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Estelle Chaillat, Annie Gentes

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Openness, graphic design and visual practices of science: exploration to promote innovation

Chaillat, Estelle^{*a}; Gentes, Annie^b

^a Co-Design Lab Telecom Paristech, Paris, France

^b Co-Design Lab Telecom Paristech, Paris, France

* estelle.chaillat@telecom-paristech.fr ; annie.gentes@telecom-paristech.fr

This article presents an ongoing research on the visual practices of experimental scientists. We look at the way scientific visuals are constructed, to understand how the processes promote exploration and expansion, which are central proprieties supporting innovation in the context of scientific research. Based on a series of in-situ and semi-directed interviews with experimental sciences imagery stakeholders, this inquiry aims at identifying proprieties of the “beautiful image of science”, using the notion of “beauty” as a basis to better understand the underlying criteria leading to decision-making in the processes of scientific imagery. This research shows that moments of openness and practices of design are present at certain stages of the imagery workflow, and could be emphasized to encourage exploration for discoveries.

Keywords: *openness; scientific imagery; graphic design; innovation*

1 Some definitions

In this article, the word “science” will be used to refer to experimental sciences, as practiced in laboratories of natural sciences: mostly biology and physics.

Design(ing) practice (Hatchuel & Weil, 2003) is used in place of the French word “conception”, defined as: action of elaborating something new in the mind, and to build it (be it material or not), (CNRTL, 2019; Larousse, 2019). We will use the words “conceptive” and “designing” as its adjectives. To refer about professional designers’ practices, we will use “practices of design”.

Lastly, the expression *act of design*, here mean: the processes, tools, and thoughts used to conceive (as a design practice) solutions to complex problems (Findeli & Bousbaci 2005; Manzini, 2016).

2 Introduction

This article is based on a review of literature on the visual practices of experimental sciences, and on design research as it looks at design effects on “ways of thinking and doing” (Manzini, 2016).

2.1 Visual representations and the work of science

Visual artefacts involved in knowledge construction (Coopmans, Vertesi, Lynch, & Woolgar 2014; Lynch & Woolgar 1990) have been studied by many disciplines since the 80's (Allamel-Raffin, 2010; Anderson, 2009; Bigg, 2012; Burri & Dumit, 2008; Cambrosio, Jacobi, & Keating, 1993; Lynch & Woolgar, 1990). It reflects an interest in the making of science as it is correlated to the mobilization of images.

Studying pictures of science offers interesting perspectives to understand paradigms of knowledge acquisition (Daston & Gallison 2012; Latour 1985). Documenting the way scientists compose visuals, in relation to their context, helps identify relationships between working context, social organization, disciplinary points of view and the way visuals – either analogical or digital – are appreciated (Amann, Knorr-Cetina, 1990; Dondero, 2009; Vertesi, 2014). These studies establish that perception, study, and understanding of a research object are redefined by its forms of representation. Taking visuals into account also leads to a better understanding of scientific rhetoric (Allamel-Raffin 2006; Fontanille, 2009; Latour & Woolgar, 1979; Merz 2009), and, more globally, capture the values, status and uses of scientific imagery (Dondero & Fontanille 2014).

Apart from this rich literature mostly from Science and Technology Studies (STS) and Visual Studies of Science (VSS), there is little research reflecting on the crafting of these artefacts *per se*: looking at their construction and questioning the processes and criteria leading to decisions in the making of images. The conditions of their production are accessible, as they have to meet the standards of scientific transparency (Dondero, 2010) but studies rarely take the visual practice as a starting **and** ending point. Some studies in VSS focuses on the relationships between works of art or design, and scientific imagery (Renon, 2016) but rarely *in situ*, despite taking into account how images are made (Allamel-Raffin, 2013; Dondero & Fontanille, 2014). Some recent works from HCI offer task-analysis of experimental work of science, reflecting on the way scientific visual processes could be improved to enhance research findings (Solano-Roman, 2018). Finally, it seems there is very little about the designing dimension that lies within experimental sciences “at work”.

If scientific images play an important role in the construction and perception of scientific objects (Coopmans, 2014; Vertesi, 2014), a lot is at stake for design in questioning the conceptive dimension of scientific image-making.

2.2 Openness and innovation

Our question is therefore at the crossroad of STS, VSS, design, and epistemology. We suggest that to better understand the conceptive parts of science, we need to elaborate on design research to better understand them.

Contemporary literature about design suggests that design reshapes *ways of thinking and doing* (Cross, 1982; Findeli, 2001; Gultekin-Atasoy, Lu, & Bekker, 2015; Manzini 2016) and can transform the known world into a preferred one (Findeli, 2012). A key concept of this research on design is openness. Openness is related to the notion of exploration, and can be defined as “the number of particular thoughts an expression may elicit in an individual” (Lagerwerf & Meijers, 2008). It expands perceptual inferences, and is thus seen as a privileged way to formulate innovative propositions, innovation relating to the capacity of expansion (Hatchuel & Weil, 2003) as well as **inventing novel ways of doing**. The notion is

already found in some scientific activities, for instance when scientific students “(...) are given the initiative of finding solutions to problems” (Simon, Jones, Fairbrother, Watson, & Black, 1992 quoted by Haigh, 1993). More importantly, scientific research can be considered as “a matter of discovering and **inventing novel ways of seeing**, identifying (...)” (Lynch, 2014).

Openness also qualifies practices of design (Self, Evans, & Dalke, 2013), supporting for instance exploration of an object (Gaver, Dunne, & Pacenti, 1999). Based on the literature from management of innovation (Le Masson, Hatchuel, & Weil, 2011), we think that it is a propriety of the *act of design* to organize conditions of openness to enhance exploration, expansion and invention of preferred solutions (Gentes, 2017).

Elaborating on this literature, we want to look at visual practices of scientists, and explore if **there are forms of openness that support exploration and heuristic in the apparently positivist field of experimental sciences.**

3 Fieldwork: interviews with scientific imagery stakeholders

To understand how openness can be organized in the context of scientists’ visual practice, we interviewed scientific imagery stakeholders (SIS). We chose these people after an ethnographic observation made at Pasteur Institute in a microbiology laboratory from March to April 2017.

3.1 Methodology

We will first explain why we used the notion of beauty to question criteria involved in the making of scientific images, then we will present our approach to focus on design-specific issues. Finally, we will present the interviews.

3.1.1 Beauty, taking care and criteria

The notion of beauty in itself appeared as an important criterion from a first series of informal interviews conducted at the beginning of our research, in October 2017. We wanted to identify themes and values that SIS thought important for science at work. The interviewees regularly told one of the authors that, “because she was a graphic designer”, they had “a nice image” to show her. Based on the anecdote theory (Michael, 2012), our intuition was there was a bigger picture behind this term “nice”, and the circumstances of its enunciation, than just a tribute to graphic design.

In addition, the two months of immersion at Pasteur raised an unexpected number of issues regarding creation, care and beauty in the work of scientists. Reflecting on it, associated with the beauty concept, were the scientists taking so much care of their images for scientific reason only?

Our hypothesis is that “beauty” as a situated notion can be used to retrace the cares that the scientists put into the making of their images, so as to understand how rules of composition, commonly-shared imagery knowledge, and aesthetics criteria guide their visual practice. That is to say, this **notion could be used to discuss visual practices of scientists, in particular to find new insight on the designing and innovative dimension of their visual work.**

3.1.2 Starting from the visuals to perform retro-designing

As part of this enquiry, we collected images given by the actors to perform *retro*-designing as taught in design schools: we analyzed visuals in relation to their pragmatic, semantic, social, and political dimensions. We made the hypotheses that confronting actors and their choice of images with this design approach could lead to interesting insights in terms of visual practice.

3.1.3 Conducting interviews with scientific imagery stakeholders

We conducted interviews with nine actors from August 2018 to January 2019 so as to discover criteria that impact the way scientific visuals are constructed and to see if the scientific imagery processes are “open” enough to support the scientific exploration and reformulation of problems.

These interviews were semi-directed, in a pragmatic constructivist inductive approach. They lasted between 58 and 73 minutes. One took place in a public place, one on skype from the scientist’s laboratory, and the others in-situ, at the workplace of the actors, in the laboratory room, at their desk, or in meeting rooms.

Our nine actors were:

- Three confirmed researchers, from quantum physics (KC), neurobiology (TG), microbiology (JU).
- Three post-doc or doctoral researchers, from astrophysics (BD), microbiology specialized in microscopy imaging for embryogenesis (QW), and neurobiology (NU).
- One researcher in mathematics and computer science, specialized in signal and image processing (JC).
- Two engineers specialized in the treatment and analysis of biologic images (NZ and QT), working with biology researchers, and medical researchers.

A few days before the interviews, we asked the actors to give us a “beautiful scientific image”. During the interview, we first asked the interviewees to present themselves, then asked: “Why is this image a « beautiful scientific image? »”. This opened the discussion, focusing on the personal appreciation of the scientists as well as on their use of images in their work. We asked about:

- The context of use, and manipulation of images at work.
- The constraints related to the making of images
- The degree of openness in the process of images-making: when the scientist’s decisions are open to discussion.

Afterward, we conducted a thematic analysis.

3.2 Preliminary Results

Out of the nine requests to obtain a “beautiful scientific image” before the interview:

- 5 actors presented images made by themselves, or by collaborators in the context of their work.
- 4 actors presented images selected from other research, from their field.

- 2 actors proposed two images instead of one.
- 3 actors presented composite images (made of several images) (fig.1, a, c.).

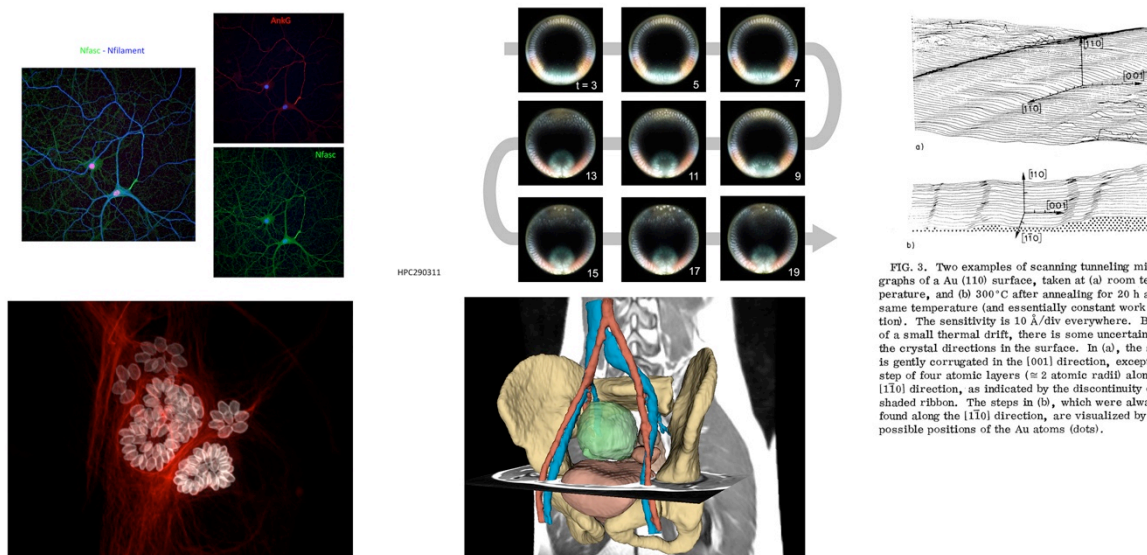


FIG. 3. Two examples of scanning tunneling micrographs of a Au (110) surface, taken at (a) room temperature, and (b) 300°C after annealing for 20 h at the same temperature (and essentially constant work function). The sensitivity is 10 Å/div everywhere. Because of a small thermal drift, there is some uncertainty in the crystal directions in the surface. In (a), the surface is gently corrugated in the [001] direction, except for a step of four atomic layers (≈ 2 atomic radii) along the [110] direction, as indicated by the discontinuity of the shaded ribbon. The steps in (b), which were always found along the [110] direction, are visualized by the possible positions of the Au atoms (dots).

 <p>a) transmitted by (TG) credits : UPMC / INERM U1127 / CNRS UMR7225</p>	 <p>c) transmitted by (QW) credits : Villoutreix P, Andén J, Lim B, Lu H, Kevrekidis IG, Singer A. et al.</p>	 <p>e) transmitted by (KC) credits : Binnig, G., Rohrer, H., Gerber, C., & Weibel, E. (1982). Surface studies by scanning tunneling microscopy. Physical review letters, 49(1), 57.</p>
 <p>b) transmitted by (JU) credits : DR1 CNRS, Institut for Advanced BioSciences, Univ. Grenoble Alpes Inserm U1209 - CNRS UMR 5309 Team « Membrane Dynamics of Host-Parasite Interactions »</p>	 <p>d) transmitted by (JC) credits : Alessio Virzi, Cécile Muller, Alessandro Delmonte, Sabine Sarnacki, Isabelle Bloch LTCl, Télécom ParisTech, et IMAG2, Hôpital Necker Enfants Malades</p>	

Figure 1. A selection of « beautiful images of science » given by five of our actors. a) neurons culture, imaged to identify « pre-nodes ». b) Colored movie frames obtained with data fusion algorithm of molecular signals and morphology during the DV patterning of *Drosophila* embryo. Retrieved from <https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1005742> c) toxoplasmosis imaged by fluorescent microscopy (white structures) that “looks like flowers”. d) dynamic 3D visualization of a human pelvis, that can be rotated in three axis. e) an “image of great importance” in the “scientific community” of (KC): “that was the first time we « saw atoms. »”. Atoms are the dark dots, and dark lines shows levels of electronic measures that attest “presence of atoms”. Retrieved from Binnig, G., Rohrer, H., Gerber, C., & Weibel, E. (1982). Surface studies by scanning tunneling microscopy. Physical review letters, 49(1), 57.

3.2.1 Qualities of images

Arguments about the notion of beauty associated with the visuals allowed us to identify several qualities:

- Emotional response: the beautiful image “appeals to the eye”, “catches the attention”
- Immediacy: results rapidly conveyed. Actors differentiated “more visual image”: “This one is a talkative image because we **directly** see the embryo’s morphology, and we **directly** see what it depicts of the process as genetic expression, through the colors put on the image”, from images “like mathematical graph”.
- Clarity: immediacy was linked to the clarity of the picture. The clarity depiction of the visual representation might be linked to the ontology of the scientific image itself: “Normally, it is on a tissue, not translucent, so they made it translucent so we can see it”.

- Mnemonic function: “When we want to transmit something, be it in a scientific article or a seminar, pictures are what people memorize the most”.

3.2.2 Scientific facts and the symbolic value of image

The most emphasized criterion was that the image should present scientific information and represent significant findings. They qualified beauty not only through the aesthetic qualities of images as described in 3.2.1., they also qualified beauty as lying in the scientific fact itself more than the “immediate visual aspect”: “a relation between two things that depict a physical phenomenon, there is a certain form of beauty, but less immediate”. Unveiling a scientific fact either contemporary or in the history of science is crucial to the definition of a beautiful scientific image according to the interviewees.

3.2.3 Importance of academic and scientific normativity versus composing, compositing, and decision-making

All actors noted the importance of the normative scientific context in relation to characteristics of their images: “we know that the core is blue, cytoskeleton is often green... there are standard colors. (...) people usually use the same colors codes”. Normativity was also linked to technical constraints, as with the fluorescent marker applied to perform fluorescent microscopy (NZ, JU, NU, TG).

However, it appeared that scientists have a composing and compositing practice that takes place at different steps of their work. They built their own technical protocols to match physical and biological constraints, and obtain the image they are looking for. This includes operations of exploration, reduction, selection, appreciation. While they do not play on contrasts, they still make choices about cropping, coloring, developing elements of the picture. What is more, the decisions made to select and define the protocols are discussed within the laboratory, to obtain a preferred solution chosen based on the pragmatic conditions, such as the technical apparel at disposition, the time allowed for the research, or the object manipulated.

Finally, they compose their images in relation with the different steps of the research work: experiments, analysis, discussion, publication. Not only was it suggested that images qualified as beautiful had more chances to be broadly diffused, they also are different versions of the same scientific knowledge.

3.2.4 Fruit of a Collaborative work and communicative artefacts and skills

Image-making appeared as a collaborative work, involving specific expertise from each scientist, but also from specific technical fields such as lab technicians specialized in scientific imagery, or engineers specialized in mathematics applied to informatics. One of our actors emphasized the value of pursuing collaborative work with researchers from different fields of experimental sciences, as in physics. In this context, images work as a common goal and support for discussion, that is enriched by the diversity of expertise and perspectives.

- To make an image, researchers consult specialized technicians
- To analyze and treat images, scientists consult specialized informatics engineers
- To discuss qualities of the image and eventual findings, scientists use digital and analog drawing tools to detail their impressions, intuitions and hypotheses.

4 Discussion: are there designerly ways of doing science?

Primary results of this inquiry suggest that, in their visual practices, scientists perform *acts of design* that are not acknowledged as such. Even if the positivist norms indispensable to perform scientific research produce effects of fixation (Hatchuel, Le Masson, & Weil, 2011), as seen for colors choices, an important conceptive dimension seems to take place in the context of their visual practice.

Indeed, scientists compose their visual daily routine on the basis of a wicked problem-solving approach, looking for plural solutions to one problem. They take care of their situated images, **adapting or inventing** processes until its satisfying considering their question of research. To do so, they **question** their imagery processes, **reformulate** their approach, and discuss it to better understand what it brings to their research, in order to construct an accurate preferred solution. They take care of their images to maximize their perceptual inference, organizing condition of openness to **enhance exploration** and **disclosure** of scientific information, but also in order to make their message clearly address the scientific community. These designing visual practices seems to **promote expansion**, as, reshaping their questions of research, they expand the findings of their field and its technical landscape.

To summarize, conceptive visual practice of scientists appears *designerly* in the way it seems to support conditions of openness and to promote innovation by means of specific operation which contribute to exploration, disclosure and expansion, as redefinition, rethinking, reformulation (Gaver et al., 1999; Hatchuel, 2001; Newton, 2004; Gentes, 2017).

5 Conclusion: Adopting a design approach to question ways of seeing and knowing

To study what stands at the crossroad of science, design, and epistemology, we developed a method that is based on interviews on what actors considered as beautiful images. This allowed us to discover forms of openness involved in the making of scientific images and in the semiotic qualities of the artefacts.

These results take place in an *Emerging design* paradigm (Manzini, 2016), which opens up perspectives on practices of design performed by people that are not labelled as designers. Manzini call it *diffuse design*, that is “the natural human ability to adopt a design approach, which results from the combination of critical sense, creativity, and practical sense”. This approach helps us question the methodology and tools utilized to produce and use visuals, and how to support the conceptive approach within experimental sciences.

Placing these objects under the scope of *designerly ways of knowing*, we may question “what they **could** be”, encouraging innovative propositions that promote further explorations. Acknowledging similarities of scientist’s visual practices with the ones identified for design should support *new ways of doing and thinking* in the context of scientific research.

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About the Authors:

Estelle Chaillat: Graduated Graphic Designer and PhD student, she is interested in the designing dimension that lay in the processes of scientific imagery. Do the processes of natural experimental sciences include design approach? What does designerly ways of doing imply? What is at stake for discovery and knowledge construction?

Annie Gentes: associate professor (Maître de conference HDR) in Information and Communication Sciences, her research focuses on extreme design and ICT. She consequently works with artists, designers and

researchers in engineering to understand their specific contribution and gamut of conceptive activities that turn technology into a cultural artifact.

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