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WOULD LEIBNIZ HAVE SHARED VON NEUMANN'S LOGICAL PHYSICALISM ?

CONTENTS

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1. A comment on interpreting Leibniz

Obviously, every Leibniz scholar is a reader of Leibniz, while the converse does not necessarily hold. Some people study Leibniz more as amateurs than as professionals, just because of being fond of his insights from which they expect a hint in their personal quests.

This paper represents such an amateur approach, hence any comments backed up by professional erudition will be highly appreciated. Let me start from an attempt to sketch a relationship between professionals' and amateurs' contributions. The latter may be compared with the letters to the Editor of a journal, written by perceptive readers, while professionals contribute to the very content of the journal in question. Owing to such letters, the Editor and his professional staff can become more aware of the responses of educated public to the journal's output.

Certainly, Leibniz scholarship should be carried out to render justice to that great mind and his achievements; in this respect it does not need to be confronted with its reception by educated public. On the other hand, there are reasons to believe that Leibniz ideas may help those who look for a philosophical sense of modern scientific results. There are scientists who find philosophical insights even in a more remote past, like Werner Heisenberg and Carl Friedrich von Weizsäcker [1981] who found them in Plato. Some other scientists, as well as educated laymen, may seek them in Leibniz. And then there is an opportunity to face their questions with the professional knowledge of Leibniz scholars. The advantage of the seekers is obvious, while the scholars may better learn to what extent Leibniz's heritage is relevant to frequently asked questions.

This paper is an attempt to read Leibniz from the angle of modern philosophical mind-body debate in the light of the software-hardware distinction. Is it right to apply such new categories to a philosophical system in which no such distinction was explicitly stated? This is a vital methodological question which should be answered, at least briefly, before one goes to the matter in hand.

When looking for the answer, let me follow a hint found in Bergson [1946] which deserves to be called *Bergson's rule*. It runs as follows:

> No philosopher's intuition can be adequately expressed, since it transcends any existing linguistic means; however, its expression can ap-

> proximate the intuition as far as new linguistic means are being provided.

Such new means may be either developed by the philosopher himself or taken from a new environment he may encounter in his philosophical development. There arises a very interesting situation when a philosopher finds some conceptual systems in his environment which oppose each other, nevertheless both help him to express his intuition. If he endorses both, then he may be judged, also by later historians, as guilty of a serious inconsistency.

However, with the Bergson rule in mind, one should exercise great caution when interpreting such cases. According to Bergson's comments to his rule, each use of a conceptual apparatus, including one borrowed from an alien system, is accompanied by a partial negation, as in the old scholastic formula *sic and non*. Bergson's notion of philosophical intuition seems akin to Brouwer's notion of mathematical intuition. In Brouwer's intuitionism, a language is seen as a device to transmit a similar intuition to fellow scholars, and not as a means of adequate formulation. In the case of a philosopher this may go so far that apparently opposing statements are being used to meet communication needs.

Leibniz's philosophical biography nicely exemplifies Bergson's rule. If he preferred to communicate his ideas in letters than to publish systematic treatises, it might have been because of his awareness of how much the originality of his philosophical visions surpassed the linguistic schemas shared by a wider public. And his endorsement both of the mechanistic and the Aritotelian framework seems to balance on the verge of inconsistency which, however, does not occur, if one applies Bergson's rule to interpret that combination.

Well, it was a historical fact that Leibniz borrowed concepts to express his intuitions from Aristotle as well as Hobbes, Gassendi, etc. What about confronting Leibniz's philosophy of mind and matter with those nowadays approaches which oppose each other but each claims to resort to computer science and cognitive science? *Had Leibniz encountered these approaches, would he have used both to express his own insights?*

This conditional question involves a counterfactual proposition as its antecedent. Is it methodologically correct in a historical study to ask such questions? To avoid this difficult issue, let me take advantage of the privileges of an amateur which I refer to at the beginning of this paper. Even if serious historians do not allow themselves to discuss counterfactual suppositions, some historical writers do, not without a hope that literary fiction may inspire scholarly research (among the masters of such counterfactual fictions there was the Polish historical writer Teodor Parnicki).

The supposition to be discussed in the sequel is to the effect that Leibniz would have taken attitide towards that nowadays debate on what I suggest to call *logical physicalism*. Had it been so, the supposition runs, he would have opted for both opposing solutions, each supported by a set of premisses found in his texts.

2. On the notion of logical physicalism

Physicalism holds human thoughts and acts to be determined by physical laws (Webster [1971]). Logical Physicalism, LP for short, holds reasoning processes to be determined by laws deriving from physical properties of the brain, hence from some hardware properties.

In the heroic times of logical empiricism people used to employ the term 'physicalism' in a different sense; that story, though, seems to be half-forgotten, so one can give this word a new meaning, as suggested in Marciszewski and Murawski [1995]. An alternative suggestion is due to Schnelle [1988] who uses the phrase 'naturalization of logic'. However, it seems desirable to have a term related to the phrase 'physics of thought' (see below). Moreover, the use of the adjective 'natural' in contexts like 'natural logic' has been already established for what Gentzen called *das natürliche Schließen*.

It was the famous physicist Roger Penrose [1988] who was bold enough to claim inquiries into *the mathematics and physics of thought*. His ideas can be in a fertile way combined with those of John von Neumann [1958] which prove crucial for the story in question.

However, when associating physics with logic and a theory of mind, one has to regard the strong hold over philosophers get by the Cartesian paradigm concerning the mind-matter relations. With respect to that paradigm, any phrase like „the physics of thought" is even worse than a philosophical heresy; it is felt as a category-mistake, like saying that numbers happen to be warm, or that some thoughts are yellow. The term *category-mistake* is due to Ryle [1949]. In the same book the Cartesian doctrine is rendered as follows. „Human bodies [...] are subject to the mechanical laws which govern all other bodies in space. [...] Minds are not in space, nor are their operations subject to mechanical laws." (p. 11). When the mechanical laws (like those stated by Newton) are identified with the totality of physical laws, the mind-body problem is doomed to be „solved" either in the Cartesian way or in the behaviouristic way (endorsed by Ryle). However, modern physics offers a more sophisticated approach, and that seems to accord with Leibniz's insights.

Had Leibniz more influence on modern minds, than Descartes seems to have even in our times, then the idea of the physics of thought would be less shocking. For Leibniz this idea would be rooted in the notion of the pre--established harmony between perceptions of the monads and the motions of the bodies. As he puts it, there is „the concord and the physical union of the soul and the body, which exists without the one being able to change the laws of the other".[1]

If so, then the laws of thought must exactly mirror the physical laws of functioning of the entity in question, and vice versa. Hence, since electronic automata are subjected to different physical laws than organic automata, i.e. monads, the laws governing their intellectual processes must be different as well. This is a physicalistic thesis on the relevance of hardware to intellectual performances, inherent in mature writings of Leibniz. On the other hand, younger Leibniz's belief in the possibility of constructing artificial reasoning automaton to entirely replace human reasoners implies the irrelevance of hardware in this important respect.

According to Bergson's rule, as mentioned above, both opposing views should complement each other in an attempt to express a live fundamental insight surpassing either formulation. It seems a great task for Leibniz scholarship to inquire into relations holding between those poles of Leibniz thought. The present paper does not aim at such a remote target. Instead, it tries to clarify the tenets of logical physicalism and logical anti-physicalism and, farthermore, to present reasons for either point as seen by Leibniz. Thus it should be treated as a prelimary study to pave the way to the more ambitious task of interepreting the alleged discrepancy in the light of Bergson's rule.

In a natural way, the main body of this study should consist of four parts, two of them providing paradigmatic statements of antiphysicalism and physicalism, the former represented by Alan Turing, the latter by John

[1] *Principes de la nature et de la grace fondés en raison*, item 3, This statement is taken from English translation, Leibniz [1973]. To render all the nuances of this important text, it is worth while to quote it in the French original and in a suggestive German translation. «Ainsi il y a *harmonie* parfaite entre les perceptions de la Monade et les mouvements des corps, préétablie d'abord entre le système des causes efficientes et celuy des causes finales, et c'est en cela que consiste l'accord et l'union physique de l'âme et du corps, sans que l'un puisse changer les loix de l'autre.». Here is the German text. „Daher besteht eine volkommene *Harmonie* zwischen den Perzeptionen der Monade und den Bewegungen der Körper, die von Anbeginn an zwischen dem System der Wirkursachen und dem der Zweckursachen prästabiliert ist; und eben darin besteht die Übereinstimmung und die natürliche Vereinigung von Seele und Körper, ohne daß eines die Gesetze des anderen zu ändern vermöchte." See Leibniz [1982], p. 6 f.

von Neumann. Then there follow two items regarding Leibniz: one concerned with his supposed anti- and the other with his pro-physicalist attitude.

3. Turing's claim as to the insignificance of hardware

(i) Is a human brain a universal Turing machine?
(ii) Is the material that constitutes a thinking device, esp. a brain, of any consequence?

Turing's answer to the questions stated above, as found in his [1950] article, is as follows. A human brain is really a kind of computer. From the so-called universal Turing machine it differs in that it may involve a random element, i.e. have instructions like that: „throw the die (the throwing may have the counterpart in an electronic process) and put the resulting number into store n (say, 1000)". Moreover, unlike the universal machine, it has only a finite store (memory).

To explain that the hardware to be used is irrelevant, Turing takes advantage of the fact that Charles Babbage's Analytical Engine was a real prototype of modern electronic computers although it was a mechanical device, using wheels and cards (Boden [1990, 46]; Babbage's ideas, going back to 1834, are discussed by Gandy [1988]).

Here is Turing's [1950] comment. „Since Babbage's machine was not electrical, and since all digital computers are in a sense equivalent, we see that this use of electricity cannot be of theoretical importance. [...] In the nervous system chemical phenomena are at least as important as electrical. In certain computers the storage system is mainly acoustic. The feature of using electricity is thus seen to be only a very superficial similarity. If we wish to find such similarities we should look rather for mathematical analogies of function."

That all digital computers are equivalent follows from the fact than they can mimic any discrete-state machine, i.e., all of them are *universal.* A discrete-state machine is one that in a deterministic way passes step by step from a definite state to another state, each step being determined by an appropriate rule. In other words, each state is a function of the previous state and an impulse. Imagine, e.g., a wheel which clicks round through 120^0 once a second, but may be stopped by a lever operated from outside; a lamp is to light in one of the positions of the wheel. Let the machine states, i.e., three possible positions of the wheel, be referred to as s_1, s_2, s_3, input signals as i_0

and i_1; t (for 'transition') is to denote that two-place function which assigns a value to each pair s_k, i_k.

$$t(s_1, i_0) = s_2 \qquad t(s_2, i_0) = s_3 \qquad t(s_3, i_0) = s_1$$

$$t(s_1, i_1) = s_1 \qquad t(s_2, i_1) = s_2 \qquad t(s_3, i_1) = s_3$$

Input signal i_1 consists in stopping the wheel and thus preserving the current state, while input signal i_0 means the lack of such move, and so allowing the wheel to reach the next from among its three possible internal states. Let another function assigns each internal state an external one which consists either in lighting or in non-lighting the lamp.

Turing's [1936-7] result is to the effect that any procedure which can be computed at all, i.e., any procedure for which there is an algorithm, can be computed by his machine called, therefore, universal. As Turing [1950] argued, a physical stuff from which such a machine is made, i.e., its hardware component, is irrelevant to its performances in any respect, also with regard to methods of reasoning. In this sense, his claim opposes logical physicalism.

4. Von Neumann's claim as to the significance of hadware

For the sake of convenience, let us repeat the questions posed in the preceding section.

(i) Is a human brain a universal Turing machine?
(ii) Is the material that constitutes a thinking device, esp. a brain, of any consequence?

While Turing [1950] answers YES to (i) — with the proviso that a brain may involve a random element, and NO to (ii), Von Neumann [1958] answers YES to (ii), which implies NO to (i). (Cp. Schnelle [1988], Penrose [1988]). Von Neumann concludes his essay as follows: „Thus logic and mathematics in the central nervous system, when viewed as languages, must structurally be essentially different from those languages to which our common experience refers." (i.e. those commonly used by logicians and mathematicians). This puts limitations to the project of creating Artificial Intelligence, unless a human creator proves able to imitate the emergence of the human brain and the conscious mind from the process of evolution (a definition of AI is found in Boden (ed.) [1990], Schnelle [1988], Sterelny [1991]).

Von Neumann's point does not imply any postulate of symbolic reconstruction of those neural systemes that would yield an alternative logic or mathematics (a different set of theorems, or different meanings of operators). What is at variance it is a different information-processing *technology* to produce concepts and theorems — when compared with that of formalized systems, Turing machine and digital computers. Technology involves hardware, i.e. a physical component, as well as software; hence von Neumann's point can be called physicalist. Is it right, then AI requires a human-like hardware, contrary to the claim involved in Turing's project.

According to von Neumann, the hardware difference between a neural device and a digital computer consists in the former's (i) being partly analog (e.g., chemical) and only partly digital; (ii) using a recording system that is not digital but statistic, what means that the sense of a signal depends on its intensity rendered as oscillations frequency.

Here is an example which combines some recent neurological findings (Fischbach [1992], Crick and Koch [1992]) with logician's reflexion. In visual awareness a significant role is played by 40-cycle-per-second oscillations in firing rate which synchronize the firing of neurons responding to different parts of a perceptual scene, and so the whole object, e.g., one's face emerges. There are specialised cells responsible for reassembling a face picture from scattered components (a parallel processing). Such integration is accompanied by abstraction as the resulting picture corresponds to faces with similar features rather than to one face alone.

To find a logical point, let us fancy the way which the human mind must have made from perceiving, say (instead of faces), the sun, the moon and round tree trunks, to the abstract concept of a circle (which, in turn, may have suggested the technological idea of a wheel). The process starts from not verbalized, even not apperceived (in Leibniz's sense) percepts being unconscious counterparts of statements like „the sun is round". In the long course of information processing, such true statements result in true Euclid's theorems on the circle; hence it is a *truth-preserving* process, charactersitic of reasoning.

Thus, perception should be defined broader, including intellectual percepts of mathematical and other abstract objects. This can be seen, e.g., in Euclid's proofs, where the perception of an object, both concrete and typical, leads to general propositions (the famous Locke-Kant problem (cp. Beth [1970], Beth and Piaget [1966], reported by Marciszewski [1994]). The logical step in question is due to applying quantifiers, a fact that shows a possible mutual dependence of perception and reasoning. Since perceiving is due to the statistical (not digital) nature of brain signals, that dependence confirms von Neumann's contention that such a logical process requires a piece of hardware (hence a physical entity) different from that found in a digital computer.

5. Why Leibniz would NOT have accepted logical physicalism

Leibniz held it possible to build a logical machine matching humans in the ability of reasoning and surpassing them as to its infallibility: *ut errare ne possimus quidam si velimus, et ut Veritas quasi picta, velut Machine ope in charta expressa deprehendatur.* (letter to Oldenburg, Oct. 28, 1675, quoted by Couturat [1901]).

In his philosophy there were premises to judge that programme impossible, but the „Zeitgeist" led him to the opposite. It was the time of extreme optimism regarding potentialities of the human mind (e.g., Descartes was ready to prove all philosophical truths in one chat). It was only needed to find proper ways of improving the actual human mind; in some programs, as that of Leibniz, those ways involved an ideal language combined with a universal calculus. Once having such a system, one could feed it to a machine as well.

Though nobody heard of Turing machine, the logical idea of formalized reasoning, as algorithmic as computation (as claimed Hobbes), was in vogue owing to the schoolmen, followed by Leibniz. A formalized reasoning requires just a sheet of paper (Turing's tape), a pencil ('calamus'), and an eraser. The steps could be so arranged that a single word was either written or erased in each step. *Nihil enim aliud est calculus, quam operatio per characteres, quae in omni ratiocinatione locum habet.* (letter to Tschirnhaus, May 1678, see Couturat [1901]).

The technological assumption required to justify Leibniz's project of a fully successful reasoning machine runs as follows: whatever can be thought by the mind can be also recorded both at a sheet of paper and in a aptly devised mechanism, as cogs of the arithmetical machine were apt to record data and operations (cp. Breger [1988]). When discussing such a programme, one should keep in mind that still at the beginning of the 20th century (e.g., Hilbert's 1900 programme) nobody was able to guess the results concerning our cognitive limitations, as Heisenberg's priciple and the undecidability or incompleteness theorems (initiated by Gödel [1930], [1931]; cp. Church [1936], Davis [1988], Gandy [1988]).

Those theorems speak against the possibility of an algorithmic solution of some mathematical problems. Another argument came from the research on the nervous system, guided by comparisons with digital computers. It proved that an enormous number of operations must be performed at the unconscious level, while their success depends on properties of the organic hardware involved. Thus they are capable neither of being verbally recorded, to be later translated into a piece of software, nor of being performed by a digital machine.

The last mentioned fact and Gödel's limitative results may shed light on each other; the optimistic component of them is to effect that the human mind can do more than any home-made machine, while the pessimistic one — that artificial machines, because of their less advanced hardware, in some cases fail to strengthen human abilities. All that might have been anticipated by Leibniz, were he more sensitive to consequences of his own metaphysics, and less eager in following his time's slogans.

6. Why Leibniz would have accepted logical physicalism

That Leibniz would not accept logical physicalism is easier to defend than the answer in the affirmative. Premisses for the former were stated by Leibniz explicitly, while those for the affirmative statement may be guessed as being implicit in his concepts of perception and of organic machines (cp. Breger [1989], Schnelle [1991]). For the same reason, though, the affirmative answer is deeper rooted in Leibniz's thought.

Leibniz failed to see the connexions between perception and reasoning — those exemplified above. Had he noticed them, he would have acknowledged the essential difference in the „technology" of reasoning between natural and artificial machines. As to perception, he voiced its non-mechanical nature in the following way: *perception and that which depends on it cannot be explained mechanically, that is to say by figures and motions.* (Monadology, item 17).

Did Leibniz admit processes of reasoning, unlike those of perception, to be of mechanical nature? This is likely if we consider his fascination with Hobbes' idea that reasoning is like computing. In the latter there does not exist any direct link with perception. In reasoning it does, but that vital fact was not likely to be discovered until the modern quantification logic, esp. in a computerized form of inferential logic mainly due to Gentzen [1934-35], came into existence.

For, it is the rules of manipulating quantifiers (and like operators, as that of description) that makes us aware of the involved relations between the concrete (as given in perception) and the general. The data-processing done by neural „face cells" (as Fischbach [1992] calls them) which results in perceiving many faces of the same class forms a generalization, rendered by the rule of introducing the general quantifier.

The rule of introducing the existential quantifier defines another kind of reasoning in which a perception yields a premiss. Usuallly, such a premiss remains unverbalized, hence not manageable by a digital computer (unless one becomes able to feed it with non-verbal representations of the objects perceived, and establish logical rules to process such representations).

The rule of concretization (i.e. eliminating the general quantifier) is of special consequence for the present discussion as it can exemplify von Neumann's claim regarding the difference between the textbook logic and the logic of our brain. The example is found in Marciszewski [1994, 145–9] where the reasoning of an ape is reconstructed in terms of a computerized system, termed Mizar MSE, of quantification logic. The system accepts an orthodox „textbook formalization" as well as another one, closer to actual reasonings, in which the general quantifier elimination conflates with modus ponens; thus, so to speak, a *macro-rule* replaces a set of single rules.

Obviously, the systems compared are identical as to the set of theorems and the meanings of logical constants (hence no alternative logic is at stake), but are different technologically, i.e. as to the mechanism of producing conclusions, depending on the hardware involved. The connexion between the quantifiers and the perception (requiring an organic hardware) as well as the macro-rule technology may form a basis for „the logical language truly used by the central nervous system" (von Neumann [1958, 82]). The example of Mizar MSE suggests a way of imitating organic reasoning with the macro-rules strategy, but the entanglement of reasoning with perception, characteristic of organic reasoners, is hardly imitatable by computers.

Had Leibniz had our present logical knowledge with its limitative theorems, accompanied by suitable biological premises, he would not have expected the full-scale mechanization of reasonings. Instead, he would have welcome such limitations as supporting his belief in the range of physical differences between natural and artificial hardware — the belief that *each organic body is a kind of divine machine, or natural automaton, which infinitely surpasses all artificial automata.* (Monadology, item 64).

References

Albertazzi, L. and R. Poli (eds.) [1991] *Topics in Philosophy and Artificial Intelligence*, Mitteleuropäisches Kulturinstitut, Bozen.

Bergson, Henri [1946] *The Creative Mind. A Study in Metaphysics*, Philosophical Library, New York. See the essay entitled 'Philosophical intuition'.

Beth, E. W. [1970] *Aspects of Modern Logic*, Reidel, Dordrecht.

Beth, E. W. and J. Piaget [1966] *Mathematical Epistemology and Psychology*, Reidel, Dordrecht.

Boden, M. A. (ed.) [1990] *The Philosophy of Artificial Intelligence*, Oxford University Press, Oxford.

Breger, H. [1988] „Das Postulat der Explizierbarkeit in der Debatte um die künstliche Intelligenz" [in:] *Leibniz. Tradition und Aktualität. V. Internationaler Leibniz-Kongreß. Vorträge. Hannover 14.–19. November 1988*, Leibniz-Gesellschaft, Hannover.

Breger, H. [1989] „Maschine und Seele als Paradigmen der Naturphilosophie bei Leibniz" [in:] von Weizsäcker, K. and E. Rudolph (eds.) [1989].

Crick, F. and Ch. Koch [1992] „The Problem of Consciousness. It can be now approached by scientific investigation of the visual system. [...]", Scientific American, Sept. 1992, vol. 267, no. 3, pp. 111–117.

Church, A. [1936] „A note on the Entscheidungsproblem", J. Symb. Log., vol. 1, 40–41; a correction, ibid. 101–102.

Couturat, L. [1901] *Logique de Leibniz l'apres des documents inédites*, Alcan, Paris.

Davis, M. [1988] „Mathematical logic and the origin of modern computers" [in:] Herken (ed.) [1988], pp. 149–174.

Fischbach, G. D. [1992] „Mind and Brain. The biological foundations of consciousness, memory and other attributes of mind have begun to emerge; an overview of this most profound of all research efforts", Scientific American, Sept. 1992, vol. 267, no. 3, pp. 24–33.

Gandy, R. [1988] „The confluence of ideas in 1936" [in:] Herken (ed.) [1988], pp. 55–111.

Gentzen, G. [1934-5] „Untersuchungen über das logische Schließen I–II". Math. Z., vol. 39, 176–210, 405–431.

Gödel, K. [1930] „Die Vollständigkeit der Axiome des logischen Funktionenkalküls", Monatshefte für Mathematik und Physik, 37, 349–360.

Gödel, K. [1931] „Über formal unentscheidbare Sätze der *Principia Mathematica* und verwandter Systeme, I", Monatshefte für Mathematik und Physik, 38, 173–198.

Herken R. (ed.) [1998] *The Universal Turing Machine. A Half-Century Survey*, Oxford University Press, Oxford.

Leibniz, G. W. [1973] *Philosophical Writings*, ed. by G. H. R. Parkinson, Everyman's Library, London, etc. Includes „Monadology".

Leibniz, G. W. [1982] *Vernunftprinzipien der Natur und der Gnade. Monadologie. Französisch-Deutsch*, Meiner, Hamburg.

Marciszewski, W. [1994] *Logic from a Rhetorical Point of View*, Walter de Gruyter, Berlin – New York. Series: Foundations of Communication and Cognition, ed. by R. Posner and G. Meggle.

Marciszewski, W. [1994a] „A Jaśkowski-style system of computer-assisted reasoning" [in:] Woleński (ed.) [1994].

Marciszewski, W. and R. Murawski [1995] *Mechanization of Reasoning in a Historical Perspective*, Rodopi, Amsterdam – Atlanta. Series: Poznań Studies in the Philosophy of the Sciences and the Humanities, ed. by L. Nowak.

Penrose, R. [1988] „On the physics and mathematics of thought" [in:] Herken (ed.) [1988], pp. 491–522.

Penrose, R. [1989] *The Emperor's New Mind. Concerning Computers, Minds, and The Laws of Physics*, Oxford University Press, Oxford – New York – Melbourne.

Ryle, Gilbert [1949] *The Concept of Mind*, Barnes and Noble, New York.

Schnelle, H. [1988] „Turing naturalized: von Neumann's unfinished project" [in:] Herken (ed.) [1988], pp. 539–559.

Schnelle, H. [1988] „From Leibniz to artificial intelligence" [in:] Albertazzi and Poli (eds.) [1991], pp. 61–75.

Sterelny, K. [1991] *The Representational Theory of Mind*, Basil Blackwell, Cambridge (Mass.).

Turing, A. M. [1936-7] „On computable numbers, with an application to the Entscheidungsproblem", P. Lond. Math. Soc. (2), vol. 42 (1936–37), 230-265; a correction, ibid. vol. 43 (1937), 544–546.

Turing, A. M. [1950] „Computing machinery and intelligence", Mind, vol. 59, no. 2236 (Oct.), 433–460. Reprinted in Boden [1990].

von Neumann, J. [1951] (lecture held in 1948) „The general and logical theory of automata" [in:] *Collected Works*, vol. V, ed. A. H. Taub, vol. 5, Pergamon Press, New York 1963.

von Neumann, J. [1958] *The Computer and the Brain*, Yale Univ. Press, New Haven.

von Weizsäcker C. F. [1981] *Ein Blick auf Platon. Ideenlehre, Logik und Physik.* Reclam, Stuttgart.

von Weizsäcker, C. F. and E. Rudolph (eds.) [1989] *Zeit und Logik bei Leibniz. Studien zu Problemen der Naturphilosophie, Mathematik, Logik und Metaphysik.* Klett-Cotta, Stuttgart.

Webster [1971] *Webster's Third New International Dictionary of the English Language. Unabridged*, Merriam Co., Springfield, Mass.

Woleński, J. [1994] *Philosophical Logic in Poland*, Kluwer, Dordrecht.

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