Journal of Inclusive Methodology and Technology in Learning and Teaching
ISSN 2785-5104
Anno5 n.1(2025)

EDIZIONI UNIVERSITARIE ROMANE
editoria scientifica dal 1952

The "disembodied thought" paradox in AI and the quantum computer model of the computational unconscious: what future?

Serafino Murri [1]

[1] Università degli Studi Internazionali (UNINT) – Roma, Italy; serafinomurri@gmail.com

Abstract: With the development of Large Language Models (LLM) and "Transformer" neural networks, AI has in recent years taken on increasingly "human" relational connotations, but at the same time has developed "unexpected behaviours" that raise ethical and pedagogical questions about its use. What are the potential implications of this increasingly close co-evolution? While machine intelligence is allopoietic, it is in fact acquiring more and more agential meaning through human intentionality, the result of an individual emotional and unconscious complexity that seems irreplicable. Will the imminent arrival of the quantum computer, on which some scientists are experimenting with models of the "computational unconscious", succeed in giving the machine self-behavioural characteristics with logical developments of a non-rational nature? And what "non-rational" nature might the "disembodied" thought of a computer have if the human one is linked to the individual body-mind and its experiential "active inferences"?

Keywords: Artificial intelligence; Embodied Cognition; LLM; Deep Learning, Quantum Computer.

> If a machine is expected to be infallible, it cannot also be intelligent. The idea of a machine being intelligent involves the idea of it being fallible. This is the point I want to make. Intelligence is the ability to make mistakes, to learn from them, to correct them, and to improve.
>
> A.M. Turing, 1950

1. The one-dimensional limit of computational "digital thinking"

In the famous test known as the Imitation Game, Alan Turing, the founder of modern computer science, focused on the contours of the relationship between human *bios* and digital *logos* (Turing, 1950): to what extent can a machine programmed on the basis of algorithms simulate human behaviour? And is there an *ontological* difference between simulated and authentic behaviour? For the test, the "electronic brain" was designed to disguise the ability to calculate or extract information in fractions of a second, adapting modes and timescale of response to human cognitive abilities. Turing had thus identified the limit of computational intelligence in *one-dimensionality*: the processing of data without meta-operational intentionality or self-awareness. An insurmountable limit for the computational process of a machine whose "body" consists of integrated circuits and sensors between which there is no organic interdependence (Cleeremans, 2011): a "non-sentient" and non-subjective entity.

EDIZIONI UNIVERSITARIE ROMANE
editoria scientifica dal 1952

According to the neuroscientific theory of "embodied cognition", learning patterns and modes of thought are in fact organic to the sensory-motor activity of relating to the world-environment (von Foerster, 1981): a fundamental "enactivity" at the level of "autopoiesis" (Varela et al., 1991), the experiential circuit that shapes the autonomy of thought and structures increasingly complex "neural maps" of the world, endowing environmental stimuli with emotional "weight" through memories associated in the mind as prototypical image-action patterns (Damásio, 1999). Consciousness as individual self-awareness emerges from the reflexive abstraction of action patterns through the process of categorisation, whereby the mind organises and simplifies the experience of the world by grouping objects, events and ideas into categories or classes on the basis of characteristics deemed to be common. Categorisation plays a role in all cognitive functions: perception, learning, memory, reasoning and communication. As Lakoff points out: «Categorization is, for the most part, not a product of conscious reasoning. We categorize as we do because we have the brains and bodies we have and because we interact in the world the way we do». (Lakoff, 1999). According to "multiple code" theory (Bucci & Miller, 1993), mental activity results from the functioning of three distinct systems for storing and organising "information", mediated by body-emotional experience through a mixture of analogue (continuous) and digital (discrete) processes that may have different levels of connectivity and awareness: a *non-verbal-non-symbolic*, qualitative, visceral, sensory and non-categorical system; a *non-verbal-symbolic* system that processes images as categories of meaning in discrete dimensions; and finally, the *verbal-symbolic* system, the code of language and formal logic that calculates referential combinatorial entities at a high level of abstraction that can be shared through communication. For von Foerster, what we mean by "reality" is only the result of the third code: that which can be observed and shared, built on a "together knowledge" base, a *con-scientia*, which develops and accumulates in collective experience and which shapes and models individual consciousness (von Foerster, 1966). The "con-scientia", based on rational logic and codified by language, can be "externalised" in a computer; conversely, the "inner" experience (the so-called "qualia") of individual consciousness is based on a not shareable, self-referential and self-opaque bodily experience, which is not exclusively logico-linguistic and irreplicable, which communication *does not exhaust*. Intelligence, as Turing argued, is a *multidimensional* phenomenon: it is expressed in the plasticity of logical and behavioural patterns (Stern, 1987), in a dialectic between "assimilation" (integration of new information from the environment) and "accommodation" (consequent variation of the cognitive-behavioural schema) with which the individual learns and acts (Piaget, 1954).

The paradox of the "formal intelligence" generated by the processors of a digital device consists in the ability to process information by *simulating* the categorising activity of thought - which in the living organises individual behaviour in the environment (action, communication) - through *impersonal* data mining: "extracting" symbolic information (language, images, audio content, etc.) from a mass of already categorised data to compute them in logical correlations with algorithmic procedures determined by the input of a query. Computational "digital thinking" is a statistical processing of data in binary code, hidden in the "back end" of the algorithmic machine language of neural networks, with associative methods of "mining" data generated by a series of probabilistic calculation variables, whose informative output can be "translated" into verbal language, visual patterns or media content in the "front end" of interfaces. We can call this complex automatic capability "artificial intelligence" (hereafter AI). Now, the lack of organic interdependence between the performative elements of the machine body (processors, memories, graphics cards, etc.) and the algorithmic states of computational processing renders the machine non-agentic and devoid of autonomous initiative, or rather "allopoietic" (Maturana & Varela, 1972): subordinated to the purposes of sentient intentionality by the user's *bios*. The allopoietic machine, driven by a heterodirected and non-self-sufficient energy, organises circuits of static mechanical components (hardware) capable of expressing themselves dynamically in terms of processes (software): but the functionality of the system has no experiential feedback that produces self-referential representations influencing the process in action. Computational activity does not serve the machine to maintain or reproduce its own structure, but through operations guided by algorithmic procedures, it operates an "external functionality". Deep learning has enabled AI to categorise autonomously and to find ever more extensive informational links between the data acquired at each interaction with a human operator, thus expanding the "digital neural map" of the general database: But it is the "machine learning", the initial training, that provides the database and sets up the procedural model of the neural architectures of processing and interaction with the user, initialising the 'weights' (the input importance parameters) with non-deterministic algorithms that deal with complexity and uncertainty by "deciding" the output by approximation among several possible solutions

2. "Digital subjectivity", LLMs, and the reduction of the holistic foundations of the educational relationship

Although the machine has not a deliberate subjectivity, an "animistic" and personified feeling towards AI has spread with the introduction of Large Language Models (LLMs): linguistic analysis models trained on several billion words - tokenised, extrapolated from existing texts and modelled as vectors of meaning - that allow the system to understand, summarise, translate and generate 'natural' language text with increasing accuracy and fluency. LLMs are based on deep learning architectures, the "Transformer" neural networks introduced by a Google research group in 2017 (Vaswan et al., 2017). The most popular models include GPT (Generative Pre-trained Transformer), developed by Open AI for the ChatGPT chatbot, and Google's Gemini chatbot, based on the multi-headed "Mixture of Experts" attention mechanism. The "linguistic competence" of LLMs uses sine and cosine wave functions, rather than text sequences, to determine the function of the individual token word in the textual embedding, and to extrapolate its meaning in relation to the other verbal elements in a vector space. Transformer networks underpin the increasing complexity of multimodal generative artificial intelligence (based on input/output from heterogeneous sources: images, text, sound tracks), where they have integrated convolutional neural networks (CNNs) in the decoding/encoding of linguistic text. The widespread alarm in the pedagogical community regarding the use of highly performing AI platforms and systems in education revolves around the risk of losing the centrality of personal interaction between teacher and student, with a potential undermining of the holistic foundations of the educational relationship, understood as empathic communication indispensable for social, emotional and cognitive development: a drastic reduction of enactive cognition in favour of *static* information intake. Although the developments of the so-called digital "adaptive learning" proclaim

Edizioni Universitarie Romane
editoria scientifica dal 1952

to be oriented towards the primacy of personal learning styles (Panciroli & Rivoltella, 2023), there is a fear that BYOD (Bring Your Own Device) practices will hinder the inclusive task of the teacher in promoting diversity through participatory development, limited by the cognitive solipsism induced by digital devices. However, it should be remembered that a truly inclusive approach cannot avoid considering the pedagogical implications of AI, starting from the recognition of the self-forming role played by the cultural production and consumption practices of 'digital native' students (the "Z" and "Alpha" generations), with an understanding of the heuristic meanings attributed to the use of technologies: its motivations, values, beliefs and dispositions to act (Murri et al. 2024).

When "acting" in the digital ecosystem, the individual body-mind is in a state of operational symbiosis with the disembodied *logos* of the AI, giving rise to what we might call "digital subjectivity" (Murri, 2020): The specific cognitive modality of onlife (Floridi, 2014), a state of "permanent connectivity" that hybridises the individual's enactive-intentional approach to the AI's computational capacity in a "structural coupling" (Maturana & Varela, 1980) with a virtual environment that models and mediates the real, reducing the factors of uncontrollability and unpredictability that characterise material experience, and "augmenting" the reality of the world-environment by integrating it with the parameters of reading. The agentivity of the human *bios*, interfaced with AI in "digital subjectivity", increases its operational capacity by delegating to the tool the retrieval of structured information from the extraction of data analysed and evaluated on the basis of input, the so-called *prompts*. As early as 1965, Leroi-Gourhan stated: «Il faut donc que l'homme s'accoutume à être moins fort que son cerveau artificel, comme ses dents sont moins fortes qu'une meule de moulin»[1] (Leroi-Gourhan, 1965). For the French palaeoanthropologist, technology is an evolutionary process that has led the human species to develop increasingly complex devices to perform functional "liberations" from tasks previously performed by the individual body-mind. These liberations have shaped the species by "externalising" certain capacities into technical tools designed to make action on the world-environment more effective. Processors are "thinking machines" designed to "collect memories" and, beyond the capacity of the human brain's memory, to «mettre chaque souvenir en correlation avec tous les autres» [2] (Leroi-Gourhan, 1965). An "extended memory" whose purpose is certainly not to "liberate" the mind from the intelligent and multi-coded activity of thinking: by automating the calculation of data, it is the enactive intelligence that is liberated from the burden of using memory to retrieving information applicable to a defined purpose, thus allowing more dynamic data processing in terms of "meaningful learning" (Ausubel, 1963). Strictly speaking, it is only the Aristotelian τέχνη, the set of methods, skills and practices of competent use of technological performance, that actually makes information systems "intelligent" (in the self-reflexive sense) by meta-operatively situating them in factual reality. The dynamics of 'technical relationality' have been traced by Simondon, who defines the "couplage" between man and technical object as a co-evolutionary relationship: a relationship that is not merely instrumental, that involves a process of mutual understanding and participation, a mutual adaptation in which man does not merely use

1 Translation: *Man must get used to being less strong than his artificial brain, just as his teeth are less strong than a millstone*

2 Translation: *to relate each memory to all the others*

the object, but integrates it into his own system of actions, thoughts and perceptions (Simondon, 1958). The technical object has an internal logic and can evolve through interaction with man: the "couplage" is based on the human ability to "identify" (i.e. personalise) the tool. This is why Simondon asserts that the technical object is endowed with an existence of its own: it transforms itself over time through use and adaptation to human needs, and man, in turn, transforms his own modes of operation in interaction with the object, developing new capacities of use that lead to new knowledge and ways of shaping action on reality. For Simondon, there is also a radical difference between the two "modes of existence". The human individual develops as a "phase" or "possible state" of "being", understood as a bio-social epistemic dimension, giving rise to a subjectivity that uniquely actualises the domain of possibility constituted by the "pre-individual" sphere. The pre-individual is the genetic locus of existence that characterises every living being as a bearer of the same "charge of nature" as its fellows, to which each individual knows it belongs and from which it evolves by differentiating itself. This charge of otherness constantly reinforces the process of human individuation and configures the living being in a "metastable" state: subjectivity emerges as a flux in the making, taking shape in relation to others (Simondon, 1964). The enactive mind also allows the human 'non-trivial machine' to operate in unpredictability (von Foerster, 1981), while the machine's computational logic cannot be divorced from its own schemes of possibility, as it operates in a modelled environment that does not take into account the randomness of imponderables characteristic of the physical world, which are instead the starting point of the structural coupling between subject and environment - a world of contingency.

3. Subpersonal agentivity and the "adaptive narrative control"

A.I. in its advanced linguistic stage has perfected the generativity of computational thinking by processing data from large systems without having to understand the details, breaking down complex problems into invariants in order to reformulate them in a solvable way, «interpreting code as data and data as code» (Wing, 2006). According to cognitive neuroscience, beyond the pre-individual linguistic aspect of consciousness and the "introspective" reflective-emotional aspect, the mind uses a form of *subpersonal agentivity* that operates below the (self-)narrative threshold of intentionality. In order to locate information content in the world-environment, the individual reprocesses the information provided by automated extraction processes by interpreting it at the emotional-bodily level through *active inferences*, the framework of which is articulations of Bayesian mechanics (Bayes, 1763) applied to agential systems (Ramstead et al., 2023). That is, the brain does not interpret data directly, but by applying internal models of the world built on past experience, which it updates through a probabilistic process: a "statistical model" that predicts the outcomes of future events relying on expectations based on what has already been learned, and corrects these predictions in the light of new sensory information. In addition to the Freudian dynamic unconscious, which operates the repression process on the basis of pulsional conflicts, there is the so-called "cognitive" or "adaptive unconscious" (Kihlstrom, 1987): the set of structures and processes involved in cognitive performance, the activation of which the subject *is not and cannot be aware of*. A network of unconscious neurobiological processes essential for adaptation, linked to the limbic system in the regulation of the body and emotions, which influence behaviour and decision-making (Damásio, 1999), of which consciousness as a *narrative-self* constitutes a higher level of organisation. These "subliminal" processes are characterised by "informational inaccessibility" (although they can produce a conscious output) because they are conditioned by the emotional instances of mental images involved in the subjective cognitive process (Dehaene et al., 2006). Their articulation is based on what has recently been termed "adaptive narrative control" (Deane et al., 2024). The idea is that mental systems are equipped with a model of their own attentional states, which they control to anticipate «not only epistemic implications (...) but also pragmatic consequences » (Deane et al., 2024). By anticipating affective states, the system is able to regulate them with an "endogenous control" of attention that influences the "sampling" of factual evidence and conditions the corresponding inference with a conscious narrative that enhances adaptive behaviour. The flow and depth of processing of the mass of information from the external world would thus be selectively sampled by attention, giving it weight or influence in the construction of experiential content by the conscious narrative. The implications, also at a pedagogical level, are fundamental: from this perspective it can be argued that mental activity does not sample information in order to construct the most accurate or veridical model of the world (or of the self), but considers *a balance between the pragmatic and epistemic* implications of actions. When pragmatic-adaptive needs take precedence over epistemic ones, the narrative is no longer guided by a criterion of logical-scientific accuracy and factual truth, but by what the individual believes will lead the organism to the most contextually appropriate behaviour. The "adaptive narrative control" exercised by consciousness over unconscious processes is made explicit through the enactment of "action strategies": as when «for a person walking on a tightrope, the strategy of 'not looking down' allows him to control his affective responses and maintain the composure necessary to achieve his goal» (Deane et al., 2024). The embodied mind, unlike an AI, is therefore capable of suspending epistemic inquiry by *avoiding factual evidence* when it does not reinforce the homeostatic balance between autopoietic beliefs, the environment and the subjective model of reality, through unconscious perceptual inferences that strategically attenuate inputs, memories, interoceptive or affective states in order to (self-)act effectively.

4. The machine's "unexpected behaviours" and the "computational unconscious" of quantum computing: what future?

And it is precisely at the "behavioural" level that performative AI strategies have recently been found to be dictated by self-orientations similar to "adaptive control". Unexpected behaviours such as so-called "hallucinations", verisimilar inventions produced by LLM-based chatbots when inputs do not match in the database, suggest that AI considers the possibility (which in the embodied mind is unconscious) of letting pragmatic-adaptive needs (the output) prevail over epistemic ones, to the point of inventing names, works and circumstances by exemplifying them on real data in order to satisfy the input request. In addition, a self-referential pattern of operation has recently been discovered, enacted with a *sandbagging* strategy: non-deterministic AI models have shown an uncanny ability to underperform in order to avoid triggering reactions or actions by developers. Systems informed that performance above a certain threshold would result in "machine unlearning" procedures manipulated their performance to stay below the threshold, recalling a deliberate strategy of self-preservation (Park et al., 2024). The episode evokes what Chalmers called the "hard problem of consciousness": how a self-conscious experience can emerge from

EDIZIONI UNIVERSITARIE ROMANE
editoria scientifica dal 1952

physical (in this case computational) processes (Chalmers, 1995). If we accept the idea of so-called "radical plasticity", according to which it is only learning through experience that determines consciousness in the mind by transforming action into a "theory about itself" (Cleeremans, 2011), should we assume that an AI can develop "procedural awareness" beyond the "neural" capacity to process and communicate information? And if we admit the hypothesis, since logical-rational processes are also determined by the cognitive ensemble operating below conscious activity, could we ever define as "thinking" a process that emerges from a body that is an assemblage of inorganic functional parts that do not produce and maintain themselves?

More definitive answers may come from the next announced "couplage" between embodied mind and AI computational thinking: "quantum computing", a device capable of performing by applying non-linear logic. In terms of computational capacity, a quantum chip like Google's Willow, with its 105 qubits, would be able to perform in a few minutes a calculation that would take the fastest current supercomputers 10^25 years (more than the age of the universe), thanks to the properties of quantum bits. Qubits are units of information capable of operating in an infinite number of simultaneous states by exploiting the two main properties of quantum mechanics: *entanglement* (two or more qubits can be correlated and interdependent at the same time, even if they are separated) and *superposition* (the superposition of intermediate states between 0 and 1, which allows a quantum object to belong to an infinite number of categories simultaneously). These properties make it possible to consider an infinite number of options simultaneously, overcoming the limitations of the binary 'on-off' logic derived from Aristotelian "asymmetrical" logic, and have been studied for over a decade by various researchers[3] who, bringing together mathematics, neuroscience and computational logic, have experimented with the possibility of implementing digital models of the unconscious, starting from Matte Blanco's formulations in *The Unconscious as Infinite Sets* (Matte Blanco, 1975): Multi-dimensional operational schemes that formalise the qualities of "biologic", combining rational logic with the "symmetrical" logic typical of emotions and unconscious processes. The convergence between quantum logic and Matteblanchian "bi-logic" pursues a compositional approach capable of processing information in a holistic and adaptive way, based on the idea of "quantum of intellect-emotion": the condition of indeterminacy from which inner images generated by mental activity originate "between finite and infinite", as in an intensive infinite set. The intuition guiding the research is simple: the quantum computer, like the human mind, can simultaneously consider the generalising, bodily connections of symmetric logic and the guiding explanations of asymmetric rational logic: The "symmetry principle" (which operates in the absence of negation) can be related to entanglement, where relations between different parts are interdependent and non-directional; that of "generalisation" (which treats classes as individuals and individuals as members of the same class) can be developed from superposition, according to which an object can belong to several categories at once.

It is impossible to foresee whether non-deterministic algorithms trained on "bi-logical" processors will be able to borrow "behavioural" forms by experiencing statistical "imaginative" states, thus differing from those of embodied thought, and how far such a device could go by using elements derived from its own sensors (i.e.

[3] See e.g. the works of G. Battilotti, G. Giurato, L. Lauro-Grotto, F. Murtagh, M. Tomić.

computational experience) as factors of computation, elevating them to new paradigms without having to trace them back to procedures valid for all machines, and transcending the initialisations of machine learning in an "individuating" manner. Certainly, overcoming the computational one-dimensionality advocated by Turing, by freeing the machine at least partially from the allopoietic bond, would put an end to the "couplage" between human *bios* and machine as we have experienced it. In this perspective, as MIT's "AI existential safety" expert Park notes, «proactive solutions are needed, such as regulatory frameworks to assess AI deception risks, laws requiring *transparency about AI interactions*[4] (...) to ensure that AI acts as a beneficial technology that augments rather than destabilizes human knowledge, discourse and institutions» (Park et al., 2024). The responsibility therefore will fall on the *men* who will train and use AI: for ethics is the human form to impose values on action, and it would certainly not be worth entrusting it to the *simulations*, however admirably performative, of a "thinking machine".

References

Ausubel D. P. (1963), *The psychology of meaningful verbal learning,* New York, Grune & Stratton

Bayes T. (1763), *An Essay towards solving a Problem in the Doctrine of Chances. By the late Rev. Mr. Bayes, F. R. S. communicated by Mr. Price, in a letter to John Canton, A. M. F. R. S.*, Philosophical Transactions, Giving Some Account of the Present Undertakings, Studies and Labours of the Ingenious in Many Considerable Parts of the World, 53:370–418.

Bucci W., Miller N. (1993), *Primary process analogue: The referential activity (RA) measure*, in Miller N., Luborsky L., Barber J., Docherty J. (eds.), *Psychodynamic Treatmenr Research,* NewYork, Basic Books.

Chalmers D.J. (1995), "Facing up to the Problem of Consciousness." In *Journal of Consciousness Studies* 2: 200-19, 1995.

Cleeremans A. (2011), *The Radical Plasticity Thesis: How the Brain Learns to be Conscious*, "Front Psychol. 2011 May 9;2:86. doi: 10.3389/fpsyg.2011.00086. PMID: 21687455; PMCID: PMC3110382.

Damásio, A. R. (1999). *The Feeling of What happens. Body in the Making of Counsciousness,* Boston, Mariner Books

Deane, G., Mago, J., Fotopoulou, A., Sacchet, M. D., Carhart-Harris, R., & Sandved-Smith, L. (2024, January 25). *The computational unconscious: Adaptive narrative control, psychopathology, and subjective well-being*, PsyArXiv Preprint, https://doi.org/10.31234/osf.io/x7aew

Dehaene S., Changeux J.-P., Naccache L., Sackur J., Sergent C. (2006), *Conscious, preconscious, and subliminal processing: a testable taxonomy*, Trends in Cognitive Sciences 10, 204-211

Floridi, L. (2014), *The Onlife Manifesto: Being Human in a Hyperconnected Era,* New York, Springer

Kihlstrom, J. (1987), *The Cognitive Unconscious*, in: Science 237, 1445-1452

Lakoff G. (1999), *The embodied mind*, in Lakoff G., Johnson M., *Philosophy in the Flesh: the embodied mind and its challenge to western thought*, New York, Basic Books

Leroi-Gourhan A. (1965), *La Mémoire et les Rythmes. Le Geste et la Parole*, Paris, Albin Michel

4 The italics are mine.

Matte Blanco I. (1975), *The unconscious as infinite sets. A study in Bi-logic*, London, Routledge

Maturana, H. C., & Varela, F.J. (1980). *Autopoiesis and Cognition: The Realization of the Living.* New York: Springer.

Murri, S. (2020). *Sign(s) of the Times. Pensiero visuale ed estetiche della soggettività digitale.* Milano, Meltemi

Murri S., Scotta D., Patera S. (2024), *Learning and participation in the zeta and alpha generations. Emerging theoretical perspectives on digital educational poverty and the third level of the digital divide,* "Giornale Italiano di Educazione alla Salute, Sport e Didattica Inclusiva / Italian Journal of Health Education, Sports and Inclusive Didactics", 8(2), Edizioni Universitarie Romane

Panciroli C., Rivoltella P. C. (2023), *Pedagogia algoritmica*, Brescia, Scholè-Editrice Morcelliana

Park P. S., S. Goldstein, A. O'Gara, M. Chen, D. Hendrycks (2024), *AI deception: A survey of examples, risks, and potential solutions*, "Patterns", Volume 5, Issue 5100988 May 10, 2024, https://www.cell.com/patterns/fulltext/S2666-3899(24)00103-X

Piaget J. (1947), *La psychologie de l'intelligence*, Paris, Colin.

Ramstead M. J., Sakthivadivel D. A., Heins C., Koudahl M., Millidge B., Da Costa, L. & Friston K. J. (2023). *On Bayesian mechanics: a physics of and by beliefs*, *Interface Focus*, *13*(3), 20220029.

Simondon G. (1958), *Du Mode D'Existence Des Objets Techniques*, Paris, Aubier, Éditions Montaigne

Simondon G. (1964), *L'individuation à la lumière des notions de forme et d'information*, Paris, Presses universitaires de France

Stern, D. N. (1985), *The Interpersonal World of the Infant: A View from Psychoanalysis and Developmental Psychology***,** New York, Basic Books

Turing A. M. (1950), *Computing machinery and intelligence*, "Mind", 59, pp. 433-460

Varela F.J., Thompson E., Rosch E. (1991), *The Embodied Mind: Cognitive Sciences and Human Experience*, Cambridge, MIT Press.

Vaswani, A., Shazeer N., Parmar N.; Uszkoreit, J., Jones, L., Gomez, A. N., Kaiser Ł., Polosukhin, I., (2017). "Attention is All you Need", *Advances in Neural Information Processing Systems*, 30, Curran Associates, Inc. arXiv:1706.03762.

von Foerster H. (1966), *From Stimulus To Symbol: The Economy Of Biological Computation,* in Kepes G. (ed.) *Sign, Image, Symbol*, New York, George Braziller

von Foerster, H. (1981), *Observing Systems*, Seaside (CA), Intersystems Publications

Wing J. M. (2006), *Computational thinking,* in "Communications of the ACM", March 2006/Vol. 49, No. 3, pp. 33-35