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Plenary Agenda Report for Research Group E-II

Space as Transformed in the History of Science

Historical Epistemology of Space: Experience and Theoretical Reflection in the Historical Development of Spatial Knowledge (Junior Research Group)

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Abstract: (a) *Topics and Goals.* The topic of this project is the historical development of fundamental structures of spatial thinking in long-range perspectives. The material under investigation extends from – still effectual – definitions of spatial concepts dating from antiquity to their transformation in post-antique technological and scientific traditions, and all the way to the most recent upheavals in our conceptions of space occurring in contemporary physics. Our focus is the question: What role was played by experience in the genesis and development of spatial concepts, and what was the impact of such concepts on the subsequent acquisition of empirical knowledge? This reciprocal interplay is being investigated through individual studies on spatial thinking during various historical periods and in various cultures. A central objective of this project is to bring to light the interrelationships between a variety of instances of spatial thinking; this involves calling attention to common structures of knowledge; grasping the genesis of new concepts as the results of transformative processes; and investigating the dependency of knowledge formation upon cultural preconditions; and hence advancing our understanding of the historical development of spatial knowledge, and in particular of the scientific knowledge of space.

(b) *Methods.* This 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 is designed to define the individual research activities and correlate 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. These distinctions are applied in the research fields characterized above.

(c) *Current State of Discussion.* One essential result of this research is the insight that the development of spatial knowledge is intimately bound up with external representations of knowledge, such as coordinated action; orienting landmarks; the lexical and grammatical structures of written and spoken language as expressing spatial relations; instruments of measurement and navigation; geographic maps; and geometric formalisms – from those embodied in Euclid's *Elements* to the field equations used in the general theory of relativity. The analysis of external representations makes possible an understanding of the long-term development of knowledge structures in terms of socially shared mental models. External representations of knowledge serve to communicate and transmit knowledge from one generation to the next, and from one culture to another. In other words: the analysis of these representations is the central method of this project in its investigation of the social reproduction of knowledge. This perspective is being further developed in the course of the group's studies on the dynamic relation between experience and cognitive structures in various historical epochs and cultures. Currently in preparation is a joint publication entitled »Spatial Thinking and External Representation«, in which the research results of the group will be assembled and related to one another.

Projects:

- »Spatial Concepts in Non-Literate Societies: Language and Practices in Eipo and Dene Chipewyan« (Wulf Schievehövel, Martin Thiering)
- »The Impact of Notation Systems: From the Practical Knowledge of Surveyors to Babylonian Geometry« (Peter Damerow)
- »Writing and Reflection on Elementary Actions and Professional Practices: The Chinese *Mohist Canon* and Its Counterparts in Greek Science« (William Boltz, Matthias Schemmel)
- »The Impact of Geographical Knowledge on the Generalization of Spatial Concepts« (Peter Damerow, Matthias Schemmel, Irina Tupikova)
- »The Transformation of Ancient Spatial Knowledge through Intercultural Transfer: The Early Modern Translation of Euclid's *Elements* into Chinese« (Jens Braarvig, Peter Damerow, Matthias Schemmel, Tian Miao)
- »The Impenetrability of Matter: Space and Matter in Early Modern Science« (Peter Damerow, Jürgen Renn, Matthias Schemmel)
- »The Transformation of Cosmological Space during the 18th Century« (Anna Holterhoff)
- »Beyond the Myth of Universal Space and Impenetrable Matter: The Overlapping Worlds of General Relativity and Quantum Theory« (Jürgen Renn, Donald Salisbury, Matthias Schemmel, Kurt Sundermeyer)

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1 Results

In the following outline, the ongoing research projects are described and at the same time linked to other research groups in the cluster.

1.1 Spatial Concepts in Non-Literate Societies: Language and Practices in Eipo and Dene Chipewyan

Fundamental forms of spatial knowledge studied by this project are those found in non-literate societies. Owing to the shared biological constitution of the human body and to universally shared experiences, certain aspects of spatial cognition are universal. Other aspects of spatial cognition are culturally specific, those shaped for instance by specific practices of spatial orientation and organization. The question of how this distinction can be verified empirically is a matter of controversy. Based on the study of spatial practices in two non-literate cultures and of (utterances in) their languages, we can distinguish between aspects of spatial cognition that are candidates for universal status (although they may be expressed differently in different languages) and aspects that are truly culture-specific (Wulf Schiefenhövel, Martin Thiering). The two cultures that have been thoroughly studied are the Eipo, who live in the highlands of Indonesian New Guinea, and the Dene, who live in the North American plains. Although the semantic and grammatical resources of the two languages differ substantially, no differences in spatial abilities have been identified which could be attributed to linguistic peculiarities. Furthermore, while the peculiarities of each culture's environment did shape their respective spatial language and practices (the importance of mountains vs. lakes; the practice of gardening vs. hunting), similar practices of spatial orientation such as the use of landmarks are discernible in both cultures. This cultural comparison suggests the existence of universal patterns of spatial cognition, namely the ability to memorize a network of landmarks, thereby allowing people to move flexibly in a given environment. Such mental structures may be referred to as cognitive maps or mental models of space. Mental models are here understood as linking present to past experiences by embedding new experiences in a cognitive network which represents past experience. That the ability to use networks of landmarks exists independently of specific cultures is corroborated by the observation of the corresponding spatial abilities, not only in children of different cultures, but in non-human primates as well. Differently from nonhuman primates, however, humans possess the ability to share mental models of space. Observable as a consequence is a historical and cumulative evolution of mental models of space which has led to elaborate cultural systems of orientation.

This work is related to cooperative activities with Research Groups C-I-1 (*The Conception of Spaces in Language*) and E-I (*Ancient Spaces as Spaces of Motion in Post-Ancient Times. Factography, Imagination, and Construction*).

1.2 The Impact of Notation Systems: From the Practical Knowledge of Surveyors to Babylonian Geometry

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 a development from elementary spatial knowledge to an esoteric art of formulating complex geometrical problems and solving them using sophisticated arithmetical tools which are applied to geometrical intuition. In light of this evidence, it is clear that the spatial cognition documented by these materials differs considerably from the type found in non-literate cultures. The new forms of representation found in the documents of surveyors, in school texts, and in the problem texts of Babylonian mathematics have been studied (Peter Damerow). It has been shown that the emergence of a new kind of spatial cognition documented in these sources resulted primarily from the growing knowledge of surveyors and from scholarly reflections on their practices. The resulting mental constructions remained implicit, but can be partially reconstructed from studying the arithmetical operations of Babylonian mathematics. It can be demonstrated that >non-Euclidian< peculiarities such as the neglect of the role of angles resulted from the surveying practices which they reflect.

1.3 Writing and Reflection on Elementary Actions and Professional Practices: The Chinese *Mohist Canon* and Its Counterparts in Greek Science

A further type of spatial knowledge is characterized by explicit definitions and by inferences in written form. Such knowledge is documented, in particular, in philosophical and mathematical texts from ancient China and Greece. In our group, research into texts of this kind has focused on the analysis of a unique source of ancient Chinese thinking, the so-called *Mohist Canon*, written around 300 BC. In a series of working meetings, attempts were made to reinterpret the *Mohist Canon* from a comparative and contextual perspective (William G. Boltz, Matthias Schemmel). We discovered that this text can be understood as documenting the reflection on elementary and practical forms of knowledge such as intuitive knowledge concerning spatial arrangements and natural processes, and knowledge obtained from the handling of mechanical and optical devices or instruments used for measurement or for astronomical observation. In this text, theoretical reflection is documented in the form of definitions of general terms, the consistent use of terminology, the resolution of apparent paradoxes, and explanations of unexpected phenomena. Texts handed down from Greek antiquity, such as Aristotle's *Physics* or Euclid's *Elements*, also document the reflection on elementary and practical spatial knowledge. A comparison of these Chinese and the Greek texts suggests that the existence of cultures of disputation and the associated emergence of argumentative textual traditions is a general precondition for this kind of theoretical reflection. While the Mohist tradition ended with the rise of the Qin Empire at the end of the 3rd century BC, the later tradition of the Greek texts reveals the different potentials of theoretical reflections on elementary experience, as exemplified by Aristotle, on one hand, and on the use of instruments (compass and ruler), as exemplified by Euclid, on the other.

This project collaborates with research groups D-II-2 (*Place, Space, and Motion*) and D-I-1 (*Cosmology*) in the form of joint reading seminars on ancient Greek philosophical and mathematical texts, e.g., Plato's *Timaeus* and Euclid's *Elements*.

1.4 The Impact of Geographical Knowledge on the Generalization of Spatial Concepts: From Ancient to Modern Maps

This research activity is devoted to the relationship between astronomical knowledge, cosmological theories, and geographical knowledge in ancient times (Klaus Geus, Matthias Schemmel, Irina Tupikova). The close interconnectedness between the cosmological hypotheses of a spherical earth and the transfer of celestial to terrestrial coordinates is well-known. We have begun to study the Chinese tradition, which exhibits a parallel case of instrumental astronomy in conjunction, however, with different cosmological ideas.

This project is affiliated with Research Group B-IV (*Applied Historical Geography*), and in particular with Klaus Geus, who participates in our activities (see above).

1.5 The Transformation of Ancient Spatial Knowledge through Intercultural Transfer: The Early Modern Translation of Euclid's *Elements* into Chinese

The research activity analyzes the intercultural transmission of geometrical knowledge and its impact on culturally-specific notions of space (Jens Braarvig, Peter Damerow, Matthias Schemmel, Tian Miao). This transversal study of knowledge transformation, which is closely related to the project on the Globalization of Knowledge, complements the more numerous longitudinal studies that exist on the transformation of ancient geometrical knowledge within the Western tradition. In 1607, the Jesuit Matteo Ricci and the Chinese scholar-official Xu Guangqi translated the first six books of Euclid's *Elements* into Chinese. Their endeavor demanded the translation of ancient Western knowledge on geometry into a different mathematical tradition, inevitably implying the transformation of that knowledge. Launched as a first step has been a detailed comparative analysis of parts of the Chinese version of the *Elements* with its European source, Christopher Clavius's edition of the *Elements*. Moreover, different versions of the Chinese *Elements* have been compared, and a study has been performed of the reception of Euclid's *Elements* in 17th and 18th-century China (Tian Miao).

This project is associated with CSG-III (*The Spread of Knowledge Through Cultures*), Markham Geller and Matteo Valleriani.

1.6 The Impenetrability of Matter: Space and Matter in Early Modern Science

The epistemological problem of the relation between matter and space played a major role in promoting the development of the Newtonian concept of space as container. This problem was investigated with a focus on alternative conceptualizations of the relation between space and matter in early modern science and philosophy (Peter Damerow, Jürgen Renn, Matthias Schemmel). Aristotelian physics and the Peripatetic tradition negated the possibility of empty space and instead concentrated on the concept of place. In opposition to this tradition, ancient atomism was based on the idea of atoms moving through empty space. In the Renaissance, a transformative development of spatial concepts was triggered by cosmological concerns, namely attempts to replace the Aristotelian world system by alternative systems which were often based on ancient atomistic ideas, including the concept of empty space, which implicitly involves the notion of space as a container.

The growing corpus of empirical knowledge on mechanics and astronomy eventually stabilized Newton's concept of universal space. In Newton's conception, gravitation is decoupled from the structure of space, which allows space to be homogeneous and isotropic. Nevertheless, this conception was not altogether convincing, allowing the debate about space and matter to continue. An advanced version of these attempts to distinguish between space and matter resulted from Kant's criticism, which attempted to eliminate metaphysical presuppositions. As a consequence, Kant's solution to the problem departed from atomism altogether, proposing an early version of matter as the appearance of repulsive and attractive forces.

1.7 The Transformation of Cosmological Space during the 18th Century

This dissertation project is affiliated with E-I (*Ancient Spaces as Spaces of Motion in Post-Ancient Times. Factography, Imagination, and Construction*, Project: »Conceptions of the Beyond in John Milton's *Paradise Lost*«).

1.8 Beyond the Myth of Universal Space and Impenetrable Matter: The Overlapping Worlds of General Relativity and Quantum Theory

This research activity deals with the transformation of the Newtonian concept of space in the revolutionary theories of relativity and quantum mechanics during the early 20th century (Jürgen Renn, Donald Salisbury, Matthias Schemmel, Kurt Sundermeyer). In a certain respect, the version of space and time presented in Einstein's general theory of relativity resembles Aristotle's more closely than it does Newton's: According to general relativity, space is no longer homogeneous and independent of matter, but is instead highly structured by its material contents. In particular, the natural motion of falling bodies results from the properties of this inhomogeneous space rather than being due to a force which is completely divorced from space, as in Newtonian physics. 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, we have focused on complementary developments. What did relativity theory imply for the concept of matter, and quantum theory for that of space? It turns out that 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 fundamental problems of modern physics are formulated in terms of a highly specialized technical language that is differentiated in disciplinary terms. A major tool of knowledge representation in the context of contemporary reasoning in physics is the use of elaborate mathematical formalisms. Recognizable nonetheless in these discussions are ancient dichotomies such as that between space and matter, and ancient questions such as the one concerning the relationship between motion, space, and geometry. This is by no means a coincidence. Instead, it suggests that these highly specialized disciplinary discourses are extensions of ancient traditions of spatial thinking. In a study now in its early stages, we are exploring the historical unfolding of this set of problems and asking what it implies for the epistemic status of the mental models of space which are operative in modern physics.

1.9 Infrastructure: A Bibliographical Database on Sources and Literature on Spatial Knowledge, a Digital Collection of Sources on Spatial Knowledge and a Corpus Data Collection

A database which assembles references to sources and literature that is pertinent to spatial language and cognition and the history of spatial concepts has been set up, and is now being continuously expanded (Sascha Freyberg, Laura Kersten, Matthias Schemmel, Martin Thiering, Irina Tupikova). The database, which currently contains around 1000 items, is openly accessible on the internet under [<http://echo.mpiwg-berlin.mpg.de/content/space>]. A digital collection of scanned images and transcriptions of sources pertinent to the history of spatial concepts has been prepared in the framework of the ECHO environment and will be further expanded (Sascha Freyberg, Simone Rieger, Matthias Schemmel). Presently, it contains around 250 texts. It is openly accessible via the ECHO website at [<http://echo.mpiwg-berlin.mpg.de/content/space>]. The group is also developing a data corpus of Eipo and Dene spatial language which has been collected in the form of written myths and field data (Martin Thiering, Wulf Schiefenhövel), and which will eventually be available online.

2 Publications Sorted by Research Activity

Spatial Concepts in Non-Literate Societies: Language and Practices in Eipo and Dene Chipewyan

Thiering, Martin. 2009. »Language Loss in Spatial Semantics: Dene Suline«. In James N. Stanford – Dennis R. Preston (eds.), *Variation in Indigenous Minority Languages*. Amsterdam/Philadelphia: Benjamins. 485–516.

Thiering, Martin. 2009. *Linguistic categorization of topological spatial relations*, TOPOI – Towards a Historical Epistemology of Space, Preprint Series Max-Planck-Institute for the History of Sciences, Preprint 373.

Thiering, Martin. 2010. »Intralingual Variation of Spatial Concepts in an Athapaskan Language«. *Cognitive Sociolinguistics: Language Variation in its Structural, Conceptual and Cultural Dimensions*, *Proceedings of the 34th International LAUD Symposium, Landau/Pfalz, 15–18 March 2010*. Essen: LAUD. 92–123.

Thiering, Martin. 2011. »Intralingual Variation in Spatial Semantics: A Case Study in Cognitive Sociolinguistic«. In Martin Pütz – Monika Reif – Justyna Robinson (eds.), *Language Variation in Its Structural, Conceptual and Cultural Dimensions*, *Duisburg Papers on Research in Language and Culture*. Frankfurt: Lang. 2011.

*The Transformation of Ancient Spatial Knowledge through Intercultural Transfer:
The Early Modern Translation of Euclid's Elements into Chinese*

Schemmel, Matthias. Forthcoming. »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.

The Impenetrability of Matter: Space and Matter in Early Modern Science

Schemmel, Matthias. 2010. *Medieval Representations of Change and Their Early Modern Application*, TOPOI – Towards a Historical Epistemology of Space, Preprint Series Max-Planck-Institute for the History of Sciences, Preprint 402. [To appear in a special issue of *Foundations of Science*.]

The Transformation of Cosmological Space during the 18th Century

Holterhoff, Anna. 2009. *Naturwissenschaft versus Religion? Zum Verhältnis von Theologie und Kosmologie im 18. Jahrhundert*, TOPOI – Towards a Historical Epistemology of Space, Preprint Series Max-Planck-Institute for the History of Sciences, Preprint 376.

Schemmel, Matthias. 2009. »Wie entstehen neue Weltbilder? Die Herausforderung der Kosmologie durch die Erfindung des Teleskops«. In Jürgen Renn – Matteo Valleriani – Jakob Staude (eds.), *Galilei und die Anderen. Hintergründe einer Revolution der Astronomie*, Sterne und Weltraum: Dossier 2009/1, 52–62.

Schemmel, Matthias. 2009. »Sidereus Nuncius«, »Galileo Galilei«. In Heinz Ludwig Arnold (ed.), *Kindlers Literatur Lexikon*, 3rd edition. Stuttgart: Metzler. 47–48.

3 Conference Contributions and Talks

Matthias Schemmel

- Participation in the Workshop *Geocentric Space* at the Max Planck Institute for Psycholinguistics in Nijmegen, Netherlands, 10 June 2008.
- »The Role of Writing for Theoretical Reflection on Spatial Concepts in Chinese and Greek Antiquity«. Workshop *Writing and the Transmission of Knowledge*, Werner Oechslin Library, 1 May 2009.
- »Das Teleskop und die Entstehung eines neuen Weltbildes durch die Transformation des Wissens«. *Tagung zur Fortbildung für Astronomielehrer*, Universität Jena, 27 June 2009.
- »Medieval Representations of Change and Their Early Modern Application«. International Conference *Philosophical Aspects of Symbolic Reasoning in Early Modern Science and Mathematics*, Universiteit Ghent, 29 August 2009.
- »Alvarus Thomas as a Missing Link between Scholastic and Early Modern Science«. Workshop *Alvarus Thomas: Reopening the Liber de triplici motu (1509)*, Lissabon, 28 September 2009.
- »Stevin in Chinese: Aspects of the Transformation of Early Modern European Science in Its Transfer to China«. Announced for the workshop *Go-Betweens, Translations, and the Circulation of Knowledge in the Early Modern Low Countries*, University College London, 13–14 November 2009.

Martin Thiering

- »Attendance of the 8th International Congress of the Society for Anthropology (Gesellschaft für Anthropologie (GfA), Munich, 14–18 September 2009.
- »Language-Specific Variation in Spatial Semantics«. 32. Jahrestagung der Deutschen Gesellschaft für Sprachwissenschaft (DGfS), AG 3 *Konzeptualisierung von Raum: Morphosyntax und Semantik spatialer Relatoren*, Antje Casaretto – Silvia Kutscher, Humboldt-Universität zu Berlin, 23–26 February 2010.
- »Intralingual Variation of Spatial Concepts in an Athapaskan Language«. *34th International LAUD Symposium, Cognitive Sociolinguistics: Language Variation in Its Structural, Conceptual and Cultural Dimensions*, University of Koblenz-Landau, Landau/Pfalz, 15–18 March 2010.
- Participation and Chair of the Workshop *Sciences of Communication in the 20th Century*, Max Planck Institute for the History of Science, 18–20 March 2010.
- »Successive Projections of Sequential and Summary Scanning in Eipo«. *Vierte Internationale Konferenz der Deutschen Gesellschaft für Kognitive Linguistik (DGKL 4)* [4th German Cognitive Linguistics Association], Bremen, 06–08 October 2010.
- »The Influence of Environmental Landmarks upon Spatial Language: What about Linguistic Relativity?«. *Third Conference of the Scandinavian Association for Language and Cognition (SALC III)*, University of Copenhagen, June 14–16, 2011.
- »The Semantic Pole in the Presumably Atemporal Processes of Spatial Categorization in Eipo«. *International Cognitive Linguistic Conference (ICLC) 11*, University of California, Berkeley, July 28 – August 3, 2009 (cancelled for 2009 and postponed to 2011 in Beijing, China).

Tian Miao

- »The Influence of Greek Mathematics in China«. Frankfurt University, 12 May 2009.
- »The Transmission of Euclid's *Elements* to China and the Influence of Euclid's *Elements* in Late Imperial China«. Max Planck Institute for History of Science, 16 June 2009.

4 Teaching Activities by Members of the Group

Matthias Schemmel

- »Die Geschichte des Raumbegriffs von der Antike bis in die Gegenwart [The History of the Concept of Space from Antiquity to the Present]«. Proseminar as a visiting assistant professor at the University of Bern, spring term 2008.
- »Eigenständige Tradition und Wissenstransfer: Die Geschichte der Wissenschaft in China [Independent Tradition and Transfer of Knowledge: The history of Science in China]«. Proseminar, Humboldt-Universität zu Berlin, summer term 2008.
- »Wissenschaftspopularisierung im 19. Jahrhundert [Popularization of Science in the 19th Century]« (together with Milena Wazeck). Proseminar, Humboldt-Universität zu Berlin, winter term 2008/2009.
- »Kants *Metaphysische Anfangsgründe der Naturwissenschaft*: Text und wissenschaftshistorischer Kontext [Kant's *Metaphysische Anfangsgründe der Naturwissenschaft*: The text and Its Place in the History of Science]«. Proseminar, Humboldt-Universität zu Berlin, winter term 2009/2010.

Martin Thiering

- »Semiotik und Sprechakttheorie: Vom Gebrauch der Zeichen [Semiotics and Speechacttheory: On the Usage of Signs]. Proseminar, Humboldt-Universität zu Berlin, Philosophie I, winter term 2009/2010.
- »Einführung in die Radikal Konstruktivistische Epistemologie [Introduction to Radical Constructivist Epistemology]«. Proseminar, Humboldt-Universität zu Berlin, Philosophie I, summer term 2010.
- »Sprache und Kognition [Language and Cognition]«. Hauptseminar, Humboldt-Universität zu Berlin, Philosophie I, winter term 2010/2011.
- »Semiotik und Sprechakttheorie [Semiotics and Speechacttheory]«. Hauptseminar, Humboldt-Universität zu Berlin, Philosophie I, summer term 2011.

5 Citation

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