Science, Technology & Innovation Studies
Vol. 7, No. 1, May 2011

ISSN: 1861-3675

STI Studies
www.sti-studies.de

Scientific images? How touching!

Katja Mayer (University of Vienna, katja.mayer@univie.ac.at)

Abstract

As contribution to the still rather marginalized study of the visual cultures of the social sciences, this article draws the attention to the visualization of social structures as node-edge diagrams in Social Network Analysis. By going beyond their mere visual dimension, it sets out to explore specific corporeal and sensual dimensions of visualization practices and respective constructions of shared meaning in the social scientific research process. The following questions are addressed: How is knowledge made explicit? How do researchers depict and look at social structures? What corporeal and embodied practices co-constitute and shape their epistemic vision?

Starting from an ethnographic encounter with a print of a network diagram at a research team meeting, this article delves into the context of its production. Taking into account the performative aspects of visual knowledge, the tangibility of depicted social relations, the elaborated metaphorical and colourful visual language, as well as the ergonomic normalizations that come with instrumentation and experience are highlighted. Analyzing knowledge production within the realms of aesthetic practices calls thus for a treatment of the scientist's body as an active agent and not as an automatism to be blended or as passive precondition. Furthermore, such an approach might broaden the outlook towards a more body-aware scientific reflexivity.

> "That would be the highest thing for me" – so saith your lying spirit unto itself – "to gaze upon life without desire, and not like the dog, with hanging-out tongue: To be happy in gazing: with dead will, free from the grip and greed of selfishness – cold and ashy-grey all over, but with intoxicated moon eyes! That would be the dearest thing to me" – thus doth the seduced one seduce himself, -"to love the earth as the moon loveth it, and with the eye only to feel its beauty. And this do I call immaculate perception of all things: to want nothing else from them, but to be allowed to lie before them as a mirror with a hundred facets." – Oh, ye sentimental dissemblers, ye covetous ones! Ye lack innocence in your desire and now do ye defame desiring on that account! Verily, not as creators, as procreators, or as jubilators do ye love the earth! (Nietzsche 2008: XXXVII)

1 Introduction

In the preceding quote, Nietzsche sneers at the advocates of an abstract mind that lays pure and disembodied in an objective sphere of judgment and cognition. As restrained observers, philosophers and scientists alike trust in genuine sight guided by reason, and the wish for an "immaculate perception", not touched or contaminated by unpredictable sensation and fleshly intervention. Nietzsche condemns this treatment of perception, describing it as a frozen stare at a supposed beautiful truth while pretending to be without desire, without the wish for manipulation and intervention. Nietzsche's critique is in line with opponents of a "spectator theory of knowledge" (Dewey 1929). Treating the knower as passive and leaving knowledge production to "mirrors" (James 1920; Rorty 1979), be they recording devices or specific representational language games, divorces knowledge and action. Thus, the such criticized oculocentrism of western cultures in the construction of truth, which trusts a certain correspondence of truth and world in accurate descriptions, produces hypocritical science (and philosophy), which always has to hide desire and creative or aesthetic intervention.

This article tunes in the critique of "immaculate perception" by addressing the performative aspects of visual knowledge production in scientific research. The handling of pictures in sciences appears paradoxal if proof should be as untouched and unaffected as possible, as subsumed by Galison (2002: 300): "We must have images. We cannot have images." Scientific objectivity and aesthetics involved in image production and perception seem incompatible, even though they obviously cannot exist without each other.[1]

The pragmatic turn towards a sociotechnical construction of knowledge in science history and science and technology studies drew attention away from paradigmatic theory building and institutionalization to the sociomaterial practices of knowledge production. A special emphasis on visual practices in these disciplines dates back to the 1970s, when authors "described scientific seeing as richly rooted in the practices of field and laboratory" (Mody 2005: 176) and reflected perception as socially constituted.[2] Studies devoted to knowledge production in the context of scientific laboratories and the related daily routines revealed the power of "inscription devices" (Latour/Woolgar 1986): the dominant role of images in the creation of evidence and their vital embedding in inner-scientific discourse, rendering them to "viscourses" (Knorr-Cetina 1999b). Investigations of meaning, logic, roles, functions and popularization of scientific images, and their orientation to "looking, gazing, reading, and other things done

[1] Zimmermann (2009) demonstrated inter alia that the notion of objectivity comes with certain aesthetics itself.

[2] See e.g. Rudwick 1976; Shapin/Schaffer 1985; Lynch 1985; Latour 1990; Lynch/Woolgar 1990; Cambrosio et al. 1993.

with the eye" (Mody 2005: 175), underline the importance of the visual dimension in the sciences. Studying the visual dimension of knowledge production, the processes of "making visible" (Rheinberger 2006), reveals the importance and indispensability of imagery in every phase of knowledge creation, even though only a few pictures, if any at all, are made public in the end. Additionally, the performative perspective of knowledge production, dealing with human and non-human agency, emphasized that scientists create what they study, they enact what they analyze (Law/Urry 2004) and scientific inquiry often opens up unintended "collateral realities" (Law forthcoming). Furthermore, such investigations dealt with the distinctiveness of visual cultures in science (e.g. Lynch/Edgerton 1988; Lynch/Woolgar 1990; Galison 1997; Knorr-Cetina 1999a; Beaulieu 2002) and diverse global "image markets" (Pörksen 1997), bringing the distribution and deployment (Burri/Dumit 2008) of scientific images outside the laboratory into the focus, e.g. the use of brain scans as "demonstrative evidence" (Dumit 2004) in courtrooms.[3]

The turn towards the visual in the sciences resulted in numerous studies of natural, technical or medical sciences. Visual cultures in the humanities and social sciences only partially move into the focus of science history and science studies (cf. Fyfe/Law 1988; Lynch 1991; Nikolow 2005). The most relevant research is done in the respective fields, like sociology (Barlösius et al. 2001; Keller 2006; Pauwels 2006), and rarely reach the science history or science studies communities. This paper is intended as a small contribution to the study of visual cultures in social sciences. It addresses the practices of visualizing social structures in the form of node-edge diagrams within the field of social network analysis that deals with large data sets. Specifically, I would like to highlight the corporeal and sensual dimensions of the procedures of making visible. How is visuality constructed in this field? How do researchers "see" social structures? What corporeal practices co-constitute and shape epistemic vision?

When dealing with the multimodalities of visualization practices in scientific research and asking how shared meaning is constructed, it is necessary to focus also on the corporeal and sensual interactions[4] of researchers and their imagery, where the scientist's body is not only treated as a simple precondition to conduct experiments with. Karin Knorr-Cetina distinguishes in her study on epistemic cultures in molecular biology between the "acting body", the "sensory body", and the "experienced body" in scientific practice. Linking these three dimensions together, the body is treated as "silent" in her analysis, working best when it is black boxed into the "empirical machinery of research". The concept of inscription is projected onto and into the body that becomes unconscious and merely intuitive: "By the scientist's body I mean a body without the mind. If the mind were included, hardly anyone would deny the presence of the body. The body, as I use the term, refers to bodily functions and perhaps the hard wiring of intelligence, but not conscious thinking", Knorr-Cetina writes (1999: 95). Similarly, when it comes to the corporeality of scientific practices (apart from a focus on bodies constructed by science), concepts like "tacit knowledge" (Collins 2001; Polanyi 1967), or implicit, personal and hardly transfer-

[3] Some of these investigations lead to the insight that in countless epistemic (and other) fields, scepticism of the appropriate application of images prevails. Especially in fields that deal with invisible, very small or distant phenomena, like particle physics (Galison 1997), astronomy (Lynch/Edgerton 1988), and brain sciences (Beaulieu 2002).

[4] Cf. Ochs et al. 1994; Griesemer 2004; Bergermann 2006; Meinel 2006; Myers 2006; 2007; 2008.

able knowledge prevail, treating embodied know-how as knowledge bound to a body and/or disciplined and trained through experience and education. Knowledge becomes describable as a process of knowing (Polanyi 1962), always knowing more than can be articulated or reflected. In line with such both valuable but also simplistic perspectives, the knowing body and the "sensory body" alike are becoming black boxed and in danger of being reduced to a rather intuitive and solely passive capacity of perception, and the sense of sight, leaving "little room to account for passion, affect, and sensory engagement" (Myers 2007: 243) in science. Even though the aforementioned approaches might at least help to challenge the philosophical duality of body and mind, they are in a way perpetuating a "myth of bodylessness" (Haraway 2004; Myers 2007: 243) into a myth of sense-lessness and fall too short in regard to the active, conscious, reflected, affective and communicative dimension of "body work" (Myers 2008) when "doing images" (Burri 2008). Therefore, the focus of this paper will be on various manifestations of corporeality in social scientific visualization practices as implicit and explicit knowledge production (cf. Hirschauer 2008: 982).

> "Whatever the pictorial turn is, then, it should be clear that it is not a return to naive mimesis, copy or correspondence theories of representation, or a renewed metaphysics of pictorial 'presence': it is rather a postlinguistic, postsemiotic rediscovery of the picture as complex interplay between visuality, apparatus, institutions, discourse, bodies and figurality." (Mitchell 1994: 16).

In line with W.J.T. Mitchell's quote, this paper strives to pay attention to "researchers' corporeal and affective entanglements with available concepts and modeling media, and with the visualization machinery" (Myers 2007: 67). It does not want to reduce the powerful roles and functions images have in the research process to their mere visual dimension. On the contrary, it will tempt a widening of perspective on visual cultures in science by grasping several corporeal and sensual dimensions of scientific practice, like Natasha Myers proposes. Pointing fingers, touching models, the haptic dimension of visuality, for example, can be conceptualized as active sensual perception, or *aisthesis*, which can lead to a wider understanding of aesthetics. An understanding that encompasses not only style, art and beauty, but the study of sensation and perception. Placing knowledge production into the realms of aesthetic experience and configuration emphasizes the body as an active agent and not as an automatism to be blended out.

In order to find out how specific scientific images "make sense", to allocate their evidential capacities within practices of exploration and demonstration, I invite the reader to follow me into a social scientific institution dedicated to social network analysis. The empirical material presented in this text is drawn from my ethnographic PhD research of visualization practices in the field of social network analysis. Over the course of four years (2006-2009), I visited several institutions, did participatory observation, interviewed scientists within and outside the core community, followed several discussion groups, and attended conferences and workshops.[5]

The controversial status of network images in public debates attracted my attention: advocates use, plead and campaign for enhanced and colorful network information visualizations to deal with complex data; opponents warn against their power of delusion and persuasion, and that they are not adequate representations of the data. I was interested in how such imagery is used in the research process, whether it is used at all, or if it is only produced

[5] The research reported here was made possible in part by support from the Austrian Science Fund FWF and the research project: P17600 Materiality and Temporality of Performative Speech Acts.

for popularization of knowledge otherwise hardly presentable.

In the course of my investigation, it became apparent that the usage of imagery is ubiquitous in network analytic research processes: graphs and node-edge diagrams served as exploratory space, rationale, and proof. My ethnographic analysis of observations and interviews shows how image practices and styles, including interpretation, are marked by the degree of expertise in imaging techniques, and that reflexivity of visual knowledge production is largely dependent on this degree of expertise (Mayer forthcoming b).

Shortly, I will recollect an event at one of the visited institutions, which employs social scientists and philosophers that are also visualization experts and working on developing a visual language for the mediation of social structures.[6] Taking this as a starting point for the examination of "how researchers' bodies become key resources in producing knowledge" (Myers 2007: 51) by means of visualizing, I direct the attention to kinesthetic or "gestural knowledge" (Griesemer 2004), narrative strategies, and the training and normalization, but also the playfulness, of researchers' perception. In what follows, I hope to show how social structures are not only becoming visible as graphic networks, but also palpable, and how this realization is connected to corporal and sensual competencies and practices. In line with Nietzsche's critique of immaculate perception, such a fragmentary and exemplary glimpse into the visual worlds of network science should emphasize the touching qualities of network diagrams, both literally and figuratively, and the "liveliness" (Haraway 1997) of cultivating a feeling for the object of research with which it is realized.

[6] A description of this event is also featured in Mayer 2009.

2 Retrospect

Social Network Analysis is a scientific method of studying social structures and group behavior. Social networks as an analytical concept consist of actors and their respective relations. Since its inception as Sociometry in the 1930s in the USA, such structures are surveyed, measured and interpreted with the help of diagrams. Actors are represented as nodes and their ties as lines or edges. This supposedly simple figure – the node-edge diagram – has a long history and can be traced back to the first conserved tree-like depictions of pedigree, and it is rich in its capacity of variation (cf. Gießmann 2008). It is to be found as a basic epistemic scheme (and realization) for a relational perspective in many scientific disciplines, like mathematics, chemistry, engineering, neurophysiology and philosophy. Nowadays it co-shapes societal self-descriptions as network(ed) societies (Mayer forthcoming a).

Sociometrists and anthropologists were formalizing social structures into ad-hoc and ex-post network diagrams even before mathematicians and especially graph-theorists were interested in real world graph problems. Jakob L. Moreno, trained as a physician and social psychologist, originally developed interaction diagrams and later "sociograms" for improvised theatre and psychodrama in the early 20th century. "Before the advent of sociometry, no one knew what the interpersonal structure of a group 'precisely' looked like." (Moreno 1953: lvi) By making structures visible, sociometrists wanted to explore the social space together with their research subjects. Sociograms should function as "social microscopes" (Moreno 1967) and should support intervention and social change through social "diagnosis and healing". With the help of sociometrists and their "scientific socialism" (Moreno 1967: xxi), participants of sociometric experiments should become active agents in matters con-

cerning their life situation once their embeddedness in social texture became evident to them.

According to Moreno, it was the sociogram that first allowed the experimental study and "precise exploration" of complex relationships, which since that time have been considered as "social networks" and "places of origin of public opinion" (Moreno 1967: 267). The field of social network analysis has been growing consistently since the 1970s, bringing with it new methodologies and visualization instruments. With the mathematization of social networks and the application of graph theory and statistical methodologies, networks can also be treated as graphs and allow computation and measurement of even very large datasets. Automatic Graph-Drawing has largely replaced manual drawings and has opened the network perspective to new scales of complexity. Sociograms come as visual surfaces of complex technical assemblages and interactive interfaces. As such, they are vital elements in the research process, be they on paper or on a computer screen.

How does a team of network analysts work with sociograms; what kind of communication do they evoke; how entangled are the researchers' bodies with the scientific image or even built into their instruments? These questions will be addressed after the following section where an encounter with a printed network diagram is staged.[7]

3 Staging

The scene of a regular weekly meeting: Monday morning at a social scientific research institution specialized in social network analysis. In addition to several computer screens, there is a projector, a flipchart and many posters showing network visualizations on the wall, which stem from completed research projects and serve as successful examples of the institution's development. After having already projected a crucial network diagram to the wall, and then having drawn a detail of it on the flipchart, five social network analysts and I are now waiting eagerly for the plotter to finish the first print of the colored and elaborated visualization. The team leader explains to me, the ethnographer, how important it is to work with such large printouts even though they are very expensive. First to explore and control the displayed content, second to examine if the intended content and its appearance are still readable after such a change of medium. Finally, as the team needs to prepare a poster for a conference; it is tested whether this image could be further developed for this purpose.

Conversations revolve around the data pool, the problems of inquiry, and the potential interpretations as the network picture is an important part of this process. Immediately after the cleaning, ordering and input of the data into the software for network analysis, the first network visualization was produced on the screen. The diagram was colored, tagged, and iteratively adjusted with automatic layout algorithms so that it became easier to read. The further composition, including the fine tuning of labels, positions, coloring of the background, nodes and lines, was done manually by a researcher, and always in comparison with the data in the tables and rankings, and several distribution graphs. Furthermore, the visualization was elaborated in regard to the institution's own corporate identity: its look that results from long engagement

[7] I want to ethnographically elaborate my observations by means of a meeting around a printed diagram, and not with the typical modes of image production in the research process that happen largely in computers, because nowadays still mainly printed or projected diagram leave the social scientific laboratory in the end. The juxtaposition of computer-aided visualization processes will help to deepen the understanding of corporeal and sensual configurations.

with the development of a diagrammatic language. Shortly before the print is ready, the director of the institution addresses me, smiling: "One always thinks, it is creative work we are doing, but in fact it is all about the coloring and exporting of JPGs." While thinking how sarcastic his statement was meant, knowing how laborious and demanding the production process is if one wanted to create an effective, contemporary and pleasing visualization, the print is ready. The network materialized like a "synoptic tableau" on the table: its surface glossy, the colors strong, the nodes and edges precisely positioned on the available space.

As soon as the bearer steps aside, the fingers of the surrounding team start traveling the picture. The team leader takes on the role of the pointer and commentator; his fingers leave traces on the paper while he remains in a dense region of the network: "What does that show, it is a clique. Where are they brokering into? … Their positioning at the periphery cannot be contingent." A researcher responds "I am not sure, I have no feeling for the data, as I did not collect it, but…" his finger trails towards one node, all eyes following, "…here seems to be the gatekeeper. Through this, one has to go to reach the key players." He knocks on the circle representing an actor. Another researcher adds "Somehow this is not well-arranged; it is far too dense. I cannot see the actors in the important clusters clearly. I would prefer to have them on the left side so that they come into my view immediately. By the way, I think there is a mistake. This institution is duplicated, here, but slightly different spelling." There is an error in the dataset, which is instantly opened by another research on his laptop and corrected. The team leader is already further in his interpretation: "But look at the center, it is so dense and rigid, it is blind. There are the most important actors…" he clenches his fist "… and they are frozen without even being aware of it. All the movement emanates from the periphery." His finger moves rapidly between several nodes at the margin of the picture. He takes his fingers from the picture and points to a poster on the wall. "It is always like this. Do you remember that study? It was similar. Look at the distribution. The clusters are connected by several loose couplings." All eyes follow to the wall and examine the reference addressed that now serves as a model for a recurrent social constellation. In the course of the meeting, many more pointers are made, and it happens that fingers are pushed away if they are blocking the sight or the path of other traveling fingers.

Based on this ethnographic encounter, the following sections will be dedicated to a further analysis of how knowledge is made explicit with the help of corporeal interaction and instrumentation, be they gestural, narrative, trained, normalized, or playful. The printed network diagram at hand serves as important working equipment beside the often solitary work in front of a computer screen. Its explorative function consists in the "materialization of questions" (Rheinberger 2006: 25). It allows for collective interpretation and is the central tool of a consolidated perspective of the data, but it is not only looked at, as shown in the story above. It is carefully constructed so that it can be seen, touched and bespoken. While being investigated for patterns and paths, it is put in reference to other pictures: on walls, on flipcharts, on screens, and even to concurrent graphs to prove that the available data mount is an actual social network and not an accidental distribution. Its referents are transversally layered (Latour 1996: 203). The network diagram is not simply referring to data, but also to the tools of its construction and to a cohort of contextual and visual knowledge, and it is embedded in a cascade of transformations. This knowledge of

data is re-ordered, but also further transformed into computable figures (Mersch 2006: 97), which shape a topography for further configuration and interpretation.

4 Pointing – grasping – touching

The introduced visualization of a social network can be regarded as part of a social scientific experimental setting. Hans-Jörg Rheinberger (1992: 26) calls the basic movement in such a setting "groping" or "thinking with hands". The fingers and hands of the observed network analysts do not only operate computers to construct effective diagrams, they operate themselves in all media and add corporeality to the present materials. The fingers undertake the missing dynamic of the static image by traveling the network and supplementing them with interaction. The forefinger is here a means in the mode of "explorare" (Mersch 2003) as it travels through the depiction, leaving trails and collecting positions. It also acts as a literal index in a mode of "demonstrare",[8] leading the gaze, outlining patterns and linking to references and even errors. This "haptic gaze" (Burri 2008: 212) is a corporeal technique, actively invoking the tactile sense to grasp depicted social relations. Network diagrams provide a material experience, and such a haptic experience leads to a "better feeling for the data", as repeatedly declared in interviews by several observed network analysts. The haptic exploration and interpretation of the plotted diagram as recollected in the aforementioned situation is a collective effort. The creation of touchable maps of social networks helps to synchronize communication through discussion and a mutual process of exposure, of pointing, and "drawing things together" (Latour 1990).

Another aspect of the importance of working closely with plotted diagrams is outlined by the team leader: "We need to print the visualizations in order to test them. You cannot test it only on the screen, especially not in a group of people. It is the combination of immersing ourselves together into the diagram, touching it, scribbling on it, and looking at it from a distance. For example, when mounted on the wall, that helps us to understand the network, or, maybe, to understand what we have done with it. Even more, it shows us whether it could be understandable to others." The comparison of the diagram's appearance from close proximity and distance in combination with pointing to or touching of its surface, guides the exploration of the research object, and it helps the assessment of its appeal to external spectators. Furthermore, the team leader points to the active and reflective dimension of the employed haptic gaze for testing and its importance in the further production of visualizations that are to be published or presented.

As mentioned in the introduction, Karin Knorr-Cetina (1999b) calls the interplay of visual images and their integration into discourse "viscourse", and relates the use of images to the telos of successful communication. But there is more to the deployment of network images than just their communicative performance. Touching the network picture highlights certain actors and links, making them more evident by the directing of attention. The synaesthetic experience of simultaneously sensing something and sensing oneself fosters the experience of evidence in the experimental setting (Bergermann 2006). Ulrike Bergermann refers to "haptic evidence" (2006: 316) that is characterized as a particular mode of proof, but is difficult to communicate other than via touching the research object and the so called "hands on" experience. The collective touching of the diagram as concerted securing or rejecting of proof enriches

[8] Showing and pointing in a demonstrational mode are employing a specific visual logic that is different to a discursive logic in regard to how meaning is constructed and stabilized (Heßler/Mersch 2009).

the analysis in the experimental social scientific setting.

"It is fun to work with the visualization, more fun than the other work, here you can be creative. But it also can be very laborious, takes a lot of different steps, different programs, until we have what we like in the end. We are sometimes cursing the software, as it is not doing what we want," a researcher says. And she continues: "Having the visualization in my hands, being able to crumple it up, or put it on the wall later as guidance is important for me. I need to get away from the screen sometimes." Another scientist and interview-partner also remarks the importance of the plotted picture in order to explore and evaluate it, but he prefers to interact with the network diagram on screen: "While we need to plot visualizations in critical project phases, where the collective interpretation, or better the collective evaluation, is needed, I can better dive into the network when I have it on the screen." He then describes his "desire for pictures" when analyzing social networks as desire for physical intervention. He continues: "I want to literally touch it; I want to immerse myself in it, mesh it." Even though on screen, the scientist associates physical touching with his actions that encompass touching the network structure with the computer-mouse: turning it, zooming in and out, switching from the 2D to a 3D perspective, and sometimes even "flying through" a visualization to "approach" certain nodes or links and examine their neighborhood closely. When asked if he is mimicking his routines from the examination of the network on screen when he explores a printed diagram, he laughs, but does not exclude this possibility. On the contrary, the team leader when asked the same question, recalls former times without interactive computer interfaces and says: "I was always groping my printed visualizations, walking them with my fingers, knocking on them, long before we had such fancy software. […] Rather the software is mimicking what we were doing all along."

In the aforementioned meeting room, there are also molecule assembly kits laying around with which the scientists sometimes model e.g. selected Levi-Straussian "elementary structures of kinship" (1947), as they explained to me referring to an influential recurring model in their knowledge practices. A researcher mentioned that such collective "playgrounds" are fundamental to their work as "one cannot always sit alone in front of the screen and stare into it." The 3-dimensional material model kit allows the researchers to tinker in detail with a pattern found in a network. Pondering about physically and mathematically possible forms of connections between a number of actors is best done via manually sticking little balls together, and then by looking at the model from different sides. It is also an aspect of theory building; when there is no 3D model kit at hand, such exemplary social patterns are scribbled on flip charts, paper or on the plotted poster of a visualization.

"I really wish for better interfaces, […] like in the movies, […] I would love to wander around in my holographic network, well, if it is not dense like a jungle.", says yet another network analyst in the interview.

While holographic interfaces are a rather utopian form, various haptic technologies (Bergermann 2006) from other research fields, like molecular biology or chemistry, or from the gaming industry, are entering the field of social network analysis. I am not aware of joystick-like command interfaces, but touch screens and 3D animations are already very common. Many programs let the analyst follow the animated mounting of the network iteratively, as if observing the algorithm at work, whereas an intervention of a printed network diagram is only possible through discussion, drawing, touching, cutting or similar acts. Computer interfaces provide more opportunities for interaction with the im-

age:[9] one can turn it, zoom in and out of it, reduce it, even fly through 3D projections of it. Colors and tags can be adapted and positions of nodes and edges changed on screen. Until recently, algorithmic work on network layouts has been largely devoted to static graphs, but the development of visualization tools is on the verge of dynamization: transforming longitudinal network data and time series into interactive network movies (Bender-DeMoll/McFarland 2006). Until this comes packaged in software, researchers have to work with rather static notions of networks when trying to visualize e.g. change in networks.[10]

The next section is dedicated to the playful, viscoursive negotiations and the metaphorical continuations of the depictions that shift the boundaries of the printed, static network picture and expand its symbolic space both with regard to the interpretative context and missing interactive dynamics. Furthermore, it will deal with the construction of a metaphorical, but nonetheless corporeal, space that adds imaginary and physical realism to knowledge production across several modes and media.

5 Enacting metaphors

The depiction of the network serves as delineation for further, metaphorical dimensions of grasping, as the aforementioned situation illustrates. The invoked metaphorical space encompasses both techniques of language and embodiment while adding narrative and corporeal realm to the social network visualizations. In the discussion of the image as described before, several metaphors and rhetorical figures become noticeable and with them certain imaginations. Whereas in social sciences the condition of their own images and rhetoric is often overlooked in favor of a focus on data and interpretation (Keller 2006), the observed institution has actively elaborated a visual language and a rich figurative repository in order to compensate missing information in their imagery. Sophisticated, iconic language is used to create the context for a relational perspective, which is often not familiar to research partners and clients. However, it also further broadens the possibilities of interpretation in the research process itself. The researchers in the observed institution are constantly refining their metaphorical repertoire: firstly to create experimental narratives that promote their relational hypotheses, and secondly to communicate their visualizations to the public.

> "Often it is as if people blank out the lines between the nodes. They only look at the nodes. […] people are not used to looking at the interspaces. They are not familiar with a relational perspective. So we have to reconstruct not only the grammar for them, like measures and diagrams, but also the semantic space, the context. We have to link it to well established semantics to help them build up mental pictures." explains the team leader.

The exemplary situation around the glossy network picture is dominated by several distinct types of metaphors which stem from economics and anthropology: spatial, like periphery, center, disciplinary, like brokerage, cluster, gatekeeper, key player, attributive, like blind, frozen, rigid, and so forth. Such figurative speech guides thinking and talking as well as gestures and makes the visualization graspable in its iconicity. With the usage of metaphors from different fields, the researchers try to focus on the interspace, drawing the attention to the relations and a bit away from the nodes, by activating common semantic repositories to establish a feeling for the relational perspective. When speaking about dense areas of the network that restrict the agency of

[9] A popular network visualization software is named "Touchgraph".

[10] To give an example: the software Pajek allows to work with longitudinal networks and to compare network structures at different points in time like time slices.

actors, in contrast to porous areas, metaphors like "frozen" or "liquid" are enacted, as exemplified by a researcher:

"We call dense and tight regions in this project frozen. But there are also liquid parts, where we find warmth or even heat. The experience of the social structures is imagined as cold or hot. Liquid means heat until the point of total disorientation. In contrast, we see frozen parts up to the complete immurement, the sclerosis."

Another researcher adds while pointing to the respective regions on the network diagram:

"Here we have the psychotic situations, like schizophrenia, and there is neurosis. We are looking for a state that is in the middle of such extremes, that is endurable, meaning neither total order, nor total dissolution. […] It is a matter of power relations, but from a very different perspective."

He is interrupted by the first respondent:

"The freezing of water is a good allegory for the situation of this network. Water freezes erratically. There are unpredictable ramifications in such a complex process. This is happening to the structures here. The freezing opens up possibilities, but closes other paths, links are cut."

This excerpt of a dialogue stems from the discussion of an ongoing project and illustrates the need to charge the network visualization with familiar concepts in order to create shared understanding. The underlying data and hypothesis are translated to work with the network image and to shape the analysis. The second researcher takes up the terminology and spins it further to grasp the objective of the project, which is to look for certain constellations of power in a corporate network. Hans Blumenberg (2001: 412) states that rhetoric creates institutions where evidence is missing. At the same time, they foster the evident patterns materialized as network visualization and make it allocatable and attributable.

Furthermore, visualization experts in social network analysis make use of visual analogies taken from other genres like pop culture, media art or from other scientific or technical fields. They experiment with displays similar to temperature scales, radar monitors, galaxies, and microscopic organic traces, to name a few. The desire for realization exceeds a purely functionalistic handling of scientific images. They are not only supposed to be efficiently readable but also "stylish and contemporary in their appearance, both in research processes and in popularization", remarked a researcher in the interview. The described plotted diagram referred to chemical structures and showed the color scheme in a box at the bottom, which looked a bit like a temperature scale. Where the employed visual analogies did not suffice to explore the dynamic attributes of the network picture, narrative and also embodied analogies were enacted.

Metaphors of force and movement are central to the discourse on social networks, which seems paradoxal since most of the published images nowadays are static. Moving fingers, knocking on nodes, clenched fists or crossed fingers when demonstrating dense network areas are the corporal equivalents to such metaphors. With such "gestural knowledge" (Griesemer 2004), still images can be made to appear more dynamic and lively.

Additionally, there are also technical equivalents incorporating metaphors of force and movement that apply such gestural knowledge by enabling haptic experience in the process of image production and interpretation. The calculation of social networks is conducted with the help of graph theory, which does not take into account the spatial positioning of nodes and edges as diagram. In order to visualize complex networks projection, procedures based on assumptions of visual efficiency and optimization of readability are needed. "The graph drawing community has developed objective criteria to measure the quality of a drawing. One of these criteria is the number of crossings between edges in the draw-

ing. We want to have as few crossings as possible. Other criteria are the length of the edges of the graph and the number of bends in the edges. The goal is to find the optimal embedding." (Mutzel & Weiskircher 1999). Careful construction is needed to allow for efficient readability and, hence, to reduce ambiguity. Approaches like distance or multidimensional scaling are also used to reduce the interpretative flexibility of social networks. So called Spring Embedders, to give an example, apply hypothetical physical forces to the ties and treat the network as a physical system, a simple analogy used e.g. also in molecular modeling (Folkers 2001: 168). These force-directed algorithms simulate springs between nodes, which pull them together or push them apart until the system stabilizes in an equilibrium state. "Generally, edges between nodes are represented as an attractive force (a spring pulling them together), while nodes that do not share a tie are pushed apart by some constraint to help prevent overlap." (Moody et al. 2005).

Some software packages even equip interface functionalities with such analogies to make them more interactive. If a node is virtually pulled with the computer mouse and then suddenly released, it will swing slowly back into its former position. This twitching of nodes is a popular occupation during meetings, e.g. when a network image is projected and discussed or while contemplating over the picture on screen. It also gives a feeling of the strength and stability of a position, as one researcher claims in the interview. In 3D models this interactive feature is used when looking through the network, when a node is blocking the view. As an applied metaphor, the (playful) spring-tie adds an extra layer of realism to the visualization, referring impressively to the technicity of the diagram and the formalization of social structures into a visualization.

Figurative and gestural enactments of printed network images as well as the equipment of on-screen diagrams with physical analogies span a metaphorical space without which the depiction of social structures would not make sense. In line with these observations, the classical epistemological distinction between seeing and feeling becomes obsolete and cannot be employed as a measure for the quality of knowledge (Bergermann 2006: 315). Making meaningful and visible social structures encompasses several corporeal entanglements. Therefore these practices help to enact social networks as epistemic things.

6 Ergonomic normalization versus taste in instrumental perception

According to my interview partners, it is vital to develop a visual language, both for the better analysis in the research process and to shift the attention towards the interspace in order to foster the relational perspective. It is important to employ aesthetic strategies like coloring of the background, the nodes and relations to add an additional information layer to the visualization in addition to captions, symbols, scales and so forth. This section is therefore dedicated to the coloring practices that involve different corporealities, such as color perception, normalization and further aesthetic issues in negotiation with the instrumental framing.

Some network visualization software come with built-in psychometric color schemes. To make the image efficiently readable the information is automatically presented carefully colored. In such settings the psychometric quantification and description of human color perception serves as basis for the automated coloring of diagrammatic properties. Colorimetric models are based on standardized comparisons of single hues and delineate human color perception through statistical averages which result from the measures of

"standard observers" in the normalized environment of a color lab. Computer monitors are assemblages of different color technologies. We are surrounded by standardized colors in our daily lives. Every industrial color product, from light bulbs to printer ink, is nowadays fit into schemes administered by the International Commission of Illumination, a statutory corporation for standardization of colors.

Visual instruments based on such normalized schemes can nowadays produce millions of discriminable colors, if not to the human eye, then supposedly to the human brain. With such ergonomic image processing "the computer acts as an extension of the eye and the brain by selecting information the scientists cannot see" (Blumenthal 1982). It seems software developers care about the scientists' eyes, and their computerized prostheses, which are confronted with a large complex visualization of a social network. It is all about the efficiency of perception, which also means that the technical extension of the eye needs to be imperceptible.

Colored actors are perceived as similar or gradually different; therefore, quantitative attributes can be communicated. Two dimensional layouts could so be furnished with a third dimension, color, and even a fourth through gradients of luminosity, and as a result more information could be communicated with one image. Automatic efficiency optimization via coloring is an imaging technology in itself, a further generative element of the image production process. In addition to psychometric color schemes making perception more efficient, they also serve the purpose of reducing aesthetic intervention by the network analyst. Normalized color usage is just one of many standardizations embedded in automatic network visualization, which inform aesthetic practices and scientific construction of evidence.[11]

Colors play an important role, not only to create distinctive and graspable interspaces for spectators with normalized gazes, but also to arrange oneself into the visual space. One researcher calls this "sich einrichten", referring to furnishing his research environment. Whereas most users apply the default color schemes and, therefore, have to deal with ergonomic decisions made for them via "standard observers", the observed experts in network image processing tweak color schemes in accordance with their own taste or so called corporate identity. They have actively chosen to develop their own aesthetic framework, and not to discipline their gaze with supposedly more efficient strategies. Several researchers working with visualizations style their networks to comply with their own aesthetic criteria: "If I spend so much time with it, then I have to feel comfortable with it.", says X, who prefers earth colors, whereas Y favors strong colors. X also crafts nodes with a slight 3D effect, and Z likes to use shades. Sitting with X and Y, we go through old diagrams together, residing in an archive on the institute's server. All of them are immediately assignable to their respective creators, even though they hold no signatures. It is their style that makes the creators identifiable. My interview partners explain their mutual stylistic influences and sometime jibe at the other's taste. This historical review of diagram production in the institution reveals the improvement in imaging

[11] Another common form of normalization is the usage of colors such as blue and red, or the positioning from left to right, to depict e.g. active and inactive actors in the network. Such normalizations bring with them credibility and plausibility (Gugerli/Orland 2002), and for social network newcomers it connects the imagery to prevalent visual cultures, especially if it converges traditional imaging techniques with common associations and new visual experiences (Gugerli 2002).

technologies and graphical language over the years. It has been a long road from the first use of default settings in network visualization software to the self-programmed algorithms that bring about more scopes for design, like the coloring of edges, fonts and keys that are vital for the development of a visual language. The elaboration of specific styles to enrich and adapt the research process in demarcation to predefined standardization shows once more the active dimension of aesthetic practices in knowledge production.

Nevertheless, the handling of instruments in order to create network visualizations shapes the daily routines in network analysis as "stable environments" (Rheinberger 2006: 29). Goethe once criticized the aesthetic deficiency of instrumental perception because it supposedly cuts the unity of perception and corporeity. He complained about the loss of sensitivity and sensual richness for substantial awareness (Goethe 1999). In network analysis model kits, computer interfaces or paper frame visualization practices. The preparation of data for input into software trains the sensitivity for the datasets and the attention for the information to be highlighted. The instrumentation distances the researcher not necessarily from her data, it brings them together in a transformation and creation processes; it provides space for sensual richness of analytical objects that are created in the research process. It makes epistemic things tangible and figuratively inhabitable.

The resolution capacities of the researchers' perception and their rich instrumental sensibility go hand in hand. Whether on paper or on screen, the tangible environment with the network diagrams as interfaces trains the researchers in the simultaneity of measuring and representation. Their representations shape and "constitute the physiognomy of the object of the research", and they can be regarded as "revelatory objects […] which simultaneously analyze what they reveal" (Lynch 1990: 154) by embedding the instrumental medialization in an associative context. Imaging practices mean singular or collective "doing images" (Burri 2008). Groping, pulling, knocking, gesticulation, transferring, overdrawing, crumpling, zooming, turning, changing perspective, coloring, highlighting, fading, and so forth both extend the sensual richness of the epistemic object, and co-constitute and enact it. Measurements and calculations are increasingly experienced at the surface of the images. Numerous changes of mode, format and media, and analytical-aesthetic interventions shape the knowledge of data and the social networks as epistemic entities. Exploration and demonstration blend into each other, being further embedded in metaphorical and aesthetic space, which is providing the logics for interpretation. But most importantly, the interviewed researchers described the epistemic imaging processes as excitingly sensual and sensible work, going far beyond the scope of "coloring of JPGs".

7 Let's keep in touch

In line with the "pictorial turn" (Mitchell 1994) in science studies, without losing sight of the various corporeal and sensual entanglements of researchers with their objects of study, this article aimed at exploring corporeal practices involved in the production of network diagrams in the social scientific research process. As part of the experimental system the network visualization unfolds its epistemic virtue embedded in a series of images through a variety of media. The ethnographic encounter with a printed network diagram in the meeting room, laying on the table presented how it is discussed in the team, being produced and interpreted with the deployment of graphs, instruments, bodies, metaphors, colors, forms, and materials, even if it emerges only shortly as a stabilized entity in the research proc-

ess. Soon after the meeting, it is changed again. By taking such epistemic images, in particular diagrams of social networks, seriously and following their production, the manifold materialities and corporealities that co-constitute the object of research through collective aesthetic experience were taken into account. It was shown how the tactile sense, the careful construction of metaphorical spaces and sensual realisms, but also the conscious rejection of pre-defined ergonomic concepts of efficient vision, co-constitute the visuality of social structures in creating a "feeling for the data". Furthermore, making visible is just one step in the creation of evidence: It is the tangibility of the networks, the rich metaphorical and colorful visual language that lead to the experience of evidence in the experimental setting of social network analysis. Networks can be literally and figuratively grasped. Additionally, it has been exemplarily shown, how senses are incorporated into instrumentation, as well as counted for to create such collective experiences and the necessary contexts for exploration and interpretation. Aesthetic practices – no matter how embodied, mediated or normalized, – make knowledge "explicit" (Hirschauer 2008: 982) when handling visualizations.

Hence, the paper suggests to open the perspective to new modes of reflexivity beyond a purely "tacit" corporeal performance. Theories of embodied knowledge and inscriptions often treat the body as passive medium that can be conditioned by training. While this is a legitimate perspective, it is too narrowly considered. This paper argues that conceptualizing corporeal visualization practices requires thinking beyond "corporeal memory" as a "bodily archive of manual and instrumental knowledge" (Knorr-Cetina 1999: 99). Such an approach falls too short when the professional gaze encompasses a dynamic interplay of imaging techniques, bodies and imaginations while making social structures visible. Corporeality in aesthetic practices should not be blended out as automatism or tacit skill; rather it should be regarded as an active and reflexive medium and criterion of epistemic practice. The corporal employment happens with purpose, actively and is both dedicated to successful communication, and part of the sensible, lively, playful, and palpable knowledge production.

References

Barlösius, E., et al. (eds.), 2001: *Gesellschaftsbilder im Umbruch – Soziologische Perspektiven in Deutschland*. Opladen: Leske und Budrich.

Beaulieu, A., 2002: Images Are Not the (Only) Truth: Brain Mapping, Visual Knowledge and Iconoclasm. In: *Science, Technology & Human Values* 27: 27-53.

Bergermann, U., 2006: Tastaturen des Wissens. Haptische Technologien und Taktilität in medialer Reprodution. In: S. Peters/M.J. Schäfer (eds.): *Intellektuelle Anschauung. Figurationen von Evidenz zwischen Kunst und Wissen*. Bielefeld: transcript Verlag, 301-324.

Blumenberg, H., 2001: *Ästhetische und metaphorische Schriften*. Frankfurt am Main: Suhrkamp.

Blumenthal, D., 1982: Image Processing. Advances Techniques Enable Scientists To Pursue New Studies. In: *NIH Record* 24(8): 11.

Burri, R. V., 2008: *Doing Images. Zur Praxis medizinischer Bilder*. Bielefeld: transcript Verlag.

Burri, R.V./Dumit, J., 2008: Social Studies of Scientific Imaging and Visualization. In: E. Hackett et al. (eds.): *New Handbook of Science and Technology Studies*. Cambridge: MIT Press, 297-317.

Cambrosio, A. et al., 1993: Ehrlich's 'Beautiful Pictures' and the controversial beginnings of immunological imager. In: *Isis* 84: 662-699.

Collins, H.M., 2001: Tacit Knowledge, Trust and the Q of Sapphire. In: *Social Studies of Science* 31(1): 71-85.

Dewey, J., 1929: *The Quest for Certainty: a Study of the Relation of Knowledge and Action*. New York: Minton, Balch & Company.

Dumit, J, 1999: Objective Brains, Prejudicial Images. In: *Science in Context* 12(1): 173–201.

Dumit, J., 2004: *Picturing Personhood. Brain Scans and Biomedical Idendity*.

Princeton NJ: Princeton University Press.

Fleck, L., 1981: *Genesis and development of a scientific fact*. Chicago: University of Chicago Press.

Folkers, G., 2001: Architektur und Eigenschaften der Moleküle des Lebens. In: B. Heintz/J. Huber (eds.), *Mit dem Auge Denken. Strategien der Sichtbarmachung in wissenschaftlichen und virtuellen Welten*. Zürich: Edition Voldemeer, 159-172.

Freud, S., 1961: Die *Traumdeutung*. Frankfurt am Main: Suhrkamp.

Fyfe, G./Law, J. (eds), 1988: *Picturing Power: Visual Depiction and Social Relations*. London: Routledge.

Galison, P., 1997: *Image and Logic. A Material Culture of Microphysics*. Chicago: University of Chicago Press.

Galison, P., 2002: Images Scatter into Data, Data Gathers into Images. In: B. Latour/P. Weibel (eds.), *Iconoclash: Beyond the Image Wars in Science, Religion, and Art*. Cambridge MA: MIT Press, 300-323.

Gießmann, S., 2008: Graphen können alles. Visuelle Modellierung und Netzwerktheorie vor 1900. In: I. Reichle et al. (eds), *Visuelle Modelle*. München: Wilhelm Fink Verlag, 269-284.

Goethe, J.W. von, 1999: Der Versuch als Vermittler von Objekt und Subjekt. In: *Goethes Werke, Band XIII: Naturwissenschaftliche Schriften*. München: C.H. Beck, 10-20.

Griesemer, J.R., 2004: Three Dimensional Models in Philosophical Perspective. In: S. de Chadarevian/N. Hopwood (eds.), *Models: The Third Dimension of Science*. Stanford: Stanford University Press, 433-442.

Gugerli, D., 2002: Der fliegende Chirurg. Kontexte. Problemlagen und Vorbilder der virtuellen Endoskopie, in: D. Gugerli/ B. Orland (eds.), *Ganz normale Bilder. Historische Beiträge zur visuellen Herstellung von Selbstverständlichkeit*. Zürich: chronos, 251-270.

Gugerli D./Orland, B. (eds.), 2002: *Ganz normale Bilder. Historische Beiträge zur visuellen Herstellung von Selbstverständlichkeit, (Interferenzen 2)*. Zürich: chronos.

Haraway, D., 1988: Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspectives. In: *Feminist Studies* 14(3): 575-599.

Haraway, D., 1997: *Modest-Witness@Second-Millenium.Femaleman-Meets_Oncomouse: Feminism and Technoscience*. New York: Routledge.

Haraway, D., 2004: From Cyborgs to Companion Species: Kinship in Technoscience. In: *The Haraway Reader*. New York: Routledge, 295-321.

Heßler, M./Mersch, D., 2009: Bildlogik oder Was heißt visuelles Denken? In: M. Heßler/D. Mersch (eds.): *Logik des Bildlichen. Zur Kritik der ikonischen Vernunft*. Bielefeld: transcript Verlag, 8-62.

Hirschauer, S., 2008: Körper macht Wissen. Für eine Somatisierung des Wissensbegriffs. In: K.S. Rehberg (ed.), *Die Natur der Gesellschaft. Verhandlungen des 33. Kongresses der Deutschen Gesellschaft für Soziologie in Kassel. Bd. II*. Frankfurt/New York: Campus, 974-984.

James, W. 1920: Remarks on Spencer's definition of mind as correspondence. In: W. James. *Collected essays and reviews*. London: Longman, 43-68.

Keller, F., 2006: Die Evidenz der Gesellschaft. Die Genealogie visueller Objekte im American Journal of Sociology. In: M. Cuntz et al. (eds.), *Die Listen der Evidenz. Mediologie, Band 15*. Köln: DuMont, 203-220.

Knorr-Cetina, K., 1999a: *Epistemic Cultures. How Sciences Make Knowledge*. Cambridge MA: Harvard University Press.

Knorr-Cetina, K., 1999b: 'Viskurse' der Physik. Wie visuelle Darstellungen ein Wissenschaftsgebiet ordnen. In: J. Huber/M. Heller (eds.), *Konstruktionen Sichtbarkeiten*. Wien: Springer, 245-263.

Krohn, W., 2006: Die ästhetischen Dimensionen der Wissenschaft, in: W. Krohn (ed.), *Ästhetik in der Wissenschaft*. Hamburg: Felix Meiner Verlag, 3-39.

Latour B./Woolgar S., 1986: *Laboratory Life. The Construction of Scientific Facts*. Princeton, NJ: Princeton University Press.

Latour, B., 1990: Drawing Things Together. In: M. Lynch/S. Woolgar (eds.), *Representation in Scientific Practice*. Cambridge, MA: MIT Press, 19-68.

Latour, B., 1996: *Der Berliner Schlüssel*. Berlin: Akademie Verlag.

Law, J., forthcoming: Collateral Realities. In: F. Domínguez Rubio/P. Baert (eds), *The Politics of Knowledge*. London, Routledge.

Law, J./Urry, J., 2004: Enacting the Social. In: *Economy and Society* 33(3): 390-410.

Levi-Strauss, C., 1947: *Les Structures élémentaires de la parenté*. The Hague: Mouton.

Lynch, M., 1985: Discipline and the material form of images: An analysis of scientific visibility. In: *Social Studies of Science* 15: 37-66.

Lynch, M./Edgerton, S., 1988: Aesthetics and Digital Image Processing: Representational Craft in Contemporary Astronomy. In: G. Fyfe/J. Law (eds), *Picturing Power: Visual Depiction and So-*

cial Relations. London: Routledge, 184-220.

Lynch, M./Woolgar, S., 1990: *Representations in Scientific Practice*. Cambridge, MA: MIT Press.

Lynch, M., 1990: The externalized retina: Selection and mathematization in the visual documentation of objects in the life sciences. In: M. Lynch, /S. Woolgar: *Representations in Scientific Practice. Cambridge*, MA: MIT Press, 153-186.

Lynch, M., 1991: Pictures of nothing? Visual construals in social theory. In: *Sociological Theory* 9(1): 1-22.

Mayer, K., 2009: Out of Touch? In: A. Böhler/S. Granzer (eds.): *Ereignis Denken. TheatRealität, Performanz, Ereignis*. Vienna: Passagen Verlag, 241-258.

Mayer, K., forthcoming a: *Objectifying Social Structures: Network visualization as means of social optimization* (submitted to Theory and Psychology).

Mayer, K., forthcoming b: *Imag(in)ing Networks*. PhD thesis. University of Vienna 2011.

Meinel, C. 2004: Molecules and Croquet Balls. In: S. Chadarevian/N. Hopwood (eds.): *Models: The Third Dimension of Science*. Stanford: Stanford University Press, 242-275.

Mersch, D., 2003: *Die Medien der Künste*. München: Wilhelm Fink Verlag.

Mersch, D., 2005: Das Bild als Argument. In: C. Wulf/J. Zirfas (eds.), *Ikonologien des Performativen*. München: Wilhelm Fink Verlag.

Mersch, D., 2006: Visuelle Argumente. In: S. Maasen et al. (eds), *Bilder als Diskurse, Bilddiskurse*. Weilerswist: Velbrück.

Mitchell, W.J.T., 1994: *Picture Theory: Essays on Verbal and Visual Representation*. Chicago: University of Chicago Press.

Mody, C.C., 2005: The Sounds of Science: Listening to Laboratory Practice. In: *Science, Technolgy & Human Values* 30: 175-198.

Moody, J., et al., 2005: Visualizing Network Dynamics. In: *American Journal of Sociology*, 110(4), 1206-1241.

Moreno, J.L., 1953: *Who Shall Survive? Foundations of Sociometry, Group Psychotherapy and Sociodrama*. Beacon N.Y: Beacon House Inc.

Moreno, J.L., 1967: *Die Grundlagen der Soziometrie*. Köln/ Opladen: Westdeutscher Verlag.

Mutzel, P./Weiskircher, R., 1999: *Automatic Graph Drawing*. MPfI für Informatik. http://domino.mpi-inf.mpg.de/internet/news.nsf/Spotlight/19990308.

Myers, N., 2006: Animations and the Propagation of Affect in the Lively Arts of Protein Modelling. In: *Science Studies* 19(2): 6-30.

Myers, N., 2007: *Modeling Proteins, Making Scientists: An Ethnography of Pedagogy and Visual Cultures in Contemporary Structural Biology*. PhD thesis. Cambridge MA: MIT.

Myers, N., 2008: Molecular Embodiments and the Body-work of Modeling in Protein Crystallography. In: *Social Studies of Science* 38(2): 163-199.

Nagel, T., 1986: *The View From Nowhere*. New York: Oxford University Press.

Nietzsche, F., 2008: *Thus Spoke Zarathustra*. Projekt Gutenberg: www.gutenberg.org/files/1998/1998-h/1998-h.htm

Nikolow, S., 2005: Kurven, Diagramme, Zahlen- und Mengenbilder. Die Wiener Methode der Bildstatistik als statistische Bildform. In: *Bildwelten des Wissens. Kunsthistorisches Jahrbuch für Bildkritik* 3(1): 20-53.

Ochs, E. et al. 1994: Interpretative Journeys: How Physicists Talk and Travel through Graphic Space. In: Configurations 2/1: 151-171.

Pauwels, L., 2006: Representing Moving Cultures: Expression, Multivocality, and Reflexivity in Anthropological and Sociological Filmmaking. In: L. Pauwels (ed.): *Visual Cultures of Science*. Dartmouth College Press, 120-152.

Polanyi, M., 1967: *The Tacit Dimension*. New York: Anchor Books.

Polanyi, M,. 1962: Tacit Knowing: Its Bearing on Some Problems of Philosophy. In: *Reviews of Modern Physics* 34: 601-616.

Pörksen, U., 1997: *Weltmarkt der Bilder. Eine Philosophie der Visiotype*. Stuttgart: Klett-Cotta.

Porter, T. M., 1995: *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*. Princeton NJ : Princeton University Press.

Rheinberger, H.J., 1992: *Experiment, Differenz, Schrift. Zur Geschichte epistemischer Dinge*. Marburg an der Lahn: Basilisken Presse.

Rheinberger, H.J., 2006: *Experimentalsysteme und epistemische Dinge*. Frankfurt am Main: Suhrkamp.

Rorty, R., 1979: *Philosophy and the Mirror of Nature*. Princeton, NJ: Princeton University Press.

Rudwick, M., 1976: The emergence of a visual language for geological science, 1760-1840. In: *History of Science* 14: 149-195.

Shapin, S./Schaffer, S., 1985: *Leviathan and the Air Pump: Hobbes, Boyle, and the experimental life*. Princeton NJ: Princeton University Press.

Zimmermann, A., 2009: *Die Ästhetik der Objektivität. Genese und Funktion eines wissenschaftlichen und künstlerischen Stils im 19. Jahrhundert*. Bielefeld: transcript Verlag.