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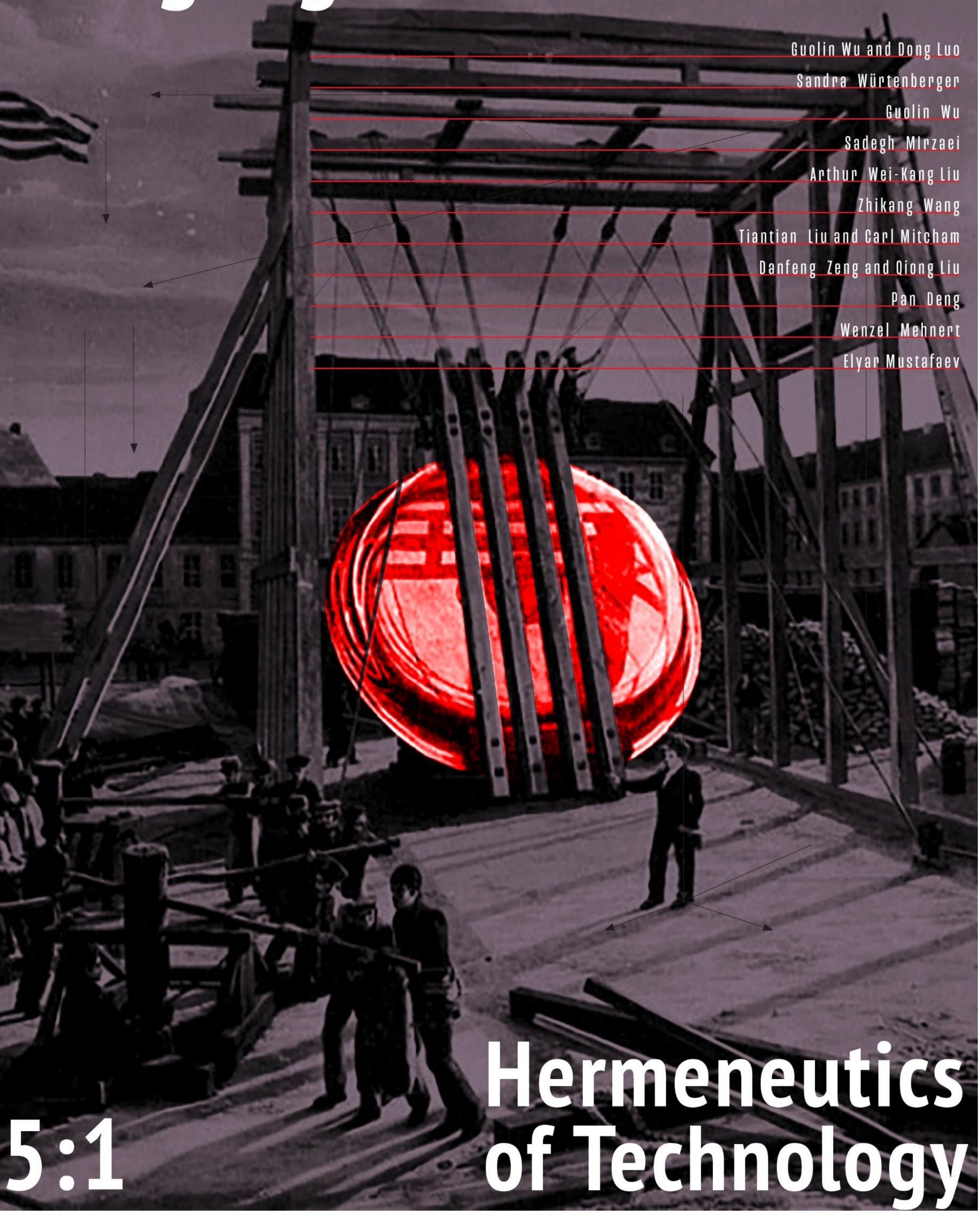

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Hermeneutics of Technology

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Editorial introduction

Hermeneutics: A Broadening Scope of Inquiry

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Abstract

The field of hermeneutics has demonstrably co-evolved with the development of texts themselves, shaped by the advancements in science, technology, and various forms of inquiry that characterize our societies. Initially focused on interpreting specific classical texts, it has broadened its scope to encompass a wider range of textual analysis. The shift extends beyond literature, now also incorporating the concept of *Dasein* in philosophical inquiry. Furthermore, the field has moved from specializing in esoteric or religious texts to a focus on the vast realm of humanistic texts. This expansion continues to embrace scientific and technological discourse, including even the complexities of quantum mechanics. The understanding of these diverse areas – humanities, natural sciences, and technology – is fundamental. After all, both scientific discoveries and technological advancements rely on our ability to comprehend the world around us. This special issue delves into the exploration of science and technology through the multifaceted lens of hermeneutics. It features nine contributions exploring a wide range of topics. These contributions begin with fundamental inquiries into human interaction and communication with things, transitioning to examinations of general scientific hermeneutics and hermeneutics of more specific scientific subjects. These include the interpretation of quantum mechanics and the birth of molecular biology. The contributions then move on toward practical hermeneutics, discussing ancient Chinese technological thought, the current use of artificial intelligence in scientific research, and Technofutures.

Keywords: Hermeneutics; Science; Technology; Quantum; AI

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Редакторская заметка

Герменевтика: расширяющаяся сфера исследований

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Аннотация
Область герменевтики явно развивалась параллельно с развитием самих текстов, формируясь под влиянием достижений науки, техники и различных форм исследований, которые характеризуют наши общества. Первоначально ориентированный на интерпретацию конкретных классических текстов, она расширила сферу деятельности и включила в себя более широкий спектр текстового анализа. Сдвиг выводит за рамки литературы: теперь включая концепцию Дазайна в философских исследованиях. Более того, эта область перешла от специализации на эзотерических или религиозных текстах к сосредоточению внимания на обширной сфере гуманистических текстов. Это расширение продолжает охватывать научный и технологический дискурс, включая даже сложности квантовой механики. Понимание этих разнообразных областей – гуманитарных, естественных наук и технологий – имеет фундаментальное значение. В конце концов, как научные открытия, так и технологические достижения зависят от нашей способности познавать мир вокруг нас. Данный номер журнала посвящен исследованию науки и техники через многогранную призму герменевтики. В нем представлены девять статей, посвященных широкому кругу тем, начиная с фундаментальных исследований человеческого взаимодействия и общения с вещами, переходя к исследованиям общенаучной герменевтики и герменевтики более конкретных научных областей. К ним относятся интерпретация квантовой механики и рождение молекулярной биологии. Тематика затем переходит в практическую герменевтику, обсуждая древнюю китайскую технологическую мысль, современное использование искусственного интеллекта в научных исследованиях и технобудущее.

Ключевые слова: Герменевтика; Наука; Технологии; Квант; Искусственный интеллект; ИИ

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Hermeneutics has evolved significantly from ancient exegesis to modern hermeneutics. It has progressed from the study of specific classical texts to broader textual analysis, encompassing not only literature but also human existence (*Dasein*), nature, and even extending to scientific and technological domains, including quantum texts. This evolution does not entail the abandonment of earlier methods but rather their expansion and coexistence with newer approaches. Initially, researchers like Dilthey envisioned hermeneutics as fundamental to the humanities, distinguishing between understanding and explanation, with understanding focusing on grasping the human psyche. However, in the 20th century, thinkers like Karl Popper and Thomas Kuhn underscored the relevance of hermeneutics in the natural sciences, recognizing that both fields require understanding (Kuhn, 2000, p. 222; Popper, 1979, p. 185). Scholars like Patrick Heelan employed hermeneutics to investigate the early history of quantum mechanics, introducing the concepts of weak and strong hermeneutics (Heelan, 1994, pp. 363-373). Weak hermeneutics directs attention towards textual material, while strong hermeneutics focuses on lived experience or practical application. Don Ihde further analyzed the interplay between technology and the world through a hermeneutical lens in *Technics and Praxis* (Ihde, 1979, pp. 4-6), and he puts forward "material hermeneutics" for the understanding of natural substances (Ihde, 2009, p. 63). In contemporary discourse, concepts such as pre-understanding, the hermeneutic cycle of understanding, and the fusion of horizons are important to both humanities and natural sciences. Understanding is essential not just for scientific discovery and technological innovation, but also for the broader interpretation of science and technology themselves, revealing inherent hermeneutic aspects within these fields. In brief, the intertwined nature of understanding in humanities, natural sciences, and technology necessitates a hermeneutic approach to interpreting and advancing these domains.

This special issue consists of papers examining science and technology through various hermeneutical lenses. The organization of these papers transitions from exploring the hermeneutics of science, encompassing topics such as the hermeneutics of quantum mechanics and molecular biology, to delving into the hermeneutics of practice and technology. This latter section includes investigations into technology in ancient China and explores the relationship between the *Tao* and ancient Chinese artifacts.

Sandra Würtenberger's (2024) paper "Communicating with Technical and Scientific Artifacts: Between Hermeneutics and Sociology of Science" discusses an attempt to bridge the gap between a traditional concept from philosophical hermeneutics and ideas from the sociology of science. The main aim is to describe a method for communication with technical and scientific artifacts. The article integrates insights from the hermeneutic concept developed by the German philosopher Hans-Georg Gadamer (1900-2002) with ideas from the sociology of science and technology that were presented by the French sociologist Bruno Latour (1947-2022) in his writings.

Guolin Wu's (2024) "A Hermeneutical Analysis of Quantum Mechanics" delves into the debate surrounding the difficulty of understanding quantum mechanics despite its successful calculations and predictions. The article explores how a hermeneutic perspective can shed light on new aspects of the understanding of quantum mechanics. In hermeneutics, interpretation encompasses two key aspects: explanation and explication.

"Interpretation," "explanation," "explication" respectively correspond to "*quán shì,*" "*shuō míng,*" and "*chǎn shì*" in Chinese. With insights from the Chinese understanding of these three notions, Wu argues that the development of quantum mechanics reflects a cyclical process of explication-explanation-explication-explanation (and so on).

Sadegh Mirzaei's (2024) "The Affinity between Feedback Mechanism and Hermeneutical Circle" distinguishes the realm of sense-making for human understanding from the scientific and technological realms of non-human experimentation and tool-making. He argues that this juxtaposition between the humane and the artifactual or the natural, linked with understanding and interpretation on one side and control and experimentation on the other, engenders what could be termed a Diltheyan schism. His paper seeks to address this schism by elucidating the connection between two pivotal concepts in engineering and the humanities: the feedback mechanism and the hermeneutic circle.

Arthur Wei-Kang Liu's (2024) "On Scientific Explanation and Understanding – A Hermeneutic Perspective" considers the intricate relationship between scientific explanation and understanding, proposing a hermeneutic framework to unite these two concepts. Liu examines the problem of irrelevance and the problem of symmetry faced by Carl G. Hempel's deductive-nomological (DN) model of explanation and various efforts to address these problems over the past seven decades. By examining understanding and explanation through the lens of hermeneutics and Kuhn's notion of paradigms, Liu suggests an approach to reconciling these issues.

Zhikang Wang's (2024) "Description, Understanding, and Explanation: How Scientific Interpretation Gave Birth to Modern Molecular Biology" discusses the intricate relationship between hermeneutics, scientific discovery, and technological progress, taking the emergence of modern molecular biology as a case study. The paper explores the distinct, yet interconnected, nature of "description-text," "understanding-text," and "explanation-text" within the scientific research process. By examining the hierarchical structure of thinking, the paper argues for a distinction of two complementary approaches to understanding phenomena through the mediation of natural language: the transformation and restoration between abstract concepts across different layers, and the interplay between intuitive images within these layers.

Tiantian Liu and Carl Mitcham's "Toward Practical Hermeneutics of Fourth Paradigm AI for Science" considers the integration of artificial intelligence and science which has ushered in a novel approach to scientific inquiry, prompting the question of how we should interpret the knowledge emanating from this fusion (Liu & Mitcham, 2024). Liu and Mitcham give an analysis of the knowledge generated through AI-driven science through the lens of the distinction between the theoretical and the practical hermeneutics which was made by Joseph Rouse. They propose that, from the theoretical hermeneutics perspective, scientific knowledge has not undergone a fundamental transformation at the theoretical level and views AI merely as another tool enhancing research efficiency, however, this perspective fails to account for the unique challenges posed by AI-enabled knowledge generation, including the emergence of data as a novel form of publication, AI-assisted writing, automated laboratories, and the opaque, unexplainable, and potentially biased nature of machine learning-derived knowledge. Liu and Mitcham then suggest the adoption of practical hermeneutics to address the aforementioned issues and for comprehending the knowledge emanating from these novel research methods within the context of scientific practice.

In their etymological and historical exploration, Danfeng Zeng and Qiong Liu analyse the meanings of the Chinese term 'Jì Shù' for 'technology' (Zeng & Liu, 2024). Their paper "Hermeneutic Analysis of Ancient Chinese Technology" shows that the term 'Jì Shù' consists of two Chinese characters: 'Jì' and 'Shù'. The two characters reflects traditional Chinese thought which takes technology as a complex of two forms of knowledge: knowledge concerning the formless or non-material aspect of technology and knowledge of the form or material aspect of technology.

Pan Deng's (2024) "Hegel on the Steam-Engine" explores Hegel's unique perspective on the steam engine. Even though Hegel did not explicitly discuss the steam engine as an integrated technology, he examined its constituent elements, namely "steam" and "machine," by tracing the former from the ancient Greek theory of four elements to modern meteorological understandings, and by understanding the latter within the framework of dialectics. Deng argues that Hegel's comprehension of the steam engine, underscoring the dialectical nature of knowledge, encapsulates his concept of "pre-scientific hermeneutics," involving a continuous process of reflecting on concepts and reality informed by empirical validation.

Wenzel Mehnert's (2024) "The Futures Circle – An Applicable Framework for Hermeneutic Technology Assessment" finally turns to "Technofutures," that is, to statements about novel and emerging science and technologies (NEST) that disrupt our understanding of the world. Although Technofutures often adopt a hypothetical and speculative stance, they are not mere predictions of the futures, but reflect the current state of affairs and composition of existing knowledge, values, and attitudes, leaving a lasting impact on the development of actual technologies. Mehnert explores how diverse perspectives on Technofutures might offer a framework for the hermeneutic assessment of the futures.

Though the topics addressed in all these papers represent only a fraction of the wide-ranging concerns of hermeneutics, they foreground its importance for understanding a world of technical and scientific artefacts. We aim with this special issue to provide a reminder of the expansive nature of hermeneutics and to inspire further research regarding the Hermeneutics of Technology, broadly conceived.

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Research article

Communicating with Technical and Scientific Artifacts between Hermeneutics and Sociology of Science[1]

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Abstract

In this article an attempt is discussed to combine a traditional concept from philosophical hermeneutics with ideas from the sociology of science. The main aim is to describe a way of communicating with technical and scientific artifacts. Thoughts from the hermeneutic concept of the German philosopher Hans Georg Gadamer (1900-2002) will be combined with ideas of the French sociologist Bruno Latour (1947-2022) which he developed in his texts on the sociology of science and technology. Before this approach is developed, the embedding and differentiation from previous hermeneutic concepts is discussed. Especially the concept of material hermeneutics developed by Ihde and Verbeek is outlined in order to contrast the new approach. – The first task of the article´s main chapter is to show the similarities between the two concepts of Gadamer and Latour, which at first sight seem very different. The second task is to use these concepts for a better description of the interaction or communication between human beings and technical or scientific objects. An approach is shown and discussed that can help to analyse the process of creation and the roles of entities generated in the course of performing science and technology, which – released into the world – become independent entities in their own right.

Keywords: Hermeneutics; Sociology of science; Philosophy of science and technology; Artifact theory; Dilthey; Gadamer; Latour

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[1] The text is based on a chapter from Würtenberger (2022, p. 291-310), translated and reframed with the kind permission of the publisher.

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Научная статья

Общение с техническими и научными артефактами между герменевтикой и социологией науки[2]

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Аннотация
В данной статье обсуждается попытка объединить традиционную концепцию философской герменевтики с идеями социологии науки. Основная цель – описать способ связи с техническими и научными артефактами. Идеи герменевтической концепции немецкого философа Ганса Георга Гадамера (1900-2002) будут сочетаться с идеями французского социолога Брюно Латура (1947-2022), которые он развивал в своих текстах по социологии науки и техники. Прежде чем разрабатывать этот подход, обсуждается встраивание и дифференциация относительно предыдущих герменевтических концепций. Специально в противовес новому подходу изложена концепция материальной герменевтики, разработанная Айде и Вербиком. Первая задача основной части статьи – показать сходство двух концепций Гадамера и Латура, которые на первый взгляд кажутся очень разными. Вторая задача – использовать эти концепции для лучшего описания взаимодействия или общения между людьми и техническими или научными объектами. Показан и обсужден подход, который может помочь проанализировать процесс создания и роли сущностей, произведенных в ходе научной и технической деятельности, которые, выпущенные в мир, становятся самостоятельными независимыми сущностями.

Ключевые слова: Герменевтика; Социология науки; Философия науки и техники; Теория артефактов; Дильтей; Гадамер; Латур

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[2] Текст представляет собой переведенной с немецкого языка и переработанный отрывок главы из книги Würtenberger (2022, p. 291-310), с любезного разрешения издателя.

INTRODUCTION

In order to discuss the ontological determination of technical and scientific artifacts or, more generally, the ontological relationship between human and non-human entities, I would like to confront Bruno Latour's concepts with Hans-Georg Gadamer's conception of hermeneutics. The question behind this is to what extent Gadamer's hermeneutics can be re-purposed in a philosophical context in order to apply it to the process of understanding and communication between human and non-human entities. The point, then, is to harness Latour's radical deconstructivism. It attempts to transcend the dichotomy between human and non-human beings, which can be descriptively illuminating, and uses it methodologically in conjunction with constructive tools.

Gadamer locates hermeneutics itself philosophically or ontologically as part of the human life process. Gadamer develops his concept of hermeneutics on the basis of Heidegger's philosophy. Thus, historicity plays a major role in Gadamer's work – in reference to Heidegger's historical showing of the events of being. This constitutes a major parallel to Latour, who in *Pandora´s Hope* thematises the temporally limited life of research objects that have their validity within their discourses over specific historical periods (Latour, 1999, p. 145-173).

EMBEDDING IN THE DISCOURSES

Before I explain my thoughts on this in more detail, I would first like to distinguish this approach from a position that makes a similar claim. This is the concept of *material hermeneutics* (Ihde, 2005) proposed by the American philosopher of technology Don Ihde, first presented in *Expanding Hermeneutics* (Ihde, 1998), and subsequently also discussed by Peter-Paul Verbeek. Ihde's aim is to transcend European phenomenological concepts, such as those of Husserl, Heidegger and Merleau-Ponty, post-phenomenologically (Verbeeck, 2003, p. 91). In *Expanding Hermeneutics*, he attempts to transfer this to the hermeneutic method (Ihde, 1998, p. 139-150). Ihde describes philosophy of technology itself as a hermeneutic matter. His starting point is Wilhelm Dilthey's interpretation of hermeneutics, which I will therefore briefly outline before discussing Ihde's concept.

One of the fundamental texts in the debate on hermeneutics in the late 19th and early 20th centuries, alongside Schleiermacher's works, is Wilhelm Dilthey's text *Die Entstehung der Hermeneutik* (*The Origin of Hermeneutics*), published in 1900 (Dilthey, 1900/1973). Dilthey first asks himself how scientific knowledge takes place in relation to individuals and explains this through individuation. Action generally presupposes the understanding of other people. The linguistic, humanities and historical sciences are based on the comprehension of the singular and its objectification.

The object of knowledge in the humanities is the immediate inner reality. The object of knowledge in the natural sciences, on the other hand, is the reflex of an actuality in a consciousness. The difficulty with the process of cognition in the humanities is that I cannot become aware of my own individuation from within myself. Only in comparison with the other, through the perception of differences, do I become aware of my own self. Other existence is conveyed in sensory facts such as gestures, sounds and actions. We reproduce these within ourselves and bring the other individuality to objective recognition (Dilthey, 1900/1973, p. 56).

Dilthey calls this process, in which inner things are recognized from outer signs, understanding. Understanding is a process in which a mental constitution is recognized from sensually given signs, e.g., "I no longer understand myself." This is said when one's own actions and decisions seem as if they were made or taken by someone else. Understanding is directed towards all products of the human mind: children's babbling, works of art, music, literature, constitutional texts, etc. (Dilthey, 1900/1973, p. 57). These all require interpretation in order to be understood. According to Dilthey, interpretation takes place as follows: Through the most strained attention, we try to understand the other and to objectify them again and again. This interpretation is always dependent on language. "Therefore, the art of understanding has its center in the interpretation of the remnants of human existence contained in writing" (p. 58, translation S.W.).[3] For Dilthey, this art of interpretation has developed slowly over time, similar to experimentation in the natural sciences. The art of interpretation is now itself scrutinized, and rules for interpretation are fixed. This gave rise to hermeneutic science. For Dilthey (1900/1973) it is the "Kunstlehre der Auslegung von Schriftdenkmalen" (rules of the art of interpreting monuments of writing) (p. 59).

For Dilthey, language is required as a means of enforcement, even if communication with the other is not limited to language alone but can also take place via other means of expression or objects. Dilthey's view of the hermeneutic process of understanding is still very ego-centered. The individual recognizes him- or herself on the basis of the formation of differences and analogies in the other. Dilthey's description of the hermeneutic process remains in the image of the hermeneutic circle. This cyclical structure of hermeneutic understanding was first described as a circle by the classical philologist Friedrich Ast (1808, p. 109-110).

Individual signs that I perceive in others help me to better understand myself by comparing them with the context of my own experience and to grasp the whole by projecting them back. The repetition of this process of understanding then leads to the cyclical structure. Another important point in Dilthey's (1900/1973) work is that he contrasts scientific research practice with hermeneutics as the scientific method of the humanities (p. 62-63).

This is where Ihde comes in, wanting to overcome the "diltheyan divide" by extending the hermeneutic method to the natural and technical sciences. The hermeneutic approach should no longer be limited to texts, but should also be extended to dealing with artifacts, whereby, as the name suggests, he limits himself to material artifacts with *material hermeneutics*. He says: "a material hermeneutics is a hermeneutics which 'gives things voices where there had been silence, and brings to sight that which was invisible'" (Ihde, 2009, p. 80). He also speaks of *visual* or *perceptual hermeneutics*. By way of the instrumental possibilities of the natural sciences, perception should be directed towards texts, but also transcend or question them.

[3] „Daher hat die Kunst des Verstehens ihren Mittelpunkt in der Auslegung oder Interpretation der in der Schrift enthaltenen Reste menschlichen Daseins."

For him, scientific hermeneutics is material in two ways, firstly because material entities are examined, and secondly because the instruments used are of a material nature. In his opinion, instruments and technologies generally serve to provide hermeneutic access and an understanding of things. Ultimately, Ihde is not only interested in exposing scientific methods as hermeneutic, but also in applying the newly acquired diversity of methods to the humanities. He exemplifies this with examples from the historical sciences and archaeology in which scientific and historical texts are critically scrutinized and refuted through the scientific examination of archaeological artifacts (Ihde, 2005). However, Ihde is not only concerned with linking methods, but generally with an ontological reinterpretation of the natural sciences in a phenomenological manner. In this he his following Heidegger and Merleau-Ponty. This becomes particularly clear in the reference to the expansion of human perceptual possibilities through instruments. Natural sciences serve people to specify their being-in-the-world or their relationship to the world in an analytical way (Verbeek, 2003, p. 91; Verbeek, 2005, p. 121-145). “Technologies are not thought to estrange people from themselves and their world anymore, but to mediate their existence and experiences. These new directions in the philosophy of technology can inform a new phenomenological approach of science [...]” (Verbeek, 2003, p. 91). This *hermeneutic turn towards things* does not only refer to the interaction between the researcher and the scientific object, but the hermeneutic interaction with artifacts takes place in all social contexts (Verbeek, 2003, p. 94).

Here I would like to make two key points. Ihde and subsequently Verbeek (2003; 2005) deal exclusively with material artifacts, so that their concept of hermeneutics cannot be sufficient for my purposes. However, the possibility of allowing hermeneutic discussion not only on the basis of a linguistic or textual tradition should be kept in mind with regard to the variety of possible interactions between human and non-human beings in Latour’s sense, or with regard to the interactions between visible and invisible entities. Verbeek summarizes Ihde’s ideas in a trend-setting way when he writes: “Human interpretations of reality are not to be understood in terms of textual and linguistic structures only, but also as mediated by artifacts. In the same vein as Latour, who claims that the social sciences have too exclusively focused on humans and forgot about the nonhumans, it can be said that hermeneutics has only been using half its capacity, occupying itself only with texts and neglecting things” (Verbeek, 2003, p. 94).

GADAMER AND LATOUR

Since I am primarily concerned with the ontological determination of artifacts and the ontological relationship between human and non-human entities in general, before I confront Latour’s thoughts with the hermeneutic tradition, I would like to address its reception and transformation by Hans-Georg Gadamer. Although Gadamer falls short of the diversity of methods proposed by Ihde, he locates hermeneutics itself philosophically and ontologically even more radically as part of the human life process. Although Ihde also ties in with Heidegger’s thinking, he overlooks the fact that in his late philosophy – explicitly in ‘*die Kehre*’ – the overcoming of Dilthey’s divide is already inherently accomplished. According to Heidegger, although people have no influence on when

‘*Sein*’ (being) shows itself, *Dasein* – literally “being-there”/“there-being,” rendered as “Being-in-the-world” – still requires *Sein* in order to show itself or become evident. Gadamer, on the other hand, is fully aware of this when he develops his concept of hermeneutics on the basis of Heidegger’s philosophy, even if this supposedly remains in the context of the humanities due to the great focus on the importance of language. Thus, in Gadamer’s work – following Heidegger’s historical visualization of events of being – historicity plays a major role. This represents a major parallel to Latour (1999) who in *Pandora’s Hope* thematizes the temporally limited lifespan of research objects that have their validity within their discourses over certain historical periods (p. 145-173).

Gadamer generally admits – like Dilthey or Ihde – that hermeneutic engagement takes place not only through texts, but also through art or the like. In doing so, he transcends Dilthey’s concept, which emphasizes empathy with the other for individual individuation. He describes hermeneutic understanding as constituting one's own being-in-the-world or the fundamental process of living. According to Gadamer, understanding proceeds by confronting the interlocutor with one’s own experiences and preconceptions, but with an open attitude that allows one’s own opinion to be revised in the confrontation with the other. Understanding is thus linked to the context of application. This is constituted by an individual question with which the other is approached. The question must have an open structure that is nevertheless guiding. This presupposes the knowledge of one’s own non-knowledge. The meaning of the answer, which only makes sense in relation to the question, does not result from the author’s original intention, but from the reader’s respective thematic confrontation. Understanding thus always takes place through understanding, and for Gadamer this is always based on language. For him, language is the basic preference of our being-in-the-world and thus stands in the middle between the self and the world. The pre-conception revised by the process of understanding leads to a different understanding on a higher level (Gadamer, 2010, p. 387-409). This Gadamerian conception of hermeneutics has been discussed not only as circular, but also as spiral.

Gadamer tries to symmetrize and dynamize the hermeneutic discussion between two partners and to think of hermeneutic development as a process in the history of the spirit as a whole. In the hermeneutic process, the interlocutors, or rather the authors and interpreters, come closer to each other in their opinions on a higher level, until finally a fusion of horizons can take place. The prerequisite for understanding is a common language horizon or living in one language. The reader or translator of a text can never fully empathise with the feelings of the writer. This is why understanding ends in interpretation and is not a mere comprehension of the other. Hermeneutic text interpretation is similar to a conversation between two interlocutors. Author and interpreter find a common language by giving meaning to the text as they put it into words. This makes communication between two partners possible, even if only one of them is really speaking. Understanding and interpreting are one and the same in the medium of the interpreter’s language (Poser, 2009, p. 220-225).

For Gadamer, language is so important precisely because it makes communication across time possible. For him, writing is not the only means of transmission, but it is the preferred one. Writing always establishes simultaneity in the present and thus creates the coexistence of the past and the present. Written tradition is not part of a past world, but rises above it into the sphere of meaning. What is recorded in writing exists in this sphere of meaning independently of the original author and his or her addressee. Anyone who knows how to read can now take part in it. What is fixed in this way has freed itself from contingency and positively freed itself for a new reference. However, one's own horizon of understanding is prior and cannot be transcended. Historians who try to place themselves in the past and free themself from their own context are doomed to failure, since they cannot problematize the preconditions for their understanding at all. Each interpretation thus belongs to its respective hermeneutic situation. Even non-linguistic interpretation, such as the interpretation of and in works of art, presupposes linguisticity. For Gadamer, words are not tools as interpreted by the philosophy of language, but refer to the interweaving of all understanding through conceptuality. Understanding and language are not mere facts, but encompass everything that can ever become an object of thought. Following Heidegger, the ontological quality of the historical is also important to Gadamer. Meaning is detached from the individual in the linguistic artifact. The fact that meaning can be reconstructed later is conditioned on the fact that the interpreter is per se part of the same intellectual-historical tradition through his or her linguistic realisation of the world (Gadamer, 2010, pp. 258-269 and pp. 387-409).

Bruno Latour comes to similar conclusions in a different way. He pleads for the recognition that non-human beings, just like humans, have a temporal horizon or a time-limited life span. Even if it seems to us, for example, that scientific discoveries have an existence in nature prior to discovery by science, it must be recognised on closer inspection that they each exist only within their relations to the scientific community or the social acceptance gained through the work of the research community. Non-human entities (including objects of research) exist because of ontological transformations that humans perform on them by releasing them into their social contexts through the assignment of determinations which render them actants of their own. If scientific views or habits change, they become obsolete and become part of history (Latour, 1999, p. 153-159).

The transformation or justification of scientific results usually takes place in several steps. For example, the direct results are first transformed by translating them into illustrations, graphs or measurement curves, by preparing obtained sample material, by schematising, by statistics or by comparing them with already existing models or findings. Latour (1999) refers to these often sequential steps of mapping as circulating references (p. 150).

Latour, like Gadamer, also turns against the classical division by philosophers of language between the material world and language as two separate ensembles between which there is a barely bridgeable gulf that must be overcome by correspondences. He replaces this dichotomous image with a mediating chain of many small translation steps. The mediation takes place from matter to form, that means to thought structures of the human mind, whereby the chain does not end on either side. Complete correspondence is thus never achieved, but only asymptotically approximated. It is important that these circulating references can be reversibly traversed from transformation step to transformation step, so that reconstruction always remains possible. From one partial reference to the next, a little material information is always replaced by formal information or linguistic analogy. However, these steps remain retranslatable in both directions (Latour, 1999, p. 91-92).

IDENTITY AND ARTICULATION

It would be worth discussing to what extent such a chain of reference can be constructed and defended even without a truly factual starting point in the matter. Perhaps, with regard to research subjects, it is sufficient if their potentiality is first conceived theoretically in order to bring them to real life through a circulating chain of artifactual manifestations, such as scientific research approaches and publications which release them into society as independent entities. In society, other defence mechanisms, such as political legitimation or social acceptance, feed their ontologies.

But back to Latour's model once again. It is only through these partial fixations gained through the circulating reference steps that the dynamic artifact (for example microorganism, chemical compound, physical effect, living being) becomes nameable as something static. For Latour, the transformations obtained through the mappings are translation aids into existing, human and social thought patterns that serve to linguistically defend or individualise the artifacts into entities in their own right. What is important here is that for Latour, the transformation of artifacts by the scientific community or other social discourses always changes all the actors involved. Latour does not see this as a mere process of transformation or translation, but rather as a gain in knowledge. He therefore opposes the classical scientific interpretation of experiments, according to which they merely transform something naturally existing into something artificially determined. For Latour actors change or grow through research. Researchers work towards their research object and vice versa. Both change and reinvent themselves in the process (Latour, 1999, p. 122-127).

As a parallel to Gadamer, it should be noted that Latour sees the individualisation of non-human beings as essentially taking place through the linguistic discourse of human beings, whereby the latter are dependent on the discursive confrontation with non-human artifacts. Thus, for Latour, it is probably not a good idea to parallelize on an equal footing written documentation and experimental findings that are obtained through instrumental methods. Rather, the transformation processes described by Latour can be integrated into Gadamer's model of understanding by adding his notion of symmetry. It is true that Gadamer's approach refers primarily to interpersonal communication through language, or at most he has in mind the communication of one person with another expression through a textual artifact. Gadamer does not transfer this to other, instrumental forms of communication and artifact types. However, as has already been mentioned, he describes the hermeneutic discussion between interlocutors or between author and interpreter as one characterised by an increase in knowledge.

This identity of thinking, language, and world, as it is shown in the ontologies of Gadamer and Heidegger, is not completely overcome by Latour, at least in his model of circulating references, since this approach retains the notion of approximation. Nevertheless, Latour overcomes the differences between thinking, language and world, but without wanting to replace them with a thinking of identity, like that of Gadamer and Heidegger. Latour's model can be read in analogy to Gadamer's hermeneutic spiral movement if the model of circulating reference is understood as the knowledge-expanding engagement of researchers with their objects of research, step by step producing either illuminating scientific texts or better graphics or models. Latour, however, does not only allow for non-linguistic forms of expression, but describes precisely the hermeneutic engagement with non-human entities. In the end, both images – circulating reference as well as hermeneutic spiral – serve only to analyse the hermeneutic discourse between two partners, whereby two new discourse partners can always enter into dialogue on the basis of their linguistically or materially fixed cognitive results.

In order to describe the confrontation and hermeneutic possibilities of an encounter in a human and non-human network of references, Latour proposes his model of propositions. For him, propositions are neither things nor statements, but actants. Latour describes these as "occasions given to different entities to enter into contact. These occasions for interaction allow the entities to modify their definitions over the course of an event [...]" (Latour, 1999, p. 141). It could also be said that propositions are possibilities of action or optional roles that an entity can take in relation to others in the network. Propositions are simultaneously possibilities and events that transform the ontologies of entities. They thus characterise the openness or processual character of seemingly closed entities and thus refer to an invisible space of possibility on the basis of which we perceive and encounter each other as seemingly limited beings. Therefore Latour goes on to write: "Propositions do not have the fixed boundaries of objects. They are surprising events in the histories of other entities" (p. 143). They are constituted by small differences among themselves – differences that are no longer of the order of magnitude of the difference between language and world in the classical picture, but necessary shifts or ontological differences between partners communicating with each other in the network.

For Latour, propositions also interact via language. However, he intends to overcome the image of language bridging the gap between matter and form through rarely sufficient correspondences. Latour therefore views propositions as interacting through articulation. All articulation is based in the linguistic, but transcends it, since on the one hand it includes other forms of expression, and on the other hand, the ability to articulate is not a purely human quality (Latour, 1999, p. 139-141). He thus sums up: "Instead of being of a human mind surrounded by mute things, articulation becomes a very common property of propositions, in which many kinds of entities can participate. Although the word is used in linguistics, articulation is in no way limited to language and may be applied not only to words but also to gestures, papers, settings, instruments, sites, trials" (p. 142).

Similarly, Alfred Nordmann argues for reading the connection between technology and language not only in terms of the philosophy of technology, but also in multilinguistic terms. In this way, the two spheres of linguistic and technical dealings with the world, which are otherwise always kept separate, could be connected with each other. He sees technology as the way we deal with things or with the material world itself. This creates a structural relationship to language, as this is the way we deal with other people. He speaks of a grammar of things that is needed within technology to make new technical developments and to make assessments about technology. However, to discuss technology as a language or containing many different languages also means that we live and work in a multilinguistic environment within the technologised world (Nordmann, 2020, p. 86-89).

CONCLUSION

I will now conclude by linking this multilinguistic idea of society or Latour’s assumption that articulation is not limited to language with Gadamer’s (2010) sentence: “Being that can be understood is language” (p. 478, translation S. W.). This sentence implies that there can also be being that cannot be understood, just as there can be language that does not tend towards being. However, the sentence points out that something can be constituted as being through the comprehension-based performance of language. In relation to technical artifacts and scientific research objects, this means that they, just like a non-humanly produced entity, come into an equal being through the creative character of the hermeneutic process that takes place not only between scientists, but also between them and their research technologies.

Thus, it could be asked whether the philosophical mediation between language and world which underlies Heidegger’s and finally Gadamer’s conceptions, can be used as a basis for a multilinguistic network communication model that goes beyond Gadamer’s hermeneutic process between two partners. Here Latour’s idea of symmetrisation comes in. It refers to existing entities extended to potential, historically possible technical and scientific entities that exist in the background of being. Symmetry is thus extended to the dualism between visible and invisible entities. Thus, Gadamer’s (2010), statement “Being that can be understood is language” (p. 478, translation S. W.) also receives a further meaning when, in the sense of Latour’s concept of articulation, being is understood as something that actively addresses me in order to be understood, and in order to become an independently existing entity through me and my language.

Such an approach can help us analyse the process of creation and the roles of entities generated in the course of performing science and technology. By engaging with the created entities, understanding emerges from their histories and the tasks for which they were created by the spiritual generative power of humans and with which they were released into the world – in which they now take on a life of their own as independent agents.

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Research article

A Hermeneutical Analysis of Quantum Mechanics

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Abstract

The calculations and predictions of quantum mechanics have been successful, but there is a debate whether quantum mechanics is understood. Understanding quantum mechanics from a hermeneutical perspective will reveal new features of quantum mechanics. This requires first of all a review of key concepts as they are rendered in German, English, and Chinese. Interpretation [Chinese “quán shì”] in hermeneutics consists of *Erklärung* [explanation – Chinese “shuō míng”] and *Auslegung* [explication – Chinese “chăn shì”]. The development of quantum mechanics reflects the iterative process of explication-explanation-explication-explanation. Quantum matter revealed by quantum mechanics is characterized by hermeneutics, fusion of horizons, and history of effects. This can be shown in respect to the delayed-choice experiment. Here, the “past horizon” of the photon becomes an unfinished history, a reversible quantum being, which can only be transformed into a classical existence through quantum measurement. A contemporary photon's “past” reality and “present” reality will be overlaid and fused to form the photon's “whole” reality. This is the photonic reality, and it involves a superimposed horizon that forms the whole of the total effect. This hermeneutic interpretation sheds light not only on the interpretation of quantum mechanics but also on the question why there are several such interpretations with a tendency for more to come. In short, the intertwining of explication and explanation, and the projection of meaning reveal that quantum mechanics is hermeneutic.

Keywords: Hermeneutics; Quantum matter; Horizon fusion; Effective history

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Научная статья

Герменевтический анализ квантовой механики

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Аннотация

Расчеты и предвидение квантовой механики оказались успешными, но ведутся споры о том, понимают ли квантовую механику. Понимание квантовой механики с герменевтической точки зрения открывает новые особенности квантовой механики. Что требует, прежде всего, анализа ключевых понятий в том виде, в каком они представлены на немецком, английском и китайском языках. Интерпретация [английское “interpretation”, китайское “цюань ши”] в герменевтике состоит из объяснения [немецкое “Erklärung”, английское “explanation”, китайское “шу мин”] и экспликации [немецкое “Auslegung”, английское “explication”, китайское “цюнь ши”]. Развитие квантовой механики отражает итеративный процесс экспликации-объяснения-экспликации-объяснения. Квантовая материя, открытая квантовой механикой, характеризуется герменевтикой, слиянием горизонтов и историей эффектов. Это можно продемонстрировать на примере эксперимента с отложенным выбором. Здесь “горизонт прошлого” фотона становится незавершенной историей, обратимым квантовым существом, которое можно преобразовать в классическое существование только посредством квантового измерения. “Прошлая” реальность современного фотона и “настоящая” реальность будут накладываться и сливаться, образуя “целую” реальность фотона. Это фотонная реальность, и она включает в себя наложенный горизонт, который формирует весь общий эффект. Эта герменевтическая интерпретация проливает свет не только на интерпретацию квантовой механики, но и на вопрос, почему существует несколько таких интерпретаций с тенденцией к появлению новых. Вкратце, переплетение экспликации и объяснения, а также проекция смысла показывают, что квантовая механика герменевтична.

Ключевые слова: Герменевтика; Квантовая материя; Слияние горизонтов; Эффективная история

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INTRODUCTION

Quantum mechanics has been a great success, however, there are many debates and difficulties in understanding quantum mechanics. From the early development of quantum mechanics to contemporary times, a variety of interpretations of quantum mechanics have emerged. Some physicists have recognized that clarifying the concepts of quantum mechanical interpretations not only solves problems of scientific understanding, but also prevents the development of quantum technology from going astray. However, researchers of quantum mechanics have not paid much attention to the study of quantum mechanics and its contemporary development from a hermeneutic perspective. In hermeneutics, there are many debates about the meaning of “interpretation” and related terms such as the notion of hermeneutics itself. In this paper, we will discuss the meanings of interpretation, hermeneutics, and related terms, and then explore the roles of interpretation, explanation, and explication in quantum mechanics, to reveal the structure and characteristics of quantum hermeneutics, and to provide a possible way forward for the correct understanding of quantum mechanics.

MEANING OF HERMENEUTICS AND ITS RELATED TERMS

Hermeneutics is the Greek word *Hermeneutike*, Latin *hermeneutica*, German *Hermeneutik*, which are derived from Hermes. In Greek mythology, Hermes was a messenger of the gods, charged to carry their will to earth. The work he did involved original meaning, translation, skill, and persuasion.

There are certain hermeneutic ideas in ancient China. Objectively speaking, Chinese hermeneutics is still in an early stage, and has not yet opened up a new way in hermeneutics.

Western hermeneutics can be traced back to the “Peri hermeneias” of Aristotle's Theory of Instruments in ancient Greece. The “Peri hermeneias” is not very extensive, mainly discussing the definitions of nouns, verbs, etc., and explaining the meaning of negation, affirmation, propositions and sentences, as well as the relationship between them. The “Peri hermeneias” does not yet cover many of the topics later pioneered by hermeneutics, such as the author's original meaning, the original meaning of the text, the meaning received by the reader, the hermeneutic circle, and so on.

The object of study of hermeneutics has shifted from canonical texts, to text in general text, and then to *Dasein*, and the trend is that it will turn to nature (including the classical world and the quantum world). Its study includes not only the study and understanding of text, the meaning of text, but also the study of methodology, ontology and epistemology of textual understanding, as well as the question of how an understanding of text is possible. And finally, hermeneutics involves the wisdom of practice.

Hermeneutik has been defined by a number of not only Western scholars. Martin Heidegger (1927/2010) wrote in *Being and Time*:

> [W]e shall see that the methodological meaning of phenomenological description is *interpretation*. The λόγος [logos] of the phenomenology of Dasein has the

> character of ἑρμηνευτική [hermeneutik], through which the proper meaning of being and the basic structures of the very being of Dasein are *made known* to the understanding of being that belongs to Dasein itself. Phenomenology of Dasein is *hermeneutics* in the original signification of that word, which designates the work of interpretation. (p. 35)

This reflects questions of ontology and methodology. According to Paul Ricoeur (1973): "Hermeneutics is the theory of the operation of understanding in its relations to the interpretation of texts" (p. 112). It can be seen that methodology has always been the core concern of hermeneutics.

Defining hermeneutics is controversial. From the perspective of the history of hermeneutics and its contemporary manifestation, the German version of Wikipedia's definition of hermeneutics is very concise and to the point: Hermeneutics (*Hermeneutik*) is the theory of interpretation of text and understanding. The definition of hermeneutics directly points out the object of study of text and understanding, and the core of hermeneutics is the German word *Interpretation*.

According to the German dictionary *Wahrig Deutsches Wörterbuch*, the meaning of *Interpretation* is: *Erklärung, Auslegung, Deutung* [explanation, exegesis or explication, construal]. This meaning of *Interpretation* can be translated into Chinese as „诠释 (quán shì)." The English equivalent of the German concept *Interpretation* is „interpretation." According to the English *Merriam-Webster* online dictionary, the main meanings of „interpretation" are: (1) the act or the result of interpreting : explanation; (2) a particular adaptation or version of a work, method, or style; (3) a teaching technique that combines factual with stimulating explanatory information. It is clear that the English word interpretation emphasizes meaning, but does not have the richer content of the German word *Interpretation*.

On the view to be developed here, *Erklärung* [explanation] emphasizes causality and elaborates reasons and causes. It can be translated into Chinese as „说明 (shuō míng)." *Auslegung* [exegesis or explication] does not emphasize causality and focuses on the interpretation of texts or events in general, and the scope of *Auslegung* is wider than that of *Erklärung*. *Auslegung* has a unique place in hermeneutics, and was first used by Wilhelm Dilthey to generalize the understanding of the *Geisteswissenschaften* or humanities, that is, the understanding of the manifestations of life as being in accordance with technology and art. He writes, "*Die Natur erklären wir, das Seelenleben verstehen wir* [Nature is what we explain and the life of the mind is what we understand]" (Dilthey, 1964, p. 144). The second passage by Dilthey reads, "*Das kunstmässige Verstehen dauernd fixierter Lebensäusserungen nennen wir Auslegung* [We call exegesis the artful understanding of permanently fixed expressions of life]" (Gadamer & Boehm, 1976, p. 126). It agrees with general philosophical practice to translate „erklären" in the first quote as "explain,", while *Auslegung* in the second quote is best translated as "exegesis" or, more commonly, "explication."

The Chinese scholar Hong Handing agrees that, according to German scholars, „interpretation" has at least two meanings: *Erklärung* and *Auslegung*. *Erklärung* focuses on illustrative and descriptive interpretation in terms of principles or wholes, while

Auslegung favors elucidative and revealing interpretation in terms of the things themselves, which we can translate as "explication."

The German *Interpretation* is translated directly into English as "interpretation", while *Erklärung* is translated into English as "explanation" ["说明 or shuō míng "], and Auslegung is translated into English as „explication" ["阐释 or chǎn shì"]. After the examination of the Chinese language, the meaning of Chinese "interpretation" (quán shì) should be: i) with the help of language, technology, people, and in accordance with the nature of things to justly, normatively, lawfully understand, explain, state reasons; ii) with the help of technology and according to laws, norms, fairness, or goodness, to open, understand, explain, or state reasons for things. The meaning of "explication" (chǎn shì) in Chinese also has two basic aspects: i) to express the gradual unfolding of things from the hidden to the obvious by virtue of one's own ability; and ii) to bring out the broad and far-reaching meaning of things by virtue of one's own ability (Wu, 2022, p. 93-95).

The Chinese word "quán shì" (interpretation) is included in the *Hànyǔ Dà Cídiǎn* [Chinese Big Dictionary]. The meaning of the Chinese word "shuō míng" (explanation) in that dictionary is: 1) description and understanding, 2) proof. From the terminological point of view, "shuō míng" (explanation) primarily highlights the meaning of causality.

It should be noted that the English translations in terms of explanation and explication are less precise, while the German and Chinese terms are more precise. In this paper, "explanation" emphasizes the meanings of proof and causation, while „explication" emphasizes the aspect of revealing a nature or hidden meaning. The English word "explanation" corresponds to the Chinese words "explanation" (shuō míng), "elucidation" (Jiěshì) and "explication" (chǎnshì). Chinese "explanation" (shuō míng) focuses more on causal relationships and has the meaning of proof; Chinese "elucidation" (Jiě shì) is more broad and general, as long as a certain account is given; Chinese "explication" (chǎn shì) is to disclose the thing from the hidden to the obvious. In short, we will compare the translations of three words as follows:

German, Chinese, English

Interpretation, quán shì, interpretation

Erklärung, shuō míng, explanation

Auslegung, chǎn shì, explication

"Interpretation" and "hermeneutics" are closely related in that the translation of „interpretation" involves not only the humanities, but also the development of hermeneutics as a whole, the natural sciences and technology. The humanities emphasize understanding, as do the natural sciences and technology.

Since the modern scientific revolution, the positive nature and validity of the natural sciences have posed a serious challenge to the humanities; do the humanities have the same scientific nature and validity as the natural sciences? In German, *Geisteswissenschaft* [humanities] is the counterpart of *Naturwissenschaft* [natural science]. In order to ground *Geisteswissenschaft* and distinguish it from natural science, Dilthey argues that the difference between the methods of natural science and *Geisteswissenschaft* is between explanation (*Erklärung*) and understanding (*Verstehen*). "Explanation" is the subsumption of individual instances, such as observations and experiments, under general laws, and employs the method of causal explanation. Understanding, on the other hand, is to enter into the inner life of others through one's own inner experience, that is, into the world of the human spirit. In other words, *Geisteswissenschaft* provides an "understanding" of the world which differs from the causal explanation of natural science.

Can't the natural sciences use hermeneutic methods? The famous philosopher of science, Karl Popper, disagreed with Dilthey's limitation of hermeneutics to the humanities alone. He argued that human knowledge of things is an explanation or explanatory hypothesis, that it is also possible to err, and that observation is permeated by theory. Understanding is the aim of the humanities as well as the natural sciences. He said: "I oppose the attempt to proclaim the method of understanding as the characteristic of the humanities, the mark by which we may distinguish them from the natural sciences." (Popper, 1979, p. 185).

Transformed by Heidegger and Gadamer, hermeneutics focuses not only on the text but, more importantly, on being. Since hermeneutics is the state of being itself displayed, the display also of the state of being of the objects of the natural sciences (e.g., micro-objects) is a kind of hermeneutics.

As Patrick Heelan (1994) said in his phenomenological study of quantum mechanics, hermeneutics has become a "strong hermeneutics" pointing to experience or practice, instead of a "weak hermeneutics" pointing to the narrow textual material (pp. 363-373). Don Ihde (2009), the founder of post-phenomenology, argued:

> The natural sciences also are deeply hermeneutical, and, on the other side, the unique hermeneutic techniques developed in the natural sciences have deep implications for the human and social sciences. (p. 64)

Generally speaking, written texts are considered the standard texts of hermeneutics, and images, sculptures, etc. are regarded as "paratexts", but in Ihde's view, material hermeneutics, which is part of the natural sciences due to the role of technology, goes beyond textual hermeneutics in the production of objective knowledge and the advancement of disciplines such as anthropology, history, and archaeology.

At present, hermeneutics mainly interprets classical, macroscopic texts (things). There are not many interpretations of the quantum world (quantum texts). While Zhiping Cao (2016) provided a more comprehensive account of Western scientific hermeneutics, his hermeneutical study of the quantum world has yet to be developed.

Since hermeneutics is a method of universal significance, it can interpret macro humanistic phenomena and also phenomena of natural science, and thus it should interpret classical phenomena as well as quantum phenomena so that people can better understand and utilize quantum phenomena and quantum world.

In fact, quantum mechanics has raised a very important problem regarding the interpretation of quantum mechanics. The interpretation of quantum mechanics is not only an external explanation of the quantum world, but also an internal explanation of the quantum world itself (including causal explanations of the quantum world). According to Heelan, quantum mechanics can be interpreted as a bridge between the physical and social sciences. In the spirit of Niels Bohr and Werner Heisenberg, he says, the physical objects in quantum mechanics are revealed as being within the process of measurement in a definite domain, socially and historically. The hermeneutic character of quantum mechanical measurements reveals close parallels to the social/historical science of hermeneutics. The hermeneutic analysis of science requires a shift from an epistemological to an ontological attitude (Heelan, 1995, p. 127).

The development of quantum mechanics reveals the importance of interpretation. A set of quantum mechanical concepts and corresponding laws constitute a quantum mechanical interpretation such that, at present, quantum mechanics involves more than 10 different interpretations, such as the Copenhagen interpretation or multi-world interpretation. Max Jammer‘s famous book "The Philosophy of Quantum Mechanics" features the subtitle "the interpretation of quantum mechanics in historical perspective." This work is a comprehensive introduction to the problem of interpretation of quantum mechanics. It compares the relationship between each major interpretation of quantum mechanics and various concepts, the similarities and differences between the various interpretations and the answers given by leading scientists to some basic questions in the interpretation of quantum mechanics, and the differences between the various interpretations in terms of basic epistemological questions; and finally lists the various objections to each interpretation so that the reader can judge for himself or herself. Choosing a theory of quantum mechanics is not only a process of acquiring the scientific laws of the quantum world, but also a question of how to choose and weigh them. For example, for a specific quantum mechanical problem, it is a matter of choice and trade-off as to which interpretation of quantum mechanics to adopt to deal with the problem.

The foregoing analysis shows that the meaning of the German word *Interpretation* in hermeneutics includes *Erklärung* (explanation) and *Auslegung* (explication), and that the Chinese word "诠释 (quán shì)" also includes both the meanings of "说明 (shuō míng, explanation)" and "阐释 (chǎn shì, explication)." The development of quantum mechanics will show that explication and explanation display the structure of the meaning of interpretation.

INTERPRETATION, EXPLICATION AND MEANING-PROJECTION IN QUANTUM MECHANICS

Natural science requires concepts as a prerequisite. Natural science needs to be based on a set of concepts, and these concepts are part of a certain history and culture. The concepts accepted by the scientific community are not necessarily accepted by non-community members, which requires the use of hermeneutic skills to make non-community members accept them. For this reason, Thomas Kuhn (2000) called these concepts of science its "hermeneutic basis," that is, its "paradigm" (p. 221). Kuhn (2000) states,

> My argument has so far been that the natural sciences of any period are grounded in a set of concepts that the current generation of practitioners inherit from their immediate predecessors. That set of concepts is a historical product, embedded in the culture to which current practitioners are initiated by training, and it is

> accessible to nonmembers only through the hermeneutic techniques by which historians and anthropologists come to understand other modes of thought. Sometimes I have spoken of it as the hermeneutic basis for the science of a particular period, and you may note that it bears a considerable resemblance to one of the senses of what I once called a paradigm. (p. 221)

With the hermeneutic basis of paradigms, scientists need only do conventional scientific research, i.e., solve specific scientific problems according to paradigms.

Kuhn (2000) also states that "[t]he natural sciences, therefore, though they may require what I have called a hermeneutic base, are not themselves hermeneutic enterprises" (p. 222). According to Kuhn and in terms of the evolution of science, there is often a scientific crisis, a scientific revolution, and then normal science. In the stage of scientific crisis, there are many phenomena that cannot be explained by the original scientific theories, and scientists lose confidence in the existing scientific concepts and scientific laws, so people begin to doubt the original scientific paradigm and try to put forward new concepts or new laws to explain the phenomena that occur.

Once a new concept or a new law accounts for key abnormal phenomena and is accepted by other scientists, this is when a scientific revolution occurs and a new scientific paradigm is formed. Obviously, in the stage of scientific crisis and scientific revolution, a variety of concepts, even bizarre concepts, are produced. Supported by some experimental evidence, some theoretical arguments, etc. the scientists who put forward these concepts need to persuade, other scholars to accept their viewpoints, and this activity is carried out until the formation of a new scientific paradigm. Undoubtedly, at the stage of scientific crisis and revolution a hermeneutic process of explanation and explication takes place, in which certain techniques (including even exaggerations of the significance of arguments) are used to persuade others on the basis of scientific, philosophical, and so on, "grounds."

At the stage of normal science where scientific theories have been accepted by scientists, is normal science just about doing specific calculations?

As a matter of fact, the basic meaning and reference significance of scientific concepts, laws of science, etc., are not elucidated during normal science, nor is it clear what the scope of application of these concepts and laws is. The so-called basic meaning of a concept or law refers to the basic meaning of the concept or law itself as expressed in science. The so-called reference meaning of a concept or law means what the concept or law refers to in science, what entity, relationship or structure it represents, and what kind of relationship it has with the objective world, revealing its direct scientific significance.

For example, after Newtonian mechanics was established in the 17th century, the concepts of force, mass, inertia, time, space, speed, acceleration, etc. were not clear and there was a process of acceptance, and the scope of application of Newtonian mechanics was being explored. Take the concept of mass as an example. Newton's 1687/2021 definition of mass is: "The quantity of matter is the measure of the same, arising from its density and bulk conjointly" (p. 1). Obviously, this definition does not give a clear definition of mass; in fact, studies in electromagnetism and quantum mechanics have shown that matter has a variety of quantities, such as charge, spin, baryon number, and so on. To what extent Newtonian mechanics is applicable, first, it is necessary to see whether Newton's laws are correct in order to judge when they are applied; second, it is necessary for new physical theories (e.g., relativity, quantum mechanics, etc.) to give the scope of application of the old theories; and third, it is necessary for extensive scientific communication (scientific description and scientific interpretation) and hermeneutical techniques (e.g., explication). It can be seen that during normal science, science is not just a work of applying science and solving difficult problems, which belongs only to explanation; at the same time, how to understand the concepts, laws of scientific theories, their precise meanings, reference significance, adaptive scope, and deeper social and cultural significance, etc., still need to be explored in depth, which belongs to explication; therefore, during normal science, the explanation of scientific theories is combined with explication, which is a hermeneutic activity or process (compare Liu, 2024).

In the founding stages of quantum mechanics, explanation and explication were complementary and alternating. One example is the introduction of the concept of energy quanta. At the end of the 19th century, blackbody radiation had accumulated empirical data at short and long waves with the discovery of Wien's law and Rayleigh’s law, respectively. Max Planck cobbled together a mathematical formula – Planck's law of radiation – based on these two laws, on the basis of which he came up with the concept of energy quanta, i.e., that energy is not continuous but has a minimum unit of energy (Wu, 2016, p. 1-3).

Planck creatively introduced the concept of energy quanta through a cobbled-together mathematical formula, which involved a process of explication, as the concept of energy quanta opened up the new science, quantum theory, of which he became the founder. However, it is because Planck's radiation law is “cobbled-together,” one has been looking for how to deductively derive Planck's radiation law from general scientific theories (including electromagnetism, thermodynamics, statistical physics, etc.), which is a process of pursuing explanation. The concept of energy quanta – including the concept of “light quanta,” later proposed by Albert Einstein, – formed the “quantum” concept of quantum mechanics, where the correctness of the quantum concept is established through the subsequent establishment of quantum mechanics and its experimental test.

In the normal scientific stage of quantum mechanics, the same hermeneutic activity takes place. In classical science, the form of scientific concepts and laws is basically determined, and hermeneutic activities are mainly manifested in how to understand the basic meaning of scientific concepts and laws, their reference and contextual significance. At the stage of quantum mechanics, the basic concepts and laws of quantum mechanics are changing, as is the formation of different groups. Each group of scientific concepts and scientific laws constitutes an interpretation of quantum mechanics. Healey (1989) defines the interpretation of quantum mechanics as a description of what the world will be like when quantum mechanics is true (p. 6).

There are more than 10 prevailing interpretations of quantum mechanics. Each interpretation of quantum mechanics is a theory of physics for understanding the quantum world, with both a conceptual and a mathematical framework. They are new ways of describing quantum mechanics, and they all describe the quantum world from different sides, levels, or perspectives.

Unlike the classical world, which can be perceived directly by the human senses, the quantum world always requires a process of gradual disclosure, a gradual change from the potential to the apparent. It is a gradual change from the potential to the manifest. The gradual disclosure of the quantum world to human beings is an explication. From the initial revelation of experiments or conceptual thinking to the process of discovering the laws of quantum mechanics, this is a process of explication and a process of scientific discovery. When the laws of the quantum world were discovered, people carried out scientific calculations and predictions under the laws of quantum mechanics, which is an explanation process, however, in this process of explanation, it is not that the concepts and laws of quantum mechanics are all completely shown and clearly understood by people, in which certain basic concepts and laws of quantum mechanics still need to be explored more deeply, which is an explication that includes the exploration of the quantum the world itself. Time, space, matter, and other ontological presuppositions need to be carefully clarified. Through such explication, people will get a clearer understanding, but also may obtain new quantum laws that will allow for new scientific predictions, which is again explanation. With the development of quantum theory, the original thought of clear understanding was later found to be insufficient, and then produced a new understanding, which is a process of explication.

It can be seen that in the process of the development of quantum theory, explanation → explication → explanation → explication → ...... is a process of constant alternation.

A basic difference between explanation and explication is that when the laws of things are discovered, people utilize the laws and concepts for scientific calculations or scientific prediction, which belongs to "explanation." Things or concepts move from unclear to becoming clearer, from uncertainty to certainty, this is "explication." Having created the concept or discovered the law that was originally thought to be clear, it is found after further exploration that there is a deeper meaning and significance, this is also "explication."

There are many interpretations of quantum mechanics, and there is a tendency for their number to increase, which is rooted in several reasons. First, there is formalization. In the creation of quantum mechanics, a formal system (i.e., a mathematical form or law) always comes first, but what exactly that formal system expresses is not clear, nor is the meaning of the physical quantities in it, and yet the formal system supersedes its explication and explanation.

Second, the role of the observer is unclear. The observer has different roles in various interpretations of quantum mechanics. In the Copenhagen interpretation, the many-minds interpretation, and the self-consistent historical interpretation, the observer plays an important role. The Copenhagen interpretation holds that the wave function comes to be described to represent all that an observer can know about a quantum system. The hidden-variable interpretation, and the many-worlds interpretation argue that observers do not play a role in quantum measurements.

Third, the meaning of probability is unclear. In the quantum world, it is the probability amplitude (wave function) that describes wave nature, and the iteration of the probability amplitude is the iteration of the wave, which in this case is a wave of quantum nature. The square of the absolute value of the probability amplitude (wave function) corresponds to classical probability. Is the classical probability here a propensity, a frequency, or a subjective expectation? The formalization of the theory, the notion of the observer, and the probability characteristic of the theory are three reasons for the proliferation of interpretations – a point made by Omnes (1999).

On the view developed here, there are four further reasons why a quantum mechanical interpretation is needed. Fourth, the meaning of the wave function (probability amplitude) is not clear. At the beginning of the creation of Erwin Schrödinger's fluctuation equation, he linked the parent function S with the unknown function by connecting it with the Hamilton-Jacobi equation and assumed $S = log\,\psi$. The meaning of the unknown function was not clear at that time, and it was later named the wave function. Schrödinger called ψ a “mechanical field scalar” and proposed an electromagnetic interpretation of the wave function ψ. Obviously, these ideas were exploratory. Is the wave function an instrumental mathematical description, or a real description of the quantum world? As Changpu Sun (2017) argues, there is no consensus so far on the quantum mechanical interpretation (p. 481) – understanding how the wave function describes the microscopic world – with the author of the present paper arguing that the wave function is a relatively structural reality (Wu, 2012, pp. 118-120).

Fifth, there is the uncertainty of the quantum world itself. On the one hand, the quantum world itself as revealed by the uncertainty principle has uncertainty, so there is uncertainty of the quantum object, as different technical conditions will produce a different nature: An instrument with a fluctuating nature produces quantum phenomena of a fluctuating nature, and an instrument with a particulate nature produces quantum phenomena of a particulate nature – which is wave-particle duality. So, on the other hand, is there only one quantum world, or are there multiple versions? Different quantum mechanical interpretations offer different views. The many-worlds interpretation holds that there is one wave function and many worlds. Thus, multiple concepts and theoretical systems are needed to grasp an uncertain quantum world.

Sixth, the role of the author, that is, of the founders of quantum-mechanical interpretations is not clear. The reason why there are different interpretations of quantum mechanics lies in the fact that there are different founders of quantum mechanics, and these authors have different projects of sense-making that produce different interpretations of quantum mechanics.

Although relativistic theories also have forms that precede explication and explanation, there is only one physical world of relativity. In contrast, the founders of quantum mechanical interpretations can construct completely different quantum worlds, even of a kind that defies people's intuitions, such as the many-worlds interpretation, the many-minds interpretation, and so on. It depends on the intention of the modeler whether or not the indeterminate quantum world is like a lump of clay that one can knead as much as one wants. It is the consciousness, intention or intent of the different founders of quantum mechanics to devise the meaning of the quantum world first, in order to promote the clarification or enlightenment of different quantum worlds. Here, sense-making is a kind of prior mastery of the quantum world, providing a basic blueprint of the structure of the quantum world and its interrelationships. Of course, the correctness of this project of sense-making must be tested by subsequent quantum experiments.

Seventh, the role of users is unclear, that is of scientists who use quantum mechanical interpretations, etc. How are they to choose between multiple quantum mechanical interpretations? There are no set criteria. Between different interpretations of quantum mechanics, there are problems of interpretation.

For each quantum mechanical interpretation it holds that explanation → explication → explanation → explication → .... The creative discovery of an equation (law) of quantum mechanics based on a certain premise is explication; and then, on that basis, the equation is used to anticipate a certain quantum experience, which involves explanation.

To have a project is to be conscious of a possible plan or design for a future thing or event. Planning confronts a world of future possibilities. It is possible to be right, and it is possible to be wrong. Projecting is prior to meaning in that it plans for sense-making. In different interpretations of quantum mechanics, each of the proposers of that quantum theory has different assumptions for sense-making, and it is human planning that is at work in advance and that is planning for meaning. For example, the many-worlds interpretation and the many-minds interpretation, etc., have different assumptions about the quantum world and consciousness.

There is also the problem of explication in respect to different interpretations of quantum mechanics. The same concept is explicated in different interpretations of quantum mechanics to make the meaning of that concept clearer. Thus, the elaboration of concepts, laws, etc., in multiple quantum mechanical interpretations is an understanding of multiple aspects of the quantum world. The existence and development of multiple interpretations of quantum mechanics reveals that explanation and explication are combined, and it reveals the intention or projection of the meaning of the founder of some interpretation of quantum mechanics. In short, the intertwining of explication and explanation, and the projection of meaning reveal that quantum mechanics is hermeneutic.

INTERPRETIVE NATURE, HORIZON FUSION, AND EFFECTIVE HISTORY OF QUANTUM MATTER

Quantum mechanics reveals remarkable features that are different from those of classical science, especially the fact that quantum matter is characterized by its interpretive nature or hermeneuticity, by a fusion of horizons, and by its history of effects.

The interpretive nature of quantum matter

Quantum matter is always subject to the interpretation of quantum theory and quantum technology, and so quantum matter reveals different states or properties.

According to Heelan (1998), The lifeworld has a furniture that comprises those physical and embodied cultural objects, both ‘natural’, like trees, and ‘cultural’, like institutions or technologies, which have names or descriptions in the language; among them are perceptual objects. All of these are (to use Heidegger’s term) *ontic beings*.” (p. 281). In terms of their field of study, the humanities and social sciences study the world (social, spiritual) as it relates to human beings, whereas the natural sciences are confronted with unknown features of the natural world that need to be explored.

Don Ihde, the founder of post-phenomenology provides an in-depth study of the relationship between human beings, technology, and the world, and he proposed four kinds of relation: the embodied relation, the hermeneutic relation, the background relation and the alterity relation. His hermeneutic relation is expressed by the intentional formula: human → (technology-world) (Ihde, 1979, pp. 4-6). Hermeneutic relations show that there is a need for hermeneutic transformation of technology between human experience and the world, with technology becoming part of the world. The quantum world and human beings are interpreted through technology, but human beings cannot grasp quantum technology directly, which needs to be converted with the help of classical technology. Guolin Wu's (2016) research shows that the intentional formula of quantum technology can be rewritten as follows: human → (classical technology – quantum technology – microcosm) and the "microcosm" in this model is the quantum world (p 312). Obviously, the relationship of the quantum world to human beings should be expressed by "interpretation."

Ihde chose hermeneutic relations to describe the hermeneutic role of technology in mediating between humans and the world. It is clear that technology provides the hermeneutic of a (quantum) world that must be true, not false, a manifestation of the quantum world as it is. For the real manifestation of the quantum world, it is necessary not only that it is preceded by a theory (including concepts) of quantum mechanics, but also that one is able to successfully create quantum technological artifacts (quantum instruments) that are based on this theory of quantum mechanics.

Ihde (2009) puts forward "material hermeneutics" for the understanding of natural substances (p. 63). For people based on different theories and technical means, the same substance may make "different" sounds or present different states, so that people can hear or see the phenomena that could not be understood before. In this way, the hidden states of natural substances are revealed continuously. For example, the observation of stars through ordinary astronomical telescopes that can see the size, color, shape of the stars, was followed by the emergence of spectroscopy, so that scientists can use the spectra of the stars to determine their surface temperature. It can be seen that with the progress of observational technologies people's understanding of the stars has become more and more in-depth and comprehensive. Therefore, the interpretation of the material text is closely related to what kind of theory people adopt and what kind of technology they use. Scientific theory and technology are important means of interpreting matter. As Gadamer (2004) put it, "It is enough to say that we understand in a different way, if we understand at all." (p. 296). In addition, the autonomy of the material text is also reflected in the effective historical nature of scientists' understanding of the material text: that is, the constant turnover and evolution of the theories of the natural sciences, their specific scientific tradition, social environment, epistemic interest and analytic mind-set determines the historical nature of scientists' understanding of natural matter.

With the deeper study of the quantum world, it has been found that microscopic particles (electrons, photons) exhibit phenomena different from those of macroscopic objects. At the ontological level, the quantum (microscopic object) itself can be regarded as a wave function, while the quantum state (property) described by the wave function is a possible state, and the quantum state we measure is the result of the interaction between the quantum and the external environment. From a philosophical perspective of science, as far as individual wave functions or the overall wave function formed by multiple wave functions are concerned, they are real and have a rich structure. This means that the wave function must necessarily be associated with the corresponding entity, and it is said that a certain wave function actually corresponds to a certain microscopic object. The wave function of a photon, for example, corresponds to the photon entity. The wave function with reality is similar to macroscopic matter with "divisibility," which is because the wave function can be decomposed into different complete basis vectors, and it may then be expanded into different complete sets of basis vectors (sub-wave functions), that is, a quantum state can be decomposed into several different sub-states.

The "divisibility" of the wave function reveals that the quantum state is a possible state, and that the specific properties of the quantum system can change under different conditions of the measurement device. The properties of microscopic particles in the quantum world change depending on the quantum theory and measurement device used by the measurer (interpreter).

Horizon Fusion of Quantum Matter

Let us examine John Archibald Wheeler's famous delayed-choice experiment, see Fig. 1. Suppose that a photon of light is emitted from a source S and directed to a beam splitter H1, which is then divided equally into two beams of light, 2a and 2b, which pass through two mirrors, A and B, so that the two rays of light can intersect at C (the second beam splitter H2). (1) When the beam splitter H2 is not inserted at C (shown by the dotted line in Fig. 1), the detectors R1, R2 are able to determine whether the photons are coming from the path B or from A, which indicates that the light has a particle nature. 2) When H2 is inserted at C, the detector is able to conclude that a photon is traveling *both* paths B and A *at the same time*, which indicates that light has wave nature. Various delayed-choice experiments were successfully conducted to test this. The original version of the experiment was realized using fast electrons (Jacques et al., 2007; 2008).

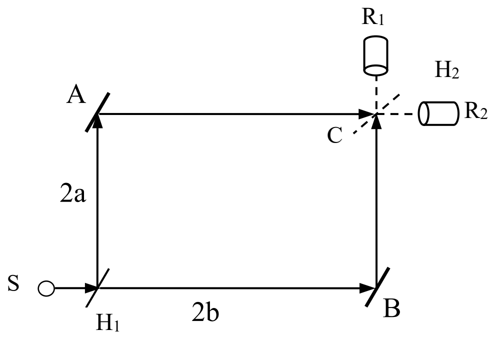

Figure 1. Experimental setup for delayed-choice

If we load the entire experimental setup at once, that is, if we decide to insert or not to insert the second beam splitter before conducting the experiment, what the experiment will show is the fluctuating or particle nature of the photon, respectively. However, Wheeler proposes that after the photon has already passed through the first beam splitter

H1 and before reaching the second beam splitter H2, one then decides whether or not to insert the second beam splitter H2, which is the core of the delayed-choice experiment. After the photon has passed through the first beam splitter, the nature of the light has already been decided, and its nature should not be affected by the change in the experimental setup later (insertion or non-insertion of the second beam splitter).

Now the delayed selection experiment is saying that even after the light has passed through the first beam splitter, i.e., the photon has been selected, we can still select the light to behave as a wave or a particle by choosing to insert or not to insert a second beam splitter, which is what Wheeler called "the present will influence the past."

The question now is, does the experiment really show that "the present will determine the past"?

The delayed-choice experiment was designed on the basis of the laws and principles of quantum mechanics, which belongs to explanation and the study of the causal relationship between the quantum world and quantum phenomena. Explanation here consists in revealing the whats and whys of the quantum world and of quantum phenomena. Wheeler and others consciously designed the delayed-choice experiment to more deeply understand the laws and principles of quantum mechanics (which belongs to explication). The experiment also highlights the significance of Wheeler and other proposers of the projection, so as to test the nature of the microscopic particles through quantum experiments. It can be seen that Wheeler's delayed-choice experiment allows for the unification of explanation, explication, and meaning projection.

Indeed, this experiment will reveal that quantum matter involves the fusion of horizons. According to Gadamer, the horizon is the region of vision that encompasses and embraces all that is seen from a given foothold. Thus, in this experiment, "horizon" can be defined as "the area through which light passes." The horizon is everything that can be seen from a certain foothold.

The light passing through the first beam splitter (H1 in Fig. 1) is fitted into the past horizon, which can be summarized as: past light + fixed measurement device → past horizon, where "fixed measurement device" refers to H1 and its related devices (including the light path). The past horizon formed by the first beam splitter is actually a reversible quantum world.

At the end of the detector, the light passes through the second beam splitter to form the present horizon, which can be summarized as: present light + changing measurement device → present horizon, where "changing measurement device" refers to whether H2 is inserted or not and its related devices (including the light path). The "present horizon" is the area formed by the present light through the changing device (the insertion or removal of the second beam splitter). The present field of view formed by the insertion or non-insertion of the second beam splitter is actually an irreversible classical world.

The existence of microscopic particles is formed by the "superposition" of the above two horizons.

(past light + fixed measuring device) + (present light + variable measuring device) → (past horizon + present horizon)

The above equation can be simplified as:

Light + delayed choice of measuring device → whole horizon → horizon in the wave or particle state → result of classical measurement (wave *or* particle nature)

The horizon of the past and the horizon of the present are formed into a whole horizon. Light in the past is an unfinished light, and it cannot simply be said that light in the past has wave or particle nature. Light is open, and until classical measurements are completed, it cannot be said what classical properties (wave or particle) it has. In delayed choice experiments, the fusion of the past horizon with the present horizon produces a classical measurement of a different nature.

For the delayed-choice experiment, Wheeler also suggested that "the present will affect the past," saying, "In this sense, we have a strange inversion of the normal order of time. Now we have the right to say that moving the mirror in or out has an unavoidable effect on the already past history of the photon." He adds, " 'Past' is just a theoretical word. In reality, there is no 'past' that exists unless it is recorded in the present. The kind of quantum device we use to place this point in the present will have an undeniable effect on what we call the 'past'" (Fang, 1982, p. 13). In terms of the fusion of horizons, the fusion of the present horizon with the past horizon does not mean that the present horizon participates in the past horizon, but rather that the present horizon is connected to the past horizon by way of an iterative nature and without a clear demarcation region, ultimately connecting with the classical measuring device to realize the irreversible measurement of light. The past horizon is indeterminate, and the determinism of the present horizon makes the past horizon determinate, thus making the whole horizon determinate.

There is an ambiguous space between the beam splitters H1 and H2, which is what Wheeler calls the "dragon" whose "head" and "tail" are clear and whose center is unclear, which indicates that: This ambiguous space is the region where the two horizons overlap, and there is uncertainty. But away from this iterative region, "past" and "present" are still clear.

Effective History of Quantum Matter

Delayed choice experiments show that the photon is not a classical particle, nor is it a classical wave, the photon is an unfinished quantum being, it is not a fixed classical being, and the photon is characterized by an effect history.

The effective history is an important feature of hermeneutics, as Gadamer (2004) says:

> The true historical object is not an object at all, but the unity of the one and the other, a relationship that constitutes both the reality of history and the reality of historical understanding.46 A hermeneutics adequate to the subject matter would have to demonstrate the reality and efficacy of history within understanding itself. I shall refer to this as 'history of effect'. Understanding is, essentially, a historically effected event. (p. 299)

For Gadamer, history is not nothingness, not a fixed object, but a reality revealed in relation.

Suppose we set a point *x* (not labeled in Fig. 1) anywhere on the light path between H1 and H2 of Fig. 1 (the reciprocal point of the 2a and 2b light paths), can we then say that the photon's past has been decided once the photon reaches the point x? Obviously not. Because until the photon is converted into a classical being (i.e., after the photon has not passed through H2), light is reversible and does not exist in a classical manner, but in a quantum state. That is, the past horizon is reversible and not fixed; the present horizon has classical determinism due to quantum measurements. Thus, as the past horizon and the present horizon expand and intermingle, there is a region of overlap between them. In this region of overlap, the past and present horizons intermingle to form part of the overall horizon, and it is in the region of overlap that the present changes the past and transforms the reversibility of the past into irreversibility, thus making the entire domain of vision deterministic. In other words, the being of the photon at H1 depends on the being of the photon at H2, and similarly, the being of the photon at H2 depends on the being of the photon at H1. The expression “the present will influence the past” is one-sided; the correct expression is: “the present and the past together influence (the nature of things).”

In the delayed choice experiment, the “past horizon” of the photon becomes an unfinished history, a reversible quantum being, and only after the quantum measurement is transformed into a classical being, the “present horizon” interacts with the “past horizon,” and the photon becomes an irreversible classical object. Only after the quantum measurement is transformed into classical being, and the “present horizon” interacts with the “past horizon,” the photon becomes an irreversible classical object. In other words, the “past” reality of the contemporary photon and the “present” reality will be overlaid and fused to form the “whole” reality of the photon, which is the reality of the photon, and it is precisely a “past” and “present” reality. This is the photon's reality, and it is the process of iterating the horizon (forming the whole field of view) that creates the total effect.

Of observation, the physicist Wheeler (1994) once said,

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> what is ‘observership’? It is too early to answer. Then why the word? The main point here is to have a word that is not defined and never will be defined until that day when one sees much more clearly than one does now (except in the foregoing obvious instance) how the observations of all participators, past, present, and future, join together to define what we call ‘reality.’ ” (p. 43)

c

Without present observation, past realities are indeterminate, and it is only when present observation transforms past realities into determinations, they together constitute, in turn, overall reality. In quantum mechanics, the result obtained from a microscopic object to a measurement is an effect history, the result of the interaction between past and present. The photon is an unfinished “text” that exists historically, and we can understand it only from a historical perspective and a holistic perspective.

When we say that the photon is effective-historical, we do not deny that the photon itself has an intrinsic nature. Effective history does not mean the denial of the past, but means that the present and the past together construct history. What is meant by history is the overall effect of the event itself and its meaning. The photon itself has an intrinsic nature; it is the unity of entity and historical effect. A photon is the photon itself and its physical meaning as a whole.

The reason why quantum measurement of quantum mechanics becomes a difficult problem is that the process of quantum measurement is an overlay of the past horizon and the present horizon formed by the measuring instrument, which is a process of fusion of horizons and a process of effective history, which is not involved in classical measurement. In the quantum measurement process, there is a unity of explanation, explication and meaning-projection.

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Research article

The Affinity between Feedback Mechanism and Hermeneutical Circle

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Abstract

Hermeneutics traditionally revolves around human experiences and sense-making, often considered distinct from the scientific and technological realms of non-human experimentation and tool-making. This contrast between the humane and the artifactual or the natural, associated with understanding and interpretation on the side of the former and control and experimentation on the other, creates what might be termed a Diltheyan wound. This paper aims to find a remedy for this wound by revealing the affinity between two pivotal concepts in engineering and the humanities: the feedback mechanism and the hermeneutical circle. Investigating their relationship at historical and conceptual levels, we find that both concepts trace back to ancient times but they both flourish in early 19th-century modern Europe. While historical synchronicity doesn't inherently imply direct influence or constitutive interaction, conceptual analysis unveils their shared abstract theme of “circular causality,” making them affinitive to each other. Both incorporate errors and misunderstandings within closed loops of cause-and-effect relationships, seeking equilibrium in an open-ended process. Despite their stability, they dynamically adapt to new conditions, accommodating multi-stable configurations. With these historical and conceptual similarities in mind, the question of priority arises: did the feedback mechanism precede the hermeneutical circle, or vice versa? Can we make a meaningful argument for their historical or cognitive precedence over each other? At the very least, an “elective affinity” is discernible – a term borrowed from Weber's seminal exploration of the relationship between Protestantism and Capitalism. We can substitute this chemical metaphor with a cybernetic one, envisioning both concepts entangled in a “closed sequence of cause-and-effect relationships.”

Keywords: Feedback mechanism; Hermeneutical circle; Circular causality; Cybernetics; Governor

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Научная статья

Связь между механизмом обратной связи и герменевтическим кругом

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Аннотация
Герменевтика традиционно вращается вокруг человеческого опыта и осмысления, которые часто считаются отличными от научной и технологической сферы экспериментов и изготовления инструментов. Этот контраст между человеческим и искусственным или естественным, связанный с пониманием и интерпретацией с одной стороны и контролем и экспериментированием с другой, создает то, что можно было бы назвать разрывом Дильтея. Целью данной статьи является нахождение средства преодоления этого разрыва с помощью раскрытия родства между двумя ключевыми концепциями в инженерии и гуманитарных науках: механизмом обратной связи и герменевтическим кругом. Исследуя их взаимосвязь на историческом и концептуальном уровнях, мы обнаруживаем, что обе концепции восходят к древним временам, но обе они процветают в современной Европе начала XIX века. Хотя историческая синхронность по своей сути не подразумевает прямого влияния или конститутивного взаимодействия, концептуальный анализ раскрывает их общую абстрактную тему “круговой причинности”, делая их родственными друг другу. Оба включают ошибки и недопонимания в замкнутые петли причинно-следственных связей, стремясь к равновесию в открытом процессе. Несмотря на свою стабильность, они динамично адаптируются к новым условиям, приспосабливаясь к мультистабильным конфигурациям. Учитывая эти исторические и концептуальные сходства, возникает вопрос о приоритете: предшествовал ли механизм обратной связи герменевтическому кругу или наоборот? Можем ли мы привести значимые аргументы в пользу их исторического или когнитивного превосходства друг над другом? По крайней мере, различима “избирательное сродство” – термин, заимствованный из плодотворного исследования Вебером отношений между протестантизмом и капитализмом. Мы можем заменить эту химическую метафору кибернетической, представляя обе концепции запутанными в “замкнутой последовательности причинно-следственных связей”.

Ключевые слова: Механизм обратной связи; Герменевтический круг; Круговая причинность; Кибернетика; Регулятор

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INTRODUCTION

The essence of humanity lies in the quest for meaning, a pursuit that takes various forms. As humans, we achieve understanding through *interpretation* – whether it be comprehending texts, attributing intentions to ourselves and others when interacting with fellow humans, or assigning meaning to the world and its objects, which inherently lack intrinsic significance. This process of sense-making distinguishes the humane from both the natural and the artificial, giving rise to the Diltheyan dichotomy of understanding (*Verstehen*) and explanation (*Erklären*), separating human sciences from natural sciences, as elucidated by Ihde (2010) in what he terms the "Diltheyan divide." This division echoes the Cartesian dichotomy of mind and body, where they are conceived so distant from each other that their very interaction turns into a formidable problem, termed by Deacon (2011) as the "Cartesian wound." Inspired by Ihde's and Deacon's terminology, we might diagnose a "Diltheyan wound" and pose the question: how can human sciences and natural sciences interact peacefully? Is there any actual interaction between them? My affirmative response focuses on exploring their commonalities. In the realm of natural and engineering sciences, we encounter the concept of "feedback mechanism," while in the humanities, the concept of the "hermeneutical circle" prevails. Through historical and conceptual analysis, we can reveal a shared theme: both concepts grapple with the intricate interdependence of entities that serve as both causes and effects *simultaneously*.

In presenting my argument, I begin by providing an exposition of the concept of the feedback mechanism and its historical development. Subsequently, I articulate the notion of the hermeneutical circle and trace its historical evolution. Through a comparative analysis of their histories, I highlight their simultaneous flourishing during the early 19th century. In the conceptual comparison, I contend that circular causality serves as the overarching abstraction, acting as a unifying theme, or *tertium comparationis*, for both. I conclude by posing a pivotal question: within their relationship, which one takes precedence? Is there a meaningful basis for prioritizing one over the other, be it through historical precedence or cognitive significance?

FEEDBACK MECHANISMS: CONCEPT AND HISTORY

Feedback mechanisms have a long history, yet the conceptual framework is relatively recent. Currently, it has seamlessly integrated into our everyday language, functioning as a loanword across numerous languages. The commonplace act of seeking "feedback" and offering it to others might seem trivial, but it has not been always so natural. This technical term has originated from within the field of engineering. Wiener, a key figure in popularizing the term, defines feedback as "a method of controlling a system by reinserting into it the results of its past performance" (Wiener, 1959/1990, p. 61). The feedback mechanism harnesses a loop between input and output to steer or regulate a system. The design need not be intricate. As Wiener notes, "Feedback may be as simple as that of the common reflex, or it may be a higher order feedback, in which past experience is used not only to regulate specific movements but also whole policies of behavior" (p. 33). While circularity is fundamental, not all circular processes qualify as feedback in the technical meaning. Feedback mechanisms are inherently goal-oriented and serve the purpose of controlling a system. A classic illustration is the thermostat, which controls the temperature of a room.

For humanists, the concept of control is a red flag and may raise concerns, potentially highlighting a strained relationship and reopening what I referred to as the Diltheyan wound. However, in the context of the feedback mechanism, the notion of control does not and should not carry negative connotations. Feedback mechanisms are goal-oriented, but these goals are interpreted by humans and are susceptible to change.

Whether in the form of tangible artifacts or conceptual models, simple or complex, feedback mechanisms can serve as valuable tools for modeling, studying, or constructing systems, ranging from living organisms and human societies to brains, minds, and robots. The systematic exploration and application of them reached its pinnacle in the 20th century under the terms of Control Engineering and "Cybernetics" – coined by Wiener[1] to mean the art of navigation toward a goal or the art of taking control

> We have decided to call the entire field of control and communication theory, whether in the machine or in the animal, by the name *Cybernetics*, which we form from the Greek *χυβερνήτης* or *steersman*. In choosing this term, we wish to recognize that the first significant paper on feedback mechanisms is an article on governors, which was published by Clerk Maxwell in 1868, and that *governor* is derived from a Latin corruption of *χυβερνήτης*. We also wish to refer to the fact that the steering engines of a ship are indeed one of the earliest and best-developed forms of feedback mechanisms." (Wiener, 1948/2019, p. 23)

Cybernetic ideas have notably affected various scientific and technological fields – such as engineering, physiology, psychology, artificial intelligence, and alike – their influence also extends into the realm of humans – most notably the postmodern and countercultural movements. Nevertheless, like many profound concepts, the roots of cybernetic ideas trace back to ancient times.

The task of identifying and individuating historical instances of feedback mechanisms from the past is a serious challenge. This challenge is common in historical research due to the discrepancies in conceptual repertoire across different ages. To avoid anachronistic errors, a viable approach involves narrating a developmental story that reconstructs the past in light of the present, pinpointing pivotal moments of inception. While microbes existed in the world, it was Pasteur who elevated them to human awareness, establishing them as indispensable actors in our modern world. Evolutionary concepts predated Darwin, yet it was he who wove together a network of people, evidence, analogies, and narratives to articulate a compelling theory of evolution. Similarly, although feedback loops were inherent in various natural and artificial processes, their acknowledgment in the consciousness of humans only materialized in the

[1] This is not a totally new term, not at least in French. As Latil (1957) writes, "Strange as it may seem, this word appears in the Littre dictionary: Cybernetics–Name given by Ampere to the branch of politics which is concerned with the means of government." (p. 15) Even Ampere did not coin the term in 1834. He borrowed it from Greek: "The word is even employed as a substantive, with the meaning "science of piloting", by Plato, who puts it in the mouth of Socrates: "Cybernetics saves souls, bodies and material possessions from the gravest dangers (*Gorgias*, 511)" (p. 16).

19th century – a developmental story that I would tell according to Mayr (1970) which remains almost unique in narrating the origins of feedback mechanisms.

In his unique exploration, Mayr outlines criteria for identification of feedback. Firstly, there must exist a command signal and a controlled variable. Secondly, there should be a closed-loop relationship between command and control with negative feedback. Thirdly, it should be possible to identify a sensor for detecting the controlled variable and a comparator for gauging the actual controlled variable against the desired value, and at least one of these two elements should be physically distinct. Applying these criteria, Mayr identifies three ancestral lines in the evolution of feedback: the water clock from the Hellenic period, the 17th-century thermostat in Europe, and the mechanisms of controlling windmills up to the end of 18th century.

According to Mayr, the water clock stands out as the oldest device embodying a feedback mechanism, with a history dating back to ancient times. A notable example is attributed to Ktesibios[2] in third-century BC Greece.[3] At the core of this water clock lies a float valve designed to regulate water flow. In this setup, a cone floats on the water's surface within a small vessel. Water enters from above and exits the vessel through a hole in the wall. The floating cone serves as a sensor,[4] reacting to the water level. If the level is too high, it rises to close the inflow; if too low, it descends to open it. The inflow of water both causes variations in the water level and is influenced by that very level, creating a closed sequence of cause-and-effect. Maintaining a constant water level results in a steady outflow, making it an effective time-measuring device. Beyond timekeeping, feedback mechanisms embedded in water clocks can serve various other purposes, like empowering automata.

Another notable gadget is an oil lamp credited to Philon of Byzantium, an inventor from a generation following Ktesibios. Unlike the water clock, Philon's oil lamp operates based on hydraulic principles, but without a floating element. Instead, it incorporates the dynamics of air pressure and vacuum. This ingenious mechanism has found application throughout history, with inventors such as Heron of Alexandria (first century AD), Banu Musa brothers (9th century), da Vinci (15th century), Leurechon (16th century), and, more recently, in modern agriculture, specifically in drinking troughs for animals (See Mayr, 1970, p. 18).

The final feedback mechanism from the Hellenic period highlighted by Mayr is a wine-dispenser crafted by Heron, an inventor from Alexandria renowned for his treatise named *Pneumatica*. Resembling the float valve of Ketebsios, Heron's device introduces an innovation: "the complete separation of the functions of sensing (float) and that of control action (valve); through this the system has become formally a feedback system in the modern sense" (Mayr, 1970, p. 21). This mechanism has a counterpart in today's toilet flush tanks.

Mayr examines similar feedback mechanisms in the Islamic golden age, notably those described by Banu-musa brothers (9th century), Al-Jazari (12th century), and Al-

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[2] His name is also written as Ctesibius.

[3] A great reconstruction of this clock can be visited in the Deutsches Museum in Munich.

[4] Mayr says the bottom of the cone is the sensor and the top of it is the actuator. This distinction is made to meet his criteria for defining a feedback system. I will return to this point.

Khurasani (13th century). Some well-known examples include the tower clock in Gaza, which had vestigial features from the Hellenic period. According to Mayr, despite minor adjustments, these mechanisms in the Islamic world bear no substantial difference from those of the Hellenic era. It was in Europe that new mechanical feedback mechanisms truly thrived.

Mayr (1970) asserts, “The first feedback system to be invented in modern Europe and independently of ancient models is the temperature regulator of Cornelis Drebbel (1572-1633) of Alkmaar, Holland” (p. 55). Drebbel, according to Mayr, comprehended the fundamental principles of feedback and applied them practically. Mayr goes on to claim that, “According to all available evidence Drebbel must be regarded as the inventor of temperature regulation and hence as the inventor of the first feedback mechanism of the West” (p. 55). Drebbel's invention was well-known in 17th century Europe, acknowledged by figures like Boyle and Hooker, and documented in the transactions of the Royal Society. Drebbel's mechanism aligns with Mayr's threefold criteria, as it senses temperature by gauging the pressure of smoke and heat produced by the furnace's fire. It has a recognizable path for negative feedback, utilizing levers to regulate the fuel valve and maintain the desired temperature. This innovative configuration could be applied to control chemical reactions or facilitate chicken hatching. Remaur (17th century), a French physicist who contributed to the development of thermostat, describes Drebbel's mechanism as “making use of these degrees of heat against themselves, so as to cause them to destroy themselves” (as cited in Mayr, 1970, p. 68).

Mayr identifies the third and final ancestral line of feedback in the mechanisms developed for controlling windmills during the 17th and 18th centuries. Windmills presented the challenge of controlling various variables such as the rate of grain input, the speed of the grinders, the distance between grinder stones, the orientation of the mill toward the wind, and the force of the wind on the sails. In response, different mechanisms were devised in Europe to regulate these interconnected variables. Notably, there emerged a speed regulation mechanism anticipating Watt's governor. Mayr (1970) notes, “A new idea was grasped with enthusiasm and imagination, but it was not always cultivated to the stage of maturity. It was only in another field, the steam engine, that the idea of feedback control became historically effective” (p. 108).

Watt's Governor, also known as the centrifugal governor, served as a regulating device for steam engines. It consisted of two interconnected centrifugal pendulums, sometimes referred to as “flying” pendulums. These pendulums rotated in response to the engine's motion, either spreading apart or coming close due to centrifugal force. This movement effectively sensed the speed of the engine. Utilizing levers, through a path for negative feedback, the governor controlled the steam valve, thereby regulating the engine's speed in response to any fluctuations. Beyond its mechanical ingenuity, Watt's governor possessed a visually captivating quality, making it one of the most iconic images in the history of technology. However, interestingly, Watt himself might not have fully grasped the impact of the device that bore his name. As Mayr (1970) points out, “One and a half centuries later, when feedback came to be regarded as a key concept not only in industrial but also in sociological matters, the character of technology had changed far beyond anything Watt could have imagined” (p. 113).

The significance for our current discussion lies not in the technical intricacies of Watt's Governor but in its profound impact on society and culture. By the turn of the 19th century, the widespread use of the centrifugal governor contributed to the integration of the feedback concept into “the consciousness of the engineering world” (Mayr, 1970, p. 109). While Mayr has elsewhere explored the intricate interplay of technology, economics, and politics (see Mayr, 1971 and Mayr, 1989), he does not extend his historical account into the realm of humanities, which constitutes the aspiration of this paper.

Before delving into hermeneutics, it's essential to loosen the tight constraints of Mayr's threefold criteria. Flexibility in our conception would prepare us for the exploration of the conceptual and historical connections between feedback mechanisms and hermeneutics, potentially uncovering shared principles and influences.

Mayr, according to his rigid account, dismisses several mechanisms that others consider as feedback devices. In a footnote, he names inventions like the south-pointing chariot of ancient China, the mill-hopper, the fly-wheel with centrifugal weights, and Huygens' centrifugal pendulum, as “erroneously” labeled by others as feedback devices (see Mayr, 1970, p. 133). Mayr's concerns can be summarized in two main worries. Firstly, he emphasizes that human action should not be part of the feedback loop. He believes that the inclusion of human contribution might result in an overly inclusive definition of feedback, potentially covering a broad spectrum of systems. Secondly, Mayr asserts that for a device to be considered feedback, it should be “designed” or “intended” to function as such.

Considering the Chinese south-pointing chariot, Mayr says that it has been labeled by Joseph Needham as the first homeostatic device.[5] It has two wheels on a single rod connected to a pointing device through a gearing mechanism. The pointing device remains stable in relation to the road, resembling a mechanical compass. While designed to be self-regulatory, Mayr rejects this as feedback due to its reliance on human involvement – the chariot driver consulting the mechanical compass to guide the chariot. An objection to Mayr's stance arises by appreciating two key points. First, Mayr's objection assumes that the desired goal is to steer the chariot. However, one might argue that the goal is to maintain the direction of the pointing device, not necessarily the chariot itself. Second, there's room to interpret human actions in terms of feedback, not only loops within the brain's neural networks but also in the loops of interaction between the body and its surroundings, which blurs the boundaries of humans and machines.[6] Moreover, even the most complex feedback systems involve human factors at some point or level.

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[5] Joseph Needham, a renowned biochemist and Sinologist, is indeed widely recognized for his monumental work, “Science and Civilization in China.” This multi-volume series, started in 1954, provides an extensive exploration of the history of science and technology in China. In another influential work, Needham, along with Wang Ling and Derek J. de Solla Price, assert that mechanical clocks originated in China rather than Europe. (see Needham et al., 1960). Unfortunately, this cannot be pursued within the scope of this paper.

[6] The coupling between mind, brain, body, artefacts, and the environment is increasingly appreciated in cognitive science (Varela et al., 2017; Clark, 2001; Newen et al., 2018;), Archaeology (Malafouris, 2013), and philosophy of technology (Ihde & Malafouris, 2019), to name but a few trends.

In other words, from the viewpoint of feedback, the human and machine can be seen as symmetrical or in Latour's terminology *actants*.

Another mechanism that does not align with Mayr's stringent criteria is the mill-hopper (*baille-ble* in French). Latil (1957), in his influential book aimed at introducing cybernetic ideas to the French public, presents it as the oldest example of a feedback mechanism predating Watt's governor. He writes,

> Here was a governor ante-dating that of Watt by at least two centuries. The grain distributor has always been called a "*baille-ble*" and consists of a wooden chute which guides and delivers the stream of grain. The end of this chute rests directly on the driving shaft of the mill, which at this point is squared or encased in a more or less square box whose edges are strengthened with metal. At every revolution the "baille-ble" received four knocks, each of which makes some grain fall out. In modern mills this principle is termed a "shock distributor." When the wind increases, the mill turns more rapidly and will receive more grain; with less wind, the feed will be diminished. (Latil, 1957, p. 117)

This is an ingenious simple feedback system. However, Mayr excludes the mill-hopper from the category of feedback mechanisms, stating, "The property of self-regulation is inherent to them. It is not the result of deliberate design, as would be the case if the comparator, the feedback path, or the sensing device could be identified as physically distinct elements. All this makes it clear that the mill-hopper has no significant place in the history of feedback control" (Mayr, 1970, p. 93). Mayr's concern revolves around the absence of *deliberate design*, presupposing that deliberate design of feedback mechanism necessitates the use of separate sensors and actuators functioning along a feedback path. However, this demand may be overly stringent, even for the centrifugal governor. Ironically, formalizing the dynamics of the governor into a neat measure-compare-adjust framework proves challenging, if not impossible. Instead, its dynamics find the best expression in differential equations, inspiring the Dynamical System approach (Port & Van Gelder, 1998; Thelen & Smith, 2002) to model human cognition and action within a dynamic framework. As Bermúdez (2020) summarizes, "It is a coupled system that displays a simple version of attractor dynamics, because it contains basins of attraction. Unlike the computational governor, it does not involve any representation, computation, or decomposable subsystems." (p. 156). In a nutshell, even the governor is not *deliberately designed* with separate sensors, comparators, and actuators and cannot pass Mayr's filter.

While Mayr's concern about the vacuity of a concept with too many instances is valid, there's also a risk in overly limiting the scope of the concept. Defining feedback requires a nuanced approach that acknowledges the complexity of systems. However, the identification of feedback should not solely rely on the inherent properties of a system, nor should it be confined to the intentions of its designers or builders. A more flexible account of feedback is needed. In the context of our current discussion, I refer to the definition of feedback as outlined in a contemporary and reputable control engineering textbook: "Feedback exists whenever there is a closed sequence of cause-and-effect relationships." (Golnaraghi & Kuo, 2017, p. 13). Importantly, the authors stress that the feedback need not be exclusively physical, enabling the modeling of ostensibly non-feedback systems within a feedback framework. This broad and inclusive perspective facilitates the recognition of a wider range of systems as instances of feedback – for example, the hermeneutical circle.

HERMENEUTICAL CIRCLE: CONCEPT AND HISTORY

Hermeneutics, the art or philosophy of interpretation, has a range of meanings and applications. At any rate, a central skill in hermeneutics is navigating the hermeneutical circle. As elucidated by George, "On the one hand, it is necessary to understand a text as a whole in order properly to understand any of its parts. On the other hand, however, it is necessary to understand the text in each of its parts in order to understand it as a whole." (George, 2021) This is a circle not only between the whole and the parts of the text, but also between the reader and the text. The interpreter's mindset, influenced by initial expectations and experiences, shapes the interpretation of the text. This, in turn, alters the interpreter's expectations and experiences, perpetuating an iterative cycle. This process, marked by its open-ended and infinite nature, culminates in what Gadamer famously terms the "fusion of horizons" (Gadamer, 2004).

The circularity inherent in the hermeneutical circle extends beyond the relationship between the whole of a text and its parts or a reader and a text. It extends to the introspective relationship within an individual, leading to a self-referential interpretive task (as spelled out by Heidegger), or the conversations between oneself and others (Rorty, 1979), or the I-Thou relations with objects or loved ones or spiritual connections between humans and the divine (Buber, 1970). Moreover, this circular process might extend to relationships between humans and machines (Grunwald et al., 2023). In each of these applications, the hermeneutical circle not only describes but also prescribes an open-ended and purposeful interplay, emphasizing the ongoing nature of interpretation and understanding.

The hermeneutic circle, like any profound concept, has a historical lineage. In ancient Rhetoric, as expounded by thinkers like Plato and Aristotle, the dynamic interplay between the whole and its parts is acknowledged in the composition and understanding of texts (see Grondin, 2015, p. 300). This circular engagement may be perceived as a necessity primarily for novice readers grappling with complex treatises, necessitating a back-and-forth exploration until a comprehensive understanding of the whole is achieved. In this perspective, the meaning of the text is presumed to be readily available to experienced readers, with the circular process serving as a crutch for beginners. Conversely, others argue that this cyclic engagement is indispensable and influences both novices and experts alike. Grondin, following a historical overview of the hermeneutical circle in ancient rhetoric, claims that this circle is mostly descriptive and turns into a philosophical "problem" in the early nineteenth century. As he writes,

> The first author to speak explicitly of a "hermeneutic circle" was in all likelihood the German classical philologist A. Boeckh (1785–1867): alluding in his lectures of 1809 to the different types of interpretation (*Auslegungsarten*), for instance, the grammatical and the historical, he says that the "hermeneutische Cirkel" between

> them cannot be entirely avoided (Boeckh 1966, 102; Teichert 2004, 1342). He influenced the Protestant theologian Schleiermacher (1768–1834), who spoke extensively of the "circle" of the whole and the parts in understanding (without, however, using the expression h. circle). (Grondin, 2015, pp. 300-301)

In regard to our discussion, the intriguing historical fact lies in the simultaneous emergence of the concept of the hermeneutical circle and feedback in the early 19th century Europe. While my brief historical sketch falls short of establishing a direct relationship between the two, it is noteworthy that the notion of circularity in hermeneutics undergoes a transformation throughout the 19th and 20th centuries. As noted by Grondin, "The point of classical, methodical hermeneutics was indeed to avoid the hermeneutical circle of an interpretation that would be tainted by its presuppositions, premises, or erroneous assumptions about the whole or the intent of a work." (Grondin, 2015, p. 299) Accordingly, two contrasting attitudes toward the hermeneutical circle are distinguishable: conservative and progressive. The conservative perspective views the circle as potentially vicious or, at best, a mere aid, posing a threat to the objectivity of understanding in the humanities, contrasting with the apparent stability enjoyed by exact sciences. Conversely, the progressive perspective sees the hermeneutical circle as virtuous and constructive. As Grodin explains, "the key is not to escape the hermeneutical circle, but, following Heidegger's famous phrase, to enter into it in the right way." (ibid). All inferences involve this kind of circularity. As Goodman (1983) writes, "This looks flagrantly circular…But this circle is a virtuous one…*A rule is amended if it yields an inference we are unwilling to accept; an inference is rejected if it violates a rule we are unwilling to amend*" (p. 64). It is noteworthy that a similar contrast can be observed in the realm of feedback mechanisms. A "conservative" feedback mechanism is any pre-programmed self-regulating device with a fixed goal, such as a thermostat maintaining a constant temperature, or any device acting with a centralized command center. On the other hand, "progressive" feedback allows for adaptability and change in goals and programs, exemplified by a cat dynamically chasing a mouse, or any system capable of self-organization without any central authority. In any case, conservative or progressive, we can discern a common theme. The key insight is in conceptualizing the notions of feedback mechanisms and the hermeneutical circle in more abstract terms, which I term "circular causality."

CIRCULAR CAUSALITY: THE TERTIUM COMPARATIONIS

One of the most enduring challenges in philosophy is the concept of causality. Philosophical perspectives on causality range from complete rejection to rigorous logical formalizations. Questions surrounding causation often delve into issues of necessity, universality, linearity, reversibility, and more. For the present discussion, the emphasis will be on exploring the aspect of linearity.

In Medieval Islamic Philosophy, a well-known philosophical principle was established as "the impossibility of circular causality." It was argued for by many. Avicenna, for instance, argued against circular causality using *reductio ad absurdum*. He invoked another principle stating that "the effect always comes after its cause." If circular causality were to exist, it would imply effects simultaneously preceding and succeeding their causes, leading to an untenable situation. Similar arguments against circular causality are found in theology, where Aquinas's well-known "argument of the first cause" for the existence of God relies on the assertion that "nothing can be the cause of itself because nothing can exist before itself." Notably, both arguments reject circular causality based on a linear conception that hinges on the temporal sequence of cause and effect, asserting that nothing can be the cause of itself since nothing can precede its own existence. This is akin to the well-known fact that an individual cannot lift oneself out of a swamp by pulling their bootstraps.

This line of reasoning leads to various conclusions: the necessity for a complex system to be preceded by an even more complex one, the necessity for the universe to be created or designed by an intelligent designer, and the necessity of the spirit for being human and the vital force for being alive. The overarching theme is similar to the claim that no machine can exhibit intelligent behavior without "a ghost in the machine." While these assertions were once persuasive, they gradually lost their potency with the emergence of feedback mechanisms, serving as a material *reductio ad absurdum* against the previously entrenched formal principle of the impossibility of circular causality. In other words, the flourishing of feedback mechanisms allowed machines to assert "autonomy" – which is "a fancy word for self-control" (Dennett, 1995, p. 366). This new material model with its manifest autonomous behavior paved the way for the construction of new mental models and new causal principles.

Instead of rejecting the possibility of circular causality on logical grounds, modern people could actually build configurations in which cause and effect were in circular relation. Of course, this kind of configuration was not alien to ancient people. Those who have attempted to construct a survival shelter using just wooden sticks arranged in a pyramid-like structure understand the phenomenon of causations interlocked: Erecting one stick after another seems impossible, but when they engage in a causal relationship in the correct manner, with precise timing, they can lean on each other, remaining stably erected without a single stick being the sole cause or effect.[7] In this configuration, they mutually support each other within closed loops of cause-and-effect relationships. However, this simple configuration was not worthy of being the foundation of causal conceptions. Complex feedback loops changed the scene. They have a similarly simple but miraculous effect, resulting in intertwined coupled systems of "circular causality". In the 19th century, the magical bootstrapping effect of feedback was increasingly appreciated in theory and practice: more complex systems might emerge out of less complex ones, the universe might have been structured without any demiurge, and the organic world might have been designed without any designer.[8] With the rise of feedback

[7] Hofstadter (2008) delves into similar configurations in his intriguing exploration of loops. One example he discusses is the common trick of sealing a cardboard box by folding its four flaps over each other in a sort of "circular fashion."

[8] In 1858, Alfred Russel Wallace likened "natural selection" to the workings of the centrifugal governor. Bateson (1979) claims, "If it had been Wallace instead of Darwin, we would have had a very different theory of evolution today. The whole cybernetics movement might have occurred 100 years earlier as a result of Wallace's comparison between the steam engine with a governor and the process of natural

mechanisms, the practical achievements displaced and re-shaped the entrenched theoretical beliefs – not only in Engineering but also in Humanities.

The linear conception of causality has a counterpart in the realm of interpretation and understanding: Traditional doctrines, such as Plato's theory of recollection, assume that understanding is possible because we already possess the necessary knowledge in hidden forms inherited from our previous lives. Knowledge is viewed as the totality of justified true beliefs. The Socratic method may be seen as not contributing anything inherently new to the knowledge already present in implicit forms; it merely brings it to explicit awareness. In this view, the world of Forms and Ideas is static and fixed, dormant waiting to be known. However, the hermeneutical circle, particularly in its progressive form, challenges this static and linear conception. The process of understanding, according to the hermeneutical circle, starts with ignorance and prejudice but gradually discovers and constructs understanding in an open-ended, infinite manner, always prepared to re-interpret and re-construct previous interpretations. As Schleiermacher puts it, "Our interpretive experience begins in misunderstanding" (quoted in George, 2021). To make it more in line with our current discussion, we might add: not only it begins from misunderstanding, but it also ends in misunderstanding. In other words, from the viewpoint of the hermeneutical circle, interpretations are always re-interpretations, and they should be.

In sum, referring back to the textbook definition of feedback as a "closed sequence of cause-and-effect relationships," the hermeneutical circle has commonalities with the feedback mechanism.[9] They both start with "error" and "misunderstanding." They both re-adjust and re-vise their initial beginnings. They both yield various equilibrium points – *attractors* in the parlance of dynamical systems – without any final absolute resting end. They are both at work in closed loops but, simultaneously, open-ended and infinite.

CONCLUSION

Our conclusion is twofold. First, historically, feedback mechanisms and the hermeneutical circle thrived at the same time in a shared cultural-technological ground, namely 19th-century modern Europe. While this might be dismissed as a mere coincidence lacking any meaningful constitutive connection, a second observation is pertinent on a conceptual level: they both share the abstract concept of "circular causality." Feedback mechanisms challenge the philosophical principle that asserts the impossibility of circular causation. Similarly, the hermeneutical circle challenges the conception that assigns fixed meanings to the texts. Juxtaposing these two, a question

selection" (p. 43). The idea of "being designed without a designer" is the core of Dennett's version of Darwinism (see Dennett, 2018).

[9] The divide between humanities and natural sciences hinges on the very distinction of reason and cause, the former being non-deterministic and the latter deterministic. However, Cyberneticians interpret the causality of feedback mechanisms as "non-deterministic teleology" (see Rosenblueth et al., 1943). Philosophers might object (for example, see Rorty, 1979, p. 240). A middle way is to appreciate that reasons are exclusively humane and different from causes, but nonetheless products of algorithmic evolution (see Dennett, 2013). This paper is a preliminary attempt to find or build this middle way.

arises: Which one has been the source of inspiration for the other? Is there any meaningful way of prioritizing one over the other, in historical or cognitive terms?

One might observe that the same circularities have always been part of the metaphors and material culture in different cultures, in different ages, and in different practices. Cyclic icons abound in ancient India (e. g. Wheel of Life) and China (e.g. Yin-Yang). The idea of eternal recurrence or cyclic nature of the universe is common in ancient cultures. Circularity is valorized by many mystical and alchemy traditions in the iconic image of a snake biting its own tail (named *Ouroboros* in Greek). More generally, the magic of self-reference has been appreciated since the time humans saw themselves in the natural mirrors of ponds (e.g. the myth of Narcissus) or through the metal and glass mirrors, or even in the mirror of lovers – as feedback loops are ubiquitous in the imagery of literature and poetry. While these might seem "just metaphors" without any practical or cognitive value, we have also mathematical and philosophical methods very similar to the feedback mechanism: the *Regula Falsi* method of mathematics in Greek, the calculus of *Double Errors* in Islamic mathematics, and the *Dialectic* in Plato or Hegel. Rehearsing all these historical examples, the similarity between the feedback mechanism and the hermeneutical circle might lose its appeal. Nevertheless, two points should be noted. First, doing a historical survey necessitates posing "ideal types", in Weber's terminology, resulting in acceptable distortion and approximations. Second, despite the long history of similar concepts, it was only in the 19th century, in modern Europe, that complex automatic machinery thrived, and it was in modern Europe that the hermeneutical circle flourished in a disciplined way. In other words, looking back at the relevant historical data, these "ideal types" are mostly recognizable in the 19th century, not before. Latil (1957), at the end of his book on feedback mechanisms, after mentioning the similarities between the Chinese ancient principle of Yin-Yang and cybernetic ideas, writes,

> But if we find ourselves agreeing with the oriental mystics, it is not because of any nebulous views on spiritual existence; we started off solely on the fundamental concepts of the machine. The reader has been present from the beginning of these concepts, for we have wished him to tread along the same path which we took in order to arrive at an understanding. The principles which have been advanced might have been arrived at by metaphysical consideration, had they been founded on thought alone, but, founded as they are *a posteriori* not *a priori,* on consideration of the mechanical functions of machines, they are of absolute authority. (p. 345)

Despite its outdated Eurocentric tone and its innocent claim for the "absolute authority" of mechanical accounts, he hints at a profound insight. While arriving at the same understanding through different paths is possible, it does not imply that we have actually exhausted all possible avenues. Looking at the ancient water clock as a feedback mechanism from our current perspective might seem obvious, but it wasn't so in ancient times. Categorizing various old ideas under the rubric of "feedback" is straightforward for us today, but it was not the case back then. To illustrate, consider "feedback" in comparison to "microbe." It is now easy for us to perceive microbes as if they were always present in our world, but it was not easy before the age of Pasteur. The same goes for feedback.

If we succeed in establishing a meaningful constitutive relationship between feedback mechanisms and the hermeneutical circle, another question arises. It could be the case that in the 19th century, the importance and power of feedback were so pronounced and experienced in material culture that people began projecting it onto the realm of interpreting and understanding texts. Conversely, it might be the case that the inherent circularity in the interpretation of texts inspired people to incorporate this circularity into artifacts. Our predicament here is not dissimilar to Weber’s question regarding Protestantism and Capitalism, and our ambivalence is similar to the choice between what he calls Materialism and Spiritualism. He finishes his thorough historical research with these sentences:

> But it is, of course, not my aim to substitute for a one-sided materialistic an equally one-sided spiritualistic causal interpretation of culture and of history. Each is equally possible, but each, if it does not serve as the preparation, but as the conclusion of an investigation, accomplishes equally little in the interest of historical truth. (Weber, 2001, p. 125)

This paper is a preliminary attempt. There is no way, and there is no need, to readily give absolute priority to one here. Weber, to emphasize the intricate relationship between Protestantism and Capitalism, refers to their connection as an “elective affinity” (*Wahlverwandtschaften* in German). This *elective affinity*, borrowing a chemical metaphor from the 18th century, describes the inclination of substances to react, or the tendency of individuals with “similar chemistry” to fall in love (see McKinnon, 2010). The term “affinity” has been utilized in the title of this paper to imply a similar meaning. Nevertheless, we can replace this chemical metaphor with a cybernetic one, seeing both the feedback mechanism and the hermeneutical circle within “closed sequences of cause-and-effect relationships.” I am not in a position to settle down the question of priority here, but I hope it is at least framed now.

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On Scientific Explanation and Understanding – A Hermeneutic Perspective

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Abstract

An explanation is a convincing, deductively valid argument that cites at least one law of nature. – This could be a definition of a scientific explanation that takes the notion of understanding seriously because explanation and understanding are intertwined concepts. To arrive at this conclusion, this analysis starts with the question of what makes an explanation an explanation. Philosophers of science have discussed this issue extensively since Carl G. Hempel presented his deductive-nomological model of explanation. It seems that the DN-model offers necessary but not sufficient conditions for explanation. Two prominent problems for sufficient conditions are the problem of irrelevance and the problem of symmetry. For the last seventy years philosophers of science tried to solve those problems, also proposing other possible conceptualizations of explanation, by invoking, for example, causality or contextuality. Those accounts can be brought together in order to solve the problems of the DN-model: By looking at understanding, a new combined account for explanation and understanding could be obtained. After highlighting the advantages and problems of some of the most prominent accounts of explanation, the concept of understanding is analyzed with respect to the notion of hermeneutics. Through Gadamer's discussion of hermeneutics and understanding as well as Kuhn's concept of paradigms, it can be shown that the natural sciences are also deeply rooted in hermeneutics and involve understanding. In the end, it can be demonstrated that understanding and explanation are two interwoven concepts. Understanding is the missing piece of the puzzle to solve the problems of explanation.

Keywords: Hermeneutic Circle; Explanatory Success; Hans-Georg Gadamer; Thomas Kuhn

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Научная статья

О научном объяснении и понимании – герменевтическая перспектива

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Аннотация
Объяснение – это убедительный, дедуктивно обоснованный аргумент, ссылающийся на хотя бы один закон природы. – Это могло бы быть определением научного объяснения, которое серьезно относится к понятию понимания, поскольку объяснение и понимание – это взаимосвязанные понятия. Чтобы прийти к такому выводу, данный анализ начинается с вопроса о том, что делает объяснение объяснением. Философы науки интенсивно обсуждали этот вопрос с тех пор, как Карл Гемпель представил свою дедуктивно-номологическую модель объяснения. Кажется, что модель предлагает необходимые, но недостаточные условия для объяснения. Двумя важными проблемами достаточных условий являются проблема нерелевантности и проблема симметрии. В течение последних семидесяти лет философы науки пытались решить эти проблемы, одновременно работая над другими возможными концептуализациями объяснения, ссылаясь, например, на причинность или контекстуальность. Эти соображения можно объединить, чтобы решить проблемы дедуктивно-номологической модели: рассмотрев понимание, можно получить новую комбинированную версию объяснения и понимания. После выделения преимуществ и проблем некоторых наиболее известных подходов к объяснению, концепция понимания анализируется с точки зрения понятия герменевтики. С помощью обсуждения Гадамером герменевтики и понимания, а также концепции парадигм Куна можно показать, что естественные науки также глубоко укоренены в герменевтике и включают понимание. В конце концов, можно продемонстрировать, что понимание и объяснение – это две переплетенные концепции, и что понимание – это недостающая часть головоломки для решения проблем объяснения.

Ключевые слова: Герменевтический круг; Объяснительный успех; Ханс-Георг Гадамер; Томас Кун

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INTRODUCTION

Scientific explanations are important objects of study since Hempel and Oppenheimer's (1948) first influential discussion of it – known as the deductive-nomological (DN) model of explanation. Ever since, philosophers of science have persistently tried to characterize explanations, their goal being to analyze what scientific explanations are, because for many of them, it seems, explanation is one of the primary goals of scientific activity (e.g. Hempel & Oppenheim, 1948; Ladyman, 2002). Explanations seem to be answers to why-question that begin with a 'because.' Yet, by explaining one thing, another follows along: understanding. This is the case because explanations (normally) provide understanding. A number of philosophers of science (e.g. Hempel, 1965a; Kitcher, 1989; Salmon, 1998a) agreed that there is at least some kind of connection between the two concepts. However, scientific understanding was widely neglected in the discussion until very recently (Regt, 2017). This paper shall serve as a contribution to the discussion of scientific explanation and understanding by looking at those concepts from a hermeneutic perspective. The main thesis is that only when the concept of scientific understanding is taken seriously, it is possible to grasp what scientific explanation is, for both concepts are two sides of the same coin.[1] From there, a new account of explanation could be developed.

My analysis starts with a short reconstruction and critique of some of the most influential accounts of explanation: the DN model (Hempel, 1965a), the causal model (Salmon, 1984, 1998b), the pragmatist model (van Fraassen, 1980), and the unificationist model (Kitcher, 1989). Of course, there are other and newer accounts of scientific explanation. Since this paper analyzes explanation and understanding in general terms, it discusses only the 'classics,' which are the departure points also of the newer accounts. In the course of this discussion, I will also identify the two main problems that have to be solved in a theory of explanation: the problems of irrelevance and symmetry. Then, I shall turn to understanding. I start with an evaluation of the influential and systematic conception of understanding which is grounded in a hermeneutic analysis of understanding for the humanities as developed by Hans-Georg Gadamer in 1960. Afterwards I argue that this concept of understanding of cultural artefacts can be transferred into the domain of natural science by an analysis of the term 'paradigm,' popularized by Thomas Kuhn in 1963. From there, I try to outline an account of explanation that is obtained by the preceding analysis of understanding. Finally, I will

[1] To be sure, explanation is not something that is exclusive to science but is also common in everyday life. Should we, then, just drop the adjective 'scientific' (in the sense of "natural-scientific") (Skow, 2016, p. 524)? I think, at least, for now, it can be said that there is a difference between explaining why the planetary orbits in our solar system are stable or why John did not come to Harry's birthday. In the first case a generalization in the form of a law is usually evoked like Newton's laws of gravity, whereas in the latter case one might say there are some social circumstances like them having had a fight one month prior to the party. *Prima facie* it should be acknowledged that there is a difference between scientific explanations and everyday life explanations. I will restrict myself to scientific explanation because most philosophers of science developed their accounts of explanation under this term, but I hope I will make plausible that the difference between scientific explanations and 'other kinds' of explanations is of degree rather than of kind. The same can be said about scientific understanding.

apply this newly obtained concept of explanation, which is inseparably intertwined with the concept of understanding, by showing that the two major problems I identified before, the problems of symmetry and irrelevance, can be solved by it.

CONCEPTIONS OF SCIENTIFIC EXPLANATION

In order to grasp the concept of scientific explanation, it is necessary to look at the different proposals for a conception of it that have been made so far. Hence, this chapter provides a brief overview of the main models and the criticism that they received. I will start with the modern starting point of a theory of explanation: the DN model by Carl Hempel. One after another I shall present the subsequent models of explanation, beginning with the causal model by Wesley Salmon, going over to Bas van Fraassen's pragmatic model, and ending with Philip Kitcher's unificationist model. I will end with Kitcher's model because all important factors relevant to my goal to set an alternative account of explanation will have been discussed by then.[2] The evaluation of these models will reveal connecting factors for a further discussion with regard to scientific understanding that will in turn illuminate the concept of scientific explanation.

The Deductive-Nomological Model

The deductive-nomological (DN) model has been and still is the most influential conception of scientific explanation of the last century which set the starting point for the contemporary discussion of a theory of explanation. For Hempel (and for many others, as the following sections will show) explanations are answers to why-questions. Hempel divides an explanation into two parts: the thing to be explained (*explanandum*) and the things that explains (*explanans*). His conception is built as follows: The explanans *S* is a combination of laws of nature *L* and sentences about the particular conditions of the situation *C*. Together they form a deductive argument that implies per "logical consequence" (Hempel, 1965a, p. 337) the explanandum *E* as a descriptive sentence of the phenomenon to be explained. Consider the following situation: A gas is sealed in an air-tight container. Now the container is heated strongly, while the volume remains the same. The pressure of the gas is measured before and after the heating and an increase in pressure is detected. This increase can be explained by the ideal gas law. If the volume is fixed and the number of particles kept constant, then the temperature of the gas is proportional to its pressure (*L*). The volume is fixed and the number of particles kept constant (*C*). Therefore, the pressure of the gas rose (*E*) (Ladyman, 2002, p. 204). This conception for singular events can be extended to explanations of uniformities as well, according to Hempel: A law can be explained if it can be shown to be a special case of a more general law.

The DN model faces two major problems, though: irrelevance and symmetry. The first major problem can actually be divided into three sub-problems (Ruben, 1990,

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[2] To be clear, there are newer accounts of scientific explanation (e.g. Strevens, 2008; Woodward, 2004), but I think the best way to get to the fundamental problems of a theory of explanation is to look at the cornerstones of this discussion – especially because newer accounts take the historical discussion and the proposed accounts as a starting point for their own accounts.

pp. 183–188): the ‘original’ problem of irrelevance, the problem of pre-emption, and the problem of overdetermination (Ladyman, 2002, pp. 203-205). For the purpose of this paper, the ‘original’ problem of irrelevance should suffice. The example which is concerned with the ‘original’ problem is borrowed from Ardon Lyon:

(1) All metals conduct electricity

(2) Whatever conducts electricity is subject to gravitational attraction

(3) All metals are subject to gravitational attraction. (Lyon, 1974, p. 247)

Even though (3), the explanandum, is logically deduced from (1) and (2), the explanans, no one would say that (1) and (2) explain (3) because it is obvious that (1) and (2) are irrelevant for the correctness of (3). One would say that all objects with mass are subject to gravitational attraction, so the attribute of electrical conductivity is irrelevant. The DN-model, however, cannot exclude such explanations that cite irrelevant premises.

The problem of symmetry involves biconditionals, which can also take the form of arguments with laws of coexistence such as the coexistence of rise in temperature and rise in pressure. There are two standard examples for the problem of symmetry. The first one is the example just used above to illustrate the DN-model. Because the ideal gas law is a law of coexistence, it is symmetrical, i.e., explanandum and the condition-sentence can be switched. This explanation also satisfies the conditions of the DN-model, while explaining the rise in temperature by the rise in pressure, but we would not normally say that the latter is the actual explanation. The other standard example is that of the flagpole: Why is the shadow of the flagpole X meters long? Knowing the height of the flagpole and the angle between the ground and the sun (assuming that light rays are linear), the length of the shadow can be derived in order to explain it. But this is the problem: In the same manner the length of the shadow and the incident angle can also be used to derive the height of the flagpole, and thus to explain it. Surely, many, if not all, would say that only the first derivation would count as an explanation.[3] The DN-model, thus, fails to determine the right direction of explanations (Bird, 1998, p. 74).

Though it evidently cannot provide sufficient conditions for explanation, Hempel’s account still seems very convincing. Some philosophers of science therefore think that the DN model provides the necessary conditions for explanation (e.g. Friedman, 1974; Woodward & Ross, 2021). In that case, the remaining task is to eliminate the problems of irrelevance and of symmetry. The solution that suggests itself is the notion of causation. In my outline above I avoided the notion of causation because Hempel himself thinks that it is not necessary for the conception of explanation (Hempel, 1965a, pp. 353–354), but if one recalls the counterexamples above, some of the problems can be solved by including causation: It is the mass and not electrical conductivity that causes gravitational attraction. The increase in temperature causes the rise in pressure. The light and the flagpole cause the length of shadow but light and shadow do not cause the length of the flagpole.

[3] In this case, it seems that the second “explanation” is either aimed at a why-question that requires a very different answer (Why does the flagpoles have height X?), or it is not aimed at an explanation-seeking why-question at all: How tall is this pole?

The Causal-Mechanistic Model

One of the most prominent advocates for a causal conception of explanation is Wesley Salmon (1984, 1990). According to Salmon, a phenomenon can be explained by showing the causal history or mechanisms that led to the phenomenon. To understand this correctly, some terminology has to be introduced.

For Salmon a causal interaction is "an intersection of two processes […] if both processes are modified in the intersection in ways that persist beyond the point of intersection, even in the absence of further intersections" (Salmon, 1990, p. 7). For example, if two cars collide, both are modified by getting dents, and those modifications persist beyond the point of collision (Woodward & Ross, 2021). The basic criterion for distinguishing a causal process from a pseudo-process is the causal process's ability to transfer a mark. In the example given above, the two cars did not have any dents until collision, and those dents were then the marks that were transferred. Therefore, a process is causal if it could be permanently altered through an intervening causal interaction (Salmon, 1984, p. 142). Furthermore, it should be added that the transfer of those marks is spatiotemporally continuous, that is, there is a continuous connection between the causal process and the causal interaction which transfers a mark. In other words, the mark can be traced back to the process via a spatiotemporally continuous connection (Salmon, 1998a, p. 116).

Salmon's account needs laws of succession that state the temporal development of a process or interaction, but there are also laws of coexistence that only limit the space of possible configurations of a system (van Fraassen, 1980, pp. 122–123). The ideal gas law is one of them. An explanation of a state of a system would then be non-causal for there is not any action involved, and thus the explanation would be non-explanatory on Salmon‘s account. Another problem is connected with quantum mechanics. As the EPR-Paradox shows that locality is violated in quantum mechanics. Therefore, since the process is not spatiotemporally continuous, there would appear to be non-causal processes in quantum mechanics. In these cases, there cannot be a causal explanation, according to Salmon's account.[4]

The Pragmatic Model

Because of the problems of Salmon's account of causal explanation, van Fraassen (1977, 1980) takes another approach to explanation. By analyzing the role of causality in explanation from another perspective, he arrives at what he calls the pragmatist account of explanation. The basic idea is that explanation is highly context-sensitive, that is, the circumstances and the people involved in an act of explanation are essential if one wants to understand causality.

He begins with an analysis of the principal idea of causal explanation. As presented by Salmon, by exhibiting the causal forks explanation shows how "[e]vents are enmeshed

[4] Salmon is aware of this problem, he even describes it as „a source of great distress" (Salmon, 1998a, p. 115) but does not seem to have an answer for it in his framework of causal explanation. He actually refers to the unificationist model of explanation, for example, as a possible solution to the explanatory difficulties of quantum mechanics.

in a net of causal relations" (van Fraassen, 1980, p. 123). He argues that explanation thereby highlights the salient factors in that part of the causal net which leads up to the event to be explained. Accordingly, events do not normally only have one explanation but more: there are as many causes for an event X as there are explanations of X. The salient factors are themselves determined by the contextual factors, namely the interests and orientations of the questioner along with the phrasing of the problem.

The pragmatic model also takes explanations as answers to why-questions, so it starts with an analysis of why-questions and concludes that adequate answers to a why-question are context-sensitive. That means that the adequate explanation varies from context to context and on what is actually asked. Consider the question 'Why is this conductor warped?'. The proposition, this conductor is warped, is the topic of the question. The contrast-class is the set of alternative interpretations of a particular question, constituting a set of propositions including the topic. This can be highlighted by putting emphasis on a single expression: Why is *this* (rather than another) conductor warped? Why is this conductor *warped* (rather than not)? Here the explanatory relevance has to be introduced in order to grasp the context-sensitivity of the topic and its relation to its contrast-class. An explanation would then show that the topic is true, that only the topic is true in its contrast-class, and that minimally one proposition bears the relevance relation to topic and contrast-class (van Fraassen, 1980, pp. 141–144).

Van Fraassen seems to believe that "[f]or any two propositions there is a candidate relevance relation that the first bears to the second" (as cited in Skow, 2016, p. 540). This means that for any pair of two propositions exists a context in which the first proposition is relevant for the second one. Salmon and Kitcher showed that van Fraassen's model cannot discriminate between good and bad explanations, for there is not any constraint on the relevance relation. Consequently, as long as van Fraassen does not propose criteria for genuine relevance relations "almost anything can explain almost anything" (Salmon, 1998, p. 183). Nonetheless, van Fraassen's account provides an important insight into the relation between idealized (scientific) explanations to the practice of explaining in everyday life, as well as the reconstruction of explanations as answers to contrastive why-question.

The Unificationist Model

Michael Friedman (1974) and Philip Kitcher (1989) introduced the unficationist model of explanation. They take scientific understanding as the goal of explanation by unifying scientific theories, thereby bringing explanation and understanding explicitly together. Due to the problems of Friedman's version (see e.g. Salmon, 1998c, p. 70), Kitcher's version will be discussed here.

The idea of the unificationist model is quite simple: An acceptable ideal explanation is part of the explanatory store *E(K),* where *K* are all statements that are accepted by the scientific community. The explanatory store *E(K)* is the set of derivations with the maximum systemization of *K*, while having fewer argument patterns than other systemizations of *K*. To understand Kitcher's model, one needs to introduce some technical terms: A schematic sentence is a sentence in which some of the non-logical words have been replaced with dummy letters. A set of filling instructions for a schematic sentence gives the information on how to fill in the dummy letters; for each term one filling instruction is needed. A sequence of schematic sentences is called a schematic argument. Furthermore, a set of sentences that describes the connections between the schematic sentences of the schematic argument is called classification for a schematic argument — it states which sentences are the premises, which are inferred from which, and which rules are used. Lastly, a general argument pattern consists of a schematic argument, a set of filling instruction and the classification for the schematic argument. In order to compare different argument patterns, Kitcher introduces the criterion of stringency (Kitcher, 1989, pp. 432–433).

He agrees with Hempel that ideal explanations are derivations, in fact, he thinks that “[*i*]*n a certain sense*, all explanation is deductive” (Kitcher, 1989, p. 448), but, contrary to Hempel, derivations are sequences of statements whose status is clearly specified, therefore showing how exactly to deduce the conclusion from the premises. In general, it can be seen as a “sophisticated version of Hempel’s deductive-nomological model” (Regt, 2017, p. 53).[5]

Kitcher’s account also solves the problems of irrelevance and symmetry. Let me shortly discuss them. Consider Lyon’s example again. It stated that all things that conduct electricity, including all metals, are subject to gravitation. However, by referring to the fact that all masses are subject to gravitational attractions, one cannot only deduce that all metals are subject to gravitational attraction but any object with a mass, so this pattern can derive the conclusion for metals and any other material, while in Lyon’s example it can only explain it for electrical conductors, requiring analogous explanations for non-conducting masses. Therefore, to explain gravitation as a feature of all masses provides a more unified account and an actual explanation.

The second problem concerns the flagpole. In principle, the height of the flagpole can be deduced from the length of the shadow and the position of the sun. Call the standard systemization which has the length of the shadow as its conclusion *E(K)* and the one which has the height of the flagpole as its conclusion *S*. Kitcher states that *E(K)* contains the “*origin-and-development*” pattern (Kitcher, 1989, p. 485). He goes on to note that the dimension of an object can be traced to the condition of its origination and the undergone modifications, so this pattern provides an explanation of the current size of an object such as the shadow by giving its history. If the pattern for deriving the size of an object by the length of its shadow is added to *E(K)*, an unnecessary pattern would be added because it does not provide any new conclusions, only serves to increase the number of patterns. This means that *E(K)* is indeed the more unified generating set, so *S* is not explanatory (pp. 485–487).

Even though Kitcher’s account seems quite convincing, it is confronted with at least the following two problems. The first problem concerns the problem of symmetry involving laws of coexistence. It seems to me that Kitcher’s account also fails to

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[5] Due to the focus of this paper, I have not discussed a more technical problems of the DN model. It concerns the characterizations of laws of nature. The derivation of a law from a more general law can always be done by the conjunction of the law to be deduced and another law, which would then be a more general law, but this derivation would surely not count as an explanation (Hempel, 1965b, p. 273). Kitcher can handle this problem (see Regt, 2017, p. 53).

distinguish the right from the wrong direction of explanation. Because both directions are in principle explanatory, without one entailing the other like in the flagpole example, it is not possible to exclude one of them from *E(K)*.

Moreover, there seems to be serious problem with what Woodward (2004) calls the "'winner-take-all' conception of explanatory unification" (p. 367). Since Kitcher considers only the unifying explanation as a proper explanation, every other explanation not part of *E(K)* is not explanatory. There is no degree of explanatoriness. For example, the theory of relativity is more unified than classical mechanics, so explanations that use classical mechanics are not explanatory according to Kitcher's account, though no one would deny their explanatory value.

Despite all the objections, Kitcher's approach lays bare a possible way of systemizing theoretical thoughts. Even if the greatest possible unification is not a necessary condition for successful explanation, it can be said that unification is at least a virtue of explanation.

Interim Result

The historical development of the discussion shows some general motives and problems that seem to be central to the conception of explanation. Firstly, every model of explanation tries to solve the two problems regarding the sufficiency of Hempel's DN model: irrelevance and symmetry. All models try to state criteria to eliminate irrelevant factors from explanations and to account for the asymmetry of explanation. Furthermore, some concepts seem to be central to the ongoing discussion of the two problems: causality, and thus temporality, and explanation as a concept with theoretical and pragmatic components. All those concepts can be brought together, and so the two problems can be solved, by turning to the notion of understanding.

SCIENTIFIC EXPLANATION AND UNDERSTANDING

The following section is dedicated to the notion of understanding, for which I will analyze its relation to explanation. This undertaking might seem a bit questionable, at least from the perspective of German philosophy. It was Wilhelm Dilthey (1883/2017) who made a distinction between two different ways of acquiring knowledge, namely explanation and understanding. He did so in order to legitimize the status of the humanities [*Geisteswissenschaften*] as epistemically valuable (Grondin, 2012, p. 123). Roughly said, understanding is the domain of the humanities because the objects of understanding are the products of the human mind that one has to 'relive' in order to understand what their author meant. Hermeneutics was the method of the humanities, as the correct way of interpreting a text in order to get to the intended meaning and thus an understanding of its author (Grondin, 2012, pp. 128–129). The processes of nature, on the other hand, cannot be 'relived' because there is no inner, perhaps psychological, character to follow and grasp, so the task then is to explain them. The phenomenological turn initiated a new perspective on hermeneutics and understanding, first picked up by Martin Heidegger (1926/1967) and then criticized and further elaborated by Hans-Georg Gadamer (1960/2010) in his work *Wahrheit und Methode* [*Truth and Method*].

Gadamer's universal hermeneutics [*Universalhermeneutik*][6] provides a conception of understanding which want to discuss here since it was widely received and also discussed in the context of a hermeneutics of natural sciences (see e.g. Bernstein, 1983; Heelan, 1977).

Understanding of Cultural Artefacts

I will discuss here the paradigmatic example of cultural artefacts that are in need of an interpretation: texts. The old problem of the hermeneutic circle arises here directly. A text can only be understood by its parts, but an understanding of the parts can only be available if the text is already understood, but it is then questionable how one should even, in principle, be able to understand a text. The answer is preconceptions [*Vorurteile*], conveyed by, for example, tradition and authorities like parents or teachers. If one reads a text, one either already has an idea of what the text might be about or begins to read it without prior knowledge of the text and draft a possible interpretation while reading it, but either way it seems that the reader is trapped in his or her preconceptions about the text. However, Gadamer emphasizes the positive aspect of preconceptions that especially come to the fore when discussing hermeneutic circle. Only because one has such preconceptions it is possible to even try to understand a text. Preconceptions are fundamental for our ability to understand, but that does not mean that the preconceptions are always right. Every text can be understood in at least one correct way and many incorrect ways. The task is to work out an interpretation of the text that is in itself acceptable, that is constructed in a manner that displays the content so that it is coherent, because the only things that can be understood are things that have united meaning. In the process of continuously drafting and redrafting interpretations of a text while reading it, one comes to an understanding of the words by seeing that maybe some of them have other meanings than presupposed. In turn this is only possible if one recognizes and acknowledges that the text could have a different view on the same matter. For real understanding of someone else's view, as expressed in a text, one needs to be open to the possibility that the expressed opinion is true, thus risking also the need to acknowledge that one was wrong. Understanding always requires checking if one's own preconceptions are true, to be adjusted or completely rejected, by valuing and weighing them against each other, all the while connecting them to old and new ideas. Thus, it is exposing them to further scrutiny (Gadamer, 2010, pp. 270–275). For Gadamer, the hermeneutic circle is, therefore, a productive circle.[7]

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[6] To be sure, when Gadamer discusses and elaborates the conception of understanding as an alternative to (natural-scientific) methods in order to obtain truths, he is occupied with the legitimation of the humanities as proper sciences as distinct from the natural sciences. He was convinced that there is no hermeneutics of natural sciences (Kisiel, 1997, p. 331). This paper is also an implicit critique of Gadamer insofar as he was too hesitant with his claim of a universal hermeneutics.

[7] It is important to note that hermeneutics and the hermeneutic circle is not referring to a method or so as did Schleiermacher. Rather, hermeneutics comes into play as soon as we seek to understand anything in the world. Here, Gadamer is following Heidegger's ideas. For him, the hermeneutic problem concerns the phenomenon of understanding and adequate interpretation [*Auslegung*]. The task of hermeneutics is to explore and reveal the requirements of understanding (Gadamer, 2010, p. 300).

An important concept in Gadamer's analysis is the horizon. A horizon is defined as a "ken that encompasses and encloses everything that can be seen from one point of view" (Gadamer, 2010, p. 207, my translation). It contains everything a person already knows and understands. When one tries to understand a text which has, so to speak, its own horizon, the unfamiliar is made familiar. That means one can judge the claims and accept, adjust or reject them by giving reasons. One can, so to speak, work with them. Thus, Gadamer is speaking of the merging of horizons because the ideas of the text become part of the reader's horizon. The ideas of the text can be related to all other ideas already understood.[8]

In this sense understanding can be characterized as an ability and skill which entails interpretation, justification and application. When one tries to understand a text, it means already interpreting, but by interpreting it, one has to think about the justification of the interpretation because others could always ask for one. Finally, a text as conveyer of truth claims challenges the reader's judgement of the things it claims to have knowledge about. So when a reader really wants to understand something, he or she already needs to know whether and why the claims are justified or not. But this application of ideas is only possible because of prior interpretation. Moreover, by applying, that is discussing and judging ideas, an interpretation might change as well. So understanding always imply all these dimensions at the same time.

In conclusion, understanding is knowing how the different concepts in a text are related to each other and how those are related to the situation of the reader. All preconceptions and prior knowledge are ordered and related, and if one reads a text that makes truth claims, one is challenged to take a stand. Either way it demands one to question one's own understanding of the matter in question by showing that there were unknown or only seemingly existent connections, thereby 'forcing' an adjustment of the understanding.

Scientific Understanding

After talking about the understanding of texts, what could scientific understanding mean? A rather striking analogy appears when looking at Kuhn's discussion of paradigms. Kuhn describes paradigms as having laws, theory, application, and instrumentation. A paradigm tells the scientist what they have to look out for, what exists, how they can access things and measure them, what concepts mean and how they are related to the world and so on. It contains the things a student has to learn to be part of a scientific community. This learning process is guided by the application of concepts, laws, and theories. In order to be able to operate in a given paradigm, one has to know

[8] The distinction of two separate horizons only arises as one becomes aware that there are two different horizons involved: mine and the other's (Gadamer, 2010, pp. 307–312). Subsequently, one needs to translate the language of the other horizon into one's own which is already part of the process of understanding because translating presupposes the understanding of the thing that is expressed. This process of translation can be thought of as looking for a common language in which one's own horizon and the other's can be understood simultaneously, implying that the view of a text on a specific matter is put into relation to other possible views that are familiar to oneself, thereby coming back to the merging of horizons (Gadamer, 2010, p. 399). Translation implies that the unfamiliar view is applied to the reader's situation. It thus does not leave the reader unaffected, since one acquires new perspectives on the matter in question.

how to apply specific concepts, laws or theories to a specific problem or situation (Kuhn, 2012, p. 47). He or she learns to see the world through the lens of the paradigm. In this way, paradigms become self-contained, incommensurable world views that span a net of concepts, which I call the conceptual net of the paradigm.

A paradigm conveys specific preconditions for it states what entities in the world exist and how they are related to each other. So, different paradigms convey different world views as the same things are seen differently (Crease, 2002, p. 37). Each encompasses everything that is familiar and understood, it also encloses it unambiguously because the problems, the things not yet understood, are clearly defined (Kisiel, 1971, p. 198). The problem of the hermeneutic circle arises here again (Kisiel, 1976, p. 181). In order to identify a phenomenon as a phenomenon one needs to already know what the thing is. Categories and relations are needed in which this phenomenon can be embedded. Instead of the text that tries to express the matter, it is now the phenomenon that is brought to expression by measurement (see also Wu & Hu, 2023). The little difference here is that during a stable period of a paradigm the data is already put into established categories, but even here some mapping of theory onto praxis must be done. The experimenter has to know how to prepare the experiment so that the things the theory talks about will be reflected in the experiment (Crease, 1995, p. 112). Afterwards the experimenter has to interpret the results: Are the results as expected? If not, why? Here, too, a merging of horizon can be seen: the horizon of the scientist within the paradigm and the horizon of the phenomenon manifested through measurement. While scientists interpret the data, they try to find a common language for both horizons and thus integrate the data into the net of concepts already known, as the gathered data is necessarily new, that is, unfamiliar. If that is not possible, then the paradigm has to be adjusted or replaced by another.

This aspect becomes even more apparent if the time of change of paradigms is analyzed. The case of classical and relativistic physics is a good example. Kuhn demonstrated that in order to understand Newton as a special case of Einstein one has to reinterpret basic concepts of Newton such as time and space. This kind of merging of horizons corresponds to Gadamer’s idea of understanding because Newton and Einstein make truth claims about things in the world. As a supporter of Einstein, one has to take the claims of Newtonian mechanics seriously and thus try to find a common language where both horizons could be understood simultaneously. This does not mean that one has to agree with the other position, rather it enables one to judge it (Kisiel, 1971, p. 207). As the theories are incompatible, one has to reject basic assumptions, but cannot therefore reject the laws of Newton, since these are empirically adequate. From the point of view of an Einsteinian, one has then incorporated und thus understood Newtonian mechanics as a part of Einsteinian mechanics. And again, the thing that is the gauge for judging this, is the phenomenon in question.

To conclude, paradigms are like horizons because they convey preconceptions about the world, everything that is already familiar. Another possible paradigm always challenges the ruling paradigm in its truth claims. If there is a change of paradigms the ideas and claims of the old one are understood in the new one either as in some way incorporated or as refuted. Either way propositions about the world are being set into relation to other propositions. The gauge here is the phenomenon to be understood. By looking for a common language of both horizons, one comes into the process of understanding which leads to a fusion of horizons where the claims of the unfamiliar horizon to one's own preconceptions and understanding of things can be judged. Even without the direct challenge of another possible paradigm understanding is always involved in science. For the experimenter it is the mapping of the theory onto the experiment. It is not the measurement itself but also the analysis of the gathered data afterwards. The still unfamiliar data have to be put into relation to the experimenter's horizon. Here, too, fusion of horizons can be observed because the 'language' of the experiment must be translated into the language of the experimenter's own horizon. In the end, scientific understanding of phenomenon or experiment therefore involves the transformation of the unfamiliar to the familiar, and by doing this, either adjusting or affirming one's own knowledge about the world, that is, what exists, how things are related, and in which way they are accessible through experimentation.

The Connection Between Understanding and Explanation

After specifying what (scientific) understanding is, I can turn to the connection between understanding and explanation and show that the connection is an essentially close one. I will also analyze the difference between giving and receiving an explanation for something. This difference is significant in that it will highlight some nuances of explanation that are foreshadowed in van Fraassen's discussion of the importance of context.

First of all, it has to be acknowledged that mere statements in and of themselves do not explain anything, even though everyday language suggests this when one says that Newton's law of gravitation explains the tides. Rather, explaining takes place only when someone is using Newton's law to explain the tides. This is because the theory and its categories have to be applied to a specific case, and that means that the person explaining already understands Newton's theory and knows which concepts are involved and how they are related. As shown above, application is always already understanding. Therefore, the person explaining must already have understood the phenomenon of the tides as well, that is, knowing how it fits into the conceptual net of the paradigm, in order to explain it. Explanation in this sense is just to exhibit the place of the phenomenon in the conceptual net of the paradigm. For example, it is one important aspect of classical mechanics that it works fine on earth and that it is empirically adequate, even though inferior to relativistic mechanics. The explaining person understands the paradigm of relativistic mechanics in a way that allows for the judgment that classical mechanics is still *good enough* as an explanation.

This view changes as soon as the roles of the explainer and the questioner are reversed. As the questioner one normally genuinely does not understand the phenomenon because one does not know how to fit the phenomenon into the conceptual net of the paradigm. This is, contrary to the case above, the normal situation in scientific research. Two different situations have to be distinguished here. In the first case the questioner is also the explainer like a scientist who tries to understand a new phenomenon or collected data, and in the second case the questioner asks someone else who already understood the thing in question. Let me first discuss the former case. There are many phenomena that are not explainable within the ruling paradigm, which means only that they are not (yet) understood. Here, the boundaries between explainer and questioner become blurry. As one poses the question, one also tries to come up with an explanation. In the process of explanation-seeking the scientist comes up with different candidates for an explanation but judges them by their fit with regard to the paradigm. If and only if an explanation can be found, the phenomenon is understood. There is obviously a difference to the other situation where the unknowing questioner meets a scientist who has the answer. This difference is not, however, whether understanding comes before explanation since one can only explain if and only if one already understands. The difference is instead one of the kinds of activity connected to each situation. In one case the phenomenon is already understood and the explanation is just asked for afterwards, whereas in the other case the process of coming up with an explanation is part of the process of gaining understanding.

In the former case the questioner looks for an explanation of a phenomenon from a person that already understood it. In this situation, explanation should provide understanding. The explainer exhibits how the phenomenon fits into the conceptual net of a paradigm. The thing here is also that the explanation is only explanatory if it can be understood from the point of view of the questioner. Here, again, a merging of horizons occurs: an explanation is explanatory for a questioner only if the questioner is introduced into the horizon of the paradigm. That also implies that a questioner who adheres to one paradigm does not initially judge as explanatory an explanation phrased in terms of another paradigm. The questioner has to go through a process of understanding in order to be able to even grant the explanation any degree of explanatory power.

Therefore, it can be said that understanding is an ability to potentially provide explanation and explanation is a social act that is set in a context, while an explanation is only explanatory when it provides understanding, that is, can be fitted into the horizon of the listener. Explanation is, thus, showing the place of the phenomenon in the conceptual net of the paradigm. Here one can see how deeply and inseparably connected both concepts are. Understanding only makes sense by being theoretically able to provide explanations for a phenomenon and explanation only makes sense when it relates to the realm of understanding. Coming back to a conception of explanation, the definition could be rephrased as follows: An explanation is a convincing, deductively valid argument that cites at least one law of nature.[9] By adding “convincing” to the definition, the dimension of understanding is added to it because convincing means that it must fit the context and there must be good arguments for the explanation to be the right explanation for a phenomenon. In this sense, the quite technical criteria of logical derivability – also

[9] I am here mostly concerned with the natural sciences, but this definition can be easily modified for the humanities, social sciences and everyday explanations. Instead of ‘law of nature’ it might be enough to say ‘common pattern’ or ‘general rule.’ Let me just make some plausibility arguments. Take the question “Why did John not attend Harry’s birthday party, despite being close friends?” Two possible explanations could be “Because they had a huge fight the week before” or “Because John is in hospital due to an accident.” Both explanations cite a common reason why someone is not attending a social event, and these reasons can be rephrased as common patterns: Whenever two people have a huge fight, they will normally need time apart, or whenever someone is seriously injured, he or she will not attend social events shortly afterwards. To be sure, whether the explanation is explanatory is still context-sensitive and it is only explanatory if it is convincing.

involving, as shown above, instrumentation, experimental preparation and theory (application) – are supplemented or rather complemented by communicative practices working with reasons within the sphere of understanding.

Three Possible Objections

There could be three objections I want to discuss shortly. The first one is directed at my conception of (scientific) understanding: relating the unfamiliar to the familiar, therefore making the unfamiliar familiar. It could be argued that science also uses unfamiliar concepts to explain phenomena. An example is the use of microphysical entities in quantum mechanics. This observation is important, and I think it actually supports my conception of understanding. Consider, again, my initial question: When is an explanation explanatory? In order for a newly introduced concept to be explanatory with regard to a phenomenon, it has to be already related in the conceptual net of the paradigm, that is, how it is related to all other concepts. Only when such a place can be found, an (unfamiliar) concept can be used in an explanation, otherwise it would be questionable what this concept might even mean. But since the concept is put into relation, it is already understood and not unfamiliar anymore. In other words, the scientists operating with a new concept must make themselves familiar with it. It is like the situation I discussed above: coming up with a new explanation for a not yet explained phenomenon. After publishing their idea, other scientists need to understand the new concept, too, and consequently judge if it makes sense to introduce such a new concept. This situation can be compared to that of first-year bachelor's students. They learn many concepts that are unfamiliar to them but that are used to explain things. However, by studying, using, and discussing them, they make themselves familiar with them. One has always to keep the perspective in mind: For whom is a concept unfamiliar?

The second objection is that not every explanation seems to cite laws and is aimed at the idea of the DN model. Consider the question "Why did the chair fall over?" An acceptable explanation could be that it fell over because John kicked it. This explanation works in everyday life because it fits into possible experiences of everyday life, but for a trained physicist, this explanation would not be the whole story, at least not in physics because this explanation is compatible also with the chair not falling over (even though John kicked it). If the chair fell over because John kicked it, other conditions come into play which physicists know as tilting moments and forces acting upon them. Physicists will thus invoke laws to explain the tilting over of the chair.

The other objection is more fundamental. One can always ask "why?" again after listening to an answer to a why-question. At some point no adequate answer can be given anymore, but if explanation and understanding are inseparably connected, do we then really understand anything? This argument overlooks something because it is normal that the why-chain comes to an end. For example, if someone asks me why there was a poor harvest this year, I could say that it was because of the severe drought. Even if I cannot say why this drought occurred in the first place, this answer is still explanatory because the concept of drought and its effects are known and can explain the poor harvest.[10] The

[10] Neil Cooper (1994) categorized understanding in more detail. He distinguished, first, between semantic and cognitive understanding. Semantic understanding is just the understanding of words. I know what the

following why-question of why the drought occurred could be an unknown connection in respect to understanding that is yet still to be found or rather made.

THE PROBLEMS REVISITED

Let me come back to the problems of irrelevance and of symmetry and show how this enriched concept of explanation can solve the aforementioned problems. The problem of irrelevance was illustrated by the example of the conductivity of metals. One can see that the fact that something is an electrical conductor is irrelevant for its being subject to gravitation. But why is it irrelevant? This is because in the conceptual net or paradigm of relativistic and classical mechanics there is no connection between gravitation and electric conductivity. The one and only concept that is connected to gravity is mass, so we cannot think of this explanation as explanatory because we already understand that only mass and gravity are directly linked together. Furthermore, we know that all conductors as objects have a mass, so we already know how to fit into our paradigm the phenomenon that conductors are subject to gravitational force. The information about its ability to conduct electricity, thus, can only be seen as completely irrelevant.

I introduced two examples for the problem of symmetry. The first problem concerned the explanation of the rise in pressure by the rise in temperature, connected to the ideal gas law. It is now clear that only one direction is explanatory, at least in this case. The scientist conducting the experiment will prepare an experimental setup such that the pressure of the gas is measured depending on its temperature which can be controlled through a heater, for instance. This experimental setup only allows one direction of explanation; the other seems abstruse in light of the experimental context and the implied causal chains, In fact, the other direction will not even come to the scientist's mind because it is quite trivial in this case.

The other problem was about the height of a flagpole and the length of its shadow. From the angle under which the supposed linear light rays hit the flagpole and the height of the flagpole, the length of the shadow is derivable. Due to the symmetry of the geometrical equations used, one can also deduce the height of the flagpole from the position of the sun and the length of the shadow. However, through personal experience and the physical paradigm involved, one can only say of the first deduction that it is explanatory. There are two possible reasons for this. First, one learned through interaction with the world that the darkness of a shadow is equal to the absence of light, so light is something in the world and darkness is only defined as the absence of light. Therefore, a shadow means that some of the light is blocked by an object, for the shadow is visible as an enclosed form within a surface that is lightened. This belief within the paradigm is also supported or influenced by our experimental practice. We can change the length of the

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words in a description of a volcano mean. Cognitive understanding, on the other hand, can be described as finding one's way and seeing connections between things, like knowing the possible effects of a volcano and its connection to other phenomena. This metaphor aligns well with the one of the conceptual net provided by a paradigm. His analysis is more thorough and could be a starting point to characterize understanding in more detail.

shadow by changing the height of the flagpole, but the opposite does not hold true.[11] I think this becomes also apparent by thinking about the implied why-questions: Why does the shadow have length X? Why does the flagpole have height X? In the former case, one directly thinks about the incident angle of the light and the flagpole as explanatory necessary and relevant factors, but in the latter case, one thinks instead of social, functional, or material factors that influenced the manufacture of the flagpole. In fact, physically speaking, it seems quite absurd to think that the height of the flagpole is determined by the length of the shadow. Again, our understanding of the construction of flagpoles predetermines the space of possible answers, rendering some unthinkable. The problem of symmetry can, therefore, be solved by invoking causality, and the problems of causality itself are solved by including the dimension of understanding. The paradigm entailing laws, theory, application, and instrumentation manifests the causal relations in accordance with the theoretical and the practical dimensions of science.

CONCLUSION AND OUTLOOK

What I have shown is that the concept of understanding joins the different accounts of explanation and solves the two major problems of the DN-model. An explanation can be defined as the active exhibition of the location of the phenomenon in the conceptual net of a paradigm. The goal of an explanation is always to provide understanding for the person that asks for one. This becomes particularly clear when one recalls that understanding is the knowledge of the relations of entities in the world, so explanation must indicate the right way of understanding a phenomenon. Once more, this demonstrates how the two ideas are inseparably linked because in order to invoke one, the other must also be invoked. Together with the characteristics of explanation stated above, an outline of a possible account of explanation can be obtained that is developed from the notion of understanding.

I think this discussion of (natural) scientific explanations can be extended to explanations in the humanities, social sciences, and everyday situations because of the interwovenness of theoretical and pragmatic considerations. A purely empiristic view of explanation is consequently not tenable. In the end, a universal theory of explanation could be obtained. This, in turn, questions the categorical divide between natural sciences and humanities, thereby bringing them closer together.

As a contribution to a hermeneutics of natural science this approach showed that explanation and understanding are two sides of one coin. Therefore, this approach can help us get a better understanding of situations where explanations fail to provide understanding. In fact, it gives us criteria for successful scientific communication, as explanations are means to provide understanding for a questioner. Importantly, however, one of these criteria is not a criterion, technically speaking. Only time will tell whether an explanation meets the „criterion“ of being convincing – but from a hermeneutic perspective one can spell out what is entailed, culturally and linguistically, in the kind of understanding that renders explanations convincing.

[11] This argumentation is similar to the manipulist account of explanation (Woodward, 2004). This supports my initial claim that understanding binds the different conceptions of explanations together.

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Research article

Description, Understanding, and Explanation: How Scientific Interpretation Gave Birth to Modern Molecular Biology

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Abstract

This paper illustrates the role and position of hermeneutics methods in science and technology through the analysis of a scientific case, namely the generation of modern molecular biology, and the difference, connection, and mutual transformation of "description-text," "understanding-text," and "explanation-text" in the process of scientific research. The results show that the interpretation and transformation of scientific text often needs a certain cultural fulcrum and that it works by means of analogy. This is complemented through natural language. The complexity and richness of language transformations allow for scientific discovery and technological innovation to break through the limitations of objective conditions. A theory of complex thinking systems illustrates these results relatively well. Through the analysis of hierarchical levels of thought, two ways are revealed for transforming things and reducing them understandability. Mediated by natural language, these two ways involve the transformation and recovery, firstly, of abstract concepts in different layers, and secondly, of intuitive images in different layers. The results all provide support for the ontological and methodological foundation of scientific interpretation methods. Science and technology are facing more and more complex objects, and mathematical induction and deduction may become more and more difficult. Therefore, scientific interpretation may become an essential way to expand new fields of science and technological innovation.

Keywords: Hermeneutics; Genetic information interpretation; Text transformation; Thinking system; Understanding

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Научная статья

Описание, понимание и объяснение: Как научная интерпретация породила современную молекулярную биологию

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Аннотация
Данная статья иллюстрирует роль и положение методов герменевтики в науке и технике через анализ научного случая, а именно зарождения современной молекулярной биологии, а также различия, связи и взаимной трансформации “текста- описания”, “текста-понимания”, и “текста-объяснения” в процессе научного исследования. Результаты показывают, что интерпретация и трансформация научного текста часто нуждаются в определенной культурной опоре, что работает посредством аналогии. Это дополняется естественным языком. Сложность и богатство языковых трансформаций позволяют научным открытиям и технологическим инновациям преодолевать ограничения объективных условий. Теория сложных систем мышления относительно хорошо иллюстрирует эти результаты. Через анализ иерархических уровней мышления выявляются два пути преобразования вещей и уменьшения их понятности. Опосредованные естественным языком, эти два пути предполагают трансформацию и восстановление, во-первых, абстрактных понятий в разных слоях, во-вторых, интуитивных образов в разных слоях. Все результаты обеспечивают поддержку онтологической и методологической основы методов научной интерпретации. Наука и техника сталкиваются со все более сложными объектами, а математическая индукция и дедукция могут становиться все более и более трудными. Таким образом, научная интерпретация может стать важным способом расширения новых областей науки и технологических инноваций.

Ключевые слова: Герменевтика; Интерпретация генетической информации; Преобразование текста; Система мышления; Понимание

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INTRODUCTION

Hans Georg Gadamer once interpreted hermeneutics as an activity generally mediated by “natural language.” Interpretation is a method through which we can analyze and solve problems from a rational standpoint, clearly explain the meaning of all aspects of things, and obtain the meaning of truth.

Since the hermeneutic approach was transplanted from theology and the humanities to the field of scientific and technological activities, scientific interpretation has gained increasing attention. However, there is still a lack of specific examination and discussion about the application and function of the interpretation method in the process of scientific cognition, especially the analysis and textual research based on specific scientific cases. The discussion of the scientific interpretation method remains to fully appreciate its importance.

Hermeneutic approaches are very important for scientific research and technological innovation - there is no doubt about this, as evidenced in the works of Patrick Heelan, Joseph Kockelmans and others (Crease, 1997). But I argue that the analysis of specific applications is more important. In my opinion, without the basis of specific case analysis, a new method is difficult to be popularized, and effectively applied. The value of the method can only be found through specific case analysis.

For this purpose, I choose modern molecular biology as the object of analysis which I think is a typical case of applying and reflecting the value of the interpretation method. The methodology followed in this case is unconventional, revealing the existence of genetic information through an analogy in the medium of natural language. The discovery process is the creation and interpretation of a series of texts, that is, the transformation and recovery of natural language, including abstract concepts and intuitive images. By deciphering description-texts, understanding-texts and explanation-texts, hermeneutics gave birth to modern molecular biology.

The text transformation first involves the understanding of the text. Therefore, at the end of this paper, a discussion of “understanding” is highlighted. Why can people understand? Einstein argued that this is the hardest thing to comprehend in the world (Vallentin, 1954, p. 24). I found that if the mechanism of “understanding” is placed within the framework of modern hierarchy theory or the hypothesis of complex systems, there will be a more reasonable explanation: The coordination between the hierarchical discontinuities (emergent or emerging) in the thinking system is realized through transformation and recovery within the conscious layers mediated by natural language. “Understanding” is based on the instinctual ability to transform language, and language naturally has the characteristics of human culture, and this explains why the application of hermeneutic methods revolves around a certain cultural element.

ONTOLOGY AND EPISTEMOLOGY OF THE INTERPRETATION OF TEXT

Scientific research is also a hermeneutic process, and scientific discovery and technological innovation are realized in the process of continuous interpretation of text. Scientific knowledge activities can be mainly divided into three steps: description, understanding, and explanation, there are accordingly the "description-text", the "understanding-text," and the "explanation-text". In a certain sense, scientific research is the interpretation of these three texts. Before formally entering the specific case analysis, it is necessary to first clarify the ontological and methodological basis of the interpretation of text.

(1) Description-texts

The empirical statements of the experimental process and results about objective object (usually using empirical vocabulary) form the original text of scientific interpretation, namely the "first text". The original text is a text formed by a simple description, and so it is defined as a "description-text." Although there are many different statements for the same object, the same process, and even the same result because of the different backgrounds of the researchers, after many observations and experiments by many people, these empirical statements eventually tend to become consistent and become recognized as empirical facts. Therefore, the description text can also be called the empirical fact text (simply the "empirical text").

To admit that the text can transmit the experience of empirical facts is to admit that the text has a certain capacity to represent reality: The description-text composed of empirical language represents existence. It is in this context that Gianni Vattimo wrote that: "the question concerning a rationally grounded understanding of texts has progressively tended towards the thinking of a general ontology" (Vattimo, 2015, p. 721). The interpretation of empirical texts will eventually involve ontologies and epistemology, because experience about existence is always based on epistemological foundations.

(2) Understanding-texts

The interpretation of a description-text is "understanding," and the text produced through understanding is an understanding-text. If the description-text represents the facts, the understanding of the description-text is also the understanding of the objective object. There is an essential difference between understanding and simple descriptive empirical statements, and understanding is a deep rational activity. As will shown below, the rational state of so-called reason is a state in which all layers of the human thinking system are coordinated. Understanding-text is a new text produced through language transformation in the state of reason, representing "theoretical facts," so it is also called "theoretical fact text" ("theoretical text" for short) which is the "second text" of scientific interpretation.

The physiological mechanism of understanding is far beyond the level of modern science, and the hardest thing in the world to understand is human understanding itself. Up to now the most advanced AI has not reached this level of understanding, or even the ability to understand in general. The reason, I speculate, is that understanding is not a step-by-step programming or statistical probability analysis. In terms of the external form of understanding, namely language transformation, AI can imitate only one part, or even a small part of it. Even the analysis of “artificial text”, that is, the text generated by AI technology, needs to rely in the end on hermeneutics methods, that is, on the transformation and recovery mediated by natural language.

The text generated by understanding is usually composed of theoretical words (the division of empirical words and theoretical words, although not very strict, is meaningful) and more strict grammatical rules. Although understanding is a very personal matter, each researcher has a different background and forms different understanding texts. By verbal communication and mutual interpretation the researchers will produce relatively consistent theoretical statements and form consistent theoretical texts, such as textbooks. Natural language is a talent of human beings which is rooted in human social culture. Therefore, in the interpretation process of transformation and recovery mediated by natural language, it shows its powerful ontological and epistemological functions.

(3) Explanation-texts

A so-called “explanation” is the interpretation of the understanding text and the text generated through explanation is the “explanation-text” which is the third text of scientific interpretation. Since understanding is the understanding of empirical text, then explanation is the explanation of the empirical text. Due to the complexity and richness of the transformation and recovery mediated by natural language, through the interpretation of a theoretical factual text, we can obtain many explanatory texts and produce a new series of observable statements, which are not included in the already known facts, except from the original empirical facts. So, the explanation-text is likely to point to new facts that are yet to be recognized as objective or instead as illusions or artefacts of the language games. However, scientific discovery and technological innovation happen precisely because the same empirical or theoretical text can produce many explanatory texts, a new explanatory text may lead to a new scientific discovery or new technology.

(4) Brief sum-up

The analysis of text transformation and recovery mediated by natural language runs through the process of description, understanding and explanation of scientific research. As a scientific and technological research method, scientific interpretation has long been overlooked, but its functions and affordances are becoming increasingly recognised for their importance. As Joseph Kockelmans, a founder of scientific hermeneutics, pointed out, when people look back at the history of science and technology they find, that natural science is born with hermeneutics, and evolved alongside hermeneutics in every aspect (Crease, 1997, p. 264). Scientific interpretation combines scientific practice with language analysis, and with the help of the cultural characteristics of natural language itself it grants to the subjective active role in scientific and technological research the basis of philosophical ontology and epistemology.

Based on the above cognizance, a typical case in biological science will be examined below to further demonstrate the interrelationship of description, understanding, and explanation, and the role of textual analysis.

THE TRANSMISSION MODE OF HUMAN CULTURE GIVING RISE TO MODERN MOLECULAR BIOLOGY

In natural science research the concept of information first started in biology, or rather, in molecular biological genetics. Before the birth of molecular biology, biological science - as opposed to the natural history of biology - set the relationship between the biological parts according to the traditional idea of physics and chemistry based on the notion of reduction. In addition to the physical and chemical concepts of interaction, some biologists have imagined “organic forces,” such as “affinity,” “vitality,” and even “willpower,” but there is no way to describe them scientifically. The biotic and abiotic could neither be distinguished nor be connected, only described, neither understood nor explained, until the molecular genetic mechanisms of organisms were revealed and interpreted as information, the results of which show us that organisms are both material and informational. Let's take a look at the process of discovering information in biological genetics.

Information Interpretation of Biological Genetics

(1) From the description-text to the understanding-text

In 1953, James D. Watson and Francis Crick discovered DNA’s double-helix structure and a special relationship between the nucleotides forming DNA molecules and amino acids of protein molecules, a relationship that cannot be explained by traditional physicochemical interactions. (The famous biologist Jacques Monod has carefully examined and discussed this matter, see Monod, 1971). Scientists explain this particular interrelationship in respect to “natural language” by using the characteristics of human cultural transmission, interpreting it as a similar text communication coding relationship (see Figure 1). A set of cryptographic books used by the whole organic world was then discovered. Thus, from an incomprehensible description text, through scientific interpretation to an understandable text, the theory of biological genetic information was finally established.

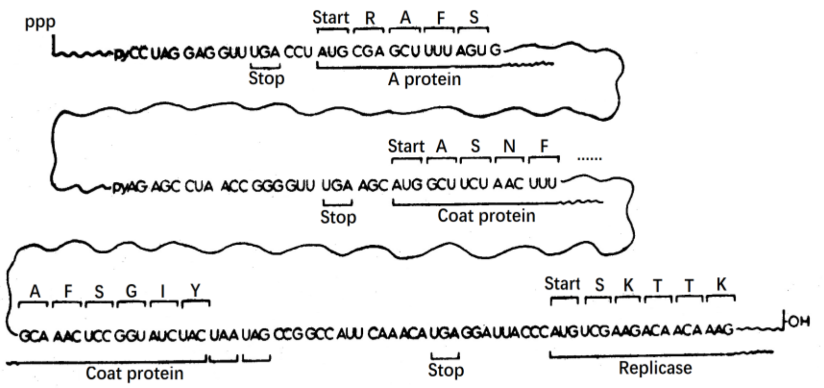

Figure 1. The understanding-text interpreted from the description text: The nucleotide program and corresponding proteins of the mRNA molecule of phage R17 (Sheng, 1976, p. 39). A bioinformation interpretation is based on a human cultural information model. The genetic characteristics of organisms are recorded in an encoded form, similar to a string of characters in human culture that is both material and informational.

The bacteriophage R17 is a relatively simple organism consisting of three proteins: a protein, coat protein, and replicase. Figure 1 illustrates the nucleotide sequence of the mRNA molecules of bacteriophage R17 and their corresponding proteins. Note that it is the product of the scientific interpretation by way of a hermeneutic method. Formally, this is similar to a language that is part of human culture: There are letters (A, G, C, U being the four nucleotides), words composed of letters (triplet codons corresponding to the different amino acids: R, S, N, F...), sentences composed of words (determining the amino acid sequence of a protein), paragraphs (determining the amino acid sequence of multiple proteins), and specialized starting and terminating symbols between sentences and sentences, paragraphs and paragraphs. The relationship between the structure of a phage mRNA molecule and the overall function of the phage is understood only by human intelligence because it is both material and informational. The origin of the special coding form of biological genetic information is still a mystery today, but it is an indisputable fact that biological heredity (or the continuation of life) can be understood and recognized only on the terms of an interaction of information.

Therefore, by way of interpretation based on the way of human cultural communication, the scientific vision really enters the information world, starting with the biological system.

(2) From the understanding-text to the explanation-text

Figure 2 shows a text that is the biological genetic code book deciphered from the above understanding-text. This text enables a full explanation of the coding relationship of genetic material and genetic information, and shows the relationship between nucleotides and amino acids at a glance - which are connected not by mechanical and statistical decisions, but by passwords. This explanation-text not only fully explains the genetic mechanism (understanding-text), but also fully explains the genetic phenomenon (description-text).

	U	C	A	G	
U	Phe/F (UUU) Phe/F (UUC) Leu/L (UUA) Leu/L (UUG)	Ser/S (UCU) Ser/S (UCC) Ser/S (UCA) Ser/S (UCG)	Tyr/Y (UAU) Tyr/Y (UAC) 【Stop】 (UAA) 【Stop】 (UAG)	Cys/C (UGU) Cys/C (UGC) 【Stop】 (UGA) Trp/W (UGG)	U C A G
C	Leu/L (CUU) Leu/L (CUC) Leu/L (CUA) Leu/L (CUG)	Pro/P (CCU) Pro/P (CCC) Pro/P (CCA) Pro/P (CCG)	His/H (CAU) His/H (CAC) Gln/Q (CAA) Gln/Q (CAG)	Arg/R (CGU) Arg/R (CGC) Arg/R (CGA) Arg/R (CGG)	U C A G
A	Ile/I (AUU) Ile/I (AUC) Ile/I (AUA) M【Start】(AUG)	Thr/T (ACU) Thr/T (ACC) Thr/T (ACA) Thr/T (ACG)	Asn/N (AAU) Asn/N (AAC) Lys/K (AAA) Lys/K (AAG)	Ser/S (AGU) Ser/S (AGC) Arg/R (AGA) Arg/R (AGG)	U C A G
G	Val/V (GUU) Val/V (GUC) Val/V (GUA) Val/V (GUG)	Ala/A (GCU) Ala/A (GCC) Ala/A (GCA) Ala/A (GCG)	Asp/D (GAU) Asp/D (GAC) Glu/E (GAA) Glu/E (GAG)	Gly/G (GGU) Gly/G (GGC) Gly/G (GGA) Gly/G (GGG)	U C A G

Figure 2. The explanation-text interpreted from the understanding-text**.** The triplet genetic code book of one amino acid is determined by three nucleotides (Sheng, 1976, p. 18)

Information Interpretation of the Biological Variation

(1) The description-text

Geneticists have observed that the phenotypic differences between two generations cannot be explained through an interaction at the same layer, i.e., the idea of acquired inheritance is untenable, which leads to the theory of the separation of germplasms and constitutions. The germplasm determines the basic characteristics of an organism in future development, equivalent to a set of instruction vectors. Evidently, this process is closer to the category of "information" than that of "pre-formation". Just as a book is the product of human culture, so germplasm and similar variation mechanisms have the function of storing information. The concept of germplasm indicates that the notion of information has entered the vision of scientists, and the objective reality of the information became accepted.

Then came the question. On one side, experiments in genetics arrived at the following statement: The change of constitution does not lead to a corresponding change in germplasm. This was shown by Weismann‘s experiment of repeatedly cutting off the tails of several generations of multiple white mouse specimen where none of the new-born animals showed a reduction (or elongation) in their tails. Hence, it was shown that a phenotypic change does not produce a genotypic change, and the acquisition cannot be inherited. But, on the other side, the archaeological study of fossils arrives at the statement Over a long course of time some species disappear, some new species are produced, and other species have been evolving. If we assume that we have no further empirical statements to settle the dispute, then we are facing a stalemate. What makes the genetic information change?

(2) The understanding-text

By the interpretation method an understanding-text was given, based on the "support" of characteristics that are shared with the mode of dissemination of human cultural information. The characteristic of human cultural information transmission is 1) that the information content depends on the composition and order of letters, words (punctuation), phrases, sentences and paragraphs in the information carrier (language), and 2) that it can only be changed by modifying the structure and order of words. Applying these same features to evolutionary biology we arrive at a new text. The content of the new text is that the changes of a genetic material carrier in the natural environment lead directly to changes of genetic information content, then to changes in genetic traits. It is also that the changes in phenotypic shape, though they are determined by genetic information, synchronized with the changes of natural environment, do not lead to changes in the content of genetic information and therefore do not alter genotypic shape.

(3) The explanation-text

From the interpretation of the understanding-text, scientists (physiologists and physicists) interpret different explanation-texts through the mediation of natural language. One of them is that biological genetic variation is the change of different material layers of macro and micro, and the change of different material layers has their own causes. The change of genetic material plays a decisive role in genetic trait variation, with the change of genetic material happening in the same material layer. This explanation-text provides an observable statement: energy radiation leads to genetic variation, and specific energy radiation can lead to specific genetic variation.

(4) The validation to the observable statements of the explanation-text

The exchange between DNA molecular bonds is the most fundamental change in genetic material, and the bond energy structure is an important component of the structure of the molecular energy field. Each bond in each biomolecule, whose energy state is different, has its own intrinsic vibrational frequency. Due to quantization, the interaction between the energy fields is highly selective, i.e., the bonds with a certain intrinsic vibrational frequency can only interact with the corresponding radiation energy field that almost has no influence on other bonds. Therefore, if this energy field is large enough, the resonance (activation speed) of the bond will greatly exceed the thermal speed of the molecule to release the stored energy. The energy state of the whole molecule will change and jump into another steady state, and then isomerism of the base molecules occurs, which leads to new sequencing of the DNA (Pullman & Pullman, 1963, p. 209).

Scientists have noticed that the genetic effects of radiation biological mutagenesis come not from direct physical interactions but from information interactions caused by physical interactions. Evidently, the same radiation energy has different effects on the germplasm and constitution of an organism, and heredity and variation can only be explained by information interactions. Experiments show that far-infrared laser radiation can lead to the generation of consistent genetic variation within populations (Wang & Wang, 1999, p. 1011-1013).

Information Interpretation of the Organism Survival and Growth

(1) The description-text

The properties and states of all layers in an active organism must be coordinated and unified; they can be adjusted at any time as the environment changes. Organisms have the invariable ability to maintain their own form and function for a period of time in the process of material metabolism and energy metabolism, while non-living things that follow traditional physical and chemical laws have no such ability.

(2) The understanding-text

How does one layer change its state of time and space according to the change of another layer? If the question is expressed in an anthropomorphic way, that is, how does one layer get to know the changes of some other layer, simultaneously reacting accordingly? In human society this is effected by one layer sending messengers to those other different layers. Based on the interpretation of human social and cultural characteristics, the description-text is transformed into an understanding text: there is information communication between different layers and cross layers of the organism.

(3) The explanation-text

All layers and parts of the organism can be coordinated in the process of survival, because they establish informational communication connections. This explanation-text presents the observable statement that various layers and parts of the organism exchange their messengers.

The results of further analysis on higher organisms suggest that there is indeed such a way of communication in living organisms. Take humans as an example, it has been found that the three messengers delivering life information between the layers of the human body are: hormones, prostaglandins (local hormones), and adenosine cyclic phosphates (cAMP). They work together to complete the task of delivering life-sustaining information in a relay way which is really similar to human communication. Hormones are the first messengers of endocrine glands directly secreted into the blood to transmit life information and instructions, such as insulin and pituitary hormones. Prostaglandins are a group of unsaturated fatty acids synthesized on a variety of cell membranes in the human body. The cAMP is a special type of nucleotide that regulates the physiological activities of cells and substance metabolism.

The main sites of human hormone production are: the pituitary gland, thyroid gland, parathyroid gland, pancreatic islets, adrenal gland and gonads, which can be compared to outposts at the highest layer of the human body, and they all activate under the coordinated control of the hypothalamus. All kinds of hormones are distributed throughout the body. although the ones that have extensive contact with tissue cells can only act on tissue cells that recognize donor information. For example, hormones bind to receptors on the target cells to promote prostaglandin synthesis on the cell membrane, then the prostaglandin activates intracellular adenylyl cyclase, converting the intracellular energy storage material adenosine triphosphate (ATP) into cAMP with the participation of magnesium. cAMP activates protein kinases within cells, producing a series of enzymatic reactions that allow cells to produce specific physiological effects. The prostate numbers and cAMP not only perform the mission of delivering hormonal information, but also constitute a tertiary amplification system of this information, making the processed information expand ten thousand times so that the hormones of several molecules can make the cell have significant physiological effects.

The role of the messengers is to convey information between the qualitative material layers in the organisms, adjusting the spatial and temporal relations of various layers. The messengers are not the independent material layers in the biological system, and the information they carry is not enough to establish a new derivative layer, but if such a communication system established by messengers were to be lost, the organism would not be able to survive in the unpredictability of the environment (Wang, 1993, p. 123-124).

(4) Brief sum-up

Since Schrödinger (1944) boldly proposed cryptological determinism, a complete biological genetic code book was deciphered in the 1960s. From that moment, biologists have used a set of concepts similar to human cultural communication to describe, understand, and explain the variation, survival, development and evolution of organisms, such as: information, vector, replication, transmission, conversion, transcription, translation, recognition, and expression. And molecular biologists have also created a set of terms of corresponding materialization mechanisms: codons, anticodons, insertions, transposons, introns, exons and operons (see Figure 3).

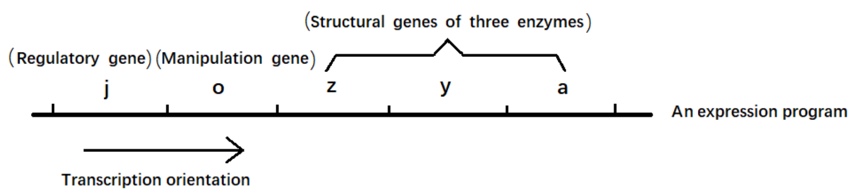

Figure 3. An understanding-text about developmental control (The "operon" model created by Jacob & Monod, 1961）.

THE UNDERSTANDING OF "UNDERSTANDING"

Albert Einstein once said, “the most incomprehensible thing about the world is that it is at all comprehensible” (Vallentin, 1954, p. 24). Really, the most difficult question in the world to understand is why people can understand. "Understanding" is in the middle position between description and explanation, and is a key feature of cognition. If the description-text cannot be understood, there cannot be an explanation of the things described, and thus predictive statements cannot be obtained. As I mentioned earlier, "understanding" is a strictly individual event. What individuals do in their rational state is something that we do not clearly understand in terms of their physiological mechanism. However, I argue that "understanding" itself can also be understood through hermeneutics. I propose to treat this question in the framework of a „thinking system," a proposal that proves to be productive.

The hierarchy and complexity of the thinking system

We can build the administrative-levels mode of the thinking system. It is organized by consciousness with many layers: direct perception / indirect perception / rational faculty / worldview / consciousness / the subconscious / top-consciousness. The existence of top-consciousness requires special emphasis. It is an as yet unclear and unconfirmed part of consciousness as it relates to the physical mechanism (Wang, 1993, p. 139). Of course, such a division of consciousness is not strict and needs to be further explored, but it seems evident that consciousness is layered hierarchically (see Figure 4).

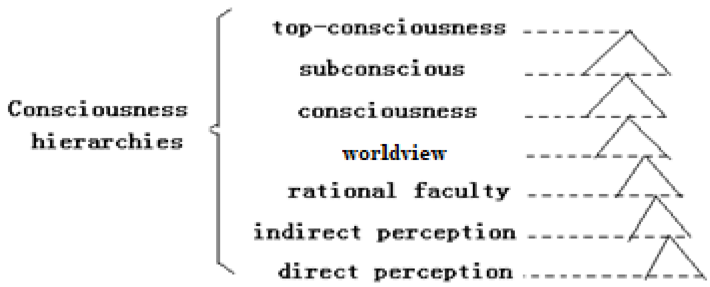

Figure 4. Hierarchical structure of the thinking system (Wang, 2006, p. 255).

The illustration about the layered structure of the thinking system is absolutely necessary to understand the completeness, creativity, and mechanisms of cognition. It reveals that human understanding, or cognition, is not a linear process, nor is it merely a leap through perception and rationality. During the process of actual thinking or cognition, many layers work together. They are conceptually distinct and can be considered independently even though they contain, restrain and influence each other, forming complex interacting relationships. This process follows a creative trajectory and its creativity comes from the complex interactions between the layers. Thinking systems have standards of values and psychology besides the general characteristics of complex systems, such as mutation, restriction, coding, and organization.

In the human thinking system, each consciousness-layer has its own substance with special form, that comes from abduction of higher layers and abstraction from lower layers, and by influence from outside the system. As in any natural hierarchy, a functioning consciousness hierarchy cannot be reduced. All layers of consciousness work together and support each other, none of them work alone. During thinking they all play a supporting role. Cognition is a complex event worked on by the whole brain (consciousness). It is unnecessary to refer to a presupposed basis or foundation of rationality. The rationality of knowledge can only be found when thinking is considered as multi-layered complex system, and when the content of one layer is supposed to be the foundation of others, and if a traversal across layers is defined as the organizastion of a new idea.

To Understand "Understanding" from a Hermeneutic Perspective

From the above analysis, it is not difficult to see that "understanding" is realized through complex interactions between the layers of thinking systems. The hierarchical theory of thinking provides a new perspective on "understanding." Through this new perspective, we find two patterns or ways of "understanding": in different layers and across layers, the transformation and recovery between abstract concepts, and that between intuitive images. The understanding-text is the result of successful transformation and recovery.

(1) Understanding through the transformation and recovery of and among abstract concepts

The concept is the core element of the thinking system, formed through the process of abstraction. Different layers of consciousness hold concepts with varying degrees of abstraction. These are expressed externally in form of words, which consequently possess a hierarchy. The interrelationship among them mirrors the interconnection between concepts.

In essence, "understanding" refers to the continuous generation of new connections among the concepts of each thinking layer (see Figure 5). This dynamic process ultimately leads to a state of mutual support and coordination, which can be described as a state of understanding, or a rational state.

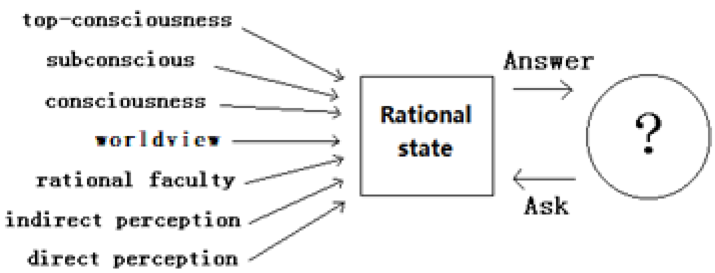

Figure 5. Understanding in the rational state.

(2) Understanding through conversion and recovery among intuitive images

In the absence of concepts or with unclear concepts, the brain's understanding of things depends on the conversion and recovery between intuitive images (intuitive models) at different layers of consciousness (see Figure 6). The visual images support each other, thus achieving an understanding of things. There are jumps and discontinuities between the intuitive models at each layer, and the connection to them depends on the intuitive experience of each person. I speculate that this is the human ability to understand instinctively.

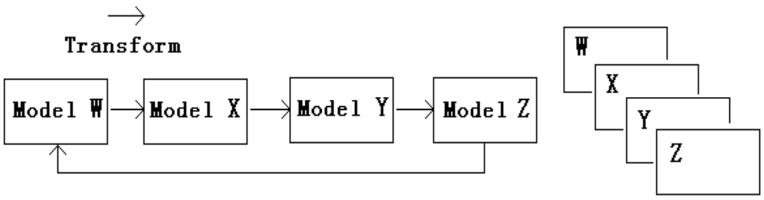

Figure 6. Understanding through different layers of intuitive image conversion (Wang, 2007, p. 267).

Understanding by conversion and recovery among intuitive images at different levels is mediated by human intuitive experience; as in the case of conceptual understanding, this kind of understanding is also characteristic of human culture. Any understanding has a certain cultural background, which was confirmed in the previous case analysis of modern molecular biology.

The hierarchical structure of the thinking system and its complexity are an important theoretical framework for us to understand "understanding."

CONCLUSION

From the analysis of the case of the birth of modern molecular biology, we can see that the hermeneutic method mediated by natural language and intuitive experience runs through the intepretive process of description, understanding, and explanation in scientific cognition. Scientific knowledge is a process of the transformation and reductive recovery of text. The mutual support and validation of "describing text," "understanding text," and "explaining text" are the most basic requirements for the interpretation of text. The interpretation of information based on human cultural exchange patterns has led to modern molecular biology, as well as many other scientific discoveries and technological innovations, such as Information Science and Artificial Intelligence (Wang, 2022, pp. 183-190). The cultural elements in natural language and intuitive experience make the hermeneutic method rely on ontology and methodology. The application of hermeneutic methods often requires a cultural moment as a fulcrum, which can be anything that the researcher has understood. With the theory of a complex hierarchical system one can obtain a clearer understanding of human "understanding." Scientific interpretation will become an increasingly important method in scientific research, because science is facing more and more complex objects, and mathematical induction and deduction may become more and more difficult. Therefore, scientific interpretation may become an essential way to expand new fields of science and technological innovation.

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Research article

Toward Practical Hermeneutics of Fourth Paradigm AI for Science

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Abstract

The combination of artificial intelligence and science creates a new method for scientific research, which has achieved magnificent success, but also raises questions of how to understand the knowledge produced by this method. Hermeneutics is a method of interpreting scripture that is widely used in the humanities such as history. Based on the history of science, Thomas Kuhn suggests that science can also be understood hermeneutically. Building on Kuhn's work, Joseph Rouse argues that there are two hermeneutics for understanding scientific knowledge, a theoretical hermeneutics and a practical hermeneutics. The knowledge generated by AI-enabled science can also be examined from the perspective of these two hermeneutics. Theoretical hermeneutics argues that scientific knowledge has not been revolutionized at the theoretical level and that AI is only another tool to improve the efficiency of scientific research. However, this approach fails to acknowledge problems of AI-enabled knowledge generation such as data as a new form of publication and AI-assisted writing, automated laboratories, the role of AI in knowledge generation, and the opaqueness, unexplainability and bias of machine learning-generated knowledge. This article suggests the need for practical hermeneutics to address the above issues and to understand the knowledge produced by new research methods in the context of scientific practice.

Keywords: AI for science; Theoretical hermeneutics; Practical hermeneutics; Joseph Rouse

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Научная статья

На пути к практической герменевтике четвертой парадигмы искусственного интеллекта для науки

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Аннотация

Сочетание искусственного интеллекта и науки создает новый метод научных исследований, достигший великолепных успехов, но также ставящий вопрос о том, как понимать знания, полученные с помощью этого метода. Герменевтика – это метод толкования священных текстов, который широко используется в гуманитарных науках, таких как история. Основываясь на истории науки, Томас Кун предполагает, что науку можно понимать и герменевтически. Основываясь на работе Куна, Джозеф Роуз утверждает, что существует две герменевтики для понимания научного знания: теоретическая герменевтика и практическая герменевтика. Знания, генерируемые наукой с помощью ИИ, также можно рассматривать с точки зрения этих двух герменевтик. Теоретическая герменевтика утверждает, что научное знание не подверглось революции на теоретическом уровне и что ИИ лишь еще один инструмент повышения эффективности научных исследований. Однако этот подход не учитывает проблемы генерации знаний с помощью ИИ, такие как данные, как новая форма публикации; написанное с помощью ИИ; автоматизированные лаборатории; роль ИИ в генерации знаний, а также непрозрачность, необъяснимость и предвзятость знания полученного с помощью машинного обучения. В данной статье говорится о необходимости практической герменевтики для решения вышеуказанных проблем и понимания знаний, получаемых с помощью новых методов исследования, в контексте научной практики.

Ключевые слова: Искусственный интеллект; ИИ для науки; Теоретическая герменевтика; Практическая герменевтика; Джозеф Роуз

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INTRODUCTION

At a January 2007 meeting of the U.S. National Research Council, Turing Award computer scientist Jim Gray gave a talk suggesting that, with the development of new methods for data collection and analysis, a new paradigm was emerging in the practice of what he called "e-science." In his words,

> Originally there was just experimental science, and then there was theoretical science, with Kepler's Laws, Newton's Laws of Motion, Maxwell's equations, and so on. Then, for many problems, the theoretical models grew too complicated to solve analytically, and people had to start simulating. These simulations have carried us through much of the last half of the last millennium. At this point, these simulations are generating a whole lot of data, along with a huge increase in data from the experimental sciences. People now do not actually look through telescopes. Instead, they are "looking" through large-scale, complex instruments which relay data to datacenters, and only then do they look at the information on their computers.
>
> The world of science has changed…. The new model is for the data to be captured by instruments or generated by simulations before being processed by software and for the resulting information or knowledge to be stored in computers. Scientists only get to look at their data fairly late in this pipeline. The techniques and technologies for such data-intensive science are so different that it is worth distinguishing data-intensive science from computational science as a new, *fourth paradigm* for scientific exploration. (in Hey et al., 2009, pp. xvii-xix)

This idea was more formally iterated in a 2009 "Perspectives" piece in *Science* (Bell et al., 2009) and became the theme of an oft-cited book (Hey et al., 2009). In 2020, the argument was expanded in a U.S. Department of Energy (DOE) report, *AI for Science*. Using the term "data-intensive science," it surveyed a "new generation of methods and scientific opportunities in computing, including the development and application of AI methods (e.g., machine learning, deep learning, statistical methods, data analytics, automated control, and related areas) to build models from data and to use these models alone or in conjunction with simulation and scalable computing to advance scientific research" (Stevens et al., 2020, p. 1).

Jim Gray and the DOE report are concerned with how to interpret the knowledge produced by the new methods of data-intensive science: *how will it fit with or advance existing scientific knowledge?* But to examine AI for science solely in terms of its knowledge-producing potential elides its practical or power-altering aspects. New methods of knowledge production invite practical as well as theoretical hermeneutic reflection. Drawing particularly on the work of philosopher of science Joseph Rouse, we seek to introduce practical hermeneutic reflection on this variously named "fourth paradigm" that is alleged to form a historically emergent complement to scientific traditions of empirical description, mathematical modeling, and computational simulation.

SIGNATURE ACHIEVEMENTS OF FOURTH PARADIGM SCIENCE

To appreciate the character of fourth paradigm science, consider some signature achievements. One highly representative example is protein 3D structure prediction. Machine learning from protein structure databases has enabled AlphaFold to predict protein structure (Jumper et al., 2021). This development dramatically reduces the time required for protein structure prediction and supersedes previous experimental methods (such as cryo-EM) to provide a more rapid method for designing new proteins.

Another example is the recent Chinese development of an “all-around AI-Chemist with a scientific mind” that can read literature, design experiments, complete experimental processes, analyze data, and finally produce predictive models to obtain material samples with desirable composition ratios (Zhu et al., 2022). Such instruments radically reduce the amount of time human chemists spend on experiments and alter the way new materials can be discovered or engineered with potential to transform the chemical laboratory of the future. Generative AI is another tool for speeding things up by quickly surveying the literature and providing first drafts for reports (Noy and Zhang, 2023).

AI for Science surveys related changes in computational materials science, digital earth systems science, computational biology, and high energy and nuclear physics. Similar transformations are occurring in the social sciences (Hill, 2020). AI’s introduction into multiple fields produces efficiencies and results that could not have been imagined with previous methods, thus exemplifying the potential of the new paradigm in scientific research (Xu et al., 2021) and in many engineering fields (Montáns et al., 2019). On the basis of such achievements, data-driven and AI-enabled research is being interpreted as a historically new, fourth paradigm of science.

THE PERSPECTIVE OF HERMENEUTICS

The philosophical name for the conscious attempt to make interpretations is “hermeneutics.” Hermeneutics was originally concerned with methods for the theoretical interpretation of sacred texts such as the Bible that were considered culturally authoritative. As the Bible was supplemented or replaced by secular texts such as legal codes or culture-defining works of art, hermeneutics became the basic method of the social and human sciences. Insofar as natural science was presumed to produce positive or causal knowledge that was self-confirming, hermeneutics was a method distinct from that which is operative in the modern natural sciences. In the philosophies of Martin Heidegger and Hans-Georg Gadamer, interpretation or hermeneutics even became the definitive difference between the human and the scientist.

The fundamental insight of hermeneutic philosophy is that there is no privileged, unquestionable, or certain beginning to thinking or living. Human beings are born into and become conscious of themselves within a context that encompasses them; they learn to understand it and themselves in a repetitive, piecemeal process that moves back and forth from part to whole and whole to part. In the hermeneutics of texts such as the Bible, for instance, early Christian theologians such as St. Augustine argued against any quick and easy interpretation of the meaning of particular words or passages in the Bible. The parts must be understood in light of the whole and the whole from the parts. It was a circular or, better, a spiral process of developing a progressively more comprehensive and adequate understanding of the text.

The 19th-century German philosopher Wilhelm Dilthey argued that the same process is foundational for the development of historical understanding. Historians work back and forth from the reading of historical documents and descriptions of previous events to the development of an understanding of what life was like at some time in the past – or perhaps in another, foreign culture in the present. To this kind of humanistic understanding, Dilthey contrasted the causal or explanatory knowledge produced by the natural sciences: knowledge of how A causes B, as a result of the peculiarly productive combination of experiment and mathematical model creation found in modern natural science.

Yet insofar as hermeneutics defines the human, not just the humanities – that is, insofar as to be human is to seek understanding of oneself through a hermeneutic engagement with the world – it must also be present in the natural sciences; it ceases to be a method peculiar to the human sciences alone. Since scientists are also human beings, and to be a scientist is just one way of being human, hermeneutics will be present in the sciences. Hermeneutics is universalized; it applies across all disciplines.

During the mid-20th century, philosophers of science began to recognize two senses in which the methods of hermeneutics are relevant to understanding the natural sciences. In one sense, the history of science requires interpretation. As Thomas Kuhn observed in an autobiographical reflection,

> What I discovered in studying Aristotle was that a text required interpretation. And by interpretation I mean something similar to what was then quite well known in Europe … as hermeneutics…. It was a way of reading texts, of looking for things that don't quite fit, puzzling over them, and then suddenly finding a way of sorting out the pieces. (Sigurdsson, 2016, p. 21)

In a second sense, even within science itself, again, as Kuhn recognized, scientists use principles of hermeneutics to find ways of sorting out pieces of experimental data and unite them into theories. Experiments cannot produce knowledge of causal relations that do not depend on interpretations about what counts as a cause or a relationship. An interpretation may be latent and un-thematized in a scientific paradigm of knowledge production, nevertheless, it is there and calls for philosophical articulation.

In the case of Kuhn and science generally, hermeneutics in both senses remains largely concerned with concepts and theories. Late in the 20th century, a new kind of philosopher of science, a science studies philosopher, began to argue that there was also a hermeneutic circle at work in scientific practices. The hermeneutic circle is present in the natural sciences when particular experimental results are interpreted in the light of theories or models and vice versa. But as experimental processes become more and more dependent on increasingly complex instrumentation, the hermeneutics of ideas demands complementation by *a hermeneutics of practice.* To understand science more fully, we need to interpret relationships between concepts and theories and relationships between scientific practices and society. One philosopher of science who has focused especially on developing a hermeneutics of practice is Joseph Rouse.

HERMENEUTICS OF PRACTICE

In *Knowledge and Power* Rouse (1987) charts a transformation in philosophy of science that emerged in the wake of Kuhn and the rejection of logical empiricist accounts that held sway in Anglo-American philosophy until the 1960s. Rouse's account is concerned in the first instance with how the opening up of the laboratory to ethnographic inspection revealed how material practices contributed as much as logical methods to the production of scientific knowledge (e.g., Latour and Woolgar, 1986). The key feature of post-empiricist philosophy is the questioning of any naïve representational theory of knowledge. Rejecting the naïve empiricist belief that scientific methods, when successful, provide direct observational access to and representations of reality, post-empiricism argues that

> scientists compare their theoretical representations with other theoretical representations rather than with the observed, uninterpreted world. The history of science is not a story of the gradual accumulation of a storehouse of knowledge about the given world. It tells instead of discontinuous changes in the overall structure of our representations and, with them, of changes in how the world appears to us. This revised picture of science has had some remarkable successes, both in resolving the many embarrassing conceptual difficulties in empiricist philosophy of science and in developing a fruitful dialogue between historians and philosophers of science. (Rouse, 1987, p. 4)

What it has not so well developed in post-empiricist philosophy, however, is an understanding of the technological power of science. As Rouse remarks, quoting Hilary Putnam: "non-realist accounts of science (such as the post-empiricist model…) seem at first glance to make the technical success of science a miracle" (Rouse, 1987, p. 6). Post-empiricist philosophy further tends to undercut the ability of science to, quoting a shibboleth, "speak truth to power" (Marmot, 2017). If scientific knowledge production is influenced by irrational power conditions, then on what basis does it claim to correct or oppose power?

According to Rouse, classical empiricism provides three views of the possible relationship between knowledge and power. First, knowledge can be applied in order to make power more effective. Second, power can be used to inhibit or distort scientific research. (Only later does Rouse note that power can also fund or support scientific research; presumably, if knowledge is being used by power, power will also be interested in supporting its production.) Third, knowledge can be liberating from the repressions of power. In all three cases, however, knowledge and power are conceived of as separate or independent, and power is located primarily in individual agents.

The received view of science-power relations is mistaken, according to Rouse. "It leads us to overlook important ways power is exercised today and to misunderstand both scientific practices and their political effects" (Rouse, 1987, p. 17). There are, for Rouse, two philosophies of science that open up possibilities for better understanding of power-knowledge relationships: pragmatism and what he calls the "new empiricism." Yet insofar as pragmatism and the new empiricism highlight solely the constructive (or co-constructive and contingent) character of scientific knowledge and the ways power relationships influence epistemic production, it fails to adequately analyze the nature of power. Rouse aims to remedy this deficiency by reintroducing practical hermeneutics.

According to Rouse, the universalization of hermeneutics – that is, the idea that both the natural and the human sciences are hermeneutical – does not do away with a distinction between theoretical and practical hermeneutics.

> Theoretical hermeneutics is a theory-dominant philosophy of science. …[I]t assigns a preeminent role to theories (i.e., a particular sort of semantic structure) within the practice of scientific research. Experiments and observations are significant only within a theoretical context. Theory guides the construction and performance of experiments, supplies the categories within which observations are to be interpreted, and mediates the transmission and application of results of research. Ultimately, theories are the end product of research: the aim of science is to produce better theories…. "Theory" has commonly signified a kind of understanding that is not tied to our practical involvements with the world. (Rouse, 1987, p. 69).

Science is not only the production of propositions interpreted within a theoretical framework; it exists in the patterns that emerge from the interdisciplinary interaction between actors, the instruments, and the objects of scientific research, constructing both the actors and the environment. "Scientific practices, and the extension of their models, practices, and constituents beyond the laboratory, reconfigure the possibilities in terms of which people can intelligibly understand and enact their lives" (Rouse, 1996, pp. 132-133). Science today can no longer be interpreted simply as knowledge production but needs to include critical reflection on the practical dimensions of research. Rouse argues for developing accounts of scientific practice as an activity within historical, social, technological, and psychological constraints.

> Scientific practices rearrange our surroundings so that novel aspects of the world show themselves and familiar features are manifest in new ways and new guises. They develop and pass on new behaviors and skills (including new patterns of talk), which also require changes in prior patterns of talk, perception, and action to accommodate these novel possibilities. (Rouse, 2015, p. 216)

Practical hermeneutics emphasizes that propositions are not abstract from practice in separate conceptual worlds but are interwoven with actual doing, producing local knowledge in a context or what Rouse calls "microworlds." Local scientific knowledge may lack a unified overarching theory, but it exists in the deployment of concrete exemplars. The expansion of technical control in science does not depend on the development of theoretical explanations of that control, and skills and practices in local, material, and social contexts are important to all explanation.

For Rouse, practical hermeneutics reveals more about the processes by which scientific knowledge is produced and contributes to a more complete understanding of science than theoretical hermeneutics. Work in the history and anthropology of science has shown that theoretical hermeneutics alone inadequately appreciates the extent to which scientific theories are dependent on the practical activities of science.

In a similar manner, Latour and other sociological examinations of laboratory life call attention to the many material and social factors behind and intertwined with scientific propositions. If one assumes that the laboratory, the equipment, and the network of social relations in which research is embedded are all external elements of scientific knowledge production, one will likely misapprehend the richness and complexity of science, a blindness that will extend to the emergence of an alleged fourth paradigm of science.

THEORETICAL VS PRACTICAL HERMENEUTICS IN FOURTH PARADIGM SCIENCE

Despite significant changes in the methods of scientific research introduced by AI, the hermeneutics of theory will continue to view science as a knowledge system characterized by the relationship between theory, concept, model, and background knowledge, a system that is advanced by new methods and instrumentations. New machines are constructed, and new skills are learned to produce evidence that supports hypotheses. Eventually, this process leads to the construction of new theories (Cornelio et al., 2023). Theory-centric advocates will argue that “hypothesis testing” remains the fundamental method of scientific research under the fourth paradigm. Functionally, machine learning is no different than Galileo’s telescope or Leeuwenhoek’s microscope; it simply adds another tool to fuel concept formation and theory construction.

However, this view obscures the conditions of AI-generated scientific knowledge and fails to appreciate the extent to which the fourth paradigm cannot be judged by the same criteria as the previous modes. In an extended examination of what she calls “data-centric” biology, Sabina Leonelli (2016) questions the adequacy of this view, confirming the need for practical hermeneutics in this area. Data is not fixed in the logical frame of propositions; data changes with material, social, technological, and institutional attributes. According to Leonelli, scientific knowledge is produced in and through these changes. On the one hand, data-driven knowledge is material and technological. The classification of data is the production of knowledge, and databases integrate standardized data, infrastructure, and processes in practice. Furthermore, data is not simply given but must be selected, tagged, and disseminated. It can also be obstructed or lost. On the other hand, data-driven knowledge is social and institutional. Social institutions are built up and surround material databases. Data “from where?”, “for whose use?”, and “to what benefit?”, are social questions that correspond with epistemic norms. Scientific data is produced in settings of scientific power. These constitutive elements contribute to Leonelli’s insistence that we understand AI-enabled knowledge as produced by and embedded in material practices.

Mathematician Weinan E 鄂维南 (2022) proposes that AI-enabled science will go through three phases: a scientist-led conceptualization period, a large-scale infrastructure construction period marked by collaboration between scientists and engineers, and an engineer-led application period. In the course of this development, there will be significant changes in the flow of experimentation and a gradual transformation of "scientific problems" into "computational and engineering problems." Theoretical superiority will be gradually discarded. Regardless, the scientific community envisions the long-term vision as advancing theory and eventually discovering scientific principles. This mismatch shows the scientific community's ambivalence toward a practical hermeneutics of the AI-fueled fourth paradigm for science.

FIVE PRACTICAL HERMNEUTIC ISSUES WITH AI FOR SCIENCE

Artificial intelligence is transforming scientific practices in terms of scientists' skills and the material conditions within which they work. New skills and material conditions influence the development of policies and standards in turn. For general purposes, the practice of data-intensive, fourth paradigm science can be interpreted broadly in terms of five overlapping themes: (1) the development of novel forms of scientific writing and publication, (2) new infrastructures, (3) automated research processes, (4) human-machine hybrid actors, and (5) new policy norms and ethics.

First, the classic process of reporting and disseminating research results – writing a paper, submitting it to a journal, where it undergoes peer review, leading to rejection or author revision before hard copy journal publication circulated by post – has been disappearing for some time. Scientific papers are increasingly multi-authored, with an increasing number of co-authors. With the increasing number of publications and their increasing specialization, peer review has become less rigorous and is often bypassed with digital pre-prints. Digital publication speeds dissemination while internet search engines intensify the information overload rather than manage it. Conference presentations and now Zoom conferencing, webinars, press releases, and podcasts contribute to the dissemination flood. AI promises only to continue such procedural trends.

Other changes are at work in the content of scientific reports. Traditional publication shared propositional results that were, in principle, justifiable or falsifiable, either by empirical or analytic repetition. Claims to empirical justification took the form of empirical data sets created by the researcher and included in or referenced by a paper. This type of publication is now being supplemented by referencing increasingly large and often independently produced data sets that have been mined by researchers using AIs that sometimes even create their own algorithms. Scientific data can even be published directly as a form of knowledge. Scientific conferences and journals increasingly request the submission of relevant datasets, including databases created by others, institutions, or instrumentation independent of human curation. Scientific data dissemination is becoming an independent form of publication.

The direct dissemination of scientific datasets that may or may not have been humanly curated and the use of that data by someone who did not produce it introduce an additional trust gap into a scientific publication. Referencing independently produced and available datasets is quite different from referencing previous scientific literature or one's own research data. In Latour's (1987) analysis, a scientific text is supported by citations from previous literature, and the more it is cited by later literature, the more reliable it becomes. Constrained by the space requirements of scientific publishing and traditional norms of reporting, data (including graphs, tables, and photographs) – as evidence in support of propositional conclusions – remains at a distance.

Citing others' datasets implies that the AI trains models using others' data. According to Latour's analysis, citation is crucial to scientific arguments, meaning that what is included in a paper needs to support one's point of view as much as possible. But citing other people's data increases the risk that trust in the dataset is far from established, and, for this reason, scientists prefer to use their own data. The publication of datasets breaks this trust even more because it is difficult to have established criteria for evaluating the merits of a dataset, as is the case with papers, and it is even more unknown what knowledge can be found in other people's datasets. These changes call for a new way to create trust based on submission to uniform regulations on the sources, methods, and formats of data.

Additionally, artificial intelligence can now generate its own scientific text. Large Language Model generative AI can already generate text that imitates human writing, but scientific propositions generated in this way are not supported by evidence. This aporia has led several universities and journals to explicitly request that the GPT series not be used for scientific writing. The analysis given by Latour on scientific texts clearly shows that behind the debate on scientific texts is a contest between scientific workers, in Latour's theory, authors and dissenters. Both are identified as individual scientists; that is to say, human beings are the subjects of scientific practice. The addition of artificial intelligence complicates the social relations behind scientific texts. When asked about AI's role in paper writing, the scientists interviewed said that AI can be a writing partner but not a surrogate. In other words, AI becomes a stand-in for a writing partner, like someone who can make suggestions and bring new ideas but who doesn't actually write the final story (Hutson, 2022). Technical work on scientific texts includes considering external opinions, and AI may be a quick and low-risk way to get such opinions. Artificial intelligence can provide a quick new perspective on the writing process and may help authors overcome the immediate compositional obstacles they face. Some also say that AI-assisted writing is like car-assisted driving. While AI will not automatically write the paper, it will greatly reduce the cognitive burden on the writer. Other scientists believe that by writing with AI, the creation of text becomes a collaboration, with the human guiding the AI and the program following directions to write the actual text. The scientist's role is no longer to type but to organize, plan, check, and evaluate.

Second, materiality shapes the way knowledge is produced. From the perspective of theoretical hermeneutics, material factors are external to knowledge production. They do not shake the fundamentals of knowledge generation. However, scientific research is significantly changed by the availability of AI to augment existing practice, especially with infrastructures.

New hardware and new software are the basic norms of new knowledge. A typical example is the field of materials science and engineering, where a 2016 study used machine learning to design new material structures using data previously “failed” (also known as “dark reaction data”) (Raccuglia et al., 2016). The materials science community is beginning to actively advocate for a data-driven approach to research, believing that this will change the way materials are discovered and that synergy and intersection around data is the way forward for the field (Pollice et al., 2021). The focus of materials science efforts is beginning to shift toward developing databases that enable scientists to search, mine, and query them, which means that infrastructure becomes a platform for materials discovery. The services that current infrastructures provide to materials discovery platforms are maturing and expanding. The infrastructure for materials data construction indexes over a hundred data sources and runs automated data queries and metadata extraction channels to facilitate automated analysis (Himanen et al., 2019).

In addition to materials science, distributed computing infrastructure in high-energy physics (Klimentov, 2020), diverse databases in biology (Arkin et al., 2018), and raw data capture to complex Earth system applications (Yue et al., 2016) all benefit from this new mode. New infrastructures mean that new space is built, new skills are learned, new process are formed, new social relationships are built, and new knowledge is generated. Generally, equipment is limited in a laboratory; AI-enabled science infrastructures expand the power of the instruments to much broader boundaries. In another sense, it changes the laboratory as well. Next, we will see the differences in auto-lab.

Third, changes in experimental processes imply changes in knowledge. A traditional pillar of practical hermeneutics was the laboratory. Scientists used laboratories to create specific environments to study particular phenomena and produce scientific knowledge. Today, automated laboratories are becoming possible. Materials science, chemistry, and nanoscience are pioneering the application of automated smart labs. Self-driving laboratories are being designed (also true in engineering design). Artificial intelligence learns relevant scientific concepts and learns how to design experiments. Intelligent experimental equipment can integrate experimental and simulation data, handle large, heterogeneous data sets, and provide precise control throughout the experiment. New Automated Intelligence Lab synthesizes different fields and consists of two main components: robotics (hardware that automatically pre-processes, conducts experiments, and measures results) and artificial intelligence (data-driven modeling and analysis of processed data). Automated intelligence labs can autonomously select the experiments to be performed based on the predefined goals of human researchers. The all-round AI-Chemist developed at the University of Science and Technology of China combines automation of mechanical operations with machine learning and computer simulation, which has the ability to perform high-level chemical research.

But Leonelli criticizes the automated lab as not belonging to practical hermeneutics. She thinks that laboratories should be places where tacit knowledge grows, which means that researchers have to physically engage with the materials, processes, and agents in order to gain knowledge of know-how. If labs were automated, then there would be tacit knowledge gained through physical engagement. From a practical hermeneutics point of view, automation could mean that people are no longer involved. This concern is not unreasonable. However, automated laboratories are still practical in a broader sense.

In fact, the design of experiments by artificial intelligence, the manipulation of experiments by robots, and the control of experimental data all grow on top of the practice of human researchers. The expressed design of the experiment is an important part of the experimental process because it enables collaborators and other scientists to monitor progress throughout. Experimental manipulation and tracking refer to the ways the process is monitored from the beginning. Tracking can easily incorporate artificial intelligence because the process involves classifying, coding, filing, recording identity, locating, and processing. Lastly, AI can control the data to control the phenomena in automated laboratories and intelligent experimental processes. Therefore, the benefits of AI involvement are apparent: automated platforms free scientific workers from repetitive tasks and reinforce isolation, intervention, and control simultaneously. Basically, the Automation Lab does not oppose the hermeneutics of practice but rather supports it. Nevertheless, the recent involvement of large language models (LLMs) in autonomous laboratories has raised concerns about the potential risks to science (Tang et al., 2024). If LLMs are seen as new agents in scientific practice, the nature of practice and related issues such as norms of knowledge, norms of action, scientific community, science and society should be reconsidered.

Fourth, the heterogeneous composition of practitioner networks creates human-machine hybrid actors. Rouse argues that, from the perspective of practical hermeneutics, knowledge is constituted not as a web of beliefs but as a web of practitioners. Practice is not only the actions performed by actors but also the complex interrelationships in which actors are understood. Rouse thinks actors belong to a practice in a strong sense; this means that to understand agents (and their motivations) requires an account of the practice in which they are involved. Furthermore, rooting actors in practice enables practical hermeneutics to distinguish between actors and non-actors. Actors and non-actors, from this perspective, are established in practice and in constant interaction with the world. The involvement of AI in the practice of science is different from the involvement of people or objects, so there needs to be more thought devoted to the nature of their agency. Some scientists are already confused about the place of AI in their research teams and wonder if it should be seen as an agent in automated laboratories and scientific publication and communication, reflecting the heterogeneous composition of actors in scientific practice, i.e., mixed human-computer actors.

Latour emphasizes the importance of relationships in practice where the object is the actor as a participant, a tack that can begin to explain AI's role in scientific knowledge production. Artificial intelligence cannot, for the moment, be an actor in the same reciprocal scientific practice as humans, nor can it manipulate and control humans in order to gain scientific knowledge. However, what Latour points out is that the object or technology plays a mediating or intermediary role in the practical activity. Similar arguments can be found in postphenomenological mediation theory (Rosenberger and Verbeek, 2015). Inevitably, scientists must deal with the infrastructure that generates the data, the algorithmic platforms that process it, the laboratories that run it automatically, the big models that generate the paper, and construct multiple and complex social relationships.

Finally, the fifth theme involves the discussion of AI as agent in ethical and legal spheres. One touchpoint in this conversation is that AI's ability to mimic some human functions indicates that it has a different role and status from other technological objects. But the issue extends beyond imitation to interdependence. In scientific practice, AI is not only able to imitate functions, but, more importantly, to realize data processing and other "cognitive" tasks beyond human comprehension. In other words, AI can replace some of the functions of scientists, such as designing experiments or reading literature. Still, scientists cannot replace some of the functions of AI, such as the processing of petabytes of data. For instance, AlphaFold2's prediction of the three-dimensional structure of proteins is based on 350,000 known protein structures and more than 200 million unknown protein structures. Thus, we could go so far as to say that human scientists and AI are linked as hybrid (heterogeneous) actors (or relational complexes, as Rouse calls them), working together on new scientific practices.

Here, there emerge new ethical issues and challenges because scientific practices are always interconnected and fundamentally influence the development of social practices. Rouse argues that norms are naturally formed in practice and that norms are reinforced while practices become comprehensible; this is also true within Latour's network of actors. The involvement of artificial intelligence in other scientific research has also generated intellectual and ethical normative issues in the field of practice, the boundaries between which are not entirely clear. For our purposes, we will focus on the ethical dimension of normativity.

Scientific data, like other data, face common privacy and security issues that concern questions of autonomy and responsibility. The paradigmatic examples of these are geospatial data and health data. The ethical checks given by the UK Statistics Authority (2021) for geospatial data include 16 aspects, including do no harm, transparency, confidentiality, and avoidance of bias; it also lists a series of ethical considerations for research and statistics: general ethical principles, potential for bias, interpretability, accountability, and confidentiality. These ethical considerations apply especially to specific geospatial data such as retrospective unique remote sensing data. In contrast, the ethical issues raised by data in the health domain have received more attention, focusing on privacy, confidentiality, informed consent, equity, justice, trust, and data ownership (Viberg et al., 2022), and suggesting various approaches and governance tools (Maseme, 2022).

The ethics of scientific data has generally been discussed within the debate about "open data," and there are additional concerns that AI-driven science brings to the fore. Open data requires breaking down geographical, disciplinary, and institutional barriers, and scientific data and AI-driven scientific research tend to be shared across time, space, disciplines, and organizations. Currently, open scientific data is guided by the FAIR principles that dictate data should be "Findable, Accessible, Interoperable, and Reusable" (Wilkinson et al., 2016). Beyond this, there is consensus that countries have an important responsibility to use policies to facilitate the flow of information at all levels and develop widespread data access. In particular, the European Union and the United States have achieved a certain degree of open access to data and have developed a set of public policies and principles.

Unfortunately, FAIR principles cannot solve the unequal problem in scientific data practice, and the risks of data openness between countries cannot be ignored. Indigenous data is a typical example. CARE principles – “Collective Benefit, Authority to Control, Responsibility, and Ethics” (Carroll et al., 2020) – were developed in the whole data life cycle to protect disadvantaged groups, and they focus on dividing power and maximizing the benefits of data-driven science. CARE principles indicate how deeply knowledge generation is imbricated in the social and ethical values of science practice.

Scientific data also faces the conflict between science and business. When it comes to trading personal data between data analyzing entities, the value of data as a commercial commodity – including the speed and efficiency with which assessing or accessing certain data can help develop new products – often takes precedence over science. This can lead to considerations at the scientific level, decisions that raise questions, consequences of the assumptions made, and processes used in an investigation that are not readily appreciated. This focus on business can easily translate into a materialization of discrimination, inequality, and potential errors in the data considered (Srnicek, 2017).

CONCLUSION

Fourth paradigm science involving AI has been promoted as another method for knowledge production, continuing the historical development from observational description of empirical phenomena, to mathematical theory modeling, to computational simulation. AI-propelled science has been celebrated for its potential to both enhance the speed of knowledge production and extend its reach. But in the AI for science vision, machine learning, deep learning, statistical methods, data analytics, automated control, and related areas are imagined primarily if not exclusively in terms of the advancement of scientific research. By contrast, Joseph Rouse and others would argue that science is never adequately understood in terms of theoretical hermeneutics alone: science is also material practices that interface with society. This lacuna calls for a hermeneutics of practice to complement that of theory. Consideration of practical hermeneutics points toward the need for a political philosophy of fourth paradigm science that engages the challenges posed by new forms of scientific writing and publication, new infrastructures, the creation of new scientific infrastructures, new human-machine hybrid actors, and the need for new policy norms and ethics.

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Research article

Hermeneutic Analysis of Ancient Chinese Conceptions of Technology

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Abstract

The etymological and historical investigation shows that 'Jì Shù' [Technology] in ancient China appeared in two Chinese characters: 'Jì' and 'Shù', which have different meaning, but have something in common. Both of them refer to art and skills, while 'Jì' sometimes refers to the craftsman, the bearer of the skill, and 'Shù' generally refers to the method, tactics, way, procedure and path to skillfully reach a certain state. Alongside this, we need to distinguish two forms of technological knowledge. One is cognitive in nature, the dominant 'Shù,' the knowledge that comes from experience; the other is 'Qì' as the object itself in its material articulation and function. This paper will show that 'Dào' has a very close relationship both with 'Jì' [Skills] and 'Qì' [Utensils]. 'Dào' is the root of all things and also the root of 'Jì.' 'Jì' bears 'Dào,' meaning that 'Jì' itself conforms to the way of nature. The evolution of the relationship between 'Dào' and 'Qì' will also be considered. Initially, ancient Chinese scholars in the Zhou, Qin, Han, and Early Tang Dynasties stated that 'Dào' stands for 'Tǐ' [Noumenon/Thing-in-itself], and 'Qì' for 'Yòng' [Utility]. The relationship between 'Dào' and 'Qì' would then be entirely reversed by the notion according to which 'Dào' stands for 'Yòng' [Utility], and 'Qì' stands for 'Tǐ.' The last stage of evolution, as we will argue, is that, taking 'Xiàng' [Image] as the medium, 'Dào'[Thing-in-itself] and 'Qì'[Utensils] would become fused together.

Keywords: The Forms of Ancient Chinese Technology; 'Qì'; 'Dào'; 'Xiàng'; Technology

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Научная статья

Герменевтический анализ древнекитайских концепций технологии

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Аннотация
Этимологическое и историческое исследование показывает, что "Цзи Шу" [Технология] в Древнем Китае выражалось двумя китайскими иероглифами: "Цзи" и "Шу", имеющими разное значение, но имеющими нечто общее. Оба они относятся к искусству и навыкам, тогда как "Цзи" иногда относится к мастеру, обладающему навыками, а "Шу" обычно относится к методу, тактике, способу, процедуре и пути. Существуют две формы знания древней китайской технологии: доминантная "Шу" и рецессивная, а "Ци" – это ее материальная форма со своей определенной структурой и функцией. "Дао" имеет очень тесную связь с "Цзи" [Мастерством] и "Ци" [Утварью]. "Дао" – это корень всех вещей, а также корень "Цзи". "Цзи" несет в себе "Дао". "Цзи" соответствует пути природы. Отношения между "Дао" и "Ци" на уровне теории претерпели два этапа эволюции. Древние китайские учёные времен Чжоу, Цинь, Хань и ранней династии Тан утверждали, что "Дао" означает "Ти" [Ноумен/Вещь в себе], а "Ци" – "Юн" [Полезность]. Отношения между "Дао" и "Ци" тогда были бы полностью противоположны представлению, согласно которому "Дао" означает "Юн" [Полезность], а "Ци" означает "Ти". На уровне практики, если принять "Сян" [Образ] в качестве медиума, "Дао" [Вещь в себе] и "Ци" [Утварь] сольются воедино.

Ключевые слова: Формы древней китайской технологии; "Ци"; "Дао"; "Сян"; Технология

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INTRODUCTION

Monosyllabic words were the main body of ancient Chinese vocabulary, which developed into disyllabic words. In Classical Chinese, a character often corresponded a word, and there were many meanings for one word. In Classical Chinese, the words expressing 'Technology' mainly included 'Jì,' 'Shù,' 'Qì,' 'Qiǎo,' 'Yì,' 'Jì Shù,' 'Jì Qiǎo,' 'Jì Yì,' 'Qì Jù,' and so on. Of these, we are going to talk about their defining features and differences throughout the paper. However, there is also another conceptual dimension that we cannot overlook. one that is invoked by the character 'Dào.' 'Dào' was not only an important category of ancient Chinese philosophy, but also the core category of shaping Chinese traditional thought and culture. A series of categories and concepts are associated with 'Dào,' for example, 'Tǐ', 'Yòng,' and 'Xiàng', which were often used by ancient Chinese scholars to expound their speculations about technology. The purpose of this paper is then to propose an interpretation of ancient Chinese technological thinking through the lenses of etymology, philosophy, and cultural studies.

THE CONNOTATIONS OF ANCIENT CHINESE TECHNOLOGY

The English word 'technology' was translated as 'Jì Shù' in Chinese. But 'Jì Shù' did not appear as a distinct concept during the Pre-Qin period of China (the period from the 21st century B.C. to 221 B.C.). They appeared and were used separately as individual Chinese characters: 'Jì' and 'Shù.' These two ancient Chinese characters had their own meanings.

First of all, there are two meanings of the term 'Jì.'

(1) One meaning refers to the art, skill, or deftness possessed by the subject in general. For example, in the *Shuó Wén Jiě Zì* [The Analytical Dictionary of Chinese Characters] we find the definition:

> 'Jì, Qiǎo Yě'
> ['Jì' is skill] (Xu, 1985, p. 406)

In the *Shàng Shū·Qín Shì* [The Book of History: The speech at Qin] it is clear that 'Jì' is something that can be predicated as an attribute of a subject, without implying a specific content:

> 'Rěn Zhī Yǒu Jì, Ruò Jǐ Zhǐ Yǒu'
> [Others have skills, just like I have one, too] (Zhang, 2009, p. 329)

(2) the other meaning refers directly to the person who is in possession of a given skill, the craftsman. It is clearly illustrated by this excerpt from the *Xún Zī·Fù Guó* [Xunzi ·Rich Country]:

> 'Gù Bái Jì Suó Chéng, Suó Yí Yǎng Yī Rén Yě'
> [Therefore, the products produced by craftsmen are used to support one person (the King)] (Zhang, 2012, p. 117)

Secondly, also in the use of the other key term, 'Shù,' we find two distinct meanings.

(1) One generally refers to the method, tactics, way, procedure, and path that the subject must employ to achieve mastery of an area that is related to the mind and heart. We can see this use in an affirmation taken from the *Zhàn Guó Cè·Wèi Cè* [Strategies of the Warring States:·The Strategies of Wei]:

‘Chén Yǒu Bǎi Zhàn Zhī Shù’
[I have methods/tactics to be always victorious]

(2) The other refers directly to art, skill, or technique. For example, we find the following in the *Lǐ Jì ·Xiǎng Yǐng Jiǔ Yì* [The Book of Rites: The Significance of the Drinking Festivity in the Districts]:

‘Gú Zhī Xué Shù Dào Zhē, Jìáng Yí Dē Shēn Yě’
[In ancient times, people gained the skill or technique from practice]

To sum up, ‘Jì’ and ‘Shù,’ while having two distinct uses in ancient Chinese, retained a very similar meaning in at least one on of their employments. These two characters were combined into ‘Jì Shù.’ Its meaning didn’t encompass ancient technique or technology until Han Dynasty (202 BC–220 AD). For example, in Sima Qian’s *Shǐ Jì ·Huò Zhí Liè Zhuàn* [Records of the Grand Historian Biographies of commodity traders] - a text that was written from 104 to 90 BC - one can read:

‘Yī Fāng Zhū Shǐ Jì Shù Zhī Rén, Jiāo Shén Jí Néng, Wéi Zhòng Xǔ Yě’
[Doctors, alchemist, and all kinds of people who make a living by their craft or skills work hard and do their best to get more money]

THE FORMS OF ANCIENT CHINESE TECHNOLOGY

There were two basic forms of ancient Chinese technology: the knowledge form and the physical form.

1. The knowledge form of technology in ancient China: ‘Shù’ refers to this form in an explicit and implicit manner.

The technological inventions and manufacturing techniques as well as operation skills and techniques in ancient China were usually recorded and handed down in the form of language under the name of ‘Shù.’ For example, Zào Zhǐ Shù [paper-making technology], Yìn Shuā Shù [art of printing], Qí Mín Yào Shù [important methods to condition the people's living]. This kind of technology, which could be written down or expressed in language, was also understood as explicit empirical knowledge (Wang, 2021). This explicit ‘Shù’ generally needed to be based on the mind and understanding of the subject, on repeated operation and diligent practice, in order to be transformed into the ‘Shù’ of the subject's operational skills.

The ‘Shù’ that was understood and mastered in the process of operation was regarded as implicit empirical knowledge.

2. The physical form of technology in ancient China: ‘Qì’ refers to this form.

Zhōu Yì·Xì Cī [*The Book of Changes, Hsi Tzu*] said: 'Xíng ér Shàng zhě Wèi zhī Dào, Xíng ér Xià zhě Wèi zhī Qì' [The metaphysical is 'Dào' and the physical is 'Qì'] (Chen & Zhao, 2020, p. 639). The metaphysical 'Dào' refers to the abstract nature and law inside things, it was thought to be formless and immaterial. In contrast the physical 'Qì' was material and had exact shapes and forms that people could perceive. In other words, it was a kind of tangible substance or physical object that was perceptible by the senses, especially the sense of touch. In the *Shuó Wén Jiě Zì* [The Analytical Dictionary of Chinese Characters] we find the definition:

> 'Qì, Mǐn Yě,' 'Mǐn, Fàn Shí zhī Yòng Qì Yě'.
> [Qì is Mǐn, and Mǐn generally refers to the vessels or utensils for food, such as bowls, dishes, cups and plates] (Xu, 1985, p. 65, 157)

From the perspective of the pattern and structure of Chinese characters, 'Qì'[器] contains four 'Kǒu'[口/mouth], which means it is not a single device, but a structural system composed of multiple components or parts in a specific form. The same or similar functional attributes of the 'utensils' form the same series of 'utensils' or 'tools' with different series serving different functions in different scenes, such as furniture, kitchenware, tools, wine, lacquer, ritual, machinery, weapons, musical instruments and so on.

THE RELATIONSHIP BETWEEN 'Dào,' 'Jì,' AND 'Qì'

1. 'Dào' as the foundation of all things, and also the foundation of the 'Jì'

At the macro-level 'Dào' was regarded as the origin of the world that existed before and beyond heaven and earth. It was the ontology of all things and the 'highest category' of ancient Chinese philosophy (Zhang & Cheng, 1990). Ancient Chinese thought generally regarded 'Tián' [Heaven] as the origin of all things, but Lao Tsu broke with this idea. He clarified this in the *Dào Dē Jīn* ['Dào' Te Ching]: 'Dào' was prior to the existence of heaven and earth, he said, namely 'Yǒu Wù Hún Chéng, Xián Tián Dì Shēng' [There is something undefined and complete, coming into existence before Heaven and Earth] (Chen, 2016, p. 169). Furthermore, in Lao Tzu's opinion, 'Dào' produced all things, it is the origin of all things. For example, he said: 'Dào Shēng Yī, Yī Shēng èr, èr Shēng Sān, Sān Shēng Wàn Wù' [The 'Dào' produced One, One produced Two, Two produced Three, Three produced all things] (Chen, 2016, p. 233).

At the micro-level, there were multiple meanings of 'Dào.'

(1) The word was used in an existential sense. For example, Lao Tzu said: 'Dào Kě Dào, Fēi Cháng Dào' [The 'Dào' that can be described is not the enduring and unchanging 'Dào'] (Chen, 2016, p. 73).

(2) It referred to the inherent nature of all things and the laws of movement and change in nature: 'The law of the Dào is its being or what it is.' For example, *'Dào' Te Ching* said: 'Zhí Gú Zhī Dào,Yí Yù Jīn Zhī Yǒu. Néng Zhī Gǔ Shǐ, Shì Wèi Dào Jì' [When we can lay hold of the 'Dào' of old to direct the things of the present day, and are able to know it as it was of old in the beginning, this is called (unwinding) the clue of 'Dào'] (Chen, 2016, p. 126). Furthermore, in Lao Tzu's opinion, 'Tián' [Heaven] was

nature. As he attached great importance to the 'Dào' of nature, he said: 'Tián Nǎi Dào, Dào Nǎi Jiǔ' [In that likeness to heaven he possesses the 'Dào.' Possessed of the 'Dào,' he endures long].

(3) It also referred to the codes and rules of conduct. *'Dào' Te Ching* said: 'Tián Zhī Dào, Lì ér Bù Hài, Shèng Rén Zhī Dào, Wéi ér Bù Zhēng' [The law of nature is good for things, but harmless to things. The law of the sages is alms, not contention] (Chen, 2016, p. 349).

Besides, Lao Tzu did not separate humans from nature, and did not neglect human subjectivity. He said in *'Dào' Te Ching* that: 'Gù Dào Dà, Tián Dà, Dì Dà, Rén Yì Dà. Yù Zhōng Yǒu Sì Dà, ér Rén Jū Qī Yī Yān' [Therefore, 'Dào' is great, Heaven is great, Earth is great, and the human is also great. In the universe, there are four great things, and the king/human is one of them]. At the same time, in Lao Tzu's opinion, 'Dào' was not far-fetched. In technological activities, artisans followed 'Dào', and 'Dào' was presented in the experiential world in the form of objects through technological activities, artisans could get in touch with it in the process of making artifacts with superb skills. For example, there was a dialog in the book of *Chuang Tzu* [Nourishing the Lord of Life] as following:

The ruler Wan-hui said: 'your art should have become so perfect!'

The cook replied to the remark, 'what your servant loves is the method of the 'Dào,' something in advance of any art' (Cao, 2000, p. 42-43).

2. 'Jì' serving to convey 'Dào,' 'Jì' conforming to natural law

'Jì' was for conveying 'Dào,' in other words, the invention of technology and the manufacture of utensils should follow and conform to naturalness. Craft, technique, utensils bore naturalness, and the latter lay in the former. *Kǎo Gōng Jì* [The Artificers Record] said: 'Tián Yǒu Shī, Dì Yǒu Qì, Cái Yǒu Měi, Gōng Yǒu Qiáo, Hé Cǐ Sì Zhě, Rán Hòu Kē Yí Wéi Liáng' [The weather is limited by the season, the land is limited by the climate, artisans are skillful and clumsy, materials are good and bad, it is best to combine these four factors] (Wen, 2008, p. 4). Generally speaking, technical invention and manufacture of apparatus were thought to be affected by climate, geography, materials, and skills, it is best to conform to the timeliness and adapt to the climate, as well as the beauty of materials and the artistic attainments of the crafts.

3. Controlling the 'Jì' with 'Dào,' 'Qì' convey 'Dào,' governance of technology

Instruments made to meet a specific need carry not only the laws of nature and technology, but also the laws of society and morality. Making tools should follow the 'Dào' of nature and technology, using tools should conform to the 'Dào' of society, 'Jì' [skills] and 'Qì' [Utensils] should be restricted by the 'Dào' of different fields. 'Jīng Shì Zhì Yòng' [Practical Knowledge of Managing State Affairs] was the basic stand and attitude of ancient Chinese thinkers on 'Jì' and 'Qì.' For example, *Zhōu Yì·Xì Cī* [The Book of Changes, Hsi Tzu] said: 'Bèi Wù Zhì Yòng, Lì Chéng Qì Yī Wéi Tiān Xià Lì, Mò Dà Hū Shèng Rén' [To produce goods for consumption, to set up works in which artisans can make utensils, and to profit the people in the world, noone has done these things more than a saint] (Chen & Zhao, 2020, p. 627). Confucianism did not completely deny technology and suppress the development of technology, it affirmed the utility of the technology itself and emphasized the social significance of technology. In terms of technological development, it paid attention to ‘liù Fǔ Sān Shì’ that could be applied to the world. ‘Liù Fǔ’ [the six elements] included ‘Shuǐ, Huǒ Jīn Mù Tǔ Gǔ’ [Water, Fire, Metal, Wood, Soil, Grain] (Yang, 1990, p. 564). These correspond to six basic technical activities in the production and life of ancient Chinese society: canals, grass-burning, smelting, farming, grain cultivation. ‘Sān Shì’ [Three affairs] included integrity, utility, and well-being (Yang, 1990, p. 564), which meant that the development of technology should follow social moral norms and benefit the country and the people (Fang, 2016). Confucians attached great importance to the social ethics of technology. They opposed the king to play through life and have no serious ambition, and they opposed the people who indulged in pleasure and did not do business. They opposed and denigrated bizarre techniques and strange artifacts outside ‘liù Fǔ Sān Shì’ [Six elements and Three affairs] (Yang, 1990, p. 564)

Lao Tzu had a sense of anxiety, weariness and caution towards the ‘Qì,’ fearing that a large number of instruments would disturb the social order and cause moral anomie. Chuang Tzu affirmed the superb skills of artisans and the function of their skills, such as cooking meat, but he also worries about alienation by way of technology. In Chuang Tzu’s opinion, where there were ingenious contrivances, there were sure to be subtle doings, and that, where there was a scheming mind in the breast, its pure simplicity was impaired. When this pure simplicity was impaired, the spirit became unsettled, and the unsettled spirit was no longer the proper residence of the ‘Dào’ (Cao, 2000, p. 172).

Mohism believed that everything had a standard, and artisan technology also had its own internal laws and norms. For example, Mo Tzu said: ‘to accomplish anything whatsoever one must have standards’ (Li, 2007, p. 22). No one has yet accomplished anything without them. The honorable people fulfilling their duties as generals and councillors have their standards. Even the artisans performing their tasks have their standards. Mo Tzu also elaborated on the standard of artisans, he said that the artisans make square objects according to the square, circular objects according to the compass; they draw straight lines with the carpenters' line and find the perpendicular by a pendulum. All artisans, whether skilled or unskilled, employ these standards. Only the skilled workers are accurate. Though the unskilled laborers have not attained accuracy, they do better by following these standards than otherwise. Thus all artisans follow the standards in their work.

At the same time, Mohism, like Confucianism, examined technological activities from the level of social ethics, regulated the social attributes of technology with ‘Yì’ [righteousness], and stressed that technology should benefit people. In Mo Tzu’s opinion, nothing was more valuable than righteousness.

4. The development and evolution of the relationship between ‘Dào’ and ‘Qì’: from ‘Dào Tǐ Qì Yòng’ to ‘Dào Yòng Qì Tǐ’

There are two main stages that mark a profound shift in the relation of ‘Dào’ and ‘Qì.’

(1) The incubation and development of the doctrine on 'Dào Tǐ Qì Yòng' ['Dào' was for 'Tǐ' and 'Qì' was for 'Yòng'] can be traced to *Zhōu Yì·Xì Cī* [The Book of Changes, Hsi Tzu] which states that the metaphysical was called 'Dào' and the physical was called 'Qì.' 'Dào' and 'Qì' officially appeared in the form of a pair of concepts. 'Dào' was the noumenon of metaphysics, It was the intrinsic nature, essential attribute as well as law and rule, etc. It was abstract and intangible, It was understood as 'Tǐ'[Noumenon] in Chinese, That was 'Dào Tǐ'. 'Qì' was a physical artifact with physical structure, external shape and functional utility. Ancient Chinese paid attention to the 'Yòng' [Utility] of 'Qì' [Utensil] that was 'Qì Yòng'. The annotators of Zhouyi in the different dynasties had little doubt about the understanding of 'Qì.' 'Qì' in the *Annotations of the Zhouyi* in the Han and Tang Dynasties was connected with 'Xíng' [Shape or Form] and 'Zhì' [Essence/Quality], that was, 'Qì' had shape and quality, so it was useful.

(2) The transformation of the relationship between 'Dào' and 'Qì' included the proposal of the doctrine on 'Qì Tǐ Dào Yòng,' and the development of its connotations. Cui Jing's *Zhōu Yì Tàn Yuán* [The Exploration of Metaphysical Theory in the Zhouyi] is an incomplete book from the Tang Dynasty, part of its contents is preserved in Li Dingzuo's *Zhōu Yì Jí Jiě* [The Collected Annotations of the Zhouyi], and they provide significant information for cultural historians. Cui Jing made comments on 'Xíng ér Shàng Zhē Wèi Zhī Dào, Xíng ér Xià Zhē Qì' [The Metaphysical was Dào and The physical was Qì]. In Cui Jing's opinion, this sentence implied the principle of 'Xíng Qì Biàn Tóng' [the flexibility of shape and utensil] (Wang, 2020). Everything in the world has shape and quality, 'Tǐ' [Noumenon] was presented in the form of shape and quality, it was visible and formable, so 'Tǐ' was 'Qì.' The presentation of 'Tǐ' reflected the 'Yòng' [Utility] 'Yong' helped its 'Tǐ,' which was perceptible but invisible. Therefore, 'Yòng' was metaphysical, and it was 'Dào'. That was 'Qì Tǐ Dào Yòng'. This understanding completely overturned the basic conclusion of 'Dào first and then Qì' and 'Dào Tǐ Qì Yòng' for a long time. 'Dào,' which was anonymous, invisible and ubiquitous, was regarded as the function and role of shape and quality, by Cui Jing. In his opinion, if there was no 'Qì,' there would be no 'Dào,'so 'Qì' came into being before 'Dào,' that was 'Dào Yòng Qì Tǐ' (Wang, 2020). In the book of *Zhou Yi Tan Yuan* he took animals and plants as an example to prove his opinion. He said that animals took their body as 'Tǐ' and 'Qì,' and took their spirits as 'Dào' and 'Yòng'; plants took their branches and stems as 'Tǐ' and 'Qì,' and ecological characteristics as 'Dào' and 'Yòng' (Li, 2016, p. 442-443). Since then, 'Qì Tǐ Dào Yòng' had been inherited and developed in the form of 'Dào Bù Lí Qì' [The invisible 'Dào' is inseparable from the visible 'Qì'] and 'Dào Yīn Qì Xiǎn' ['Qì' bears Dào, 'Dào' is revealed through 'Qì']. For example, Yanwu Gu (1994) said: 'Fēi Qì Zē Dào Wú Suō Yǔ' [Without 'Qì', Dào has no sustenance] (p. 32). And Xuecheng Zhang (1994) said: 'Dào Bù Lí Qì, Yōu Yǐng Bù Lí Xíng'['Dào' is inseparable from 'Qì', just like the shadow is inseparable from the body] (p. 132-133). In other words, the laws of things could not exist apart from objective things. Sitong Tan (1994) said: 'Dào' was 'Yong', 'Qì' was 'Tǐ', so that the functions (attributes) would appear only if the entity (substance) was established before; so if 'Qì' existed, 'Dào' would not disappear (p. 390).

5. The fusion of 'Dào' and 'Qì': Taking 'Xiàng' as the medium

Ancient Chinese scholars divided the world into 'Dào' and 'Qì.' In order to explain the relationship between 'Dào' and 'Qì' and avoid their separation, Ancient Chinese scholars set up 'Xiàng' [Image] to express their intention. That is, although the words say nothing, the 'Xiàng' can. Words fail in conveying meaning, images help out. In other words, ancient Chinese scholars abstracted the images of everything in the objective world into 'Guà Xiàng' [the images of hexagrams which include paintings, pictures and numbers)], and the sixty-four hexagrams of *Zhōuyì* [The Book of Changes] were the symbolic system of 'Guà Xiàng'. The makers who drew inspiration from 'Guà Xiàng' constructed and designed the structure and the model of *'Qì,'* seeking the solution of technical problems, then creating the images of things that do not exist in the real world. With 'Xiàng' as the medium, the makers realized the combination of 'Dào' and 'Qì.' The world had evolved from the duality of 'Dào' – 'Qì' to the triad of 'Dào' – 'Xiàng' – 'Qì.'

CONCLUSIONS

To sum up, the ancient Chinese conceptions of technology are rich in connotation and diverse in form. Ancient Chinese thought and elaboration of the relationship between 'Jì' and 'Dào' and between 'Dào' and 'Qì' formed the unique tradition of technical thought in China. Ancient Chinese technology is not only production process and operation skills, but also an art of creation, and a wisdom that conforms to 'Dào' and thereby demonstrates its meaning and significance, reflecting not only the laws of nature and technology, but also social ethics and a value orientation.

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Research article

Hegel on the Steam-Engine

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Abstract

Hegel did not witness the unveiling of the granite bowl in Berlin's city center, which was crafted and polished using steam engine technology. His comprehension of the steam engine significantly impacted the evolution of scholarly thought in Europe around 1800. While Hegel's works did not explicitly delve into the “steam engine” as a complete concept, his examination of its parts, “steam” and "machine,” was very thorough. In natural philosophy, Hegel meticulously detailed steam as an individual physical element, from the ancient Greek theory of four elements to modern meteorology. While he discussed the relationship between steam, air pressure, and heat, he did not address the perspective of the steam engine in technical applications. Instead, he continuously engaged in reflection at the scientific level of the relation between physical elements and individual objects, arising from the dynamic interaction between concepts and real-world objects within the framework of dialectics. Therefore, Hegel's understanding of the steam engine embodies his concept of “pre-scientific hermeneutics,” involving continuous reflection of concepts and reality through empirical validation. He thus drew on contemporary meteorological research to demonstrate the dialectical relationship between physical elements and individual bodies, as well as the laws of motion that constitute meteorological elements such as air and water. However, in a complex and variable climate, these motions could be transient and incidental. And so, in his exploration of the scientific principles of the “steam engine,” Hegel did not delve into the transformation of these principles into technology or the resulting revolution in social productivity and the accompanying societal ramifications.

Keywords: Steam; Machine; Atmospheric pressure; Heat; Dialectics

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Научная статья

Гегель о паровом двигателе

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Аннотация
Гегель не был свидетелем открытия гранитной чаши в центре Берлина, которая была изготовлена и отполирована с использованием технологии парового двигателя. Однако его понимание парового двигателя существенно повлияло на эволюцию научной мысли в Европе около 1800 года. Хотя в работах Гегеля не рассматривалась явно "паровая машина" как целостная концепция, его исследование ее частей, "пара" и "машины", было очень тщательным. В натурфилософии Гегель подробно описал пар как отдельный физический элемент, от древнегреческой теории четырех элементов до современной метеорологии. Хотя он обсуждал взаимосвязь между паром, давлением воздуха и теплом, он не затрагивал перспективу парового двигателя в технических приложениях. Вместо этого он постоянно углублялся в рефлексию на научном уровне об отношениях между физическими элементами и отдельными объектами, вытекающими из динамичного взаимодействия между концепциями и реальными объектами в рамках диалектики. Поэтому гегелевское понимания парового двигателя воплощает его концепцию "донаучной герменевтики", предполагающую постоянное отражение концепций и реальности посредством эмпирической проверки. Таким образом, он использовал современные метеорологические исследования, чтобы продемонстрировать диалектические отношения между физическими элементами и отдельными телами, а также законы движения, составляющие метеорологические элементы, такие как воздух и вода. Однако в сложном и изменчивом климате эти движения могут быть преходящими и случайными. Итак, в своем исследовании научных принципов "парового двигателя" Гегель не вникал в трансформацию этих принципов в технологию или в возникшую в результате революцию в общественной производительности и сопутствующие социальные последствия.

Ключевые слова: Пар; Механизм; Атмосферное давление; Тепло; Диалектика

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INTRODUCTION

In the Winter Palace of Saint Petersburg, resides a unique piece of artistry. It is an oval bowl crafted from jade, known as the “Tsar of Bowls” (Kolesar, 2006). This jade bowl, made from Revnev jade (Russian: Ревневская яшма / Revnevskaja jaschma), dates back to the period between 1820 and 1843. The creation of this artifact relied entirely on manual labor, including years of painstaking polishing and refining, and its transportation required the effort of 720 barge haulers. This stands in stark contrast to the “Granite Bowl” located near Humboldt University in Berlin, crafted during the same period, which was processed using steam engine technology, symbolizing the technological advancements of the era. The production and transportation processes of both bowls not only reflect the level of technological productivity of the time but also mirror the cultural and technological shifts of the era. It is within this context that the philosophy of Hegel unfolds, his theories intricately linked to the technological innovations of the era, particularly the steam engine.

STEAM ENGINE POLISHED “GRANITE BOWL”

In Berlin's “Lustgarten,” an impressive historical relic prominently stands in front of the Altes Museum: a massive granite bowl, weighing 75 tons and measuring 22 feet (6.9 meters) in diameter. This exemplary piece of early 19th-century Prussian craftsmanship (Einholz, 1997), was meticulously crafted between 1827 and 1828 by numerous artisans, with the assistance of engineering tools such as capstans. The granite boulder, once cut, was transported to Berlin via the Spree River. Over the following years, this bowl underwent precise polishing and finishing, aided by a ten-horsepower steam engine (fig. 1). This process not only showcased the technological advancements of the time but also reflected the unique cultural ethos of the region, leading the people of Berlin to humorously nickname it “Berlin's Largest Soup Bowl” (Suppenschüssel). Even Johann Wolfgang von Goethe, the literary giant of that era, bestowed a special name on this piece – the “Granite Basin” (Granitbecken) (Goethe, 1828), further emphasizing its emblematic status in the social and cultural milieu of the period.

I would suggest three primary reasons for Prussia's keen interest in using artificial stone to create landmarks within urban landscapes in the 19th century. Firstly, following the French Revolution, Classicism emerged as the dominant artistic style in Europe. German architect Karl-Friedrich Schinkel, a representative of German Classicism, utilized Greek temple architectural elements to shape the entire cityscape of Berlin, the capital of the Prussian monarchy. In this context, the granite bowls served as “imperial signifiers” in the urban landscape of that era (Einholz, 1997). Secondly, there is the association between granite and the Biedermeier style. In German, “Biedermeier” conveys the idea of an “upright and simple” citizenry, representing an artistic style that emerged from a self-aware citizenry. The aesthetic orientation of this style, as seen in its portrayal of family themes, clear design, and choice of building materials, also mirrored the optimism of the middle class in the industrial era toward technological progress.

Lastly, the victory of the feudal nobility over Napoleon led to a cautious critical attitude among the intellectual class, prompting German philosophers to turn inward and embrace Romanticism. This position valued the inner world, emotions, passion, and mysticism, endeavoring to construct philosophical systems within the realm of personal life. Against the backdrop of the Carlsbad Decrees and the political conditions in Prussia at the time, Hegel's legal philosophy, though somewhat conservative in form, had already been integrated as the objective spirit in his *Encyclopedia* (1817, in manuscript form, Hegel, 1974).

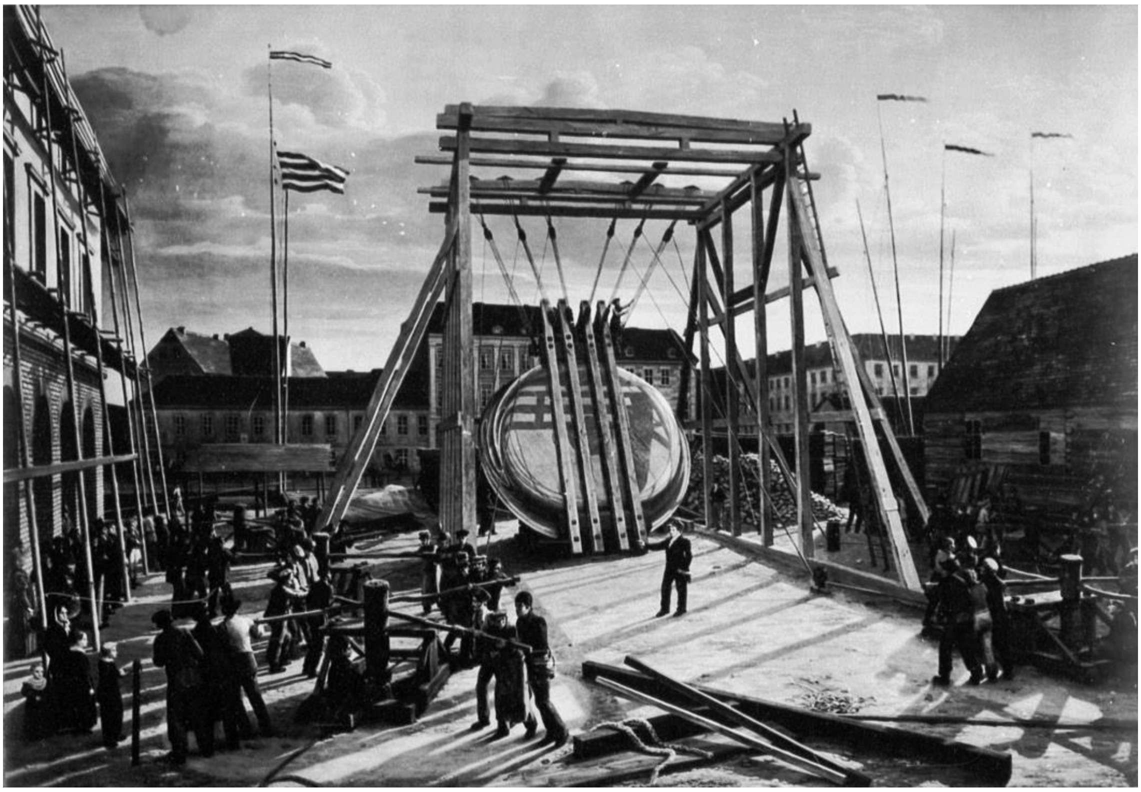

Figure 1. *Aufrichtung der Granitschale im Packhof zu Berlin* (Erection of the Granite Bowl in the Berlin Packhof). This is one of three paintings by Johann Erdmann Hummel which documented the polishing, erection, and final display of the granite bowl, highlighting how 19th century Berlin is literally mirrored in the industrially manufactured bowl. (The original painting from 1831 was destroyed in 1945. This pre-1940s photograph is in the public domain at commons.wikipedia.org.)

In his publication On the English Reform Bill (Über die englische Reform bill) in 1831, Hegel explicitly mentioned the "steam engine" for the first and only time. He stated: "The English mob committed an act of extreme folly, specifically targeting a certain entity for special interests – the destruction of the steam engine" (Hegel, 1970d, p. 553). Despite seldom mentioning the steam engine in his writings, its use and impact in the reality of that time, particularly in Berlin where Hegel resided, were significant. This reveals an important historical fact: Despite Hegel's works not delving deeply into the steam engine, this technology had become an indispensable part of industrial and everyday life in the 19th century, exerting a profound influence on Hegel's era.

Geographically, during Hegel's time in Berlin from 1828 to 1831, his residence at Am Kupfergraben 4a was near the iconic granite bowl, with Humboldt University, where he taught, just separated by a river. Unfortunately, Hegel succumbed to cholera on November 14, 1831, the same day the granite bowl was unveiled in front of the Altes Museum (Einholz, 1997). As a result, it is probable that he only heard about the transportation, processing, polishing, and finishing of the granite bowl, and never witnessed its completion. This presents an interesting phenomenon: Despite living in an era of rapid technological advancement, Hegel, as a philosopher, may have kept a certain distance from the assimilation of technology with official narratives. This leads to the question: At what point in Hegel's philosophical texts did the steam engine, a pivotal achievement of the Industrial Revolution, become a part of effective knowledge in the realm of typical philosophical thinking? To address this, one must delve into Hegel's philosophical writings to examine how he addressed the issues of “steam” and “machinery.”

HEGEL ON STEAM

In Hegel's *Encyclopedia of the Philosophical Sciences: Part One* he classifies the science of philosophy into three main groups: I. Logic, which centers on the science of the idea in itself and for itself, which is essentially the form of pure thought. II. Philosophy of Nature, which examines the science of the idea in otherness or externality, linking concepts with the corresponding realms of objects in the real world. III. Philosophy of Spirit, exploring the idea of returning to the self from otherness (Hegel, 1970b, p.63). This division highlights Hegel's view of the Philosophy of Nature as a dynamic developmental process based on the latest scientific research findings of his time. He stresses that philosophical science must be consistent with natural experience. Also, its genesis and development are predicated upon and conditioned by empirical physics. Furthermore, Hegel points out the limitations of traditional physics from the perspective of the Philosophy of Nature, emphasizing that concepts within this domain are directly related to their corresponding realms of objects within a certain scope in the real world.

In his *Encyclopedia of Philosophical Sciences: Part Two*, which was published in 1830, Hegel categorized the philosophy of nature into three distinct domains: Mechanics, Physics, and Organic Physics. From his Jena period onwards, Hegel dedicated years to extensive research in the field of natural philosophy. The fundamental concept of Hegel's natural philosophy is articulated in section 281 of *Encyclopedia of Philosophical Sciences: Part Two*: “Individual bodies contain various specific determinations of the totality of elements as their subordinate links. These determinations exist directly in a free, self-determined form within the bodies; hence, they constitute the universal, physical elements of individual bodies" (Hegel, 1970c, p.158). Here, with the term "physical elements" Hegel primarily refers to air, fire, water, and earth. Unlike the concept of elements in Mendeleev's periodic table, Hegel's "physical elements" primarily relate to differences in the number of basic states of matter, rather than qualitative differences. Therefore, the differences between air, fire, water, and earth lies mainly in the differences in states of matter aggregation: fire symbolizes energy (referencing Plato's *Timaeus* and Heraclitus), water represents the properties of liquids (referencing Thales), air signifies the form of the atmosphere (referencing Anaximenes), and earth denotes the solid state. Pirmin Stekeler suggests that the differences among these four elements are "conceptual-logical" (Stekeler, 2023).

In subsequent discussions, Hegel mentioned that "physical elements are a kind of actuality, not yet dissipated into abstract chemical entities" (Hegel, 1970c, p. 159). To understand the concept of "matter dissipated into abstract chemical entities" (zur chemischen Abstraktion verflüchtigte Materie), it is first important to recognize that among the four elements – air, fire, water, and earth – gas is primarily associated with the property of dissipation (volatilization). Secondly, "abstract chemistry" refers to the transformation of matter (Verwandlung), following the principle of equivalent exchange. Hegel points out: "The predominant concept in Empedocles' philosophy, and one that first appeared in his philosophy, is that of combination or synthesis. As a combination, it presents for the first time the unity of opposing entities" (Hegel, 1970e, p.346). The "synthesis" (Synthese) or "combination" (Vermischung) that Hegel discusses here refers to this kind of material transformation. The most direct manifestation of this transformation (Verwandlung) is not air, fire, or earth, but water. Water can exist in three states: liquid, solid, and gaseous.

I understand Hegel's analysis in section 282 of the *Encyclopedia of Philosophical Sciences* regarding air as a form of negative universality. In section 283 concerning fire's negating and destructive qualities, it becomes evident why he shifts his focus to water in section 284: "This neutral entity [...] lacks incessant activity in itself, but is entirely the possibility of process, of solubility; moreover, it can assume the form of gas and solid, states beyond its unique condition, beyond its indeterminacy. Such an element is water" (Hegel, 1970c, p. 167). Hegel presents two comparisons here: Firstly, there is the comparison of air and water, both exhibiting elastic characteristics and apparent solubility. Thus, distinguishing between air and water in terms of solubility at a speculative level poses a challenge, necessitating further differentiation through modern natural scientific research. Secondly, there is the comparison of fire and water which are opposites in their processual attributes – fire represents movement and destructiveness, while water symbolizes stillness and the ability to dissolve other substances. Arguably, the solubility of air and water becomes the central theme of Hegel's philosophical discourse after section 284.

Indeed, within section 286 of the *Encyclopedia of Philosophical Sciences*, titled “The Process of the Elements,” Hegel articulates a nuanced concept: “Despite contradicting their unity, different elements and their mutual differences are unified within individual identity” (Hegel, 1970c, p. 170). This individual identity establishes a dialectical relation between physical life on earth and meteorological processes. Although intricate, the essence of this statement lies in investigating the relationship between physical elements and individual entities, which is further illustrated in “meteorological processes” (meteorologischen Prozeß). Hegel's discourse encompasses two significant semantic layers. Firstly, it reveals the intricacy of interactions among elements and how these interactions become manifest in broader natural phenomena. Secondly, it highlights the central role of individual identity in these interactions, particularly in maintaining unity amidst diversity. Together, these meanings form Hegel's distinctive perspective on comprehending the natural world.

As previously stated, the terminological concept utilized in argumentation is directly correlated with its corresponding sphere of real-world objects. Within this framework, the concept denotes tangible elements, whereas individual entities constitute the realm of real-world objects. Hegel defines the interplay between these two as a “dialectical relationship.” Within this encompassing dialectic, “individual bodies” (individuelle Körper) may exist in varying stages of development, within specific contexts and environments. Hegel observes, “When air and water are subjected to conditions distinct from those of the entire earth, their manifestations in free, elemental connections differ entirely from their manifestations in individualized connections with individual bodies” (Hegel, 1970c, p.172). Therefore, when attempting to comprehend the diverse “individual bodies” originating from “physical elements” (Physikalische Elemente), consideration must be given to their developmental stages, specific contexts, and environments. Here, Hegel's dialectical relationship emerges as the conundrum of reconciling the universality of physical elements with the particularity of individual objects. In the parlance of contemporary social sciences, this pertains to examining the relationship between multiple independent variables and dependent variables.

Secondly, by the 18th century, meteorology had advanced beyond its previous status as a component of astrology and basic pneumatics as proposed by Aristotle. It had established itself as an independent branch of applied physics (Wolf, 1952). Hegel viewed meteorological processes as large-scale chemical processes in nature. He expressed that, “Meteorological processes are the manifestation of individual genesis, where individuality dominates various free qualities that seek separation, bringing them back to a point of concrete unity” (Hegel, 1970c, p. 186). In other words, meteorology during Hegel's time represented the study of the atmosphere as a comprehensive mechanical, physical, and chemical process. If this meteorological knowledge fails to integrate with the specific conditions of empirical objects, it remains merely abstract and lifeless knowledge at the level of understanding. Hegel utilized a wide range of contemporary meteorological research, including studies on humidity, in an attempt to demonstrate, within the framework of his natural philosophy, the dialectical relationship between physical elements and individual bodies, as well as the laws of motion that constitute meteorological elements such as air and water. However, in a complex and variable climate, these motions could be transient and incidental.

In his *The Jena System*, Hegel discusses the presence of water as humidity (steam) in the air: "The water that turns into the air is different, it contends against the earth" (Hegel, 1986, p. 66). He presents two different viewpoints regarding water dissolved in air: On the one hand, he believes that water can dissolve in the air and condense back into the liquid state through temperature changes; on the other hand, he cites the research of de Lüc and Lichtenberg, who attempted to prove through empirical evidence that air neither dissolves water nor contains dissolved water (compare Lichtenberg & Kries, 1800). During Hegel's time, theories of water vapor primarily consisted of two explanatory models. One is the theory of "elastic" air proposed by Saussure, the other was advocated by de Lüc and Lichtenberg, suggesting that steam is independent and mechanically mixed with air. These theories offer distinct interpretations from the perspectives of chemical dissolution and mechanical mixture, playing different roles in explaining the formation of rain.

Saussure and de Lüc reached different conclusions regarding water evaporation and condensation through their invention and manufacture of instruments. Saussure investigated humidity changes with temperature by enclosing elastic steam, dissolved in air, in an airtight shell (Wolf, 1952), while de Lüc conducted quantitative studies on atmospheric temperature, air pressure, altitude, and humidity. De Lüc critiqued the hypotheses of Leibniz and Bernoulli, emphasizing the non-fixed relationship between fluctuations in atmospheric pressure and the amount of steam in the atmosphere (de Lüc, 1797). Despite using organic media to manufacture hygrometers, de Lüc could not establish an absolute proportional relationship between changes in mass and size of a substance and changes in humidity in the air. Studies like these laid a crucial foundation for the development of meteorology and physics, reflecting the progress in scientific technology of that time.

During Hegel's time, numerous hypotheses regarding the formation of rain were put forth in the field of meteorology, along with extensive observational efforts using various instruments. However, Hegel stressed that the concepts people used, and the physical elements abstracted from them are fundamentally a "process" (Prozess). In his perspective, the earth and climate serve as the tangible bearers of these physical elements. People often mistake physical elements and their processes for individualized objects as they tend to grasp the forms of existence, states of motion, and variables from paradigms or theorems rooted in thought. For instance, in natural science research, there is a tendency to start from physical laws, such as Newtonian mechanics, in order to analyze specific phenomena encountered in experience. Yet, Hegel believed that while physical laws might hold on a subjective level, they require further verification when faced with objective natural objects. This standpoint sharply contrasts with Kant's dualism (the division between the thing-in-itself and the phenomenon) as upheld in the *Critique of Pure Reason*. Hegel, however, strived to establish a close dialectical relationship between the pure forms of logic and empirical objects in natural philosophy. This close connection is achieved and completed through reflective thinking. In this process of reflection, concepts (the terminological concepts used in argumentation) establish a dialectical relationship with their corresponding realms in the real world, demonstrating Hegel's profound understanding of the relationship between entities and processes, and how he integrates philosophical thought with concrete findings in natural science, proposing a new perspective on truth in the realm of natural philosophy.

HEGEL ON THE STEAM-ENGINE

Hegel's travels in September and October of 1822 took him through Netherlands and Belgium, where he discovered that the steamboat journey from The Hague to London only took 24 hours (Jaeschke, 2016). Although Hegel had only sparingly referenced the concept of the “steam engine” in his writings, in *The Jena System III* he extensively explored the relationship between steam and power, drawing on Dalton's law of evaporation.

Dalton's law of evaporation emphasizes that the rate at which water evaporates from a surface is directly proportional to the disparity between the saturated water vapor pressure and the actual water vapor pressure in the air on the surface. It is inversely proportional to the air pressure above the surface and directly associated with the wind speed above the surface. In essence, Dalton established the relationship between the rate of evaporation from a surface and the various factors on which the evaporation depends (such as wind, air temperature, and humidity), formulating it as a linear function. Within this framework, assuming that steam and air mix in the same container space, this involves the issue of mutual pressure and the movement distance of particles between steam, as an elastic fluid, and air. In a marginal note in *The Jena System III* (Hegel, 1976, p. 65), Hegel cites Dalton's original text. As stated by the editors of Hegel's collected works, this citation comes from the 1803 volume 13 of *Annals of Physics*, published in Halle, titled “Further Discussion of a New Theory on the Nature of Mixed Gases” (Weitere Erörterung einer neuen Theorie über die Beschaffenheit gemischter Gasarten).

First, the section quoted by Hegel mainly explains: “The space occupied by a certain gas is inversely proportional to the pressure it is under. The absolute distance between these particle centers must vary according to different circumstances and is difficult to ascertain; however, in certain cases, it is possible to express their relative distances in different elastic fluids” (Hegel, 1976, p.329).

Second, Hegel highlights in *The Jena System III* the latent energy of vapor as an elastic fluid: “Potential steam, elastic fluid, condenses at a certain temperature, producing more heat than an equal amount of water at the same temperature” (Hegel, 1976, p.67). The actual contact of dissimilar particles in mixed elastic fluids results in interactions between them, akin to the resistance observed in inelastic bodies, creating a polarity-like resistance between air particles and steam molecules. Hegel observes significant energy released during the process of steam molecules condensing and transforming into water, describing this energy as "free and sensitive." Furthermore, Hegel references Gren's remarks on Mr. Watt in "Outlines of a Theory of Nature" (Grundriß der Naturlehre), to support the assertion that the thermal content in steam significantly surpasses that in boiling water. Hegel indicates that if the steam is enclosed in a non-evaporating container, its temperature may rise up to 943 degrees (Gren, 1800). With Gren's support, Hegel identifies a physical law in the phenomenon of steam expanding, releasing energy, reducing temperature, and condensing into water: When the cohesive form of a body changes, its energy shifts towards the thermal substance. This law applies to various evaporation phenomena, including the volatilization of mercury and oxidizer reactions. Hegel's examination of this specialized individual physicality emphasizes investigating the relationships of pure quantities of bodies (such as specific gravity) and their cohesive forms, exploring how they ultimately transform into heat or other forms of energy mediums.

Finally, Hegel discovers his exploration of individual physicality within the conceptual framework of "the process of the earth" (der Prozess der Erde). He observes: "The process of the earth is constantly stimulated by the universal self of the earth, which is the activity of light, representing the original relationship between the earth and the sun. Consequently, the process of the earth undergoes further differentiation based on its position relative to the sun, a position that dictates climate and seasons, among other factors" (Hegel, 1970c, p. 178). According to Hegel, the process of the earth will ultimately disintegrate and become a natural existence devoid of self-consciousness. However, within this process lies a crucial phase: the emergence of human life and the actuality of spirit. Human life and spirit can represent the process of the earth within the logic of "being for itself" (Fürsichsein). Therefore, despite Hegel not disclosing the scientific mechanisms behind natural phenomena such as the formation of rain (he only clarifies the cyclical transformation of water and its philosophical implications), his thought shifts from the natural world to the spiritual and rational structure of humans, returning once again to the system of speculative philosophy. This serves as the crux of Hegel's philosophy, demonstrating how he integrates natural scientific phenomena with human spirit and rationality to deeply contemplate and interpret the natural world within his philosophical framework. This approach reflects Hegel's effort to connect the natural sciences with human spirituality and rationality, thereby providing profound insights into the philosophical interpretation of natural processes.

Regrettably, in his exploration of the scientific principles of the "steam engine," Hegel confined himself to citations and investigation without delving into the transformation of these principles into technology or the resulting revolution in social productivity and the accompanying societal ramifications. In *The Jena System*, Hegel examined the connection between labor and tools, viewing tools as dynamic entities that could only modify nature through human labor. In contrast, machines represented a further conceptual advancement of tools, bringing about not only catastrophic consequences for the natural world but also deceiving it. Hegel labeled this extreme development of machinery as "the cunning of reason," leading to the alienation of human instincts from nature, enabling nature to exhaust itself (Hegel, 1976, p. 207). In his later work, *Principles of the Philosophy of Law*, Hegel elaborated on the relationship between the division of labor and machine production, noting: "Furthermore, the abstraction of production leads to increasingly mechanized labor, until ultimately, humans can step aside, replaced by machines" (Hegel, 1970a, p. 353). As time progressed, Hegel in his Berlin period recognized the positive impact of machinery on the general welfare of the state, social classes, and division of labor. However, due to cholera, he passed away on the day of the unveiling ceremony of the granite bowl, thus missing the opportunity to firsthand witness the national significance symbolized by the era of the steam engine. The absence is immense for aesthetics, law, and other philosophical considerations in real philosophy, which according to Hegel incessantly progresses and evolves based on the principle of concept and reality.

CONCLUSION

I suggest that Hegel's examination of the steam engine reflects the foundational methodological approach in his philosophical thought. This approach involves establishing a dialectical relationship between concepts (terminological concepts used in argumentation) and their corresponding domains in the real world. These concepts stem from the pure forms of thought in logic; however, the merging of logical concepts with the tangible objects of real philosophy necessitates ongoing reflection for adjustment and refinement. This could partially elucidate why Hegel didn't delve deeply into the technical aspects of the steam engine and its resulting social impacts: His focus was more on the transformation of dialectical relationships among physical elements in natural philosophy and the delineation between specialized individual physicality and the earth's processes. Furthermore, I contend that Hegel's noticeable reduction in lectures and writings on natural philosophy during his time in Heidelberg and Berlin may be ascribed to the challenge of identifying concept-reality correspondences that align with his dialectical trichotomy amidst the significant shifts in scientific research and technological innovation during the early 19th century.

Since the Jena period, Hegel has consistently emphasized the significance of natural science in his philosophy, in addition to being actively involved in the Mineralogical Association and the Physical Society. The substantial incorporation of natural science materials is notably conspicuous in *The Jena System III*. This is undoubtedly influenced by the intellectually stimulating academic environment at the University of Jena. While Hegel initially showed interest in Watt's steam research in his *The Jena System*, this interest did not continue in his later philosophical work. This could be due to geographic limitations, his academic focus on philosophy, or the incomplete industrialization in the Prussian Kingdom where he lived. Regardless of the reason, Hegel's understanding of the steam engine as a machine went beyond the traditional European perspective, which viewed machines as anthropomorphized and ontologized clockwork mechanisms. His perspective laid the groundwork for the Young Hegelian school and Marx, marking a significant development in the industrialization of machinery.

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Research article

The Futures Circle - A Framework for Hermeneutic Technology Assessment

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Abstract

Technofutures, meaning statements about new and emerging technologies (NEST) disrupting the world as we know it, often follow a purely hypothetical and thus also speculative manner. At the same time, they shape the way we think and discuss NEST and leave an impact on the development of the actual technology. Scholars from Science and Technology Studies (STS) and Technology Assessment (TA) have turned towards technofutures as objects of interests, to better understand the content, the spreading, and the impact of techno-visionary communication. The shared characteristic of these approaches is that they view technofutures not as predictions of what may or may not happen, but as reflections of current state of affairs, i.e., compositions of existing knowledge, values, and attitudes. One of these approaches is Hermeneutic Technology Assessment (TA), which focuses on analysing how technofutures attribute meaning to NEST. This paper gives an insight into the different perspectives on technofutures and suggests a framework for the hermeneutic assessment of technofutures: The Futures Circle. The framework gives guidance through an otherwise often rather erratic research and contributes to the methodological reflection on Hermeneutic TA.

Keywords: Hermeneutic TA; Technofutures; Technology Assessment; Method; Framework; Ricoeur

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Научная статья

Круг будущего – основа герменевтической оценки технологий

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Аннотация
Технобудущее, то есть заявления о новых и появляющихся технологиях, которые меняют мир, каким мы его знаем, часто следуют чисто гипотетической и, следовательно, также спекулятивной манере. В то же время они формируют то, как мы думаем и обсуждаем новые и появляющиеся технологии, и оказывают влияние на развитие самой технологии. Ученые из области исследования науки и технологий (STS) и оценки технологий обратились к технобудущему как к объекту интереса, чтобы лучше понять содержание, распространение и влияние техно-визионерской коммуникации. Общей характеристикой этих подходов является то, что они рассматривают технобудущее не как предсказания того, что может или не может произойти, а как отражение текущего положения дел, то есть совокупность существующих знаний, ценностей и отношений. Одним из таких подходов является герменевтическая оценка технологий, которая фокусируется на анализе того, как технобудущее придает значение новым и появляющимся технологиям. Эта статья дает представление о различных взглядах на технобудущее и предлагает основу для герменевтической оценки технобудущего: "Круг будущего". Данная концепция дает руководство для в противном случае часто весьма беспорядочных исследований и способствует методологическому осмыслению герменевтической оценки технологий.

Ключевые слова: Герменевтическая оценка технологий; Технобудущее; Оценка технологий; Метод; Рамки; Рикёр

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INTRODUCTION

New and emerging technologies (NEST) come with the promise of disrupting the world as we know it while at the same time lacking the proof of their actual impact. Technologies such as humanoid robots, smart lenses, synthetic biology, quantum computers, carbon dioxide removal, in-vitro meat, nuclear fusion reactors, and many others share the characteristic of not yet being fully functional devices but being expected to become part of our society in the near future (Rotolo et al., 2015). This means that, except for a few prototypes in R&D departments or research institutes, NEST exist primarily in the way we talk about them, meaning the shared expectations of these technologies and their potential applications. These expectations are called „technofutures" (Grunwald, 2012). They exist in many forms and have different origins. Among others, technofutures can be the outcome of foresight processes to assess potential impacts of a technology as in classical or consequentialist Technology Assessment (TA) (Grunwald, 2010); they can be authored by science managers who promote a certain technology in the political or public sphere, so called Visioneers (McCray, 2013); they can be written by science fiction (SF) authors, who are inspired by emerging technologies to explore potential futures in thought experiments or use them as metaphors to reflect on current social issues (Mehnert, 2022). In sum, technofutures form an important discourse surrounding NEST. They communicate the technology towards a diverse group of stakeholders, attribute a certain meaning to the technology and create expectations long before it can be said that these might actually be fulfilled. While technofutures deal with potential future scenarios, they are created at a time when there is limited or no existing knowledge regarding the likely trajectory of the respective technology, the potential products that may emerge from its development, or the possible repercussions of utilizing such products. This being said, technofutures often follow "a purely hypothetical and thus also speculative manner" (Grunwald, 2014, p. 276). At the same time, they shape the way we think and discuss emerging technologies and leave an impact on the development of the actual technology, which creates a paradoxical dynamic between fiction and actual impact.

Facing the situation that technofutures, despite (or because of) their fictional character have an actual impact on the development of the technology, scholars from Science and Technology Studies (STS) and TA have turned towards technofutures as objects of interests. They developed approaches to better understand the content, the spreading and the impact of techno-visionary communication (Brown et al., 2000; Jasanoff & Kim, 2015; Lösch et al., 2019). The shared characteristic of these approaches is that they view technofutures not as predictions of what may or may not happen, but as reflections of the current state of affairs and compositions of existing knowledge, values, and attitudes. One of these approaches is Hermeneutic TA (Grunwald, 2016, Grunwald et al., 2023), which focuses on analysing how technofutures attribute meaning to NEST, rather than predicting the impact of NEST. Hermeneutic TA is concerned with understanding the cultural context, the creation, and the impact of technofutures on the development of NEST, with the goal to better inform society and policymaking.

This paper offers an insight into the different perspectives on technofutures and offers a framework for a structured assessment. Building on Ricoeur's narrative hermeneutics, the framework will take into consideration different forms of figurations that become relevant when understanding how meaning is attributed through technofutures. Therefore, in a first step, I will explain what I understand technofutures to be, will then highlight different research perspectives, and at the end bring them together in form of the aforementioned framework. With this paper I aim to contribute to the methodological reflection on Hermeneutic TA and offer a structured guidance through an otherwise often rather erratic research approach.

A DEFINITION Of TECHNOFUTURES

Futures as Different Worlds

Technofutures are statements about the world changed by the consequences of a new technology (Nordmann, 2014). While these statements may occasionally incorporate a loosely defined timeframe, the primary emphasis lies in the nature and quality of the claimed change(s). Depending on the statement, the consequences are framed as positive or negative, concluding in ethical, cultural, economic, social, political, or ecological changes (Lösch et al., 2016). Nordmann (2014) describes this relation between future consequences and our current world in the following way:

> The future begins when a difference arises that sets the world of the future apart from that of the present. In the discussion of emerging technologies, for example, one usually posits a transformative innovation that introduces a qualitative difference, and then wants to know what the consequences of the innovation will be in that future world. (p. 132)

Consequentialist thinking is at the centre of technofutures and aims at creating pathways into the alleged future. These pathways represent a plausible sequence of implications originating in our present (i.e., if X occurs today, it might result in Y tomorrow, and this, could lead to Z the day after). The method of thinking in implications facilitates the envisioning of a world that deviates from our own, as these ramifications might change minor or, at times, major aspects of our already known world (Mehnert, 2023b). Based on the depiction of these worlds through technofutures (i.e., talks, presentations, videos, actual images, and other media), we can judge whether we would like to live in such a world or what we should do to prevent it. Nordmann (2014) writes:

> [Technofutures] are made to be beheld and judged not by future generations but by people like us who, akin to tourists, encounter another way of living, consider its pros and cons, and might end up trying to integrate it with their world at home. (p. 90)

Nordmann therefore proposes changing the way we talk about technofutures. Instead of saying that this imagined future is a different world, he removes the temporality from the phrase and says: it is a different world that is being imagined here (p. 89). With this rhetorical trick, Nordmann takes away the predicative effect of technofutures and understands them as one of many possible alternatives to the actual world. This takes away the heaviness of framing the future as determinant prediction and instead positions the depicted future as one alternative world. The perspective on the imagined world also allows to weigh the advantages and disadvantages and, in the end, to decide to support this world in its emergence or to prevent it. Technofutures thus become discussable in terms of their implied hopes rather than the probability of their realisation.

The Attribution of Societal Meaning

As change is at the core of technofutures, we can break them down to a causal structure of “if-and-then” (Nordmann, 2007). This structure suggests a function of an emerging technology (“if”) and continues with a positive or negative consequence that demands attention (“then”). Typical examples are: if it should be possible to create a direct interface between brains and machines, then this device threatens an invasion of privacy (Nordmann, 2007); if we can grow meat in a lab, then we can solve today’s devastating effects of meat production (Ferrari & Lösch, 2017); if we produce autonomous weapon systems, then these systems might be hacked and used against citizens (Mehnert, 2019); if we create devices that capture carbon dioxide from the air, then we can solve the looming climate crisis (Ornella, 2022).

Through implying that a technology will have a certain function (“if”), and that this function will cause an impact on society (“then”), technofutures attribute meaning to the emerging technology way before the technology is available. It also involves associating a potential benefit or risk to society, individuals, or nature with the specific technology under consideration. This way the technology becomes societally meaningful (Grunwald, 2019, p. 105) and appears to be relevant for different actors who will have to position themselves towards or against the technology and the implied world. With regard to the actual development of the technology, the attribution of meaning becomes crucial for the social acceptance or rejection of the respective technology as it forges alliances (Ferrari & Lösch, 2017) or guides policy and decision-making processes that ultimately determine whether research and development should be promoted or regulated (Grunwald, 2019, p. 106). As technofutures shape the discourse on emerging technologies the analysis of technofutures and understanding the process of attributing societal meaning to the technology becomes relevant to offer better orientation. This highlights a necessity formulated by Grunwald (2016), in the following way:

> We must deal explicitly with the issue of how these meanings are created and attributed, what their contents are, how they are communicated and disseminated and what consequences these attributions of meanings have in the RRI debates and beyond, e.g., for public opinion forming and political decision making. (p. 14)

Instead of looking for potential consequences of an emerging technology, this perspective on technofutures addresses questions such as: What assumable functions and consequences are attributed to the technology? What are these assumptions informed by? How is the attribution of meaning constructed and communicated? Are the consequences framed as positive and negative and who is framing them? To answer these and similar questions, Grunwald (2016) proposes to deconstruct the attributed meaning through an approach he calls Hermeneutic Technology Assessment:

> The hermeneutic approach (…) will contribute to the development and application of a new type of reasoning and policy advice in debates on future technology beyond traditional consequentialism. Its objective is to allow deciphering the meanings assigned to NEST developments as early as possible in order to allow and support more transparent and enlightened debate. (p. 4-5)

The aim of hermeneutic analysis is to reflect on existing technofutures and thereby deconstruct the inherent attributions of meaning. According to Grunwald (2016), hermeneutic analysis contributes to a critical-reflective and enlightening attitude towards the various debates on emerging technologies (p. 169).

When delineating the methodological approach, Grunwald remains broad, primarily because hermeneutics employs diverse methods depending on the research question and the objects of interests. For example, discourse analysis enables the investigation of actor networks and communication dynamics, methods of qualitative social research, such as laboratory research or participant observation, allow the investigation of the construction of technofutures, while deconstructive methods of philosophy of science illuminate the genealogy and history of concepts and ideas conveyed in technofutures (Grunwald, 2016, p. 180). Regarding text formats, Grunwald refers to hermeneutic approaches from linguistics or cultural studies, while for artistic formats he suggests analysing stylistic devices or the transfer of connotations, as such transfers often also implicitly provide attributions of meaning through associations and metaphors, which must be made explicit to make technofutures the subject of a comprehensible discussion. Furthermore, the literature often points towards a set of questions like these:

> What are the cognitive and normative elements? Is the overall construction of a vision with the identified elements ‘rational‘? What are the hidden premises and inexplicit norms of the visions? How are visions used in public debate? Where do the visions originate from – culturally or historically? What do visions tell us about us today? What are the differences between the diverging visions? (Grunwald, 2013, p. 31)

These questions point at a critical, deconstructive and reflective research approach towards technofutures. However, if taken together, the questions are often rather large, include diverging perspectives and appear to be overwhelming when being treated all together. Therefore, I want to offer a structure for a hermeneutic process that follows the narrative hermeneutics by Ricoeur (1984) which he lays out in his work on “Time and Narrative.” Ricoeur describes an approach to narrative that does not only look at the plot structure and inherent constellations of a story but rather at the larger context. For this, he suggests a hermeneutic approach that follows three perspectives that he calls Prefiguration (or Mimesis 1), Configuration (or Mimesis 2) and Refiguration (or Mimesis 3). This approach of narrative hermeneutics separates the analytical process of hermeneutic TA into three distinct perspectives which I will explain in the following.

THREE PERSPECTIVES Of HERMENEUTIC TA

As we do not have any direct access to the future, the only knowledge we can use to think about futures is our present-day knowledge, meaning our values, fears and expectations, our culturally shared assumptions of the future, and our ways of 'constructing' visions. This "immanence of the present" (Grunwald, 2012, p. 99) also situates futures in the present. Therefore, hermeneutic TA understands visions of the futures not as pointing to future technologies or to their anticipated consequences, but rather as present processes of attaching societal meaning to new technologies. The following perspectives move the content as well as the processes of generating, disseminating, and contesting technofutures to the focus of TA.

Prefiguration: Cultural context of Technofutures

Although visions of technological futures describe ideas about future developments they are always tied to the respective present of the actors, whereby (consciously or unconsciously) the present, i.e., the authors perspectives, perceptions of the world and deeper cultural patterns, are inscribed. Therefore, the culturally shared imaginaries, where these imaginaries come from, which hopes or fears they express, what values they hold and how this refers to the culture of origin play an important role in hermeneutic TA. In this regard, Wei-Kang Liu (2023) points out that part of hermeneutic TA should be a cultural-linguistic analysis which "uncovers the cultural-historic background of visions together with their implicit meanings" (p. 25). The following examples will give a better understanding of the perspective on prefiguration.

Grunwald uses the term ciphers to describe that technofutures refer to themes, that are implicitly presupposed but not always explicitly addressed. He understands ciphers as signs or abbreviations that have a function and a meaning in a certain context, which, however, remains blurred to some extent: "Ciphers refer to something outside of them, but without uncovering it in its entirety" (Grunwald, 2012, p. 121, authors translation). Technofutures refer for example to already existing imaginaries of human beings (*Menschenbilder*), human-machine interactions, social imaginaries (Castoriadis, 1975; Taylor, 2003), or worldviews. In this way, technofutures are prefigured by culturally shared imaginaries, hopes, fears, and ideas of a better world – while at the same time claim, that this better world could (only) be achieved through the technology. For example, the vision of human enhancements follows an understanding of the human as a machine that can be upgraded to become more efficient. Not only is this understanding of the human a debatable image, it is also only one of many understandings of what it means to be human, which leaves out the necessary imperfection and submits to a capitalistic logic of growth (Coenen, 2010). While the development of the technology continues, this understanding of human as a machine will be inscribed into the actual technology. Hence, technofutures are not just about the future but point at current problems, longings or hopes, as well as bigger issues beyond the vision itself.

This dynamic is also interest of research in the field of STS, when tracing the social, cultural and historical peculiarities in the development of technologies. Suchman (2006) points out that imaginaries spread within a society through information and communication networks and materialise in new technologies. In this regard, Haraway speaks of materialised refiguration (1997) and emphasises that in new technologies the immaterial histories, longings, and needs of a culture connect with the material world. According to this perspective, technoscience and culture do not exist in a vacuum, but are intertwined, as can be empirically examined, as has been done when analysing visions of robots and how imaginaries spread through different cultural spheres (Telotte, 2016) or how the development of artificial intelligence (AI) is inspired by cultural imaginaries and driven by the wish to achieve something outside of the actual technology (Cave et al., 2020).

Connecting to existing imaginaries can also blur the view on the actual development. Barbrook (2007) for example examines how imaginaries of AI have overshadowed the actual development of the technology. From the 1950s on, computers were perceived under the imaginary of becoming sentient machines, while the technology was used for the production of cybernetic weapon systems (p. 40). The assumption was that once the technology matured enough, thinking machines would be inevitable and artificial consciousness (AC) would be achieved within the next decade (p. 19). This imaginary, which was spread by AI-pioneers, was taken up by IBM which announced in 1961 that it would give top priority to the development of AC, while IBM's computer machines continued to be used mainly as weapons systems. According to Barbrook, the imaginary and hope of an artificial consciousness legitimized the continuous research for smarter weapons.

To examine the influence of the cultural present on technofutures in the realm of policy making, Jasanoff & Kim developed the concept of sociotechnical imaginaries, meaning collectively shared, institutionally stabilized, and publicly enunciated visions of desirable futures shaped by a culturally shared understanding of social coexistence and social order which will be achieved using emerging technologies (Jasanoff, 2015, p, 19). With a background in political science, Jasanoff & Kim focus primarily on publicly available, nation-state positions on emerging fields of technology. In their study “Containing the Atom” (Jasanoff & Kim, 2009), for example, the two scholars compare the U.S. government's stance on nuclear technology with the position of the South Korean government. They show that the cultural-historical background plays a decisive role in envisioning the technofuture and therefore in acting upon the technological development in the present. To be precise, against the backdrop of reactor accidents such as Three-Mile Island, the US-government saw itself in the role of containing nuclear risks and developed the self-image of a responsible regulator who develops effective containment strategies. In South Korea, on the other hand, the technofuture of nuclear energy followed the assumption that nuclear power would promote prosperity and growth. Rather than seeing the future of nuclear power as an uncontrollable risk that needed to be contained, the Korean government viewed nuclear technology as an important step in the nation's economic and military construction. With their comparison, they showed how different imaginaries of social life and order and the imaginative resources available are co-producing the visions of goals, benefits and risks of science and technology in the future (141).

The role of the *Zeitgeist* is also expressed in the artefacts of everyday culture, like SF. Using the cyberpunk genre as an example, Mehnert (2021) traces how the popular framing of the future as techno-determinist nightmares depicted in these stories points at the structure of feeling of the 1980s. Cyberpunk fictions tell stories of dystopian worlds, in which a fictional society is entangled in high technologies of various kinds. Often, the characters are enhanced by cybernetic-implants, connect to a shared cyberspace-matrix through bodily sensor-stimulations, and interact with human-like A.I.s on an everyday basis. Despite the technological progress, though, the inhabitants of this world struggle to survive, as the sociotechnical environment renders them powerless – left with the only option to hack the technology to redeem some form of autonomy. These stories represent a feeling of losing oneself in an ever-faster pace of technological progress, mixed with the paradigm of a neoliberal economy and the false promises of free markets postulated by politicians like Margaret Thatcher and Ronald Reagan in the 1980s. This feeling became the breeding ground for cyberpunk and defined an aesthetic of a technofuture that endures to this day.

These and other examples show that technofutures link societal hopes and fears to the ideas of new technologies and provide a glimpse of a social future, perceived as utopian or dystopian, to be achieved or prevented by technology. Iser, pointing at the cultural prefiguration, mentions that every text inevitably contains a selection from a variety of social, historical, cultural, and literary systems that exist as referential fields outside the text (Iser, 1993, p. 4). Or as Ricoeur (1984) puts it, the author is composing the plot, "grounded in a preunderstanding of the world of action, its meaningful structures, its symbolic resources, and its temporal character" (p. 54). They select and rearrange the elements they find, inevitably leave out elements, overemphasize others and bring them into a deliberate coherence. Hence, besides the elements that are mentioned in technofutures, it is also important to reflect on which elements are not mentioned and (intentionally or unintentionally) left out. Read in this way, technofutures tell us more about the desires of a particular cultural than the potential of technologies themselves (Sturken et al., 2004, p. 7).

Configuration: Mediatization of Technofutures

To be analysed hermeneutically, the imaginaries, that inform the thinking about the future, need to be lured into a form or a *Gestalt* (Iser, 1993) – in other words: a medium. Although imaginaries of futures, i.e., fantasies, daydreams or other purely cognitively existing futures that individuals hold, also have an impact on individual actions and decisions, they cannot be analysed unless explicitly expressed and shared. Thus, it is important to call to attention that technofutures are constructed and that the construction process is shaping their meaning:

> Techno-visionary futures do not exist per se, nor do they arise of their own accord. On the contrary, they are 'made' and socially constructed in a more or less complex manner. Futures – be they forecasts, scenarios, plans, programmes, visions, speculative fears or expectations – are 'produced' using a whole range of ingredients such as available knowledge, value judgements and suppositions. (Grunwald, 2013, p. 29)

As Grunwald emphasizes, the way how futures are constructed, that is, which ingredients are used and coherently assembled, is decisive for their content and becomes relevant for the assessment of the vision (Grunwald, 2010, p. 100). In this regard, Wei-Kang Liu (2023) speaks about "visioneering assessment", emphasizing that the content of visions are usually analysed in great detail, while the process of constructing is often overseen. Consequently, visioneering assessment has the task to uncover the process in which visions are constructed. This process, of course, differs from medium to medium, as each medium asks for different construction processes. In the context of hermeneutic TA, technofutures are usually part of a mediated discourse on NEST in scientific, policy and public spheres. Thus, they are present in form of texts, pictures, presentations or performances, slides, objects, prototypes, tables, film or video, sound, and many other media formats. These mediated futures become the corpus of a hermeneutic analysis while the process of mediatizing technofutures in itself is also impacting the content.

The role of the medium plays a decisive role in constructing technofutures, as it predefines a certain set of codes that authors have to submit to. To assess technofutures thus also means to address the affordances and restrictions of the medium. In this context, Ernst and Schröter ask about the mediality of futures and how the medium, with its respective design rules but also as epistemology, contributes to technofutures. They refer to the concept of technoimagination by the media philosopher Villem Flusser (1998, p. 209), whose thesis is that new media lead to a new form of imagination and media upheavals thus change the power of imagination itself (Ernst & Schröter, 2020, p. 61). Dickel (2023), relating to McLuhan's (1964) famous quote "the medium is the message," emphasizes that the materiality of technofutures, the question of how and by which material means and practices technofutures are expressed, as well as the media technologies that enable, structure, and shape the production and reception of technofutures become important (Dickel, 2023, p. 159). He points out, that each medium requires not only different processes of production but also assembles different actors and requires different technologies. This, in return, also has an impact on the content: If futures take the form of texts or are turned into movies, the technologies of writing texts or producing movies will shape the outcome. Working with movies, for example, forces you to become specific by showing the technofuture, whereas text allows to stay more abstract and use more general concepts. Or in other words, it is easier to say "in the future, everyone will be happy" than to show, how happiness will look like in the future and what it is caused by.

The most intuitive medium to express visions of futures is language. Texts thus become important, which in turn necessitates literary studies and textual analysis as means for a hermeneutic assessment. In particular, the role of metaphors used in visions about emerging technologies become of interest for critical reflection (Inayatullah et al., 2016). Metaphors are crucial to how we make sense of our world and how we conceptualize things through another. As emphasized by Lakoff and Johnson (2003), metaphors shape not only our understanding of the world but also our experience of and actions within it. Analysing the metaphors used to express visions allows to reflect on the underlying prefiguration – and also offers creative and playful approaches to reimagining alternative futures (Fischer & Marquardt, 2022). To provide an example, Nordmann

(2014) points out that the term emerging technology is already a metaphor, as it suggests the emergence of new technological capabilities which "can be linked to a rising tide – it will just go on and on, and at some point, the dams to a new world with new capabilities, opportunities, and risks will simply break" (p. 92). Framing a technology as emergent, hence, already attributes the meaning that this technology will one day flood our world and create impact. The metaphor implies that the coming of the technology is inevitable and that it will have some kind of an impact, thus reducing the questions of its development to the question of when rather than if, why or how.

Beyond metaphors, the way technofutures are told and the storylines in which they are embedded also become of interest to a hermeneutic TA. Gransche (2015, p. 252) and Grunwald (2016, p. 3) emphasize the similarity of technofutures to stories, as both articulate processes of change. Thus, an important mechanism for giving meaning to NEST is the narrative about future impacts and consequences. These narratives include perceptions, issues that are seen as problems, expectations and hopes, concerns and fears that lead to questions and controversy. In other words, technofutures can be seen as stories that represent a systematic imagination of the interplay of future technologies with future society (Lösch et al., 2019, p. 1). The simplest storyline of technofutures follows the beforementioned "if-and-then statement" (Nordmann, 2007), which suggests a technological development ("if") and continues with a consequence that demands attention ("then").

The storylines (i.e., patterns of argumentation) and the tropes being used (i.e. recurring motifs or arguments) show similarities across different technologies, as they have become an often used repertoire for moral argumentation about NEST (Swierstra & Rip, 2007, p. 4). Therefore, technofutures are not simply an expression of individual attitudes or preferences, but they can be seen as expression of a culturally shared inventory of narratives, which are used to give meaning to a technology that is yet unknown. Typical examples of such a narrative are opening Pandora's box, as has been observed in the context of nanotechnology (Macnaghten, et al., 2010), or the inverse King Midas narrative, defined by Swierstra and Rip in the following way: "Whereas the mythical Greek king turned everything he touched into gold, modern (Western) civilisation turns everything into a means of destruction (and both Midas and civilisation got into trouble)" (Swierstra & Rip 2007, p. 9).

While aforementioned narratives are attributing a rather alarming meaning to the technology at hand, more positive narratives emphasize the potential benefits created through the technology. A popular one is the narrative of technological progress, in which tools and machines promise relief from physical labour, new forms of industrial value creation, unlimited prosperity, and better medical care for a longer and healthier life. Following this narrative, emerging technologies are always accompanied by the promise of social, cultural, and moral progress (Grunwald, 2010, p. 22). This narrative has been severely challenged, in particular as the societal benefits of technological progress are increasingly overshadowed by the emergence of modernisation risks that pose an irreversible threat to nature, animals, and human life (Beck, 1986, p. 17) or by overemphasizing on the progress idea and following the logic of technological solutionism (Morozov, 2014), implying that emerging technologies are capable of solving social problems while overshadowing alternative pathways that would build on social instead of technological innovation.

Language is one of many vehicles being used to present technofutures. In addition to text, visualizations of new technologies also play a central role. For example, the debates around human enhancement, nanotechnologies or synthetic biology are largely driven by futuristic-looking images and inspired filmmakers to join in artistic debates (Grunwald, 2014, p. 285). In the context of film, “diegetic prototypes” (Kirby, 2010) help to envision the debated technology and share their potential impact with a greater audience. Kirby highlights that Filmmakers, scientists, and engineers use cinematic representations of new technologies to reduce fears of the technology, to create a desire in the audience for these technologies to become reality, or to normalize new technologies by depicting their use in familiar contexts. The visualization of technologies shares the meaning attributed to the technology in a low-threshold way, which is why visualisation of different forms play an important role in the public perception of technology. A hermeneutic analysis thus also takes the design of the diegetic prototypes, the context in which they are depicted, the visual references the awake but also the design of the images or films themselves into focus. This ultimately emphasizes the importance of media- and design-theory for the discussion of technology futures.

Furthermore, technofutures of similar media (e.g., film, text, images, etc.) do not only follow the specific codes of the medium but also of the specific genre. Steinmüller (2016) speaks of different forms of symbols (*Zeichensorten*) that are used in the exploration of the future. Examples are trend-reports written by a research institute, a descriptive scenario as an outcome of a TA process, a corporate vision or an advertisement for a future product or a SF-story written by an author. Each of these examples can come in the medium of text but represent different genres, as they are differently aestheticized, i.e., constructed in accordance with the aesthetic codes of each genre. To give an example, unlike the scientific experimenter or the future researcher, who is bound in his thought experiments to the principles internal and external consistency, stringent argumentation, plausibility, and more (Grunwald, 2009), the SF-author is bound to the aesthetic principles of a narration: How does a coherent and exciting plot develop? How can the fictional characters act psychologically convincingly in unusual situations? Which conflicts and which resolutions are suitable to convey the message? (Steinmüller, 2016, p. 329) In other words, one reason for the dystopian depiction of technology in SF is the restriction of the genre and its dependence on conflicts. Conflict is a necessity in the genre of SF-stories, which often resolves in framing of future technology as an evil actor responsible for a dystopian future (Mehnert, 2019).

The difference between the genres is often hard to identify. For example, technofutures by tech companies, so called “*Leitbilder*” (Dierkes et al., 1996, p. 18), are a genre which follows its own codes but has overlaps with SF. In terms of content, terminologies like Cyberspace or Metaverse originated in SF but got adopted by the industry as a common vision, as using popular semantics can be useful to translate abstract innovation processes to stakeholders outside of research and improve communication between research and industry or fundraising for research projects (Schröter, 2004, p. 32).

However, while both genres follow the same speculative epistemology, they pursue different goals: Whereas SF visions can be understood as fantastic entertainment, tech visions demand potential plausibility from the recipients to legitimise the companies research of the technology, to find strategic partners or to attract new fundings (Haupt, 2021). To achieve this goal, actors pursue different rhetorical strategies and use particular aesthetic codes that postulate the projected change not only as desirable and necessary, but rather as familiar and natural (Mehnert, 2023a). This goal oriented and strategic perspective will become relevant in the next chapter.

Refiguration: The reception and impact of Technofutures

There has been a considerable increase in technofutures in recent decades (Grunwald, 2018). One reason for this is the increasing socialisation of development processes. Innovations arise from collaborations between, for example, entrepreneurs, developers, sponsors, communication experts, politicians, and others. Coordinating this cooperation requires shared visions that enable the actors to understand the importance of innovation and work together to realise (or prevent) these technofutures. Therefore, the third perspective, the refiguration, looks at how technofutures are impacting the discourse on emerging technologies.

Technofutures are used as strategic resources in political and technological agenda-setting processes. For example, they can create hypes and motivate actions through a fear of missing out or stimulate other activities necessary to realise or prevent the respective technology (Rotolo et al., 2015, p. 28). They also attribute roles and responsibilities, as van Lente & Rip emphasize. technofutures contain a script of the future world in which relevant actors, explicitly or implicitly, are positioned exactly as characters in a story. This positioning is strategic and has an impact on the present. Since the visions are often public or semi-public statements, they require a response from the actors being positioned. An actor who rejects the role must react (e.g., by protesting against or contesting the nature of the vision). In this way, alliances get forged, positions defined, and discourses formed (Van Lente & Rip, 1998, p. 218).

Due to this discursive character, technofutures can be understood as "socio-epistemic practices" (Lösch et al., 2019). They can shape the actual development paths by, for example, legitimising or defaming research on the technology, coordinating the cooperation of different actors, mobilising supporters for or against development, and much more. As said before, technofutures are socially constructed, that is, there are authors and producers who create these futures with a certain intention and a strategic goal in mind. This goal can vary and can either be to entertain, as in some form of SF, or to persuade its audience, as for example in corporate visions of emerging technologies. Regarding the later, the term *Leitbild* is used for technofutures that are intentionally guiding the development process of an emerging technology (Mambrey et al., 1995, Dierkes et al., 1996). Dierkes et al. describe the *Leitbild* as a general ideal or vision of a desirable future moment associated with the means of technology, a family of technologies or a technical system (p. 18). Dierkes emphasises that *Leitbilder*: (1) are mediated translations of an abstract innovation process into tangible ideas; (2) explain the special significance of a technology to politicians, industry managers and sponsors to forge alliances; (3) and give purpose to the developers work by embedding it in a larger idea (e.g., fighting climate change or progressing the future of humanity) (p. 29).

However, whether a particular technofuture is accepted as a *Leitbild*, or whether it will have any impact on the actual development, depends on whether it is ascribed validity. technofutures that leave an impact in one way or another are those that portray the described technology and its effects as inevitable (Nye, 2004, p. 160) – and are persuasive enough to be believed in. According to Grunwald, the validity of technofutures is decided discursively (Grunwald, 2009, p. 30). It is therefore not only the content of technofutures that determines its validity but rather its social acceptance. In this sense, technofutures entail a paradox: As said before, they are speculative and therefore fictional, however, to be impactful, they have to be accepted as if they would become an actual future present and convince addressees of their non-fictional character. Thus, an impactful Technofuture becomes “a fiction that masks its fictionality” (Iser, 1993, p. 13).

However, fictionality might not become a sufficient criteria to judge on technofutures (as all technofutures are necessarily fictional by definition). Esposito emphasises that reducing technofutures to the opposition between real (plausible) and non-real (fictional) would neglect their social relevance. Fictions, Esposito continues, should rather be understood as useful and functional concepts that are developed based on comprehensible rules on which there is agreement among the participants (Esposito, 2007, p. 57). Roßmann (2021) stresses the fictional character of technofutures and compares them to a “make-believe game” (Walton, 1990), a children's game in which all players imagine an object as something else and adjust their behaviour accordingly. Roßmann gives the example of children who pretend that tree stumps in a forest are bears and react to the stumps as if they were encountering a bear. Transferring the analogy to technofutures, the bears become the technology and the children become the stakeholders (e.g., developers, politicians, users, etc.). The premise of the ‘game’ is, that the technology will arrive at a time later than now and all stakeholders involved have to react as if the premise would be true, for example by supporting the development, discussing on potential impacts and defining regulations to prevent them. With this regard, van Lente & Rip give the example of Moore's law (Van Lente & Rip, 1998, p, 203). This ‘law’ claims that the calculation power in an integrated circuit doubles about every two years. Although it is far from an actual law, the vision is treated by the actors as if it would become a reality in the future. By acting upon this vision, Moore’s law has become a self-fulfilling prophecy, trapping the actors in a game-theory dilemma in which each actor strongly suspect the other actors to continue the research and progress the development, while no one wants to run the risk of falling behind. Moore's law has become a plausible fiction in this sense. Thus, the attribution of validity to a technological future depends only to a limited extent on its content, its rhetoric, and its arguments, but also on the perception and the way stakeholders relate to it – or in other words, to refigure the social dynamics surrounding emerging technologies and to leave an impact, technofutures demand from their recipients the willing suspension of disbelief (Coleridge, 1817).

This invites for a reflection on the concept of plausibility, which is not an objective attribution but rather subject to social negotiation processes and individual imaginative capacities. As Fischer and Dannenberg note, plausibility arises on the basis of coherence with previous concepts and thus coherence with the socially constructed perception of reality. In the social constructivist sense, one's own perspective on reality also prefigures the judgement of futures and limits the space of possibilities to those futures that align with current concepts and are considered conceivable from the present (Fischer & Dannenberg, 2021, p. 10). When referring to previous concepts or to be considered conceivable from the present, clearly indicated fictional technofutures from SF play an important role. To give an example: the brain-machine interface is part of several technological vision, including *Leitbilder* as well as SF-novels, films and games. These visions form a discourse on human enhancement (Coenen et al., 2010; Jebari, 2013) and evoke different ideas of what the device could do or might cause; e.g. the interpersonal communication without the use of language (Nicolelis, 2015; Dugan, 2017), the promise of salvation and the fusion of human and machine as the next stage of human evolution (Kurzweil, 2006), or a form of socio-economic division between people with and people without access to the neurointerface which can be called neurocapitalism (Meckel, 2018). Some technofutures also imagine the possibility to upload the mind to a computer and promise to hold the key for life after death (Cave, 2020). These visions do occur in SF but are also shared by researchers like and visioneers like Elon Musk (2020, 46 min) or the neuroscience company Nectome, which announced to be able to scan the brain structure of a living person to revive their mind on a computer (Regalado, 2018) – which would inevitably lead to the death of the person. Although these claims have soon be revoked by the company, the vision of mind-upload still exists a strong and disputable *Leitbild* within the discourse on neurotechnology and is validated by some (Mehnert, 2023a). One of the reasons why companies can publicly announce their work on presumable imaginative technology is that these technologies are conceived as plausible, as they are coherent with previous concepts and are conceivable from the present – at least in SF. Besides the technological discourse, mind-upload and brain-computer interfaces are an established trope in SF since the cyberpunk movement in the 80s (Mehnert, 2022). The different stories, films and video games that surround this technology normalize the technology and create a familiarity with something otherwise strange. Or as SF-researcher Sherryl Vint (2020) puts it:

> Ideas such as mind-uploading and other human augmentation have similarly become normalized by a milieu in which things such as self-driving cars or smart AI assistants that respond to voice commands have created a perception that futures envisioned by yesterday's sf seem destined to become our futures. (p. 173)

What this example shows is that SF-visions on neurotechnology refigure corporate technofutures and not only shape the meaning of the technology, i.e., their functions and their potential impact, but posit the technofuture as a valid and plausible pathway of development. On the one hand, we can say that the corporate technofutures on mind-upload are prefigured by the human need for immortality, as "heaven is a really powerful computer" (Seung, 2012, p. 254). On the other hand, SF mind-upload visions refigure the way we think about neurotechnologies today. They normalize a mechanistic image of man, as well as ideas of what would be desirable – or supposedly necessary – improvements. This is also accompanied by a refiguration of the concept of 'mind', which was previously defined by philosophy or religion, and is now defined as that which is measurable; everything that can be measured by technical devices becomes the mind while everything that cannot be measured because science considers it irrelevant or because the devices cannot capture it technically, is ignored and is therefore no longer part of the refiguration of the concept of mind. Technofutures thus refigure our idea of what is possible, refigure existing concepts (like mind but also intelligence in the context of A.I.) and construct expectations of the future.

FRAMEWORK TO ASSESS TECHNOFUTURES

As became apparent from the above examples, hermeneutic TA has different focal points. Defining a clear method that fits to all would necessarily reduce the complexity of the topic to an unintended degree. Rather than a strict set of rules, hermeneutic TA suggest an approach to technofutures to reflect on their role in the present. For this purpose, different methods, depending on the research question and the formats being analysed, become useful.

One promising structure for an assessment process builds up on the narrative hermeneutics of Ricoeur’s mimetic circle (Ricoeur 1984, p. 71; see Gransche 2015, p. 241). Ricoeur brings into focus the intertwining of the sociocultural fabric and narrative from three different perspectives. He writes:

> Hermeneutics (…) is concerned with reconstructing the entire arc of operations by which practical experience provides itself with works, authors, and readers. (…) What is at stake, therefore, is the concrete process by which the textual configuration mediates between the prefiguration of the practical field and its refiguration through the reception of the work. (Ricoeur 1984, p. 53)

This creates a holistic view that analyses technofutures by focussing on the three perspectives described above: (1) prefiguration, (2) configuration and (3) refiguration. These three perspectives create a circle (or rather a spiral with different altitudes), as the refiguration informs the prefiguration and one vision can become the basis for another. With a cultural studies approach to narrative analyses, Erll (2010) summarizes Ricoeur's circle as follows:

> A narrative text is (1) prefigured by its cultural context with its specific symbolic order. It (2) configures (…) extra-literary elements (…) into an exemplary temporal and causal order. In the act of reading, finally, the narrative composition is actualised. It becomes part of the symbolic order of a cultural formation, which is thereby (3) refigured and here the circle closes. (p. 93).

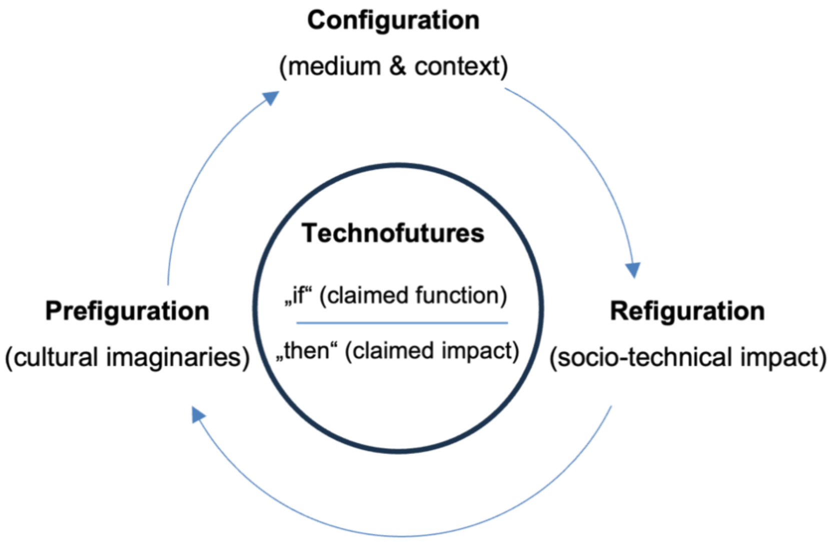

Figure 1. The Futures Circle Framework to hermeneutic TA based on Ricoeur's (1984) narrative hermeneutic

With regards to hermeneutic TA and the aforementioned characteristics of technofutures, Ricoeur's narrative hermeneutic allows us to assess the societal meaning of technologies, attributed within technofutures, by analysing the three perspectives in the following way:

(1) Prefiguration

The first perspective looks at the content of technofutures, how they are entangled in cultural presumptions and informed by socially shared imaginaries. This perspective also reflects on the expressed desires, hopes, fears and needs that are inscribed into the respective visions. It understands technofutures as ciphers and identifies the larger themes addressed as well normative statements made.

(2) Configuration

As technofutures come in different forms, e.g., scenarios, simulations, diagrams, trend-extrapolations, plans or pop-cultural artefacts, this perspective looks at the way they are constructed. This perspective reflects on the form (e.g., the role of the medium, the performance, the context in which it is embedded), the rhetoric (e.g., the language, narratives and verbal or visual metaphors used), as well as illustrative material (e.g. tables, pictures, movies or other pieces of art).

(3) Refiguration

Lastly, the third perspective focusses on the impact of technofutures and the way they change current discourses or change already established concepts. Although technofutures are always an expression of current states and processes, they have an impact on the present and shape these states and processes. This perspective includes, among others, the way that stakeholders position themselves towards the future but also how the technofuture impacts other discourses and is spread through society.

CONCLUSION

Technofutures are socially constructed narratives about the impact of a potential technology at a moment later than now. They are created at a time, when there is no sound information available on the claims made, thus rendering them as fictional or speculative expressions of how the world might change due to the impact of this technology. Although they are speculative in nature, they have an impact on the development of technologies as they forge alliances, give arguments for or against the technology, create hypes through which funding is stimulated, and many more. As technofutures are an important communicative element in the context of technological development, it becomes necessary for a conclusive Technology Assessment, to not only theoretically understand impact and role of technofutures on the development process, but also to have the empirical methods and structured approaches to analyse technofutures, their cultural context, their process of creation as well as their spreading through society.

This article offered a framework to structure a hermeneutical Technology Assessment process. It follows the heuristic of Paul Ricoeur's narrative hermeneutics and separates the analyses into three perspectives: (1) Prefiguration, looking at the cultural imaginaries inscribed into the Technofuture, (2) configuration, looking at the process of constructing the mediated technofuture, and (3) refiguration, looking at the socio-technical impact of the technofuture. This structure allows us to organise the process of hermeneutic TA and to deliberately consider the three different perspectives for a holistic analysis.

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Research article

A Philosophical Analysis of Moral Choices in the Game *The Witcher 3: Wild Hunt*

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Abstract

Initially, video games that emphasized morality either had a simple measure for the level of good and evil with an unambiguous interpretation provided by the developers, or else morality was built into the plot of the game where a morally "right" or "wrong" choice led to the corresponding ending. Some more recent games, however, present a more complex and ambiguous system of moral choices. This paper conducts a philosophical analysis of moral choices in the game *The Witcher 3: Wild Hunt* based on a study of 100 variants of story progression. The method adopted is to analyze the content of the choices presented to the player along the course of the main plot and the side quests. The paper will then attempt to isolate recurring elements and the variety of decisions possible in the game world. The analysis revealed that 25% of the quests offer a choice between salvation and destruction, with 15% of the quests having a strong impact on the main plot of the game. Family relationships matter in 32 % of the quests, influencing the decision-making. 40% of quests involve an ethical choice between personal good and the good of others. There is no simple logic that allows the player to predict the consequences of a particular choice. The main goal of this study is to highlight the diversity of ethical concepts reflected in game scenarios, which facilitates the discussion of moral issues and ethical dilemmas in both virtual and real worlds.

Keywords: Philosophy; Moral choice; The Witcher 3: Wild Hunt; Ethics in video games

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Научная статья

Философский анализ моральных выборов в игре “Ведьмак 3: Дикая Охота”

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Аннотация

Изначально видеоигры, в которых подчеркивалась мораль, либо имели простую систему измерения уровня добра и зла с однозначной трактовкой, предоставленной разработчиками, либо мораль была встроена в сюжет игры, где морально “правильный” или “неправильный” выбор приводит к соответствующему финалу. Однако некоторые более поздние игры представляют собой более сложную и неоднозначную систему морального выбора. В данной статье проводится философский анализ морального выбора в игре “Ведьмак 3: Дикая Охота” на основе исследования 100 вариантов развития сюжета. Принятый метод заключается в анализе содержания выбора, представленного игроку в ходе основного сюжета и побочных квестов. Затем в статье будет предпринята попытка выделить повторяющиеся элементы и разнообразие решений, возможных в игровом мире. Анализ показал, что 25% квестов предлагают выбор между спасением и разрушением, при этом 15% квестов оказывают сильное влияние на основной сюжет игры. Семейные отношения имеют значение в 32 % запросов, влияя на принятие решений. 40% квестов предполагают этический выбор между личным благом и благом других. Не существует простой логики, позволяющей игроку предсказать последствия того или иного выбора. Основная цель данного исследования – подчеркнуть разнообразие этических концепций, отраженных в игровых сценариях, что облегчает обсуждение моральных вопросов и этических дилемм как в виртуальном, так и в реальном мире.

Ключевые слова: Философия; Моральный выбор; Ведьмак 3: Дикая Охота; Этика в видеоиграх.

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INTRODUCTION

Video games, which were previously seen purely as entertainment, are now being created to be increasingly complex and deep, giving the players the opportunity to make moral decisions that affect the future plot of the game. This allows game developers to create worlds where players can make decisions that affect the characters and environment. Such games are called role-playing games, or RPG.

Role-playing games, as the name suggests, are built around the player taking on a role in the game world that allows for meaningful interaction and choices within the game world. These games leave the limits of what a character could do entirely in the hands of the player, provided that the actions taken are allowed in the game.

Game developers often use morality and ethics to control the situation and set limits. However, they are rather complex philosophical concepts. Generally, morality refers to "universal truths, societal rules or principles" or general guidelines on how to live and behave (Schrier, 2017). Wines (2008) defines morality as a code or set of principles that activate an individual's behavior, decisions, or actions. Tierney (1994) explains that ethics is "an individual's reaction to public morality in terms of reflexive involvement, evaluation and choice" (p. ix). Ethics may be considered as "the science that deals with the question of right and wrong in human behavior" (Meng et al., p. 134). Morality touches all areas of human life, and as such, all of them are potential fields for the study of morality and knowledge in games.

To examine the application of the above terms, we have taken as a case-study *The Witcher 3: Wild Hunt*, developed by CD Projekt Red studio. It is a popular fantasy role-playing game from 2015, in which the characters and setting are directly taken from the work of Polish writer Andrzej Sapkowski. In every *Witcher* game, the player takes control of an already formed character. This comes with certain limitations in terms of what actions are available to the player. The limits of what Geralt of Rivia, the game's protagonist, is willing to do are determined by his established sense of morality. Geralt is a witcher, a mutated monster slayer trained from childhood, traveling the world killing monsters in exchange for payment. He is unwilling to be unnecessarily cruel to innocents or betray those close to him, but he can be quite self-serving – or willing to allow injustice to happen so as not to get involved in conflict. Thus, the player is often given the decision – explicitly or implicitly – to simply stay out of it, even in situations where leaving would surely cost someone's life. While this is possible, the player can also take a more active role in events and intervene. This creates a sense of cooperation between Geralt and the player in terms of moral decision-making, as Geralt sets boundaries and the player moves within them. The narrative is told on behalf of Geralt, who is trying to find his adopted daughter Ciri and to unravel the mystery of the Wild Hunt. The game features a deep and morally complex story in which players will have to make difficult choices and face consequences that affect the world and its characters. *The Witcher 3* boasts a rich cast of memorable characters, each with their own unique story and motivation. This role-playing game is not only known for its visuals and engaging story, but also provides players with many difficult moral choices that force players to ponder philosophical questions of ethics and justice. It thus reflects Shafer‘s (2012) finding of a strong relationship between morally activated reasoning of players and moral choice.

In the following, we will take a brief look at the general theoretical underpinnings of moral choices in video games, and give examples from different games, before coming back to *The Witcher*.

MORAL CHOICES IN ROLE-PLAYING GAMES

We should begin with what a moral choice is. Such a choice is the act of overcoming internal conflict. If there is no conflict, it is not a moral choice, but a decision. Choice always requires that there be at least two options to choose from. It is important to realize that choices are different from actions, reactions, and calculations. For example, breathing and blinking are actions, not choices or reactions. Quickly jerking our hand away when we touch something hot or catch a falling phone would be a reaction, while a calculation is a decision made based on reason and logic.

Videogames can create a large number of variants of story progression, depending on players' choices, and sometimes these choices can have more than just consequences in the storyline. Virtual worlds of computer games differ significantly from the real world. Even physical laws and social norms can be violated there (Bylieva, 2023). Ethically unacceptable actions such as murder, theft, etc. are frequently among game strategies. At the same time, in some cases, the logic of the game takes into account the moral choice of the heroes.

Moral choices that are made in a game activate the same areas of the brain as in everyday life. Vaal and a number of other evolutionary ethicists have argued that morality is an innate property of humans. Evidently, video games cannot negatively affect these facts. Thus, the design of moral dilemma situations and choices in video games is predicted to improve. This means that games will be able to build on existing moral qualities, and possibly improve them. At the moment we have only a few such video games, but this is one future format of computer games (Piskunova & Krutko, 2017).

Moral models in video games tend to be rather shallow. The most common method is a simple axiom by which “good” actions promote and “evil” actions diminish the player's moral rating. This game mechanism first appeared in *Ultima IV* (publisher: Origin Systems, 1985) which “attempts to make the player feel personally invested or responsible for the decisions they make” (Zagal, 2009, p. 4). It was widely adopted, e.g., in *Star Wars: Knights of the Old Republic* (Bioware, 2003), *Fallout 3* (Bethesda, 2007), the *inFamous* series (Sucker Punch, 2009-2014), *Fallout: New Vegas* (Obsidian, 2010), and *the Mass Effect series* (BioWare, 2007-2012)). It is a simple binary model, but nonetheless problematic. Such a reduced approach (called ‘morality meters’) does not allow for the creation of a realistic scenario and system since in reality there is no single "correct" moral system that can be used to make decisions. Thus, players may have different assessments of the morality of actions, and in general consider the linear calculation untenable, as Melenson (2011) remarks, objecting to an 'omniscient axis [and] transparent proxy for developer opinions' (p. 67). Another question arises regarding the comparability of the morality of different actions on the same scale, for example in *Fallout 3* one can "compensate for mass murder by heaping water bottles on beggars" (Formosa et al., 2016, p. 220). Sicart (2013) remarks that such "ethical cognitive friction introduces tension between procedural and semiotic levels and potentially generates moral reflection" (p. 94). Researchers think that the consequences of such an unbalanced moral system include the moral disengagement of the players when they feel limited by the choices available to them or when they see no consequences of their in-game choices (Formosa et al. 2022; Iten et al., 2018).

The narrative level of the game presupposes the immediate consequences of choosing a certain action or course of action, and the systemic level involves earning points at a certain interface. The second option is evaluative, with the role of the game designer as a "divine judge." The first narrative option is deterministic, has cause-and-effect relationships and leads to certain consequences. And yet, seemingly non-deterministic narrative-based decision trees in games are often articulated according to a binary good/evil moral system (Sicart, 2010). In later games, the line between "evil" and "good" choices started to be presented as more and more blurred, confronting players with much more complex ethical problems for which there is no unambiguous "positive" answer. The resulting ambiguity in assessing a player's choice is compensated in a number of games by the ability to see the statistics of the choices of other players (creating something like a statistical ethical system). Thus, games provide good material for research. Much data-driven empirical research is based on surveys of some players' opinions and the gaming choices they made (e.g., Formosa et al., 2022; Hartmann & Vorderer, 2010; Holl et al., 2020; Klimmt et al., 2006; Weaver & Lewis, 2012).

It is often quite difficult to integrate in a natural manner the moral system and the plot of a game, however, there are a variety of original concepts. Moral choices can influence the appearance of an avatar. Thus, in the game *Black & White* (Lionhead Studios, 2001), the skin of an animal incarnation will lighten if it helps local residents. The character's appearance changes most radically depending on the events of life in the *Fable* series (Lionhead Studios, 2004-2010). In this game, "karma" became more than just a number in stats or a modifier in dialogue. One can see it with one's own eyes once the heroes receive a halo and begin to emit light, and the villains grow small horns. The choice can also affect the ending of the game. For example, decisions made to kill or not kill monsters affect the conclusion of the game *Undertale* (Toby Fox, 2015) in an unexpected way - considering that usually in games the killing of monsters is definitely morally positive. In contrast, in the role of an ordinary customs officer players face increasingly complex moral choices, and there is no reward or punishment for them in *Papers, Please* (Lucas Pope, 2013). All 20 existing endings happen as the consequences of too dangerous actions (failed to defuse a bomb – died, touched poison – died, did not break the rules on the orders of the boss – imprisoned, took a bribe – imprisoned, helped the opposition – died or imprisoned, etc.). Formosa et al. (2016) employ the *Four component model* of moral expertise (moral motivation, moral sensitivity, moral judgment, and moral action) for analyzing *Papers, Please*.

In the world of video games there is a unique opportunity to explore philosophical aspects of human nature and morality, and one of the most obvious and interesting illustrations of this phenomenon is the game we will consider in depth, *The Witcher 3: Wild Hunt*. Of particular interest in the organization of the game is the moral system: both because it is executed very thoroughly (the creators paid a lot of attention to it), and because the choices in the game are very numerous, do not fit into a simple system, and require special research.

MORAL MECHANICS IN THE WITCHER 3

A key feature of the moral mechanics in *The Witcher 3: Wild Hunt* is a significant emphasis on the consequences of a hero's choices. These consequences extend to ordinary NPCs (minor characters), to the main characters, and to the configuration of the entire world of the game. Accordingly, choices can have an impact within the story of a single, self-contained quest, but also on other quests, and on the outcome (epilogue) of the game’s main plotline. Already in the first two entries in the series (2007 and 2011), three features (rarely seen in other games) of this type clearly stood out. First, the player can be presented with a decision-making scenario in a situation of incomplete knowledge. Secondly, the outcome of a choice is not obvious or immediate – even going as far as an actual deception or the subversion of expectations in a number of cases. And, thirdly, the game features acute dilemmas, including those affecting gameplay possibilities (within the game world, these are often “life and death” choices, not to mention the fact that their themes deal with violence, abuse of power, various forms of discrimination, etc.). In addition, following one of the main lines of Sapkowski's saga, the authors of the game invariably show both the protagonist's desire to avoid choosing sides and Geralt's inability to remain on the sidelines due to decency and honor, due to friendship and love bonds.

Time after time, the creators emphasize the absence of models of fixed justice, thus depriving the player and his hero of claims to the image of a knight in shining armor. Grey morality or the need to choose between two evils – this is the paradigm of the game's challenges that appeal to morality. In general, *The Witcher 3* is perhaps the best example of how moral issues in the game are built not on the usual models (such as “blind following,” “fixed justice,” and “accumulation of deeds”), but on a complex combination of the player's freedom of decision and the need to play a role. The witcher cannot become anyone, so the gamer is forced to play out (albeit in his own way) a given role in two senses: both by virtue of the boundaries already set by Geralt's character, and by virtue of plot constraints (unlike most modern RPGs, there are here no 2 or 3 ways to complete the same quest). All this allows us to refer the moral gameplay of *The Witcher 3* to a model with an emergent moral system.

In *The Witcher 3: Wild Hunt* players are given the unique opportunity to face a variety of moral dilemmas that bring a deep element of philosophical analysis to gameplay. A few specific examples of such moral choices should be considered.

The quest "Saving Souls" is a great example of the moral choices that characterize the game series. In this quest, Geralt finds a group of witches who have placed a curse on themselves. This curse can be broken, but it requires sacrifice. Geralt must decide whether to save these souls, by sacrificing something important, or to seek something to gain by betraying them. Choosing to save souls involves prioritizing ethics and compassion over personal gain. Geralt shows mercy by helping the witches rid themselves of the curse, even if it doesn't directly benefit him. Indeed, betraying the witches may give Geralt some benefit, such as financial reward or the chance to avoid certain risks. However, this decision calls into question his morals and integrity. The game may offer options that allow you to balance between these two extremes. For example, Geralt can try to find a way to minimize his losses without completely betraying the witches, or he can try to negotiate a compromise.

The "Bloody Baron and family drama" quest presents another one of the most memorable and morally challenging dilemmas in the game. It revolves around Philip Stranger, known as the Bloody Baron, and his family problems. In this quest, Geralt first learns the history of the Baron and his family, which includes the disappearance of the Baron's wife and daughter. As Geralt investigates, he learns about the family's tragic secrets, including the Baron's alcoholism, his penchant for domestic violence, and the effects of his actions on the family. So, the moral scenario for Geralt to operate in now includes:

1. The fate of the Baron's family. Geralt must decide whether to help the Bloody Baron reunite with his family. This choice presents Geralt with a dilemma: on the one hand, the desire to help the man reform and restore his family, on the other hand, the realization that the Baron was a rapist, and his family may no longer wish to associate with him.

2. Attitudes toward the Baron. How to treat the Baron – with sympathy, understanding his complex personal history, or with contempt, condemning his past actions? This decision affects not only the Baron's fate, but also Geralt's own moral image. The game offers different options for the development of events depending on Geralt's choices. He can actively help the Baron in his search for his family, be more passive or even hostile. Each choice has its own consequences and reflects Geralt's moral principles.

There may be moments in the quest when Geralt discusses with the Baron or other characters the moral aspects of the situation. For example, Geralt may give his opinion on the Baron's past, his actions, and the possibility of redemption.

As the story progresses, the player will also have to make decisions about the fate of the witch Keira Metz, decisions that can have profound moral implications. These examples illustrate how *The Witcher 3* provides players with many complex moral dilemmas that actively influence gameplay and force players to consider philosophical questions of ethics, justice, and the consequences of their actions in the game's virtual world. It is now time to turn to the consideration of some specific storytelling and gameplay elements that characterize the game's moral choices.

1. *Dialog choices*. In an analysis of the quests in the game, it was found that in approximately 35% of cases the player's dialog choices affect the plot of the game. This indicates a significant influence of the player's decisions on the development of the final events.

Here is an example of dialogs from the quest “Bloody Baron and family drama”:

- Geralt: “You can try to improve, but it won't change the past.”
- Baron: “I know. But I want to save my family, I want my daughter to know I'm not just a monster.”

Geralt's selection:

a. To help the Baron find his family.

b. Refuse help, believing that his past actions do not deserve forgiveness.

2. *Impact on the world.* The analysis shows that about 24% of the quests have no direct impact on the world of the game, which emphasizes the diversity of game scenarios and the player's ability to choose less meaningful quests.

3. *Family relationships*. The analysis notes that family relationships are an important element in about 32% of the quests. This demonstrates the depth of the plot and relationships between characters. Family relationships are a factor that may have a destructive effect on any moral system, making the result of choices uncertain.

We can see that, f. e., in the quest “In Ciri's Footsteps,” where we have an internal monologue of Geralt:

- Geralt (thinking): “Ciri as a daughter... We need to find her before the Wild Hunt does.”

This dialog emphasizes Geralt's emotional connection to Ciri, influencing his decisions and motivation in the game.

4. *Impact on other quests*. About 32% of quests have an impact on other quests, emphasizing the complexity and interconnectedness of the storylines in the game.

Quest: Blood Ties.

Example Dialogue:

- Geralt: “Your actions in Novigrad could lead to war.”
- Werner: “It's a big game, Geralt. Some sacrifices are inevitable.”

This choice can influence subsequent political events and story quests in the game.

5. *Political decisions.* The analysis showed that political decisions mattered in 26% of the quests, indicating the complexity of the moral and political dilemmas faced by the player.

Quest: “Imperial Audience.” Example Dialogue:

- Anna-Henrietta: “You must choose sides in this war, Geralt.”

- Geralt: “Witchers try to remain neutral. But sometimes the choice is unavoidable.”

This dialog underscores the complexity of the political decisions Geralt faces.

In *The Witcher 3* each quest is a unique journey into a world of moral dilemmas and emotional decisions. For example, in the quest “Twisted Firestarter,” where about 60% of players choose to help an arsonist, we see the emotional toll and moral choices that affect the characters' fate and relationships. This is one of many quests where players have to choose between good and evil, sometimes without a clear understanding of the consequences of their decisions. Let's break this quest down in more detail. In this fictional quest, Geralt arrives in a small town where the locals accuse a certain alchemist of using forbidden magic, leading to a series of fires. The alchemist, in turn, claims that his research can help fight the local drought, and that the fires are the work of someone else.

Moral Choice:

a. Justify the alchemist. Geralt may decide that the alchemist is innocent, and his research can be of benefit. This choice involves defending science and progress, even if society doesn't understand them.

b. Condemn the alchemist. Geralt may believe that the alchemist's experiments are too dangerous and should be stopped, even if he is innocent of arson. This choice reflects the side of caution and protecting society from potential threats.

Depending on Geralt's decision, the quest can develop differently. If he protects the alchemist, he must find the real arsonist, which may lead to unexpected discoveries. If Geralt decides to stop the alchemist, this could lead to the loss of potentially important scientific knowledge.

Example Dialogue:

- Alchemist: “My research can help everyone! These fires are not my fault!”

- Geralt: “Even if you're not guilty of arson, your experiments could be dangerous. Or are you sure you can control the forces you experiment with?”

In the “Missing Person” quest, where the player decides the fate of a missing person, about 40% face a difficult ethical choice between personal good and the good of others.

Geralt meets a man named Duncan, who asks him to find his brother, Bram, who disappeared during the Griffin raid on the village. Bram was taken prisoner during the attack and was last seen in the forest surrounded by wolves.

Geralt follows the tracks that lead him to the place where Bram is hiding from the wolves. He must either kill the wolves to save Bram or use his skills to distract them and save the man without spilling blood.

Moral Choice:

a. Saving Bram. Geralt must decide how to save Bram. He can choose a more aggressive approach, killing the wolves, or a more peaceful approach, trying to save Bram without violence. This choice reflects Geralt's attitude toward violence and its effect on the world.

b. Further Decision. After rescuing Bram, Geralt is faced with another choice. Bram wishes to return to the village, but fears he will not be welcomed there because might be accused of cowardice and leaving his fellow villagers in distress. Geralt can advise Bram to return and try to rebuild his reputation or stay in the refuge to avoid potential problems.

Example Dialogue:

- Bram: "I'm afraid to go back. They'll say I'm a coward and left them to their fate."

- Geralt:

(If advised to return): "You saved your life, and now you can help others. Go back and prove that you are not a coward."

(If advised to stay): "The world is harsh. Sometimes it's better to stay in the shadows than face injustice."

At the same time, many quests, such as "On Death's Bed," have a significant emotional impact, touching on themes of loyalty and betrayal. In this quest, about 70% of players are faced with a decision that can dramatically alter relationships with key characters and affect the course of the main plot. Moral dilemmas, affecting about 50% of quests, often involve choices between lesser and greater evil, good and evil, and between Geralt's personal interests and the good of other characters. These difficult moral decisions heighten the emotional impact of the game and make each player choice memorable. The quest "On Death's Bed" is one of the quests available in the White Garden, the game's starting location. This quest involves a moral choice that presents the player with a dilemma between personal gain and an act of mercy. The protagonist meets a woman named Lena who is seriously injured by a poisoned monster. The only medicine that can save her is the Potion of the Winding Meadow, a rare herb that is not easy to find. Geralt must find this herb, which requires exploring the surrounding area. He can use his skills as a pathfinder to find and gather the rare herb.

Moral Choice:

a. Save Lena. Geralt can choose to use the potion he found to save Lena. This demonstrates compassion and mercy as he forgoes personal gain to save another's life.

b. Sell or Keep the Potion. Geralt may instead decide to sell the potion or keep it for himself. This decision is based on practicality and personal gain, but it calls into question his moral principles.

- Tamia, the local herbalist: "Only the Potion of the Winding Meadow can save her. But it's a rare herb, Geralt."

- Geralt:(If decides to help): "I'll find the potion. Every life is precious."

- (If decides to sell/save): "The potion could be of use to me. There is no mercy in these lands."

These examples emphasize how *The Witcher 3* challenges players to make difficult moral choices that affect their perception of the game world and the development of the story. Each decision made in these quests not only shapes the experience of the game, but also evokes deep emotional reactions, making each player's choice memorable.

Let's break down the key quests that affect the player's moral choices.

"Missing in Action": In this quest, the player is faced with a moral choice that can seriously affect the course of the story. About 40% of the players are faced with a difficult ethical dilemma, choosing between their own interests and the good of society. For example, a player will have to decide whether to help save the life of a missing person, risking their own safety, or leave them to fend for themselves. This choice can lead to different consequences in the game and demonstrates the complexity of moral dilemmas in the game world.

Figure 1. Moral choices in the *Ladies of the Wood* quest

"Return to Crookback Bog": This quest revolves around helping the Bloody Baron get his wife back from Kron. It is an optional quest, the outcome of which depends on the choices made in the "Whispering Hill" quest. The Baron and Geralt encounter some monsters and a beast in the swamp. The outcome varies depending on the decision to free or kill the spirit of the forest, which affects the fate of Anna, the Baron's wife, the Baron's reaction and the direction of the game's plot. Salvation is the key element here, which is typical of about 25% of quests. The quest has no impact on the world and is not tied to political decisions, allowing the focus to be exclusively on the player's personal choices.

"Wild at Heart": In this quest the players meet Niellen, a hunter from Blackbough, who is looking for his missing wife Hanna. Geralt decides to help Niellen and begins to investigate. During the investigation, Geralt discovers that Niellen is actually a werewolf, and his wife disappeared after finding out about it. The player is faced with a moral choice: hide the truth about his wife's fate from Niellen, or reveal everything to him, leading to his transformation into a werewolf and a possible fight with him. This quest illustrates a recurring theme of moral dilemmas in *The Witcher 3*, where the player's decisions often carry serious consequences and affect the game's plot. Salvation plays a key role here, which is seen in 15% of the quests. The strong impact on the world and the lack of importance of family relationships indicate the complexity of the moral decisions faced by the player.

“A Towerful of Mice”: In the Mice Tower quest, Geralt is tasked with helping Keira Metz break the curse on Fyke Isle and its tower. While investigating, Geralt discovers the history of the tragedy that occurred on the island. A curse was placed on the tower after a local lord killed his subjects, fearing they had contracted the plague. Among those killed was his daughter Anabelle, who fell in love with a local alchemist. She became a ghost, cursing the tower.

Geralt is faced with a moral choice: help Anabelle's spirit leave the tower by carrying her bones to her lover, or leave her there. Depending on Geralt's decision, the outcome of the quest will vary. If Geralt decides to help Anabelle, she is reunited with her lover, but ends up killing him, after which the curse is lifted from the island. If Geralt decides not to help her, the curse remains. Here the player is encouraged to save (20% of quests), with dialog choices affecting the story. Family relationships are important, but world impact is not applicable. This quest exemplifies moral dilemmas in the game, where the player's choices can have significant consequences for the story and characters.

“Ghosts of the Past”: During this quest, Geralt meets Letho from the School of the Serpent, a former witcher who played an important role in the previous game. This quest is only available if the player chose to let Leto live in *The Witcher 2* or indicated that he was alive during a visit to the Nilfgaardian Palace. In this quest, Geralt helps Leto deal with the dangers that threaten him. The player will have to make an important choice regarding Letho's fate: help him or betray him. This quest exemplifies the theme of the consequences of choices, where decisions made by the player affect the plot and relationships with characters. This quest has a neutral impact on the world (15% of quests) and no impact on other quests, which is unique to the 10% of quests.

“Blood Ties”: with a focus on salvation has an impact on other quests 10% of the time, although family relationships and moral dilemmas are not key aspects. In this quest Geralt helps a Nilfgaardian woman find her son who has gone missing in the war. He investigates the clues using his witcher senses and discovers that the son tried to desert and was killed. Geralt can tell the woman the truth about his son's death or lie. Regardless of his choice, she thanks him and rewards him with a small reward. This quest emphasizes the theme of moral dilemmas in the game involving war and family relationships.

“Last Wish”: This quest presents the choice of salvation which will affect the plot. While having a strong impact on the world, it will not have an important impact on other quests (occurs 15% of the time). Geralt helps Yennefer in her quest to find a genie in order to break the magical bond between them. Yennefer wants to make sure that their feelings for each other come from their own hearts and not because of a magical source. Geralt and Yennefer travel to the island of Skellige, where they search for the genie. In the course of the quest, Geralt is faced with a moral choice: support Yennefer in her quest to sort out their relationship or refuse to do so. The quest is important to the romantic storyline between Geralt and Yennefer, as it determines whether or not their romantic connection will continue. It is one of the key moments in the game, emphasizing the importance of the choice and its impact on character and plot development.

"Pyres of Novigrad": This one presents a choice of destruction that affects the plot and has a strong impact on the world (found 15% of the time). "Pyres of Novigrad" is the key quest in Novigrad, where Geralt is searching for Ciri. During the quest, Geralt is confronted with the horrifying reality of the persecution of mages and other magical beings by the Church of Eternal Fire and the Witch Hunters. Geralt seeks help from Triss Merigold, who is also hiding from the Witch Hunters. During the quest, Geralt helps Triss rescue some of the mages, which emphasizes the theme of choice and consequences in the game, especially in regards to relationships with key characters and the political aspects of The Witcher's world.

"A Matter of Life and Death": It is a quest with a neutral impact, affecting other quests and having a weak impact on the world (occurs 8% of the time). In this quest Geralt assists Triss Merigold in rescuing mages from Novigrad who are being pursued by the Witch Hunters. The quest begins in Novigrad and is important to the development of the romantic storyline with Triss. Geralt must infiltrate the Masquerade Ball to help Triss find and rescue Albert, a young mage who is being pursued by the Witch Hunters. The quest provides the player with a number of moral choices, such as deciding whether to assist Triss in the mage rescue, which may involve deception and confrontation with the Witch Hunters. Also, depending on the player's actions and interactions with Triss, the quest may affect Geralt's romantic relationship. This quest exemplifies the themes of choice and consequence that characterize *The Witcher 3*, where the player's decisions affect the fate of the characters and the course of the story.

"A Deadly Plot": This presents a salvation choice that does not affect the plot or family relationships, having little impact on the world (occurs 7% of the time). In this quest Geralt conspires with Dijkstra and Vernon Roche to assassinate King Radovid. The quest begins after completing the quests "Count Reuven's Treasure" and "Now or Never." During the quest, Geralt meets with the conspirators to discuss the plan and then follows the trail to find a missing spy, who turns out to be Thaler. The quest has a significant impact on the game's ending and allows the player to decide on their involvement in the political events of the game. After completing the "A Deadly Plot" quest, the next significant quest is "Reason of State." In this quest, Dijkstra offers Geralt to participate in an assassination attempt on King Radovid. An important point in this quest is Dijkstra's suggestion to kill Vernon Roche and his allies in order to seize power in the Northern Kingdoms himself. The player will have to make a difficult moral choice: support Dijkstra and betray Roche, or protect Roche, which will result in Dijkstra's death. This choice affects the political balance of power in the Northern Kingdoms and the outcome of the game. This moment emphasizes a recurring theme of *The Witcher 3*, where the player's decisions have long-term consequences for the game's world and its characters.

Thus, we can conclude that there are many moral choices in the game, from those that are fairly easily resolved to those that cause serious internal conflict. In some cases a player has to choose between a lesser and a greater evil. Popular conflicts are between self-interest and helping others, as well as between duty and family/friendship ties. At the same time, there is no simple logic that allows the player to predict the consequences of a particular choice. So, the consequences of some actions are insignificant, others affect the plot, and others affect the entire game world.

CONCLUSION

In the context of an article exploring the philosophical aspects of moral choices in a game, it is important to note how these choices reflect basic ethical concepts. For example, various quests may provide the player with opportunities to balance the consequences of their actions with principles such as justice, compassion, or selfishness. In addition, the importance of family relationships and their influence on the player's decisions emphasize the importance of ethical dimensions in moral choices.

The analysis of quests in the game reveals the variety of ethical dilemmas that the player faces, emphasizing the importance of aspects such as the consequences of actions, values that can be contrasted, and the influence of personal relationships on decisions. All of this helps the player to explore and understand the ethical dimensions of their actions and their impact on the virtual world of the game, and can provoke discussion of morality and ethics in the real world.

These and other examples of moral choices in *The Witcher 3: Wild Hunt* illustrate how games can become a platform for philosophical reflection. They force players to not only make decisions, but also to weigh the consequences and reflect on important moral principles, ethics, and justice. As a result, this game not only offers entertainment, but also encourages players to think about complex philosophical questions, making it a unique work in the world of video games.

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