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Special Feature

Leonardo da Vinci: Cause, effect, linearity, and memory

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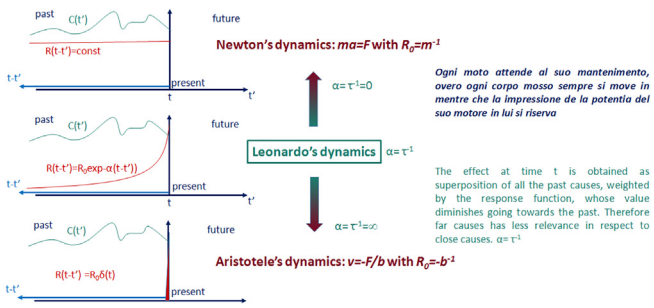
HIGHLIGHTS

- Leonardo da Vinci's physics concepts were analyzed.
- The principle of causality introducing a system impression was discussed.
- Leonardo hypothesized a general law on linearity (pyramidal law).
- Leonardo conciliated the Aristotle's and the Newton's positions.
- The dynamics of Leonardo was framed within the modern linear response theory.

GRAPHICAL ABSTRACT



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ABSTRACT

In this contribution, some textual portions of the Leonardo da Vinci's work were analyzed with the aim to highlight how, moving from Aristotle and going beyond him, he combines the intermediate positions that, from the Greek philosopher, passing through Buridan, arrive to Newton. This has been performed following a path that passes through the formulation of the principle of causality, the use of the concept of linear relationship (pyramidal law) between cause and effect and the introduction of a duration of the impression (memory) of mechanical systems. In the framework of the studies aimed to a valorization of Leonardo as a scientist, which is a crucial aspect in the analysis of the Leonardo genius, the present work sheds a new light on his intuitions about some fundamental physics concepts as well as about the conceptual model that, several centuries later, will be formalized in the modern linear response theory.

Introduction

In approaching some text portions which compose the "scientific production" of Leonardo, who used to fix with excelled attitude and pictorial vehemence even the most rigorous theories of dynamics, the following epistemological considerations are assumed as fundamental:

(i) At the time of Leonardo physics was not an autonomous field of investigation characterized by independent investigation methods and hence it was not separable from philosophy, being by definition *physicus* someone dealing in a general way with the *physis*, i.e. the vast and complex science (in the primordial and authentic sense of knowledge) of Nature. In a broader and also more respectful meaning of the term, the *physicus* was the "philosopher of nature".

Furthermore, the so-called *scientia* should be interpreted as a form of universal knowledge and, when this is not the case, it aspires to be *Sapientia* (as in the case of hermetic-alchemic

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writings, where operations on the material world have as their own purpose the operations on the human mind).

Following the Aristotelian pattern, knowing the "things of Nature" means: (i) to investigate the causes responsible for what happens (*efficient cause*), (ii) to explain which material agent provides the basis of the investigated process (*material cause*), (iii) to investigate to which form the matter tends (*formal cause*) and finally (iv) to understand the *final cause*, that is the purpose of the process.

In the effort of investigating Nature, the *tetrapartita* division is not far from the Leonardo view, who used the four fundamental variables – that, in his dynamic theories, are the motion, the weight, the force and the percussion [1] – and the four constitutive elements of the sublunar world according to the Aristotelian cosmology, also in agreement with the neoplatonic models and the philosophy coming from the Arabs (we know that Leonardo knew, for example, Rhasis).

(ii) For the philosophers of Nature, which can be considered as the direct emanation of the *Platonic One* or the *Christian God*, the laws of the material world (i.e. immanent as part of the visible world) must correspond to the laws of a transcendent (i.e. invisible and superior) world, that, albeit in a way susceptible to constant investigations (all metaphysical and cosmological questions are constantly subjected to comments, elucidations, corrections or refutations over the centuries), do not aspire to "separate" themselves from the general questions of human knowledge: medicine, architecture, astrology, music, etc.

In this sense, our approach to the Leonardo's work aims to fill the epistemic gap between the method of today's exact sciences, which is often separated from the human sciences one, and the widely used analogical method adopted by Leonardo. Leonardo, in fact, had an approach to knowledge which today can be defined as "systemic": he possessed the notion of complexity of interdependent phenomena and therefore he contemplated them to discover their secret dynamics. However, his culture did not conceive the use of analysis as a discriminating or separation criterion, enslaved to a single domain of knowledge; therefore his admirable analytical efforts were always at the service of the profound and metaphysically justified reasons of the *synthesis*.

Up to the eighteenth century, the speculations on the material world were in many cases originated by a "qualitative" interest rather than by a "quantitative" one, and to such speculations the analogical method applied powerful syntheses that interweaved mythology, astrology, natural sciences, medicine, mathematics, etc. Leonardo interpreted the analysis instances basing his approach on the measurable quantities, on the experiments and on the replicability of the phenomena, all these features characterizing the future science in the sense conferred by the post-Newtonian episteme; however, Leonardo blended tradition and innovation, analytical-quantitative spirit and analogical-qualitative method.

(iii) Within the culture of Leonardo the laws of physical motion were not always separable from their ethical consequences, nor from their metaphysical roots since, thanks to the prevailing Aristotelian *auctoritas*, the motion was local (i.e. *locomotion*); furthermore, it was also alteration of quantity and change of quality, i.e. the motion regulated, for example, the flow of the humors in the human body and determined its physiology and character, illness and health. The same laws of sublunar nature (the "second nature" that regulates the elementary world) were not wholly autonomous from the celestial world.

In the question of motion, in fact, Leonardo expressed an appreciative "apostrophe" towards the real causative agent of the motion on Earth, i.e. the *Primo mobile* of Aristotelian origin, saying: "O mirabile giustizia di te, primo motore, tu non hai voluto mancare a nessuna potenzia l'ordine e qualità dei suoi necessari effetti!", i.e "O admirable justice of you, first engine, you did not want to miss at any power the order and quality of its necessary effects!" (A 24r.). Leonardo falls within "a great conception of magic-metaphysics relative to Nature" [1].

In our analysis we will attempt an exegetical path that compares the homologies and the differences among the passionate and often elusive observations of the Leonardo *physicus* and the clear assumptions of the contemporary scientific dictate. The sources that we have taken into account are: (i) sources of which Leonardo had direct knowledge and which intersect almost all the fields of his time knowledge, without having the pretension of an integral, systematic and less than ever exhaustive screening [2]; (ii) sources contemporary to Leonardo from which he may have viewed the unmistakable philosophical profile of the Medicis' Florence; we know that Leonardo read, for example, the Platonic Theology of Ficino [3]; (iii) indirect sources, i.e. the ancient and modern critical studies that, with variously modulated critical purposes and aims, have collected, preserved and thought about the work of Leonardo; such sources are the expression of the work of historians of art, scientists, philologists or philosophers; (iv) the assessment of the fundamental contribution, but certainly and unfortunately less traceable, constituted by the corporative knowledge transmitted orally to Leonardo in his training workshop ("bottega").

The cognitive corpus handed down by a corporative way constituted *sensu stricto* the so-called "secrets of the trade" [4]. The foundational contribution of the tradition of "bottega" to the Leonardo's hermeneutics also seems to have been today revalued [5]. It is important to remind that the "pittore" belongs to the same guild of "medici e speziali" and in this sense Leonardo can be placed in the philosophical context of Dante [6].

In the following, some phrases transcribed by the Leonardo's notebooks are presented, together with their translation, with the aim to clarify the meanings attributed to the introduced terms and quantities by Leonardo. Our analysis proposes a new interpretation of these statements in the light of the principle of causality, of the relations of linearity existing between cause and effect and of the concept of memory expressed, in the terms appropriate to him and to his time, by Leonardo.

The complex principle of causality in Leonardo

"Nessuno effetto è in natura sanza ragione; intendi la ragione e non ti bisogna sperienza" (Codex Atlanticus, 147 r. a.)

No effect is in Nature without cause; you understand the cause and you do not need any experience.

This statement represents a formulation of the principle of causality, according to which each effect is linked to its own cause. The knowledge, through experience, of the cause that has determined a given effect allows to identify phenomenological relationships between the defined quantities making possible the prediction of the behavior of the system and hence making the experience no longer necessary.

"La gravità, la forza insieme col moto materiale e lla percussione sono le quattro potentie accidentali colle quali l'umana spetie, nelle sue mirabili e varie operationi pare in questo mondo dimostrarsi una seconda natura. Imperoché con tali potentie tutte l'evidenti opere de' mortali anno loro essere e lloro morte" (Codex Arundel, P 12v, 151v.)