1 TURING AND AUTOMATED TEXT PROCESSING

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ABSTRACT: Turing's contention that all mental functions can be reduced to computable operations seems to be questioned precisely by applied computation to text processing. Criticisms have been addressed to the test proposed by Turing for an empirical verification of his conjecture, both from an objective and a subjective point of view, namely by Penrose and Searle. Automated text processing allows us to transpose Searle's objections into a linguistic context and to show that they raise the same questions as those brought up by Penrose, i.e. the problems of computability and indeterminacy. These very questions were among Turing's last concerns and he seemed to envisage a coupling of indeterminate descriptions of physical phenomena with scientifically computable predictions of their objective states. A proper discussion of these problems requires however, as S. Barry Cooper suggests, a full recognition of the new scientific paradigm emerging from the advancement of physics in the 20th century. In this respect, both Merleau-Ponty's epistemological reflections and, on a more formal level, the foundational implications of the new calculus of indications introduced by the English mathematician George Spencer Brown, prove themselves to be highly relevant suggestions.

1 MIND, LANGUAGE AND THE TURING MACHINE

By general consent Alan Turing's seminal paper on the 'universal machine',[1] is now recognized as 'the founding work of modern computer

1 Cf. Turing (1936-37). 'Th[is] paper [...] gave a definition of computation and an absolute limitation on what computation could achieve' (Hodges 2013).

science' (Hodges 2013). However, certain results of applied computation seem to belie some of Turing's most philosophically engaging contentions. This is the case — under discussion here — of automated text processing, whose procedures and current applications clearly defy some basic assumptions of artificial intelligence (AI), a field of study that admittedly finds its earliest motivations in Turing's ideas.[2]

According to Andrew Hodges 'Turing was a mathematician' and 'not really a philosopher,' but it was not so 'curious,' as Hodges suggests, that his 'best-known paper should appear in a journal of philosophy.' For, although Turing's contribution to science chiefly consisted in 'his treating the subject of symbolic logic as a new branch of applied mathematics, giving it a physical and engineering content,' it is nevertheless true, as Hodges himself admits, that Turing always 'had in mind something greater.' As he seems to have imparted to his assistant in 1944, he had the idea of 'building a brain,'[3] and these 'provocative words [. . .] from the outset announced the relationship of Turing's technical computer engineering to a philosophy of Mind.' But that deep-rooted assumption of his is precisely what is called into question by the results of computation as applied to the automated processing of text. It is then worthwhile to dwell on how Turing connected the working of what he called '*automatic* machines' to 'what the *human mind* can do when carrying out a procedure' (Hodges 2013).

2 THE TURING TEST

Since 1945 Turing was convinced that 'computable operations were sufficient to embrace all mental functions performed by the brain,' but in order to asses the potentialities of computation as opposed to those of the human brain, in his renowned article *Computing Machinery and Intelligence* published in *Mind* in 1950, he decided 'to bypass discussions of the nature of thought, mind, and consciousness,' and 'to give a criterion in terms of external observation alone' (Hodges 2013). According to Turing, 'the question "Can machines think?"' would then

2 Cf. Turing (1950), and Hodges (2013): '[Its] contention was that the computer, when properly programmed, could rival the brain. It founded the "Artificial Intelligence" program of coming decades.'

3 Cooper (2012, 3): 'Turing himself is said by Andrew Hodges to have spoken to Donald Bayley in 1944 of "building a brain".' Cf. Hodges (2012, 290): 'Alan had also told Don Bayley from the start of their collaboration that he wanted "to build a brain".'

'be described in terms of a game which we call the "imitation game"' (Turing 1950, 433). In this game 'a human being and a programmed computer compete to convince an impartial judge, using textual messages alone, as to which is the human being.' This 'thought-experiment,' which nowadays could readily be tried out, is now usually called 'the Turing test' for intelligence. It should have offered an empirical criterion to verify the hypothesis that 'computable operations' are 'sufficient to embrace all mental functions performed by the brain' (Hodges 2013).

Such a conjecture takes Turing beyond the mere characterization of algorithmic procedures as what is 'calculable by means of an L.C.M.' (Turing 1969 [1948], 7), i.e. by a*Logical Computing Machine* — the designation that he himself used to apply to the machine he had described in his fundamental 1936 article, *On Computable Numbers*. In other words, Turing did not confine himself to asserting that the definition of an algorithmic procedure as an effective, or mechanical, method (the so-called 'Church Thesis') could be considered equivalent to the definition of 'computability by a Turing machine' (Church 1937, 43). He 'had something further in mind' and esteemed 'that the computational capabilities of any *physical* device must (in idealization) be equivalent to the action of a Turing machine.' Therefore, according to Roger Penrose,

> it seems likely that he viewed physical action in general — which would include the action of a human brain — to be always reducible to some kind of Turing-machine action. Perhaps one should call this (physical) assertion 'Turing's thesis', in order to distinguish it from the original (purely mathematical) assertion of 'Church's thesis' (Penrose 1994, 20–21).

Quite understandably an ample discussion has ensued on what Penrose suggested calling 'Turing thesis' and many reservations have been addressed to the idea that the 'imitation game' that Turing described in his 1950 *Mind* paper — the so-called 'Turing test' — should be accepted as a verification test for his strong physical hypothesis on the relation between the logical operations of the Turing machine and the physical operations of a human brain. Here we shall consider only two critical positions — one taken by a physicist (Penrose) and the other taken by a philosopher (Searle) — that typically exemplify two different points of view on how to account for the relationship between the logical and the physical aspects of the operations of the human mind.

3 PENROSE'S RESERVATIONS

As it has been recalled, Penrose draws a distinction between Turing's logical thesis, that is equivalent to Church's thesis, and Turing's physical thesis, that Penrose does not think is tenable. According to Penrose, the operations of the mind are not computable, because the laws that make them physically possible are quantum laws and, accordingly, they are not of a deterministic kind. Andrew Hodges, in a lecture delivered in Hamburg in the year 2000, summarizes Penrose's views in the following way:

> Gödel's theorem tells us that we can see the truth of statements which cannot be proved by the application of a formal system of rules. Using Turing machines, this argument can be put in the form of showing minds able to perform uncomputable operations. Gödel also took this view of the mind's power, but unlike Gödel, Penrose insists on a materialist or physicalist base for mental faculties and deduces that there must be uncomputable elements in physical law which the brain exploits when it performs the uncomputable work of seeing the truth. Penrose locates these elements in the as yet unknown laws governing the reduction of the wave-function in quantum mechanics. Hence Penrose explicitly contradicts 'Turing's Thesis' in the form he has given(Hodges 2002).

Thus, whereas Turing's interest, in the years following 1950, was wholly turned to 'the potential of computability, and of his own discovery that all computable operations can be implemented on a single, universal, machine' (Ibid.), Penrose holds that 'the function of the brain cannot be simulated by a computer program, because of its quantum-mechanical physical basis.'

According to Hodges, Penrose 'has taken up' precisely 'the two themes that Turing found most difficult to fit into his thesis of computable mental functions — Gödel's theorem and the quantum-mechanical reduction process' of the wave function (Hodges 2008, 21).[4] But whereas Turing, in his last years, privately disclosed his intention to recast the laws of quantum mechanics in order to solve the predictability problem of the reduction process,[5] Penrose does not move away from Eddington's position, referred by Turing himself, according to whom 'on account of the indeterminacy principle in quantum mechanics no such prediction is even theoretically possible' (Turing 2004, 112–13).[6] The problem, then, seems to originate from the way of understanding the indeterminacy principle and its import: apparently Turing never gave up his project, aimed at expanding the applicability range of computation, whereas Penrose insists on the indeterministic consequences of quantum mechanics. In collaboration with the anesthesiologist Stuart Hameroff, Penrose has recently put forward a theory[7] that tries to provide a tangible explanation of uncomputable mental phenomena on the basis of physical processes of 'orchestrated objective reduction' — discrete events that would come along in the microtubule that organize the cell interiors of brain neurons and that would be at the root of 'conscious causal agency' (Hameroff 2012, 1–2). Penrose himself summarizes his position as follows:

> I have tried to stress that the mere fact that something may be scientifically describable in a precise way does not imply that it is computable. It is quite on the cards that the physical activity underlying our conscious thinking may be governed by precise but non-algorithmic physical laws and our conscious thinking could indeed be the inward

4 Cf. Penrose (1989).

5 Turing (1953–54): 'I'm trying to invent a new Quantum Mechanics but it won't really work.'

6 On this text of Turing's 1951 broadcast,B. Jack Copeland writes (2012, 651): 'Turing's lecture *Can Digital Computers Think?*was broadcast on BBC Radio on 15th May 1951 (repeated on 3rd July). [...] In modern times, *Can Digital Computers Think?*was virtually unknown until 1999, when I included it in a small collection of unpublished work by Turing ('A Lecture and Two Radio Broadcasts on Machine Intelligence' by Alan Turing, in *Machine Intelligence* 15) and again in *The Essential Turing* in 2004. The [...] published text [...] is from Turing's own typescript and incorporates corrections made in his hand.' As to Eddington himself, in his Gifford Lectures delivered at The University of Edinburgh in 1927, he overtly states (1928, 307): 'It is just this simple prediction that the principle of indeterminacy expressly forbids.'

7 Cf. Penrose (1994).

> manifestation of some kind of non-algorithmic physical activity (Penrose 1990, 653).

Penrose, then, criticizes what he calls the 'Turing's thesis' on the basis of the indeterminacy principle and his explanation of the un-computability of mental operations is clearly objectivist in nature and characterized by strong reductionist leanings.

4 SEARLE AND THE CHINESE ROOM ARGUMENT

Quite different in nature are the criticism leveled by Searle at the Turing test, at its adequacy and the programme of artificial intelligence. Searle thinks of a practical set-up for the 'imitation game' proposed by Turing in order 'to argue that intelligence of a human level could be evinced by a suitably programmed computer' (Hodges 2008, 14). Searle's *Gedankenexperiment*(Searle 1980a, 417), though, would be such as to disprove the validity of Turing's verification procedure. Searle himself describes his 'refutation' of the Turing test as follows:

> Imagine a native English speaker, let's say a man, who knows no Chinese locked in a room full of boxes of Chinese symbols (a data base) together with a book of instructions for manipulating the symbols (the program). Imagine that people outside the room send in other Chinese symbols which, unknown to the person in the room, are questions in Chinese (the input). And imagine that by following the instructions in the program the man in the room is able to pass out Chinese symbols that are correct answers to the questions (the output). The program enables the person in the room to pass the Turing test for understanding Chinese, but he does not understand a word of Chinese (Searle 2001, 115).

Now if the man in the room is not in a position to understand Chinese just because he carries out the instructions of the programme, neither can a computer: 'just manipulating the symbols is not by itself enough to guarantee cognition, perception, understanding, thinking and so forth' (Searle 1990, 26). So, Searle comes to the conclusion that 'implemented programs are not constitutive of minds': the man can pass the Turing test, but he does not understand Chinese, for 'he has only the formal syntax of the program and not the actual mental content or semantic content that is associated with the words of a language when a speaker understands that language.' If the questions are put to him in his native English, the man understands them, but if they are put to him in Chinese he does not understand them and, in this case, 'he is acting as a digital computer.' Hence, the Turing test fails to distinguish real mental capacities from simulations of those capacities: 'simulation is not duplication, but the Turing test cannot detect the difference' (Searle 2001, 115).

As it has been said, 'Searle's Chinese room argument [...] is perhaps the most influential and widely cited argument against claims of artificial intelligence (AI)' (Hauser 1997, 199), or more accurately against 'a Turing-style test of machine understanding' (Bishop 2012, 581). And 'although the last thirty years have seen tremendous controversy over the success of the Chinese Room Argument, a great deal of consensus over its impact has emerged' (Bishop 2004, 47). So, even one of those who have criticized it, admits that Searle's argument 'has rapidly become a rival to the Turing Test as a touchstone for philosophical inquiries into the foundations of AI' (Rapaport 1988, 83). Searle's controversial target is indeed artificial intelligence. His criticism, though, is deliberately leveled only at the so-called 'strong AI', that is to say at the claim that 'an appropriately programmed digital computer [...] that satisfies the Turing test, would necessarily have a mind,' and not at the positions of the so-called 'weak AI,' namely the view that the computer 'is a useful device for simulating and therefore studying mental processes,' without implying that an implemented programme would 'automatically guarantee the presence of mental states' (Searle 2001, 115). What the Chinese room argument shows is only that 'computation, as defined by Alan Turing and others as formal symbol manipulation, is not by itself constitutive of thinking' (116).

As a matter of fact, Searle does not maintain that a machine or a computer 'can't think,' for also 'the brain is a machine,' a biological machine, but nevertheless always a machine that can think and carry out computations. Besides, Searle does not think either 'that only brains can think,' for 'there is no logical obstacle' preventing that a machine endowed with the same 'causal powers' as a brain, could duplicate its activity 'to produce the biological process of thinking.' So, also according to Searle, thinking is the product of the causal action of a machine, but he categorically denies that the mental processes produced by a brain, or by a machine 'able to duplicate the specific causal powers' of a brain (116), could be reduced to sheer 'formal or syntactical symbol manipulations.' Mental operations cannot be 'defined purely in terms of formal or syntactical symbol manipulations' and, on that basis, there is 'no way to get from the syntax to the semantics.' For,

> minds have mental or semantic contents. (For example, in order to think or understand a language you have to have more than just the syntax, you have to associate some meaning, some thought content, with the words or signs.) (115)

In short, to put it 'in the linguistic jargon,' formal symbol manipulations 'have only a syntax but no semantics (Searle 1980a, 422), and 'syntax by itself is neither constitutive of nor sufficient for semantics' (Searle 1990, 27).

It is worth mentioning, though, that in his 1980 paper, where he expounds his Chinese room argument, Searle spells out his reflections from a philosophy of mind point of view and describes the mental contents produced by the 'causal properties' of a brain as 'intentional states'(Searle 1980a, 421). As to the notion of 'intentionality,' albeit dissociating himself 'from certain features' of its common understanding, Searle follows 'a long philosophical tradition' that conceives of intentionality as 'that property of many mental states and events by which they are directed at or about or of objects and states of affairs in the world' (Searle 1983, 1). Accordingly, 'many of our mental states' are 'in this way directed or intentional' (Searle 1979, 74) and can be 'defined in terms of their content' as, for instance, 'a certain mental content with conditions of satisfaction, a direction of fit (see Searle 1979),[8] and the like' (Searle 1980a, 423). Therefore, Searle clearly adopts a

8 The 'phrase "direction of fit" was first used' (Humberstone 1992, 20) by the philosopher of language J. L. Austin (1953). It means both the 'illocutionary point,' or purpose, 'to get the words (more strictly, their propositional content) to match the world,' and the purpose 'to get the world to match the words' (Searle 1979b, 3). The notion, so described, distinctly recalls Husserl's conceptions of *Erfüllung* and *erfüllende Bedeutung*or Thomas Aquinas' correspondence theory of *adaequatiorei et intellectus*.

subjectivist point of view. More precisely, by accepting the notion of intentionality, understood as a conscious state of mind, Searle posits an unconditional 'ontological subjectivity' (Searle 1991, 46; see also 2002, 22–23) and regards as scientifically acceptable 'the first-person point of view' (Searle 1980b, 451). Assuming that the mind basically consists of 'conscious experiences' (Searle 1992, 63) of a 'private' and 'introspectable' kind (Hauser 1997, 206), this conviction or 'thesis', as it has been defined by Larry Hauser (2005), states that 'the ontology of the mental is essentially a first-person ontology' (Searle 1992, 20). So it is no surprise that in describing the condition of the man located in the Chinese room, Searle refers explicitly to the personal 'point of view' of that man, to 'his' *own* point of view (Searle 2001, 115), namely what the man perceives as his own first-person conscious mental state; nor is it surprising that he does so advisedly, even though, in the opinion of his critics, it is precisely by 'privileging the first person' that Searle 'fatally biases the thought experiment' he had himself proposed (Hauser, 1997: p. 205). But what Searle wants to maintain is precisely a subjectivist and anti-reductionist idea of the mind. Indeed, in his opinion, the endowment of mental capacities is related to the presence of ascertained intentional states and 'any intentional state is either actually or potentially a conscious intentional state,'so that 'the attribution of any intentional phenomena to a system, whether "computational" or otherwise,' depends on 'a prior acceptance of our ordinary notion of the mind,' i.e. the 'conscious "phenomenological" mind' (Searle 1991, 47).

5 A LINGUISTIC TRANSPOSITION: THE DIGITAL TEXT

The Chinese room argument proposed by Searle does not address directly the issues of indeterminacy and computability. Searle insists rather on the subjective aspects of mental activity and brings attention to the capacities that the mind must necessarily possess and that cannot be reduced to the mere manipulation of symbols. However a more careful analysis can highlight that precisely those issues that at first glance seem to be, if not ignored, at least set aside — the question of uncertainty and the question of computability on which Penrose insists — are indirectly reintroduced by the arguments that Searle puts forward, first, on the ability of the mind to associate to symbols appropriate semantic content and, secondly, on the presence in the mind of conscious experiences and intentional states. It is then possible to show, taking into account the consequences of the application of computational procedures to the analysis of literary texts, that the criticism leveled at the Turing Thesis by Penrose and Searle, from respectively different points of view, one subjective and the other objective, can be considered in fact complementary and to a large extent convergent. Beyond the concrete results obtained on the linguistic and literary level, automated text processing reveals all its theoretical significance in making the linguistic implications of Searle's argument and of Turing's thesis quite explicit, and in showing the intrinsic complementarity of the two different orientations that call into question the validity of the Turing test.

Now, from a computational point of view, text is considered as data, i.e. as a form of representation of textual information, namely as 'information coded as characters or sequences of characters' (Day 1984, 1). We must therefore ask whether this form of representation of textual information is adequate, both from the point of view of the exhaustiveness of the representation, and from the point of view of its functionality. As to the exhaustiveness, it can be easily understood that a printed or a manuscript page, namely the conventional form of representation of a text viewed as 'literary material as originally written by an author' (Ibid.), contains much more information than the mere sequence of its characters. The common approach to solve the problem consists in inserting, in the sequence or string of characters that provides textual data and constitutes the digital representation of a text, some markers or tags capable of representing the specific linguistic and textual properties of certain segments of the string. Apart from supplying missing information, data *markup* — or *text encoding*, as it is called as well in current usage — is also used for assigning a structure to the string of characters, in order 'to process textual data as structured information' (Buzzetti 2009, 48) and 'to distinguish information and knowledge from mere "digital stuff"' (Cover et al. 1991, 197–8), i.e. from sheer textual data, or *flat* text, comprised by an unstructured string of characters.

In hindsight though, this solution is inadequate, not only with regard to the exhaustiveness, but also and above all in respect of the functionality of textual representation. From the first point of view, it can be observed that the character string, or any part thereof, does not constitute a 'chain' of 'signs' (i.e., words, phrases or alphabetic symbols representing phonemes), as defined by Hjelmslev:

> 'The signs form *chains*, and the elements within each sign likewise form chains. We shall use the term *relation* for the function (dependence, relationship) between signs or between elements within one and the same chain: the signs, or the elements, are *related* to one another in the chain' (Hjelmslev 1970, 32).

Therefore, what is processed by the computer is not the representation of a linguistic sign or, for that matter, the representation of the elements that make it up, but only the representation of a sequence of characters. However, the major drawback of a digital representation of the text consisting of a string of encoded characters, concerns its functionality, that is to say its ability to allow the execution of all analytical and critical operations necessary for the study of the text. In computational terms, this capacity depends on what operations can be applied to the data structure produced by the insertion of tags in the string of characters. Now, the standard markup system adopted by the scientific community for the encoding of literary texts[9] assigns to the string of characters a hierarchical tree structure. But if, from a literary point of view, we regard the 'structure' of the text more properly as 'the set of latent relations' among all its parts (Segre 1988, 34), the limitations of the structure imposed by the standard form of markup on text representation can be immediately seen, both as its exhaustiveness and its functionality for text analysis and automated text processing are concerned.

Apparently, the origin of this difficulty depends on the non-recognition of the true nature of the text, namely on overlooking that 'the nature of the text is not material': the visible text is 'always an image' and 'only an image' (315). As a result, we tend to ignore that 'the sign is an entity generated by the connection between an expression

9 Cf. *TEI: Text Encoding Initiative*: 'The Text Encoding Initiative (TEI) is a consortium which collectively develops and maintains a standard for the representation of texts in digital form. Its chief deliverable is a set of Guidelines which specify encoding methods for machine-readable texts, chiefly in the humanities, social sciences and linguistics' (http://www.tei-c.org).

and a content' (Hjelmslev 1968, 52) and so we think that by processing the data structure obtained by marking the text up, we process the text itself, and we mistake the real structure of the text for just the structure of its expression. On the linguistic level, all this seems to confirm Searle's objection, namely that processing textual data and manipulating character symbols does not amount, in general, to the exercising the linguistic competence that constitutes a distinctive character of the author or the reader of a text. Manipulating symbols, in this case a string of characters, does not mean processing semantic content, and so symbolic computation applied to text processing actually strengthens the critical reservations leveled at the Turing test.

6 ARTIFICIAL INTELLIGENCE AND SEMANTIC INDETERMINACY

The artificial intelligence response to this objection, textual and linguistic in nature, consists essentially in an effort to ensure the 'congruence of syntax and semantics' and, even when we find the admission that 'we have no example of a language or a formalism in which syntax and semantics are congruent, 'we still find the idea that the solution may consist in a 'representational formalism' that satisfies this condition, in order to prevent that 'the *structure* of syntactic constructions [be] unrelated to the *structure* of semantic constructs' (Goldfarb 2008, 1888). Supporters of strong AI maintain that the formalization of ordinary language is sufficient for this purpose, since to formalize or 'to give the logical form' of a sentence is 'to describe it in terms that bring it within the scope of a semantic theory' (Davidson 2001, 144). This position was expressed in the most clear and explicit way by John Haugeland through the assertion of the so-called 'Formalists' Motto: "You take care of the syntax, and the semantics will take care of itself"' (Haugeland 1989, 118). This principle derives directly from the *Physical Symbol System Hypothesis* (PSSH) propounded by Newell and Simon in their Turing Award lecture, namely from the assumption that 'a physical symbol system has the necessary and sufficient means for general intelligent action' (Newell and Simon 1976, 116). This hypothesis implies that physical symbolic systems, such as digital computers, 'when we provide them with the appropriate symbol-processing programs, will be capable of intelligent action' (Nilsson 2007, 9).

The hypothesis of Newell and Simon does not take into account, however, a fundamental property of literary language, specifically that in general a one-to-one correspondence between the structure of the expression of the text and the structure of its content is hardly to be found, because the relationship between syntactic and semantic constructs is essentially an indeterminacy relation. Consequently, the attempt to normalize everyday language, to ensure the congruence of the two structures, would deprive it of what can instead be considered the main feature on which rests the whole of its expressive power. As we have seen, the expression and the content are the two fundamental components of the text and they constitute its two main levels of analysis. In essence, it can be said that 'the expression plane refers to the material aspect of the linguistic sign,' and 'the content plane to the semantic aspect, there not necessarily being a one-to-one correspondence between both aspects of the linguistic sign' (Bussman 1996, 425). This lack of correspondence can be accounted for by considering that the material aspect, or for that matter 'the image'(Segre 1988, 315) of the literary text, is not unique, but only one of the possible expressions of its content, just as, if you consider a given expression or 'image' of the text, the content that is being associated with it from time to time is only one of its possible interpretations. Samuel Beckett has admirably shown, in so an enlightening way, this essential aspect of the text:

> There are many ways in which the thing I am trying in vain to say may be tried in vain to be said (Beckett 1965, 123).

In specific linguistic terms, this relationship between expression and content, or to be precise 'between [linguistic] form and meaning,' can be described as a relationship of mutual dependence between the two phenomena, characteristic of every natural language, of *synonymy*, i.e. 'more than one form having the same meaning,' and *polysemy*, i.e. 'the same form having more than one meaning'(Leech 1981, 94). This relationship presents all the characteristics of an indeterminacy relation: if the expression is fixed, the content remains undetermined, as well as, if the content is fixed, the expression remains undetermined. So, if the meaning of a word depends on its rules of use (Wittgenstein

1958; 2009), [10] and on its potential relationship to all other terms, it is quite clear that its specification remains open and potentially undetermined. The shortcomings of formalization and the absence of a one-to-one correspondence between the syntactic and the semantic structure of natural languages confirm the objective presence of phenomena of indeterminacy in the processes of association of semantic contents to linguistic signs of material nature. Searle's criticism, that thinks presents computers as lacking in the mental abilities required to bind to mere syntactic symbols appropriate semantic contents, is borne out by the undetermined features of the phenomena related to the semantic functioning of natural language. Automatic text analysis based on the processing of encoded character strings actually amounts to no more than the mere manipulation of the structure of the text expression and does not solve the problem of processing its semantic structure, thus revealing the inadequacy of Newell and Simon's *Physical Symbol System Hypothesis*. The kind of linguistic analysis that exposes automatic text processing provides an objective confirmation to Searle's mind-related criticism and sheds clear light on all its indeterministic implications.

7 LINGUISTIC SELF-REFERENCE AND INCOMPUTABILITY

Besides the undetermined relationship between syntactic and semantic structures, in natural languages another important phenomenon quite relevant to our examination can be observed. Tullio De Mauro refers repeatedly to the 'reflexive meta linguistic property' peculiar to natural languages (De Mauro 1982, 93–94; 2002, 89; 91–93) and Louis Hjelmslev maintains that 'owing to the universalism[11] of everyday lan-

10 'If we had to name anything which is the life of the sign, we should have to say that it was its *use*' (Wittgenstein 1958, 4); hence, 'it disperses the fog if we study the phenomena of language in primitive kinds of use in which one can clearly survey the purpose and functioning of the words' (Wittgenstein 2009, 7^{e}). Or, in a nutshell, 'what do the words of [a] language *signify*? — How is what they signify supposed to come out other than in the kind of use they have?' (Wittgenstein 2009, 9^{e}).

11 'In general, an everyday language differs from all other kinds of languages (e.g. the mathematician's symbolic language or the chemist's language of formulae) by not being made especially for particular purposes but being of use for all purposes. In an everyday language we can [...] formulate anything whatsoever. [...] This is why the Polish logician Tarski [...] rightly says that everyday languages are characterized in contrast to other languages by their "universalism"' (Hjelmslev 1970, 104–5).

guage, an everyday language can be used as metalanguage to describe itself as object language' (Hjelmslev 1970, 104–05). Literary language is therefore self-reflexive, a feature whose implications pose directly the problem of computability. Any attempt to avoid the circularity of self-referring statements leads inevitably to an infinite regress. The Platonic Third Man Argument[12] proposes a solution that finds its formal logical counterpart in the introduction of the modern theory of types, but with regard to it[13] Gödel proved his famous theorem on the undecidable propositions of *Principia Mathematica* (1931) and provided a proof that the system of Russell and Whitehead contains propositions true but not demonstrable. In short, by acknowledging the 'liar paradox' as 'one of his sources of inspiration' and by dealing with it in the scope of 'the formal theory of proofs' (Longo 2010, 17), Gödel showed, with all the cogency of a rigorous proof, that a circular, or self-referring proposition cannot be demonstrated recursively and implies an infinite regress — it is in this sense that Penrose (1996) asserts, for instance, that 'repeated Gödelization[14] does not provide us with a mechanical procedure for establishing the truth of [undecidable] sentences'[15] concerning the halting state of a computation process.

This purely logical and abstract result, obtained from linguistic and formal considerations, not only heavily influenced the developments of the theory of computation and imposed decisive limitations on the programme of artificial intelligence, but it is rich in consequences also

12 'Plato never refers to any argument as the "Third Man". The moniker derives from Aristotle, who in various places (e.g., Metaphysics 990b17 = 1079a13, 1039a2; Sophistical Refutations 178b36 ff.) discusses (something akin to) the argument at Parmenides 132a–b in these terms' (Rickless 2012).

13 'The true source of the incompleteness attaching to all formal systems of mathematics, is to be found [. . .] in the fact that the formation of ever higher types can be continued into the transfinite (cf. D. Hilbert 'Über das Unendliche,' *Math. Ann.* 95, p. 184), whereas in every formal system at most denumerably many types occur. It can be shown, that is, that the undecidable propositions here presented always become decidable by the adjunction of suitable higher types' (Gödel 1962, 62 n. 48[a]).

14 The so-called *Gödelization* or *Gödel numbering* is the technique used by Gödel to represent the formulae of a formal system through natural numbers: 'Gödel used a code that represents the strings of symbols that were expressions of a formal system using natural numbers. Since these formal systems were designed precisely to deal with natural numbers, right away statements regarding the formal system could, through the code, be converted into statements about natural numbers, and thus be expressed within the system itself' (Davis 2008, 52).

15 See Penrose (1994, 114).

for the philosophy of mind. Actually inspired by Gödel's platonic convictions, the proof of the existence of true but non demonstrable formulae suggests that here are 'some tasks the mind can solve' but 'cannot' be solved by 'digital computers' (Schimanovich 1989, 77–78). Gödel's theorem brings to the fore that the semantic import of linguistic self-reference cannot be explained, reductionistically, in purely syntactical terms, as well as, in an altogether similar way, first-person experience and the self-reflexive capacity of the conscious mind cannot be traced back to simple third-person objective descriptions, no matter whether produced by the very same conscious subject directly involved. The semantic knot of the relationship between language and metalanguage exceeds its purely syntactic solutions and, in the same way, the sheer capacity of computation cannot act as the whole of our mental faculties. 'Natural language,' as it can be seen, 'quickly outstrips our computational reach' (Cooper 2011, 134).

Once again, recast in linguistic terms, as our examination of automated text processing demands, Searle's observations on ontological subjectivity, and in particular on its conscious, intentional, and self-reflexive dimension, clearly show their direct connection to the computability issue. Gödel's incompleteness theorem, an objective logical result concerning the nature of formal symbolic systems, proves to be fully congruent with Searle's observations on subjectivity and the nature of mental faculties.

8 INDETERMINACY AND INCOMPUTABILITY UNSOLVED

Our discussion so far, through the examination of the theoretical underpinnings of automated text processing, brings to the foreground, in correct theoretical terms, the basic themes of the subject-object relationship, namely the metaphysical issue of the fundamental distinction between absolute subjectivity and absolute objectivity.[16] It is not possible here to address this issue in depth and we will confine ourselves to some observations concerning the arguments discussed so far in an effort to define the problem.

We showed that objections have been raised to the Turing test, both from an objective, as in the case of Penrose, and from a subjective point of view, as in the case of Searle. Penrose's objectivist stance traces back

16 Cf. Merleau-Ponty (1968).

the *incomputability* of mental operations to the *indeterminacy* of certain physical processes of our brain. Searle's subjectivist stance, in its turn, stresses the need to associate intentional semantic contents to the symbols we employ and insists on the subjective ontological essence of consciousness and of all mental states, but we tried to show that also Searle's subjectivist views bring to the fore, through their linguistic underpinnings, the *indeterminacy* of the relationship between syntax and semantics and the *incomputability* of the self-reflexive assertions of natural languages.

Turing himself had already dealt with these questions. Andrew Hodges confirms that in his later years Turing 'puzzled over the standard view of reduction of the wave-function in quantum mechanics' (Hodges 1999, 54). As we already mentioned, Turing was trying to 'invent a new quantum mechanics' (Turing 1953–54), and he spoke about it to Robin Gandy in these terms: 'Description must be non-linear, prediction must be linear' (Gandy 1955). His new approach was radically reversing the classical point of view that combined a subjective, epistemic and probabilistic uncertainty to an objective and physical 'strong determinism' (Penrose 1987, 106–07).[17] As a matter of fact, the classical notion of probability, understood in a Laplacian sense, is an epistemic one, whereas the notion of 'probability amplitude,' introduced by quantum mechanics, does not consist any more in 'the measure of an ignorance,' but 'is physical,' objective, and 'describes nature' (Vuillemin 1996, 264–65). The probabilistic *description* of a physical state objectively undetermined can thus be considered as a subjectively reliable *prediction* of what we may happen to know about it. Thus, according to Turing, and keeping to what we can glean from his occasional hints, the linearity of the wave function would make our knowledge of objective physical states computationally predictable, whereas their description would be cast in uncertain probabilistic terms:

> on the one hand, one has deterministic continuous evolution via Schrödinger's equation, involving superpositions of basis states. On the other, one has probabilistic non-local

17 'According to strong determinism, it is not just a matter of the future being determined by the past; the *entire history of the universe is fixed*, according to some precise mathematical scheme, *for all time*' (Penrose 1989, 559). This modern idea has been described as 'a variant of Laplace's scenario' (Calude et al. 1995, 117).

> discontinuous change due to measurement' (Cooper 2011, 138–39).

It can therefore be assumed that Turing intended to associatethe epistemic certainty of the law-like prediction of our way of knowing certain physical phenomena with the objective indeterminacy of their observational description. If the classical point of view combined physical determinism and epistemic uncertainty, the quantum mechanical point of view combines instead epistemic predictability and physical indeterminism.

9 THE SUBJECT *VS* OBJECT DUALISM

This unusual kind of inversion is not so puzzling as it might seem at first glance. On the one hand, it calls into question the 'Laplacian model,' without clearly indicating an alternative model. The 'discovery of incomputability' shows indeed where the problem lies, by bringing to light that 'modeling the universe is definitely not an algorithmic process' (Cooper 2011, 134), or that the description of the universe cannot be computable, whereas the prediction of its states can, although described in an uncertain way. Thus, with regard to complex non-computable phenomena, such as 'non-deterministic chaos' and 'non-linear dynamics' (Bischi, 2004), or in respect of a possible 'mathematical modeling' of the 'connection between mental activity and the workings of the brain' (Cooper 2011, 153), it remains an open question 'whether we have computational or predictive difficulties due to mere complexity of a real-world computational task, or because of its actual incomputability' (137). But the opinion that 'there is no distinguishable difference between the two possibilities' bespeaks the lack of a clear 'answer' to a 'paradigm change' that remains still 'uncompleted'(134).

However, on the other hand, the reversal between an objective and a subjective view of indeterminacy and computability recalls the figure of the 'chiasm' or 'reversibility' introduced and discussed by Maurice Merleau-Ponty (1968, 263) and it offers the opportunity of a solution to the concerns raised by the change of theoretical paradigm imposed by the new developments of 20th-century physics, that lead to 'contest the very principle of [the] cleavage' between subject and object and 'make the contact between the observer and the observed enter into the definition of the "real"' (16). The seminal idea of the *chiasm*, only sketched by Merleau-Pontyin his unfinished work, *The visible and the invisible*, originates from calling into question 'the "consciousness-object" distinction' and from the awareness that 'starting from this distinction, one will never understand' (200) the relationship 'between me and the world, between the phenomenal body and the "objective" body, between the perceiving and the perceived.' For this relationship is a relation of 'exchange' and of constant 'reversal' (215) between 'an inside and an outside,' between 'a visible' and 'a seer' (272), between an object and a subject, since always and unfailingly 'what begins as a thing ends as consciousness of the thing' and 'what begins as a "state of consciousness" ends as a thing' (215). This means that 'the sensible' must be understood 'in the twofold sense of what one senses and what senses' (259) and that 'the relation of my body as sensible with my body as sentient (the body I touch, the body that touches)' consists in the 'immersion of the being-touched in the touching being and of the touching being in the being-touched' (260). In other words, 'there is a body of the mind, and a mind of the body and a chiasm between them' (259).

The structure of the chiasm proves to be a complex structure that requires identity and distinction at the same time. Now, 'this structure' — the 'touched–touching' — actually 'exists in one sole organ.' Each of my fingers is phenomenal finger and objective finger, outside and inside of the finger in reciprocity, in chiasm, activity and passivity coupled. The one encroaches upon the other, they are in a relation of real opposition [. . .] There is no coinciding of the seer with the visible. But each borrows from the other, takes from or encroaches upon the other, intersects with the other, is in chiasm with the other.'

And yet, at the same time, there is a sense in which

> it is *the same* who is seer and visible: the same not in the sense of ideality nor of real identity. The same in the structural sense [. . .] of openness, of another dimension of the "same" being.'

A being that consists in 'the *antecedent* unity me-world,' which is

> a unity before segregation, before the multiple dimensions [. . .] Not an architecture of noeses-noemata, posed upon

> one another, relativizing one another without succeeding in unifying themselves: but there is first their underlying bond by *non-difference*' (261).

Admittedly, 'the chiasm binds as obverse and reverse ensembles unified in advance in process of differentiation' (262). It implies 'transcendence,' or 'identity within difference'; for it goes 'against the doctrine of contradiction, absolute negation, the *either or*' (225) and makes up 'a world that is neither one nor two in the objective sense' (262). Hence, the opposition between subjective and objective does not come out as a static opposition, but as reversibility, exchange, and constant inversion of the two contrary points of view.

10 A PARADIGM CHANGE?

Merleau-Ponty's position does not call into question the '*truth* of science' that is based on 'the scientific deduction-experimental fact parallelism.' Scientific truth is not 'to be contested,' but neither 'to be understood as a proof of a *realism* of science' (1968, 226), namely as a confirmation 'that the physical object in itself pre-exist[s] science' (15). On the contrary,

> today, when the very rigor of its description obliges [science] to recognize as ultimate physical beings in full right relations between the observer and the observed, determinations that have meaning only for a certain situation of the observer' (15),

a paradigm change becomes clearly necessary, to wit a 'revision' (22) of the 'objectivist ontology' through 'the re-examination of the notions of "subject" and "object."' (23) and the acknowledgment of the 'inherence of the subject and the object of science' (226) in the interconnection of the chiasmic relationship.

Now it is precisely the absence of an explicit recognition of this state of affairs that takes Penrose and Searle, for opposite reasons, to underestimate the true character of the phenomena of *indeterminacy* and *incomputability* that definitely stem from this intrinsic inherence and inseparability of the subjective and objective dimensions and require a full acceptance of the new epistemological paradigm. Penrose tries to restrain the two phenomena on the objective plane, whereas Searle argues in defence of the irreducibility of their subjective dimension. So, Penrose, by rendering logical incomputability physical and objective, ought to be able to solve the problem of a suitable *theory*, that 'should contain non-algorithmic elements of some essential kind' and remain 'deterministic but non-computable' (Penrose 1989, 559), as is the case, for instance, with the theories of deterministic chaos; therefore, he tries to propound a 'more sophisticated' theory (181), as he calls it, that would avoid the obstacle posed by the predetermining force of scientific generalizations. Searle, in his turn, by asserting the intrinsic subjective nature of incomputable phenomena should be able to propound a suitable *ontology*, that would ensure an objective and scientifically sound dimension to his contention that 'consciousness has a first-person ontology and so cannot be material, because material things and processes all have a third-person objective ontology' (Searle 1998, 51). The need to counter the 'materialist,' who argues 'that there really isn't such a thing as consciousness with a first-person, subjective ontology' (45), takes him 'first to distinguish between epistemic subjectivity and objectivity' and then 'to distinguish that from ontological subjectivity and objectivity' (Faigenbaum 2003, 144), in order to justify the character 'epistemically objective' of 'ontological subjectivity' (Searle 2002, 43).[18] So Searle admits that 'science is by definition objective' (Ibid.): his *subjective* indeterminist ontology commits him to epistemic objectivity. Conversely, Penrose's *objective* indeterminist ontology requires a non-predictive theory and commits him to epistemic subjectivity. To justify indeterminacy, an objective assumption has to find a *subjective* backing, just as a subjective conjecture has to find an *objective* validation. The difficulty is not overcome, but only moved over to the other side of the subjective-objective cleavage. Neither Searle nor Penrose acknowledge that the problem could

18 'Many philosophers and scientists also think that the subjectivity of conscious states makes it impossible to have a strict science of consciousness. For, they argue, if science is by definition objective, and consciousness is by definition subjective, it follows that there cannot be a science of consciousness. This argument is fallacious. It commits the fallacy of ambiguity over the terms objective and subjective. Here is the ambiguity: We need to distinguish two different senses of the objective-subjective distinction. In one sense, the epistemic sense ("epistemic" here means having to do with knowledge), science is indeed objective. [...] But there is another sense of the objective-subjective distinction, and that is the ontological sense ("ontological" here means having to do with existence)' (Searle 2002, 43).

be tackled only by accepting a radical change of paradigm and that 'we will get out of the difficulty only by renouncing the bifurcation of the "consciousness of" and the object' (Merleau-Ponty 1968, 141). From this point of view, 'the doubling up of my body into inside and outside — and the doubling up of the things (their inside and their outside)' is precisely what produces the 'chiasm,' that is to say the reversibility of the subjective and the objective, in a relationship where 'there is not identity, nor non-identity, or non-coincidence' (264), or there is not 'reversal' nor dialectical 'synthesis' (155), but 'there is inside and outside turning about one another' (264), 'encroachment (*empiétement*)' (202), overflow, overlapping, and 'overdetermination' (270).

11 SPENCER BROWN'S NEW CALCULUS

All this raises the problem of finding a suitable formal model to represent the conceptual structure of the relationship between the subjective and the objective — a model able to specify in a rigorous way not only the peculiar features of the linguistic phenomena of indeterminacy and self-reference, but also to comprise the overall conceptual structure of the new scientific paradigm induced by the advancements of 20th-century physics and biology. A considerable contribution in this respect can be provided by the 'calculus of indications' propounded by the English mathematician George Spencer Brown in his *Laws of Form* (1969), a work published on the 'recommendation' of Bertrand Russell to his publisher (Spencer-Brown 2010, vii)[19] and reviewed in *Nature* by Stafford Beer as 'an extraordinary book' that succeeds in 'the laying down of a proper basis for a new epistemology' (1969, 1392–93).

The primitive notion on which Spencer Brown bases the development of all mathematics is the notion of 'distinction.' The 'idea of distinction' is assumed 'as given,' and therefore 'the form of distinction' is taken for 'the form' itself (1969, 1). And just as a distinction 'is not description' (77), but an 'act' by which 'a space is severed or taken apart,' so the form too is understood as 'the way we represent such

19 As a blurb printed on the dust jacket of the first English edition of the *Laws of Form*, Bertrand Russell wrote: 'In this book Mr. Spencer Brown has succeeded in doing what, in mathematics, is very rare indeed. He has revealed a new calculus of great power and simplicity. I congratulate him' (Blackwell and Ruja 1994, 464).

a severance' (v). This act of severance from which 'a universe comes into being' is, as the author himself declares at the start, 'the theme of this book';it constitutes

> our first attempt to distinguish different things in a world where, in the first place, the boundaries can be drawn anywhere we please. At this stage the universe cannot be distinguished from how we act upon it' (Ibid.).

And just as in this act there can be no separation between the object of the distinction and the subject that draws it, the same happens with the form that represents it and sums up in itself all its ambivalence. 'The first [. . .] proposition in this book' has therefore a 'constructive' and operational character that involves the subject, for it is not a sheer objective description, but an 'injunction' (von Foerster 1970, 14), just as it should be, according to Spencer Brown, 'the primary form of mathematical communication' (1969, 77). And this initial 'command'(von Foerster 1970, 14) — 'draw a distinction' (Spencer Brown 1969, 3) — has to be accepted, it has to be carried out, 'otherwise nothing will happen at all' (Luhmann 2006, 43). This first proposition is indeed 'an exhortation to perform the primordial creative act,' and

> after this, practically everything else follows smoothly: a rigorous foundation of arithmetic, of algebra, of logic, of a calculus of indications, intentions and desires; a rigorous development of laws of form, may they be of logical relations, of descriptions of the universe by physicists and cosmologists, or of functions of the nervous system which generates descriptions of the universe of which it is itself a part'(von Foerster 1970, 14).

'The drawing of a distinction,' this original act, is then Spencer Brown's 'primary concept' the primitive notion that he takes as the sole starting point for 'the foundations of mathematics' (Whyte 1972, 291) and for its application in all other sciences. The *Laws of Form*are in fact 'an approach to mathematics, and to epistemology, that begins and ends with the notion of a distinction' (Kauffman n.d., 1)

The notions of 'distinction' and 'indication' are both distinct and identical. According to Luhman, 'it is striking that a distinction contains both a distinction and an indication' (Luhmann 2006, 44) and, as

Patricia Ene puts it, 'Spencer Brown differentiates between "distinctions" and "indications," by saying' (2013, 203) that 'we cannot make an indication without drawing a distinction' (Spencer Brown 1969, 1). Now, in his words, 'a distinction is drawn by arranging a boundary with separate sides so that a point on one side cannot reach the other side without crossing the boundary' (1969, 1). Hence, the 'distinction and the division of a space into a distinguished subspace (marked state) and an undistinguished subspace (unmarked state)' are treated 'as his basic undefined terms' (Gould 1977, 317). Accordingly, if 'one side is indicated as *something*, the other remains unmarked as *anything else*' and if no distinction is drawn 'there is no side to be marked or excluded at all' (Ene 2013, 203). All this generates the 'mark' (Spencer Brown 1969, 4), which is called the 'cross' (6) and is the only symbol of the system: 'let a state distinguished by the distinction be marked with a mark' (4):

$$\urcorner.$$

In this regard,

> 'it should be noticed how, by condensing all distinctions into a primary one, and all indications to the same name or token, the only explicit symbol of this calculus, $\urcorner$, acquires a double sense. On the one hand it represents the act of distinction, of crossing the boundary in an indicational space. On the other hand it is a value, the content of a distinction' (Varela 1979, 111).

The only symbol of the calculus, therefore, represents not only the contents or the *value* of a distinction, the state distinguished by it, but also the *operator* that performs the act of distinction. In Spencer Brown's calculus of indications, the two aspects of the representation that occurs between an object being represented and a subject representing it, remain inherently connected in their chiasmic interrelationship. The ambivalence of the symbol allows an operational representation of their intrinsic reversibility.

The 'ingenious choice for the notation of an operator $\urcorner$ which does several things at one time' is therefore the 'clue' to the development of the whole system (von Foerster 1970, 14). So, Spencer Brown uses this symbol 'either to denote (call) the marked state or as an instruction to cross the boundary between marked and unmarked states' and, in the same way, 'uses a blank to denote the unmarked state (or as an instruction to stay where you are)' (Gould 1977, 317–18). In addition to this, 'these operations may operate on each other, generating a primary arithmetic' and are defined by two axioms (von Foerster 1970, 14)that are the 'law of calling,' or 'form of condensation' (*a*), and the 'law of crossing,' or 'form of cancelation' (*b*) (Spencer Brown 1969, 1–2; 5):

$$(a) \qquad \urcorner\,\urcorner = \urcorner$$
$$(b) \qquad \overline{\urcorner|} =$$

These two axioms 'are used to prove that every arithmetical expression can be reduced to either a single cross or a blank' and to derive other theorems; 'an "algebra" is then formed by incorporating variables into the object language' (Gould 1977, 318) and using as axioms two equations previously proved. For this 'primary algebra' it is possible to prove a 'completeness' theorem (Spencer Brown 1969, 50) that is 'the analog of completeness theorems for axioms systems for Boolean algebra,' or 'a version of the completeness of the Propositional Calculus for elementary logic' (Kauffman n.d., 30–31). Subsequently 'infinite expressions which "re-enter" themselves are considered'; equations involving such re-entry 'are called "higher degree Boolean equations"' and it is shown that 'they may have zero, one, or two solutions in terms of marked and unmarked states' (Gould 1977, 318).

12 INDETERMINACY AND INCOMPUTABILITY: A MATHEMATICAL SOLUTION?

It is at this point that the development of the system proves to be of particular interest as regards debated theoretical issues specifically relevant to our discussion. Spencer Brown shows that his 'primary algebra' can be developed 'to such an extent that it can be used as an [. . .] algebra of numbers' and

> when this is done it is possible to see plainly some at least of the evidence for Gödel's and Church's theorems of decision. But with the rehabilitation of the paradoxical equations undertaken in Chapter 11, the meaning and ap-

> plication of these theorems now stands in need of review. They certainly appear less destructive than was hitherto supposed' (Spencer Brown 1969, xiv–xv).

The 'rehabilitation' of the 'paradoxical equations' to which Spencer Brown alludes in the *Introduction* to the first English edition of his work (xv) takes place through the introduction in the 'algebra of logic' (xiii) of 'imaginary' (99) and 'complex values,' that are the 'analogs, in ordinary algebra, to complex numbers,'a result that Spencer Brown defines as 'the most significant thing' that his calculus of indications allows us to do (xv). Now, the capacity to 'extend the concept [of imaginary number] to Boolean algebras'

> means that a valid argument may contain not just three classes of statement, but four: true, false, meaningless, and imaginary. The implications of this, in the fields of logic, philosophy, mathematics, and even physics, are profound (Ibid.).

Whereas in 'ordinary algebra' complex values are normally allowed, 'in Boolean algebra' they are not admitted. Remarkably, 'Whitehead and Russell introduced a special rule, which they called the Theory of Types, expressly to do so,'i.e. to prevent the development of 'the more advanced techniques' that are currently applied in ordinary algebra. To overcome this serious impediment that hinders all 'our reasoning processes' (xiii)

> all we have to show is that the self-referential paradoxes, discarded with the Theory of Types, are no worse than similar self-referential paradoxes, which are considered quite acceptable, in the ordinary theory of equations (xiv).

The impact that the introduction of imaginary values in logic can have on Gödel's theorem and on Church's and Turing's theses concerning the nature of computation is immediately apparent. Clearly 'the fact that certain equations plainly *cannot* be solved without the use of imaginary values' means that '*there* must *be mathematical statements* (whose truth or untruth is in fact perfectly decidable) *which cannot be decided by the methods of reasoning to which we have hitherto restricted ourselves*. 'If we draw inferences by means of ordinary logical methods 'we should *expect* to find theorems which will always defy decision,'but the power of the calculus of indications shows us 'that they *can* be decided by reasoning of a higher degree, 'namely by using imaginary values and self-referential expression of a kind that has 'its own form within it' (99–100).

The implications not only logical, but also epistemological and scientific of the calculus of indications are indeed far-reaching. According to Luhmann, who uses Spencer Brown's calculus in sociology for his 'applications to systems theory,' the 'analysis of form' that a calculus of this kind allows us to do, 'could be pushed far beyond systems theory,'perhaps to the point that 'one could even "redraw" semiology and semiotics with the help of its tools' (2006, 44–45). But besides the possible applications in the field of linguistics, specifically affecting the analysis of the text, Spencer Brown's calculus of indications and its 'laws of form' have a more general 'scientific' and 'philosophical importance' (Whyte 1972, 291). They have a considerable bearing on the issues here discussed of indeterminacy and computability. More specifically, with regard to the problems of incomputability and indeterminacy of the mental and linguistic phenomena, as we have seen, Barry Cooper observes that 'a crude mechanical connection between mental activity and the workings of the brain will not do the job' and maintains, instead, that 'mathematical modeling is needed to clarify the mess' (2011, 153). But if, in this connection, 'there are good reasons for looking for a more fundamental mathematical model' than those hitherto applied (155) — a new model, to wit, capable of 'describing local elementary interactions between components' (147) of an observed system 'on which to base a definable emergence' — and if 'the chief reason is the need for a general enough mathematical framework, capable of housing different computationally complex frameworks' (155), on the basis of the considerations carried out so far, it does not seem so rash to surmise, that there may be as many good reasons to regard Spencer Brown's calculus as one of the most reliable and promising candidates.

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