878).

Rule: All the beans from this bag are white
Result: These beans are white
Case: These beans are from this bag

In this paper Peirce does not use still the term 'abduction' for this kind of inference. He uses the terms 'hypothesis,' 'a fair guess' or 'supposition'. As in the case of induction, this hypothetical inference is not necessary but merely probable and is also a kind of ampliative or synthetic reasoning. Hypotheses may be very diverse, but all of them have in common that they are formulated to explain an observed phenomenon. Peirce illustrates his exposition with examples from natural science (from the presence of marine fossils in the interior of the country we infer that the sea once was upon this land) and from the human sciences (from the documents that refer to Napoleon Bonaparte we infer that he really existed), and with a very appealing personal experience that deserves quotation:

I once landed at a seaport in a Turkish province; and, as I was walking up to the house which I was to visit, I met a man upon horseback, surrounded by four horsemen holding a canopy over his head. As the governor of the province was the only personage I could think of who would be so greatly honored, I inferred that this was he. This was an hypothesis. (*CP* 2.625, 1878)

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3. The logic of abduction

Abduction is a kind of inference characterized by probability. The conclusion reached by abduction is conjectural, thus only probable, but to the researcher the conclusion seems totally plausible. In Peirce's mature thought this plausibility, this intuitive force of abduction, is where its validity resides: 'probability proper had nothing to do with the validity of Abduction, unless in a doubly indirect manner' (*CP* 2.102, 1903). In his later years Peirce coined the terms 'retroduction,' or reasoning backwards, and 'abduction' to refer to the process of adoption of an hypothesis. He dedicated a lot of writings — a good amount of them still unpublished — to the study of this operation. The study of abduction becomes so important for Peirce that he does not hesitate to write that the question of pragmatism 'is nothing else than the question of the logic of abduction' (*CP* 5.196, 1903).

Since the texts of Peirce which illustrate his notion of abduction could be multiplied almost indefinitely, I have preferred to quote only the following lengthy one, which until now has remained unpublished:

> *Abduction* is that kind of operation which suggests a statement in no wise contained in the data from which it sets out. There is a more familiar name for it than *abduction*; for it is neither more nor less than guessing. A given object presents an extraordinary combination of characters of which we should like to have an explanation. That there is any explanation of them is a pure assumption; and if there be, it is some one hidden fact which explains them; while there are, perhaps, a million other possible ways of explaining them, if they were not all, unfortunately, false. A man is found in the streets of New York stabbed in the back. The chief of police might open a directory and put his finger on any name and guess that that is the name of the murderer. How much would such a guess be worth? But the number of names in the directory does not approach the multitude of possible laws of attraction which would have accounted for Kepler's laws of planetary motion and in advance of verification by predictions of perturbations etc., would have accounted for them to perfection. Newton, you will say, assumed that the law would be a simple one. But what was that but piling guess on guess? Surely vastly more phenomena in nature are complex than simple. By its very definition abduction leads to a hypothesis which is entirely foreign to the data. To assert the truth of its conclusion ever so dubiously would be too much. There is no warrant for doing more than putting it as an interrogation. To do that would seem to be innocent; yet if the interrogation means anything, it means that the hypothesis is to be tested. (*MS* 692: 24–25, 1901)

Peirce was deeply impressed by this phenomenon of the introduction of new ideas in scientific research, which is totally unexplained by a mere

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calculation of probabilities. The phenomenon of scientific creativity involves the combination of abduction, deduction and induction.

> To abduction corresponds the task of introducing new ideas in science; in a word, creativity. Deduction draws the necessary and verifiable conclusions that *should follow* if the hypothesis would be true, and induction confirms experimentally the hypothesis in a certain number of cases. They are three kinds of reasoning that do not occur independently or in parallel, but integrated and cooperating in the successive steps of the scientific method. (Génova 1997, 56–57)

The starting point of research is always abduction. It generates the hypothesis that suggests what experiments must be performed, in which directions it is necessary to look. The scientist, without a previous hypothesis, can not determine what kind of experiment is necessary for further research. For this reason, it is striking that most of the contemporary philosophers of science who analyze the scientific method tend to ignore completely the logical problem of the source of hypotheses or scientific theories (Génova 1997, 117; Hanson 1961, 20). For them, scientific method starts when a theory is available to be confirmed or refuted by experiments; the origin of the new ideas is considered an issue belonging to psychology or sociology of knowledge. The origin of hypothesis is regarded as a question totally alien to logic; it is considered, in Peirce's term, a 'supernumerary logic' (*MS* 692: 26, 1901)

In my view, a crucial means for overcoming the scientistic materialism still dominant in our culture lies in the understanding of creativity. If we were able to understand a little better the process of generation of new ideas, we would better understand what constitutes human rationality. For most of our contemporaries, however, creativity is confined to the realm of the unknown, to the realm of the genius or of chance. It is not part of scientific knowledge, because it is not reducible to physicalist language or to a mathematical algorithm. In this sense, it is clear why modern attempts to formalize this inferential process (for instance, Josephson and Josephson 1994) have avoided entirely the human dimension of the process.

We have reached the heart of the matter: Why do we abduce? Why do we generate hypotheses? From where does abduction spring? This is the logic of surprise, to which I refer in the title of this paper. The final part of this paper is dedicated to considering this set of questions.

4. The logic of surprise

At the very beginning of Western philosophy, Aristotle stated that 'wonder' is the starting point of all search of knowledge. In his well-known

passage at the beginning of the *Metaphysics*, he asserts that it is 'owing to their wonder that men both now begin and at first began to philosophize; they wondered originally at the obvious difficulties, then advanced little by little and stated difficulties about the greater matters' (982b 12–17). In this vein, William Shea, head of the European Science Foundation, commented recently that 'no high-tech will replace our ability to wonder at ourselves' (Shea 2000: 2). This assertion is true, but it should be complemented with Peirce's thesis that the trigger of all genuine research is surprise. It is not only that wonder moves us to research, but that wonder surprises us and demands our understanding.

In Peirce's *Collected Papers* there are 127 occurrences of 'surprise' (and related terms), most of them in his texts after 1901. Surprise arises from the breaking of a habit, it 'breaks in upon some habit of expectation' (*CP* 6.469, 1908). Our activity of research begins when we realize that we had some erroneous expectation, which perhaps we ourselves were not even conscious of having. 'Each branch of science begins with a new phenomenon which violates a sort of negative subconscious expectation' (*CP* 7.188, 1901). Our beliefs are habits, and as such, tend to force the human being to continue in belief until something surprising occurs, some new internal or external experience breaks that habit. A 'surprising' phenomenon demands a regularization that makes the surprise disappear through the creation of a new habit.

Research starts with the acknowledgment of some anomaly, of something surprising What makes a phenomenon surprising? It is not mere irregularity. 'Nobody is surprised that the trees in a forest do not form a regular pattern, or asks for any explanation of such a fact. So, irregularity does not prompt us to ask for an explanation' (*CP* 7.189, 1901). Mere irregularity creates no surprise where no definite regularity is expected, because in our life irregularity is 'the overwhelmingly preponderant rule of experience, and regularity only the strange exception' (*CP* 7.189, 1901).

> In what a state of amazement should I pass my life, if I were to wonder why there was no regularity connecting days upon which I receive an even number of letters by mail and nights on which I notice an even number of shooting stars! But who would seek explanations for irregularities like that? (*CP* 7.189, 1901)

An event that can be answered in an habitual form does not cause any surprise. On the contrary, a 'surprising' fact requires a change in our rational habit of belief; it demands an explanation. An explanation makes the facts rational, that is, it enables the acquisition of a belief that explains the fact, rendering it reasonable. When the phenomenon is reasonable it is no longer surprising. In Peirce's words:

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> [W]hat an explanation of a phenomenon does is to supply a proposition which, if it had been known to be true before the phenomenon presented itself, would have rendered that phenomenon predictable, if not with certainty, at least as something very likely to occur. It thus renders that phenomenon rational — that is, makes it a logical consequence, necessary or probable. (*CP* 7.192, 1901)

The phenomenon of surprise has no relation to Cartesian doubt, which for Peirce is a mere 'paper-doubt' (*CP* 5.445, 1905; 5.416, 1905). Genuine doubt always has an external origin, usually from surprise, and cannot be produced by an act of the will (*CP* 5443, 1905). 'There is every reason to suppose that belief came first, and the power of doubting long after. Doubt, usually, perhaps always, takes its rise from surprise, which supposes previous belief; and surprises come with novel environment'. (*CP* 5.512, 1905). Surprise produces some irritation and demands a hypothesis; it forces us to seek an abduction which make the surprising phenomenon into a reasonable one. The late Donald Davidson related the following story of an inferential misunderstanding that all of us understand well, because in one or other way we have suffered similar experiences:

> It was a warm day, doors stood open. I lived in one of a row of attached houses in which faculty members were housed. I walked in the door. I was not surprised to find my neighbor's wife in the house: she and my wife often visited. But I was slightly startled when, as I settled into a chair, she offered me a drink. While she was in the kitchen making the drink I noticed that the furniture had been rearranged, something my wife did from time to time. And then I realized the furniture had not only been rearranged, but much of it was new — or new to me. Real insight began when it slowly came to me that the room I was in, was a mirror-image of that room I was familiar with; stairs and fireplace had switched sides. I had walked into the house next to mine. (Davidson 1985: 347; see also Wirth 1998, 120)

Davidson explains that his faulty interpretation was an error in the process of hypothesis adoption, because he was able to accommodate the growing evidence against his supposition that he was in his own house 'by fabricating more and more absurd or far-fetched explanations' (Davidson 1985: 347). All of us have personal experience of similar phenomena. For example, while driving we may lose our way without notice, and we try to convince ourselves that we are still on the right path, interpreting what we see according to our expectations.

We are now in a better position to understand clearly the logic structure of abduction. According to Peirce's explanation in the seventh of his 'Lectures on Pragmatism' it is the following (*CP* 5.189, 1903):

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> The surprising fact, C, is observed;
> But if A were true, C would be a matter of course,
> Hence, there is reason to suspect that A is true.

This is the logical structure of all abductions. The key for understanding it properly is to realize that the trigger of abduction is the surprising character of the fact referred to in the first premise, and the 'motor' the work of imagination in the second premise. In the second premise, one discovers that if some hypothesis were true it would render the surprising fact to be a matter of course, something normal, reasonable, and thus something not surprising. If this is the case it is reasonable to think that A is true. Not only are detective stories full of abductive reasoning, but our everyday lives contain many examples of its effective use. Medical diagnoses, for instance, follow its structure: from certain surprising symptoms and a classification of diseases, some particular disease is chosen to make those symptoms reasonable (Eco and Sebeok 1983; Niño 2001).

Creativity lies essentially in the way in which the subject relates the elements available in the different realms of his or her experience. This is not only an inferential process: 'The abductive suggestion comes to us like a flash. It is an act of insight, although of extremely fallible insight. It is true that the different elements of the hypothesis were in our minds before; but it is the idea of putting together what we had never before dreamed of putting together which flashes the new suggestion before our contemplation.' (*CP* 5.181, 1903). This — as Fontrodona has argued lucidly (2002) — is what a good business manager does: to combine the elements of a problem in such a way that the problem can be understood as an opportunity.

5. The rational instinct

Although our hunches often fail, as illustrated by Davidson's anecdote, the really intriguing question concerns the frequency in which we guess correctly, both in ordinary life and in scientific research. A surprising feature of scientific research is that it can reach a true explanation after a relatively few number of attempts (Génova 1997: 68). This is illustrated by Peirce in the sixth of his 'Lectures on Pragmatism' (1903):

> A man must be downright crazy to deny that science has made many true discoveries. But every single item of scientific theory which stands established today has been due to Abduction. But how is it that all this truth has ever been lit up by a process in which there is no compulsiveness nor tendency toward compulsiveness?

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> Is it by chance? Consider the multitude of theories that might have been suggested. A physicist comes across some new phenomenon in his laboratory. How does he know but the conjunctions of the planets have something to do with it or that it is not perhaps because the dowager empress of China has at that same time a year ago chanced to pronounce some word of mystical power or some invisible jinnee may be present. Think of what trillions of trillions of hypotheses might be made of which one only is true; and yet after two or three or at the very most a dozen guesses, the physicist hits pretty nearly on the correct hypothesis. By chance he would not have been likely to do so in the whole time that has elapsed since the earth was solidified. (*CP* 5.172, 1903)

These are the questions that lie at the foundation of all the scientific enterprise: Why do we get theories right and why we do it in a relatively easy way? For Peirce, the explanation of this surprising phenomenon of the human ability to choose easily and correctly between those innumerable hypotheses lies in 'that man's mind must have been attuned to the truth of things in order to discover what he has discovered. It is the very bedrock of logical truth' (*CP* 6.476, 1908). Peirce appeals in his 'A Neglected Argument for the Reality of God' (*CP* 6.452–6.485, 1908) and in several other places (*CP* 1.80, c. 1896; 1.630, 1898; 5.589, 1898, 6.10, 1891; 6.567, 1905) to *il lume naturale* — borrowing the expression from Galileo — in order to explain this surprising ability to guess the right answer from a great variety of possibilities. It is 'the simpler Hypothesis in the sense of the more facile and natural, the one that instinct suggests, that must be preferred; for the reason that, unless man have a natural bent in accordance with nature's, he has no chance of understanding nature at all' (*CP* 6.477, 1908).

This ability of guessing right is neither blind nor infallible, but is an *instinctive* ability, similar to the animal instinct of flying or nest-building of ordinary birds (*CP* 6.476, 1908). Since abduction is a kind of inference instinctive and rational at the same time, Ayim has suggested calling this ability the *rational instinct*. This guessing instinct is a result of the development of our animal instincts and of the process of rational adaptation to our environment (Ayim 1974: 42). It could be also called *creativity*.

Peirce appeals to the affinity between mind and universe to explain the development of classical mechanics despite poor experimental support:

> our minds having been formed under the influence of phenomena governed by the laws of mechanics, certain conceptions entering into those laws become implanted in our minds, so that we readily guess at what the laws are. Without such a natural prompting, having to search blindfold for a law which would suit the phenomena, our chance of finding it would be as one to infinity. (*CP* 6.10, 1891)

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But, the ultimate explanation of that surprising efficiency of human scientific creativity has to be found, according to Peirce, in the peculiar affinity between our cognitive abilities and nature, that refers in the last analysis to the divine creation of the universe and of the human mind. This conviction of Charles Peirce was probably inherited from his father Benjamin:

> If the common origin of mind and matter is conceded to reside in the decree of a Creator, the identity ceases to be a mystery. The divine image, photographed upon the soul of man from the centre of light, is everywhere reflected from the works of creation … 'In the beginning God created the heavens and the earth.' Without this treasure of faith, the omnipresent ideality of science terminates in an impoverished and powerless pantheism. With it, the observed ideality is the divine thought, and the book of Nature is the divine record. (Benjamin Peirce 1881, 31 and 36)

For Peirce, the explanation of the efficiency of our scientific creativity, of our abductions, is to be found in God, and the proof of that is another abduction. In his 'Neglected Argument for the Reality of God' of 1908, Peirce makes a 'Big Abduction' that might be put in the following terms (following the pattern of *CP* 5.189, 1903):

> The development of science is a really surprising fact
>
> If God were the creator of human cognitive abilities and of nature that development would be a matter of course
>
> Hence, there is reason to suspect that God is the creator of human minds and nature.

This may sound a little strange to our positivistic ears, but this is the 'surprise' of the logic of surprise. 'Experience is our great teacher; invariably it teaches by means of surprises' (*MS* 309, 1903). To explain this in detail would require another paper (Nubiola, forthcoming).

Note

* In previous years, I have presented several lectures in Argentina, Mexico and Spain about my ideas on the role of surprise in abduction, and finally, thanks to the kind invitation of Floyd Merrell and Joao Queiroz, these ideas will go to print for the first time in this special issue of *Semiotica*. In this research I am heavily indebted to the work of my doctoral student Gonzalo Génova (1997) with whom I learned a lot about abduction. I also want to thank Erik Norvelle who revised my English.

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