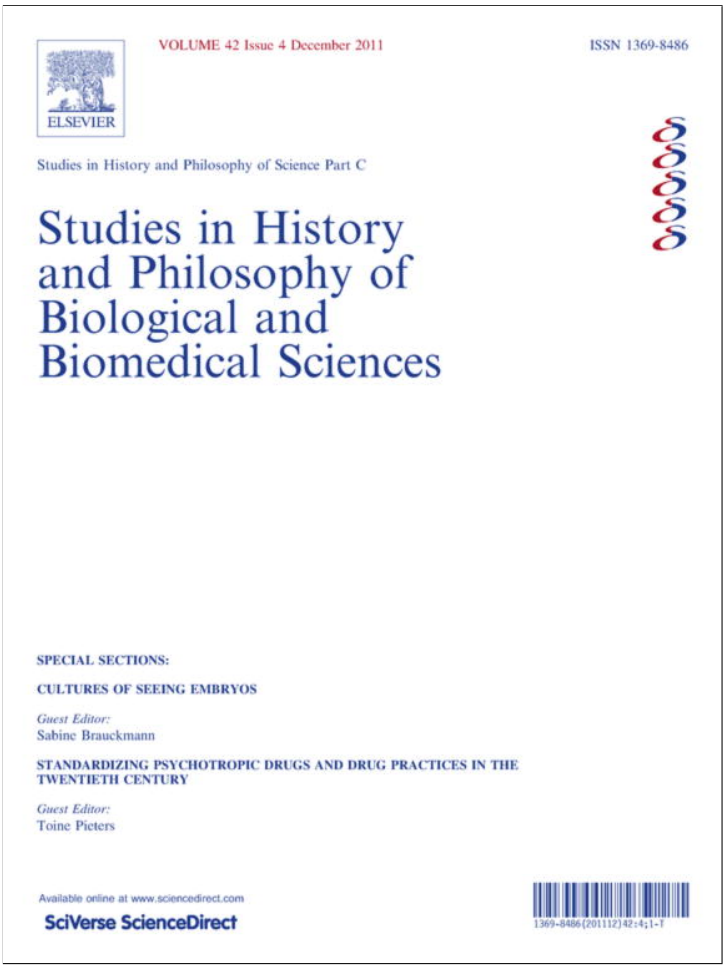

Studies in History and Philosophy of Biological and Biomedical Sciences 42 (2011) 391–394

Contents lists available at SciVerse ScienceDirect

Studies in History and Philosophy of Biological and Biomedical Sciences

journal homepage: www.elsevier.com/locate/shpsc

Inducing visibilities: An attempt at Santiago Ramón y Cajal's aesthetic epistemology

Erna Fiorentini

Institute of Art and Visual Studies/Institut für Kunst- und Bildgeschichte – IKB, Humboldt Universität zu Berlin, Dorotheenstrasse 28, D-10117 Berlin, Germany

ARTICLE INFO

Article history:
Available online 19 August 2011

Keywords:
Visibility
Perception
Imaging
Selection
Assemblage
Microscopical drawing

ABSTRACT

In this paper, I consider Santiago Ramón y Cajal's strategy of histological observation and imaging in terms of what I call "induction of visibility" (Fiorentini, 2011). Cajal's strategy of visibility induction drew upon both rational and aesthetic visual sensibility, and considered this interplay to be a constitutive element of knowledge production. I propose to describe Cajal's fundamental attitude towards visually inferred knowledge in terms of an "aesthetic epistemology".

Juan Fernandez, the protagonist of Santiago Ramón y Cajal's (1852–1934) novel *The Corrected Pessimist* of 1905, realized upon waking up one day that his eyes had suddenly been turned into microscopes. After several vicissitudes connected with his enhanced visual sensibility, he reflected:

> In the organic world the impression of ugliness and repugnance comes from our inopportune looks at its constitutive elements (cells, fibres, membranes, appendices, etc.). [Though] in all things there is something beautiful and attractive. It's all a question of placing oneself at the right point of view. (Ramón y Cajal, 2001, p. 151)

Addressing the aesthetic dimension of observation, this passage summarizes Cajal's fundamental conviction that controlling vision and visibility in every sense broadens the horizon of understanding. This attitude is the very foundation of his methodology of observation and imaging, which relied upon what I call "induction of visibility" (Fiorentini, 2011). Cajal's method opened new dimensions in histological observation and visualization: because it was decidedly visually oriented, his approach was revolutionary at the time when he began what he termed his "honeymoon with the microscope" (Ramón y Cajal, 1988, p. 252) as a young assistant in Saragossa in 1877. As Cajal remembers, in fact, he was at that time very much at odds with the general disposition towards microscopic observation, and

> excessively surprised by the almost total absence of objective curiosity on the part of our professors, who spent their time talking to us at great length about healthy and diseased cells without making the slightest effort to become acquainted by sight with [them] ... perhaps the majority of the professors in those days ... was never willing to muddle [their] mind by looking through the ocular of a magnifying instrument. (Ramón y Cajal, 1988, p. 252)

Cajal's method, moreover, bundled for the first time objects, their perception, and their representations as epistemological tools. In Cajal's conception, to optimize the visibility of the object's structures was the first step towards an enhanced perceptual ability. This ability alone was then able to evoke the meaning hidden behind the structures and to make it visually available for further reflections. In order to reach this optimum of visibility, Cajal adopted a complex methodology based upon a multiplicity of procedures. Ranging from staining and drawing to photography and animation, they complied with his manifold skills, namely his expertise in specimen preparation, his trained sharpness of visual judgment, and his artistic talent for the visual presentation of the

E-mail addresses: erna.fiorentini@hu-berlin.de, e.fiorentini@fu-berlin.de

1369-8486/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.shpsc.2011.07.008

evidence inferred from observation. Around 1900, Cajal's methodical multiplicity in experimentation and image techniques certainly matched an upcoming general attitude that was becoming of crucial importance in many field of knowledge so disparate as the sciences, archaeology, and criminology. Nonetheless, Cajal's methodical multiplicity exceeded the standards of histology around 1900, since it applied to two dimensions of visualization simultaneously: on the one hand, to the specimen, where the most urgent problem was making structures *inside* the three-dimensional object visually available for investigation; on the other hand, to the image, where the histologist had to transfer his perception and his analysis of three-dimensional structures into two-dimensional visual systems such as drawings or photographs. Cajal's method combined not only different ways of observing, but also manifold routes of rendering objects and observation visible. In this, it enhanced the methodologies used by early and contemporary microscopists in order to guarantee the certainty of their observations, such as the use of different microscopes for the same observation.

So, although embedded in a broader state of mind about visualization, Cajal's methodology displayed own features. The most important was the combination and tight intertwinement of two main strategies, namely selectivity and assemblage. The need for selectivity concerned first the very object the histologist must investigate. Since histological specimen, left in their natural state, are completely opaque, their structure needs to be purposely and selectively brought into view. As Cajal noticed,

> structures of formidable complexity appear under the microscope with the colourlessness and the simplicity of architecture of a mass of jelly. The other natural sciences are more fortunate in that they work with objects of study which are directly accessible to the senses. Only histology and bacteriology are obliged to fulfil the preliminary and difficult task of making visible their special objects of study before they can commence the work of analysis. (Ramón y Cajal, 1988, pp. 526–527)

Thus, to make visible the neuronal structures in a thick section of, say, a human cerebral cortex, and to show, as Cajal states, their "precise arrangement and their relations with other, extracellular structures" (Ramón y Cajal, 1988, p. 520), the histologist ought to find "some staining method which would be highly selective for the framework referred to" (Ramón y Cajal, 1988, p. 518). To this end, Cajal optimized the silver-salt staining method introduced by Camillo Golgi, using "purely and simply hot, free, nitrate of silver, capable of being precipitated by physical processes on the neurofibrillar skeleton" (Ramón y Cajal, 1988, p. 522). With this method, to his "delight and surprise", Cajal was able "to make neurofibrils of almost all nerve cells besides numerous types of axonic terminal arborizations, [appear] splendidly impregnated with a brown, black and brick red colour and perfectly transparent" (Ramón y Cajal, 1988, p. 523).

This ideal selective visualization Cajal obtained in his samples, however, was more than a means to simply show what was hidden in the cells. For Cajal, differential visualization was also able to refine the investigator's perception. He was convinced that "a strictly differential [staining] technique is something like the acquisition of a new sense directed towards the unknown" (Ramón y Cajal, 1988, p. 526). Visualising structures in this way, Cajal argued, "brings out interesting and unexpected details of structure" (Ramón y Cajal, 1988, p. 529) and is therefore essential to improve the sensibility of the observer and to refine his ability of judgment. This enhanced spectrum of perceptual ability, in its turn, broadens the insights about the structures observed.

According to Cajal, the next step towards an amplified cognition of the structures was making these insights visible in images. Here, Cajal applied the selectivity parameter as well, but optimized it using a technique of visual assemblage. Instead of reproducing the whole field of view seen in the microscope, he first recorded in individual drawings the specifics of meaningful elements he saw in different focal planes. Cajal constructed then a complete image of a certain cell by compiling these specific individual depictions (Sotelo, 2003, p. 76, Fig. 7). Such images were composites built up from a highly differentiated selection of partial visualizations. However, they were not additive visual compounds. They reorganized the precise sketches collected in different drawing sessions in a singular drawing and visualized the cell's three-dimensional structure as it could not be observed directly, but only deduced from the sum of the singular observations.

In a letter to his pupil Fernando de Castro in 1927, Cajal called this strategy "combining the images", arguing that "without this trick, my book on neural centres would have required more than 3000 figures" (Sotelo, 2003, p. 76, Fig. 7). This assembling procedure was very much criticized. Cajal mentions for instance a Swedish neurologist Henschel, who had disapproved these composed images because of their artificial character. Cajal responded to this criticism:

> The only artificial expedient was the combination of the cells observed in various serial sections ... it was unquestionably necessary to make use of this procedure. Otherwise, a very large number of figures would have been necessary, resulting in an essential loss of exact and clear representation. (Ramón y Cajal, 1922, p. 166, my translation)

Combining, assorting, grouping, assembling the images was for Cajal part of a programmatic attitude in which the one-to-one correspondence between observation and image played a minor role. Cajal aimed instead at optimizing the results obtained observing the visibility induced in the specimen. First of all by critically extracting visual data from multiple sessions of observation; after that, by reorganizing these visual data in a reasoned assemblage. In this way, a new visibility was induced in the drawing. It was a generalized outline of the organization of the three-dimensional system under investigation, a dimension that would have not been visually available otherwise. Combining the singular images in this way, Cajal improved their individual content and sublimated their power of evidence. Eventually, this combining imaging process showed not the actual structure, but the conclusions he drew from the multiplicity of the structure's forms and from their mutual relations.

This strategy of combination allowed Cajal to elaborate visual evidence sequentially, and to rearrange the images of individual structures according to possible new insights about their organization in the overall environment. In this sense, Cajal's combined drawings have been rightly considered "imperishable sketches," and as such, they could be "updated on the basis of future studies" (Sotelo, 2003, p. 7). Cajal was indeed convinced that, no less than good microscopic preparations, "good drawings ... are pieces of reality, scientific documents that conserve indefinitely their value and whose revision will always be advantageous, whatever the interpretations to which they give rise" (Ramón y Cajal, 1899/1904, Preface to Vol. 1; translation by De Felipe & Jones, 1992, p. 243). As visual documents with fundamental, but not conclusive value, drawings can undergo revision. Accordingly, Cajal often reconsidered his sketches over the years, modifying them according to new insights and reflections.

In describing these versions of the drawings and their variations, scholars have spoken of the "styles" of Cajal's drawings, using a genuine art historical notion of style that refers to the line movement and the treatment of masses inside the image (Pérez de Tudela Bueso, 1987). The different fashion of Cajal's styles is man-

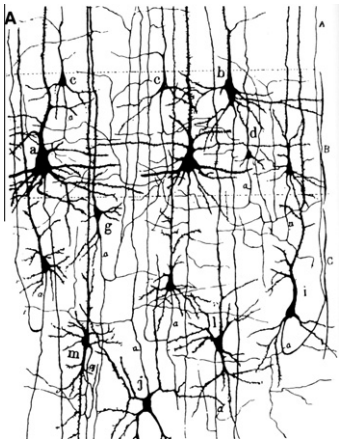

Fig. 1. Santiago Ramón y Cayal, Drawing showing cells in the deeper layers of the visual cortex of the cat, printed in Ramón y Cajal, 1899, Fig. 18.

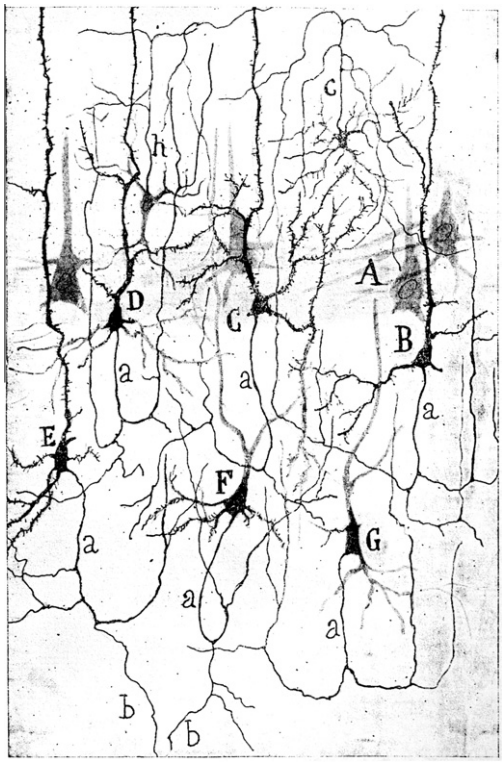

Fig. 2. Santiago Ramón y Cayal, Drawing showing cells in the deeper layers of the visual cortex of the cat, printed in Ramón y Cajal, 1921, Fig. 11.

ifest in Figs. 1 and 2. Both images represent the deeper layer of the visual cortex of a cat in two publications: the first article was a general study of the sensorial spheres (the Flechsig centres) of humans and of several animals, including the cat (Ramón y Cajal, 1899); the second article returned to the discussion and the results of the previous study to investigate more specifically the human visual system by means of the cat's visual cortex, given the similarity between both systems (Ramón y Cajal, 1921). In 1899 Cajal represented the deeper layer of the visual cortex in a very stylized, linear, and flat way (Fig. 1). In the 1921 article he enhanced the visual effect by visualizing more elements and different focal planes. For this, he modified the original drawing using pen, ink and several colours and shadowing with differently hard pencils (De Felipe & Jones, 1992, Fig. 5B). Thanks to the new half-tone reproduction technique, he was then able to adapt this complex revision of the drawing for printing (Fig. 2). In the earlier image, an accomplished draughtsman such as Cajal would have surely as well been able to visualize all the three-dimensional structures that are visible in the more refined illustration of 1921, despite of the constraints of the early lithographic reproduction technique, which according to De Felipe (1992, p. 242) was inadequate to convey depth. It is likely that the two-dimensional linearity of the 1899 image derives primarily from a focused view on a specific level of the three-dimensional structure, which in the drawing was purposely brought to the fore in a schematic way. Conversely, the complexity of the later image seems to take into account three-dimensional relationships that Cajal had not previously seen, or more likely had not previously looked for. Indeed, the new image not only reinterprets, but also reshapes and enriches the first, and this difference is evidence of a changing view of the problem.

The variation of complexity in these examples shows how central drawing was to Cajal. To be sure, he actually used an astonishing eclectic spectrum of visualisation methods, ranging from optically unaided sketching to the use of the *camera lucida* and the abdication of vision in favour of automatic techniques such as the contemporary photomicrography (Ives, 1903). However, he was not fond of optical instrumentation for drawing. For instance, Cajal's opinion about the *camera lucida* was that "one must not build up hopes about the advantages of these apparati [sic]. The *camera lucida*, even when one is accustomed to its use by long practise [sic], is only useful to fix the contour of the principal objects: any labour of detail must be done without the aid of that instrument, which has, in addition, the inconvenience of dazzling the delicate details" (Ramón y Cajal, 1889, p. 39; translation by De Felipe & Jones, 1992, p. 242). Similarly, despite his long and advanced experience with photomicrography, Cajal did not deem it an adequate method of visualization, did "not consider ... photographs technically perfect at all, not even passable" (Ramón y Cajal, 1926, p. 212; translation De Felipe, 1992, p. 245). Accordingly, Cajal always juxtaposed drawing and photography in his visualization practices (De Rijcke, 2008), emphasizing the superiority of rendering by freehand drawing as "the best procedure when one has some habit and liking for [artistic] painting" (Ramón y Cajal, 1889, p. 39). Indeed, Cajal's conviction was that drawing could do more than simply reproducing forms accurately. In fact, "the first condition of the microscopist drawer [sic] is to know how to see and to interpret what he sees" (Ramón y Cajal, 1889, p. 39). Drawings, thus, are not self-explaining for Cajal. He considered them to embody interpretation, thus posing new questions to the eye of the scientist and provoking him to reconsider the specimen in search of new answers.

Consequently, Cajal's highly sophisticated drawings do not reproduce a given three-dimensional visibility, but rather induce an advanced form of it. De Rijcke (2008, pp. 290–302) has elaborated on Cajal's practices of representation in terms of abstraction processes, tying them with the notion of 'attention' in Cajal's daily working routines. I prefer to describe Cajal's representation processes in terms of the induction of a new visibility that does not abstract observed forms, but synthesize relevant particulars of them into an expanded framework that is able to represent factually extant structures otherwise inaccessible to visual perception. Cajal's images neither convey naturalistically three-dimensional impressions, nor abstract them into symbols. They rather make visible what the observer inferred to be the fundamental structures needed to understand possible relationships among existing individual elements. So, in Fig. 2, what generates depth is the superimposition of singular two-dimensional representations. This superimposition of two-dimensional structures allows the viewer to infer the possible three-dimensional correlation between them.

In this example, Cajal did not abstract three-dimensionality; he rather put it into a reliable, 'nearly three-dimensional' format, that is, in a sophisticated two-dimensional construction resulting from the process of selecting, distinguishing, and reassembling visual features.

Through the stepwise selective visualization of spatial relationships via the judgment of the observer, Cajal's practices of visibility induction organized the passage from the material to its image through the filter of selective and synthetic virtuosity. This virtuosity aimed at creating an expanded mental image of the structure hidden in the cells. In this logic, methods inducing visibility in the object should enhance the observer's ability and sensibility in distinguishing contents. The coordination of eye and hand deriving from this controlled visual curiosity helped to reach the best and most informative representation of these contents. In order to unveil the mysteries of the cells in this way, the investigator should shape his visual habit starting "with the attitude of a fascinated spectator" (Ramón y Cajal, 1988, p. 252). The "right point of view" (Ramón y Cajal, 2001, p. 151) from which to do this resided in the insights in the real structure and at the same time in the stepwise optimization of the singular visual records. This process of optimising induced a new visual context in which the combined image could be developed, serving as fundamental instruments to convey the reasoning about the observed structures as well as the conclusions drawn from them.

While the processed specimen froze a certain state of given object under certain conditions, Cajal's composed drawing expressed a composite insight in this state. This insight first evolved from the act of creating and processing multiple visibilities. The visibility induced in the object crystallised for Cajal a particular state of the investigated matter that contained all the potential knowledge that the scientist can infer from it. But knowledge about this state could not develop until the judging extraction of features for imaging was complied and a decision was made about which mode of imaging could convey best the selection and effectively bind the attention of the image's beholder. In other words, it was the act of visual reassessment into representation, the act of processing the visible into images that produced the special knowledge about the object. Consequently, the process of imaging did not primarily make the object visible. It rather induced, in a new medium, the visibility of the knowledge inferred from the object.

Cajal's practices of visibility induction disclose "what happens between the cognitive observer and the object of cognition" (Rheinberger, 2009, p. 128; my translation) in terms of an intriguing two-sidedness, of a necessary simultaneity of epistemic and aesthetic judgement. While the former provides the insights necessary to understand the observed structure, the latter controls the mediation of these insights through images and affects the extent to which knowledge is noticed and appreciated by the beholder. In this logic, processes of visibility induction can be separated neither from the rational nor from the aesthetics. As for the rational component, these processes apply knowledge (so for instance the knowledge about the chemical reactions needed to make only certain structures visible in an opaque mass); they at the same time generate knowledge (so while visually analysing the structures made visible in the specimen). The aesthetic component enables then the observer to transfer this generated knowledge into the image dimension. Accordingly, Cajal incorporated programmatically the aesthetic dimension in his method. He was convinced that "the artist and the microscopist cannot be separated" (Ramón y Cajal, 1889, p. 39) and focussed his attention on the discovery of structures "adorned by many features of pure beauty" (Ramón y Cajal, 1988, p. 415). His faith in the power of aesthetic stimuli belonged to Cajal's construction of the "right point of view" producing knowledge through the critical induction of visibility. He considered aesthetic sensibility during histological observation and judgment to be a crucial, indispensable factor triggering scientific curiosity and generating knowledge. Indeed, he was convinced that

> however poor and incomplete may be the objective vision of the scientist, he will even be able to affirm that the illogical and anti-aesthetic elements in the scientific conception of a phenomenon necessarily imply error or misunderstanding in the idea of the investigator. (Ramón y Cajal, 1988, p. 414–415)

Cajal's strategy of visibility induction referred to rational and aesthetic visual sensibility likewise, and considered both to be constitutive elements of knowledge production. In this sense, Cajal's practices of observation and visualization can be considered part of an 'aesthetic epistemology' implementing the conviction that "art and science ... coincide in one aspect, the aesthetic aspect, [and that] every scientific work is also a work of art" (Croce, 1992, p. 27).

Acknowledgements

This paper belongs to the author's long-term project "*Induction of Visibility. An Attempt at the Notion of Aesthetic-Epistemic Action*"/"*Induktion von Sichtbarkeit. Ein Versuch zum Begriff der ästhetisch-epistemischen Aktion*", funded by the Heisenberg-Programme of the German Research Foundation/Deutsche Forschungsgemeinschaft—DFG.

References

Croce, B. (1992). *The aesthetic as the science of expression and of the linguistic in general* (C. Lyas, Trans.). Cambridge: Cambridge University Press (First published 1902).

De Felipe, J., & Jones, E. G. (1992). Santiago Ramón y Cajal and methods in neurohistology. *Trends in Neurosciences, 15.7*, 237–246.

De Rijcke, S. (2008). Drawing into abstraction. Practices of observation and visualisation in the work of Santiago Ramón y Cajal. *Interdisciplinary Science Reviews, 33*(4), 287–311.

Fiorentini, E. (2011). Aesthetic-epistemic actions. A proposition on slides, drawings and the induction of visibility. In I. Löwy (Ed.), *Microscope Slides. Reassessing a neglected historical resource* (pp. 48–58). Berlin: Max Planck Institute for the History of Science. preprint 415.

Ives, F. E. (1903). Stereoscopic photomicrography with high powers. *Transactions of the American Microscopical Society, 24*, 23–26.

Pérez de Tudela Bueso, M. A. (1987). *El grafismo, base fundamental para el científico: D. Santiago Ramón y Cajal*. Madrid: Facultad de Bellas Artes de Madrid.

Ramón y Cajal, S. (1889). *Manual de Histologia Normal y de Tecnica Micrografica*. Valencia: Aguilar.

Ramón y Cajal, S. (1899/1904). *Textura del Sistema Nervioso del Hombre y de los Vertebrados*. Madrid: Moya.

Ramón y Cajal, S. (1899). Estudios sobre la corteza cerebral humana. *Revista Trimestral Micrográfica, 4*, 1–63.

Ramón y Cajal, S. (1921). Textura de la corteza visual der Gato. *Archivos de Neurobiologia, II, 4*, 338–362.

Ramón y Cajal, S. (1922). Studien über die Sehrinde der Katze. *Journal für Psychologie und Neurologie, 29*(1–3), 161–181.

Ramón y Cajal, S. (1926). Démonstration photographique de quelques phénomènes de la régénération des nerfs. *Travaux du Laboratoire de Recherches Biologiques de l'Université de Madrid, 24*, 191–213.

Ramón y Cajal, S. (1988). *Recollections of my life*. New York: Garland.

Ramón y Cajal, S. (2001). The Corrected Pessimist. In S. Ramón y Cajal (Ed.), *Vacation stories: Five science fiction tales* (pp. 122–168). Urbana: Univ. of Illinois Press.

Rheinberger, H. (2009). Sichtbar Machen. In K. Sachs-Hombach (Ed.), *Bildtheorien—Anthropologische und kulturelle Grundlagen des Visualistic Turn* (pp. 127–154). Frankfurt am Main: Suhrkamp.

Sotelo, C. (2003). Viewing the brain through the master hand of Ramón y Cajal. *Nature Reviews Neuroscience, 4*, 71–77.