EXCELLENCE CLUSTER TOPOI

PROJEKTBERICHT | RESEARCH REPORT

RESEARCH GROUP (E-II) EPISTEMOLOGY OF SPACE

HISTORICAL EPISTEMOLOGY OF SPACE

Research results of the period from
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Description of research question, approach and results

Research question

What role was played by experience in the genesis and long-term development of spatial concepts, and what was the impact of such concepts on the subsequent acquisition of spatial empirical knowledge?

Research methodology and approach

The project utilizes a broad concept of experience, one which extends from interactions between biological organisms and their environments all the way to the systematic production of knowledge by means of the complex experimental systems of modern sciences. Traditionally, experiential spaces that are distinguishable in this context have been investigated by a variety of disciplines, including developmental psychology, cognitive anthropology, cognitive linguistics, ethnology, archaeology, and the history of science and technology. In the framework of this project, these various disciplines are coordinated with one another with regard to their research potentials and results related to the historical development of spatial cognition. In order to integrate the relevant subject-specific research results, our group has elaborated a joint theoretical framework which defines the subprojects and correlates them with one another. This entails the development of a specialized terminology for the description of space and knowledge. We distinguish between the following spaces of experience: (1) The immediate experiential space of the individual in the process of ontogenesis is the proximal environment, within which he/she moves and acts with objects and also interacts with other individuals. (2) The space of movement of a society is the natural and man-made local environment within which individuals or specific groups of individuals move. This space can be relatively extensive even for non-literate societies, as exemplified by certain Micronesian societies which are distributed across widely separated islands. The society's space of movement may also transcend the spatial boundaries of the inhabited territory, for example in cases of military campaigns, expeditions, or voyages of discovery, which do not correspond to a stable extension of this territory. (3) The organized space of a society is the territory which is politically controlled and economically administered. (4) Cosmological space is the entire universe known, or assumed to exist, by a given society. (5) Technical-experimental space is the space accessible to a society by means of technical devices and systematic experimentation. We further distinguish between a variety of forms of knowledge, including anthropomorphic, instrumental, mathematical, and theoretical types.

Results

The project has shown, by way of exemplary cases treated in the subprojects, that it is possible to identify the experiential sources that were instrumental in the construction of cognitive structures of spatial thinking under different historical and cultural conditions. The relations between the spatial experiences and cognitive structures relevant for the studied cases suggest a logic of development according to which originally contingent historical developments turn into necessary preconditions for later cognitive developments. (An introductory account on the historical epistemology of space is provided in chapter 1 of the group's joint publication: Matthias Schemmel [ed.], *Spatial Thinking and External Representation: Towards a Historical Epistemology of Space.* Pre-print Series Max Planck Institute for the History of Sciences, Berlin: MPIWG Edition Open Access, 2014).

The biological evolution of spatial cognition has brought about pre-cultural spatial abilities such as object permanence and cognitive mapping skills which humans share with other animal species, in particular some non-human primate species. By studying spatial language and practice in two recent non-literate societies, Eipo and Dene Chipewyan, it could be shown that cultural systems of spatial orientation that have developed independently from one another build upon the same natural conditions of spatial thinking. Although language and practice in the two cultures are highly adapted to the respective ecologies and display huge disparities, they further share a general dependency of their spatial terminology on concrete practical contexts and an absence of material means with the exclusive purpose of the intellectual control of space. (The results of this subproject will be published in chapter 2 of *Spatial Thinking and External Representation*.)

Mesopotamian proto-cuneiform and cuneiform clay tablets dating from the era of the invention of writing (around 3200 BC) to the development of Babylonian mathematics in the Old Babylonian period (around 1900–1600 BC) document the impact of notation systems. It has been shown that the emergence of a new type of spatial cognition, differing considerably from the type found in non-literate cultures and developing into an esoteric art of formulating complex geometrical problems and solving them using sophisticated arithmetical tools which are applied to geometrical intuition, resulted primarily from the growing knowledge of surveyors and from scholarly reflections on their practices. By studying the arithmetical operations of Babylonian mathematics, it has been demonstrated that their ›non-Euclidian‹ peculiarities such as the neglect of the role of angles resulted from the surveying practices which they reflect. (The results of this subproject will be published in chapter 3 of *Spatial Thinking and External Representation*.)

A further type of spatial knowledge is characterized by explicit definitions and by inferences in written form. While the origin of this type of knowledge is usually uniquely ascribed to ancient Greek culture, it has been shown that similar developments occurred independently in ancient China, as is documented in the so-called Mohist Canon, written around 300 BC. (The results of this subproject will be published in chapter 4 of *Spatial Thinking and External Representation*.)

Despite these similarities, the European and Chinese knowledge systems developed differently so that the transmission of European scientific knowledge to 17th century China remained a challenge. A specific result of the group's research is the marginalization of deductive structure in the processes of translation and reception (Matthias Schemmel, "The Transmission of Scientific Knowledge from Europe to China in the Early Modern Period", in: Jürgen Renn [ed.], *The Globalization of Knowledge in History,* Edition Open Access 2012). The close interconnectedness between the cosmological hypotheses of a spherical earth and the transfer of celestial to terrestrial coordinates in the European tradition suggests that a further difference of the Chinese knowledge system plays a role in explaining the absence of spherical terrestrial coordinates in Chinese cartography. The difference consists in different relations between geographical, astronomical, and cosmological bodies of knowledge. This result has still to be corroborated by further research (chapter 5 of *Spatial Thinking and External Representation*.) At the same time, the relations between different bodies of knowledge were everything but monolithic in the European case, as the diverging argumentative strategies for geocentrism in Aristotle and Ptolemy illustrate (Irina Tupikova, Irina and Pietro Daniel Omodeo, *Aristotle and Ptolemy on Geocentrism: Diverging Argumentative Strategies and Epistemologies*, TOPOI – Towards a Historical Epistemology of Space, Preprint Series Max-Planck-Institute for the History of Sciences 422, Berlin 2012).

Experience plays a complex role in the early modern transformation of spatial concepts. While Copernicus' heliocentrism was not immediately corroborated by direct observation, experience did play a role in the long process of its establishment (Matthias Schemmel, "Wie entstehen neue Weltbilder? Die Herausforderung der Kosmologie durch die Erfindung des Teleskops". In: Jürgen Renn, Matteo Valleriani, and Jakob Staude [eds.], *Galilei und die Anderen. Hintergründe einer Revolution der Astronomie, Sterne und Weltraum: Dossier* 2009/1, 52–62.). An example is the knowledge reflected in the cometary pamphlets, which often do not explicitly discuss the heliocentric hypothesis but still document a gradual "Copernicanization" also of the non-scientific or not highly academic discourses (dissertation project). New discursive contexts informed by practical experience and systematic experimentation also propelled the development of concepts of motion and velocity, closely related to that of space. This can, in particular, be observed in early modern interpretations of medieval diagrams employed in the context of the investigation of the motion of fall (Matthias Schemmel, "Medieval Representations of Change and Their Early Modern Application." In: *Foundations of Science* 19/1 [2014], 11–34).

Early modern science was, in its first phase, confronted with almost irreconcilable problems concerning the internal structure of the newly developed theories. On the one hand, the basis of experiences of the growing empiricism was still by far too small for successfully constructing a theoretical framework that due to its explanatory power could be generally accepted as a theoretical basis for generating hypotheses and validating them by interpreting empirical results. On the other hand, the pretense to be able to compete against the universal explanations of the Aristotelian tradition made comprehensive theoretical systems with a comparable claim of validity an inevitable necessity. In this context, Newtonian mechanics emerged from a reflective abstraction on the integration of the empirically informed fields of terrestrial and celestial mechanics. Nevertheless, this conception was not altogether convincing, allowing the debate about space and matter to continue as Kant's solution to the problem, which departed from atomism altogether, proposing an early version of matter as the appearance of repulsive and attractive forces, illustrates. (The results of this subproject will be published in chapter 6 of *Spatial Thinking and External Representation*.)

The conceptual break of the concept of space of modern physics was mainly brought about by a reorganization of the knowledge of classical physics in the relativity revolution, not by new empirical insights (Jürgen Renn, and Matthias Schemmel, "Theories of gravitation in the twilight of classical physics." In: Christoph Lehner, Jürgen Renn, and Matthias Schemmel [eds.], *Einstein and the Changing Worldviews of Physics*. Boston: Birkhäuser, 2012, 3–22). An example is Einstein's use of the equivalence principle, which may entirely be formulated within classical physics and which, when considering an approximate coordinate transformation to an accelerated frame, led him to interpret gravitation in terms of spacetime curvature (Alexander Blum, Jürgen Renn, Donald Salisbury, Matthias Schemmel, and Kurt Sundermeyer, "1912: a turning point on Einstein's way to general relativity." In: *Annalen der Physik* 524 [2012] 1, A11–A13). While it is generally appreciated that relativity theory revolutionized our understanding of space and time, and that quantum theory revolutionized our understanding of matter and radiation, the subproject on the overlapping worlds of general relativity and quantum theory focused on complementary developments. It turned out that historically these questions were discussed from the earliest periods of development of the two theories, including in particular the question of the relationship between the two. (The results of this subproject will be published in chapter 7 of *Spatial Thinking and External Representation*.)