Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
C. R. Biologies 329 (2006) 348–353
COMPTES RENDUS BIOLOGIES
http://france.elsevier.com/direct/CRASS3/

Neurosciences

Science and craftsmanship: The art of experiment and instrument making

Sven Dierig

Max-Planck-Institut für Wissenschaftsgeschichte, Boltzmannstraße 22, 14195 Berlin, Germany

Received 15 November 2005; accepted after revision 15 February 2006

Available online 3 May 2006

Abstract

In his two-volume monograph *Untersuchungen über thierische Elektricität*, the Berlin physiologist Emil du Bois-Reymond described the relation between nervous electricity and muscle mechanics by way of a long series of experiments. This work is a key text in the history of the experimental life sciences. But it not only contains new findings about the functioning of muscles and its nerves. Du Bois-Reymond practiced an art of experimentation in which aesthetics of mechanical craftsmanship allied itself with the science of physiology. Experimentation, as du Bois-Reymond understood it, was simultaneously an epistemic and an aesthetic practice. The goal of his science was thus producing both knowledge and aesthetic success. ***To cite this article: S. Dierig, C. R. Biologies 329 (2006).***

Résumé

Science et dextérité manuelle : l' art d'expérimenter et de construire des instruments. Le physiologiste berlinois Emil du Bois-Reymond a décrit, dans sa monographie en deux volumes intitulée *Untersuchungen über thierische Elektricität*, les relations entre l'électricité nerveuse et la mécanique musculaire à la suite d'une longue série d'expériences. Ce travail constitue un texte clé dans l'histoire des sciences expérimentales du vivant. Cependant, il ne contient pas seulement des résultats nouveaux concernant le fonctionnement des muscles et de leurs nerfs. Du Bois-Reymond pratiquait un art expérimental alliant une esthétique de l'art manuel à l'analyse physiologique. À ses yeux, l'expérimentation tout était une pratique épistémique et esthétique. Son objectif de scientifique était donc de produire à la fois de la connaissance et de l'esthétique. ***Pour citer cet article : S. Dierig, C. R. Biologies 329 (2006).***

Keywords: Emil du Bois-Reymond; 19th-Century neuroscience; History of experimentation; Science and instrument making; Aesthetics of Science

Mots-clés : Emil du Bois-Reymond ; Neuroscience du XIXe siècle ; Histoire de l'expérimentation ; Science et fabrication d'instruments ; Esthétique de la science

1. Introduction

The 1825 painting by the Berlin architect Karl Friedrich Schinkel, *Blick in Griechenlands Blüte* [View of Greece's Glory] shows a temple in the process of be-

E-mail address: dierig@mpiwg-berlin.mpg.de (S. Dierig).

1631-0691/$ – see front matter
doi:10.1016/j.crvi.2006.03.006

ing built. Looking down from an elevation down onto a Mediterranean city landscape, the beholder of the picture could imagine himself in the midst of a construction site: with muscled men and stone masons at work, cable winches, an iron jack, a cog-driven hoisting apparatus, and artisans and builders beneath a shading tent. This scene is a stark contrast to the visual expectations linked to Antiquity in the age of neoclassicism. While standard depictions of Greece usually show the monuments either in their finished state or as ruins, Schinkel here painted ancient architecture in the process of becoming [*Bildung*]: the cooperative work of construction [1]. Central here were the creative artist and the role of hand craftsmanship in man's production of the beautiful. "In all things, man should form itself [*bildet sich*] beautifully, so that every activity exuding from him will be thoroughly beautiful in both subject and execution": this was Schinkel's famous artistic imperative [2 (p. 249)]. For him, every act was an artistic task.

In the foreword to *Vorbilder für Fabrikanten und Handwerker*, a collection of models for commercial artisans that Schinkel edited together with the Prussian industrial reformer Christian Peter Wilhelm Beuth, this artistic idealism was applied to practical concerns and transferred to then current needs. The models shown in the 1837 book, drawings of lamps, vases, furniture and other everyday items, were intended to show craftsmen how necessary and useful it is to give their products not only technical perfection, but also the greatest consummation of form. Only an execution that unites the two can bring the work of the craftsman closer to artwork, moulding it with the stamp of formation [*Bildung*] and giving it a more enduring value than the costliness of the material from which it was made [3 (p. V)].

The aesthetic linkage between *Bildung* and craftsmanship intended by Beuth and Schinkel also proved well-suited for understanding the use of craftsmen's tools in the laboratories of natural scientists around 1840 as a form-giving artistic task. The experimentation of the Berlin physiologist Emil du Bois-Reymond represents an example of this. His *Untersuchungen über thierische Elektrizität* [4–7] seems like an attempt to provide alongside *Vorbilder für Fabrikanten und Handwerker* a model for the craftsmanship of experimental scientists. If one replaces in the passage quoted above "the work of the craftsman" with "the work of the experimenter", it would read like a Du Bois-Reymondian instruction for how to work in the laboratory. In the sense of Schinkel and Beuth's *Vorbilder*, the *Untersuchungen* are the result of an art of craftsmanship directed at the mutual interpenetration of technical perfection and consummation of form. Engaged together in creating beautiful forms, as in Schinkel's painting, hand craftsmanship and science found their way to one another at both the workbench and the laboratory table.

2. Growing and becoming

Like his generation as a whole, du Bois-Reymond was fascinated by phenomena of growth and development, in both a direct biological sense and in terms of categories of individual or historical growth [6,8]. When it came to the development and formation of individuals [*Bildung*], children and vegetation – the children in the garden – was a typical emblem of the age. In 1845, in the style of the romantic artist Phillipp Otto Runge, du Bois-Reymond drew a kindergarten of the natural sciences, using it to illustrate the membership card of the *Physikalische Gesellschaft zu Berlin* [Berlin Physical Society], of which he was one of the co-founders. The drawing showed an exotic-looking imaginary plant. Between its stems and leaves there are young boys cavorting around the various branches of the natural sciences [9]. The image suggests that the children using their research instruments help to encourage the growth of natural scientific knowledge. The individual development of the researcher actively engaged with laboratory instruments is a prerequisite for this historical process. He experiences "pleasure" because he sees how he is "progressing", du Bois-Reymond wrote at the beginning of his experiments to his friend Eduard Hallman. "I am growing, we want to see where to" [6 (p. 204), 10 (p. 93)]. In a public lecture ten years later, he used a child as a model to illustrate the development of an experimental scientist:

> "*Observe a child in the tender age of development as it begins to discover the external world with a fresh gaze and to place the causes of his sensations outside himself. He sits at a table: he has been given a spoon to play with. Accidentally, the spoon reaches the edge of the table and falls clamorously to the floor. His small face is transfigured as often as one repeatedly raises the spoon for the child, it repeats joyously the same attempt; but he still did not know that bodies are heavy, that an unsupported body rushes toward the earth, how should it? Only experience, some of it painful, will in the course of time impress this truth upon him so effectively greatly that he will think it self-evident*." [11 (p. 29)]

The spoon in the nursery corresponded to du Bois-Reymond's galvanometer on his laboratory table. This precision instrument consisted basically of two magnetic needles hung one over the other on a silk thread beneath a glass cylinder. The lower needle floated inside a copper wire spool, the above own, visible from outside, over a scale divided into degrees. On the copper wire electrical current directed the magnetic needles around the axis of the thread. The operation of the sensitive galvanometer, which was highly subject to disturbances, required a significant degree of hand–eye coordination. In other words: a successful experiment required the experimenter's having gone through a rigorous process of physical development. Self-perfection or completion in using the instrument was rule number one in du Bois-Reymond's laboratory. In January 1848, he wrote to his friend Carl Ludwig:

> "*Very soon I was also able to translate the pain that the burning of a frog's foot caused to the animal into electromagnetic motion, and with unfailing practice and perfection of the experimental technique I don't see why it should not ultimately also be possible to translate the change in the so-vital current of the opticus of a pike into a magnetic equivalent*." [12 (p. 5)]

The experimenter practicing at the galvanometer is also figured in the branches of the science plant drawn by du Bois-Reymond. One of the boys is shown doing chin ups on a magnet. Du Bois-Reymond here depicted himself twice: as gymnast and as researcher. In so doing, the use of the galvanometer was linked to the physical experience in the gymnasium that du Bois-Reymond regularly visited while working on the *Untersuchungen* [6,13]. The drawing of the boy exercising on the magnet suggested that gymnastic equipment and laboratory instruments had a similar kind of relationship to the body working on or with them [14]. The practiced gymnast and the practiced experimenter, both were the result of a physical self-perfection. Just like a gymnast on the bars or horse, the experimenter formed himself by exercising and perfecting himself on the laboratory equipment. The appendix to the *Untersuchungen* contains an illustration of the experimenter formed by laboratory work. In this depiction, du Bois-Reymond gave himself the appearance of an ancient art figure: an idealized image of a beautiful youth, the classical symbol for physical perfection, works at an experiment using a galvanometer [4,14]. The beholder was thus to understand that experimentation in the laboratory is a form-giving physical art. If the exercising experimenter is an artist on his own terms, the trained experimenter himself is also a work of art.

Art historians consider Schinkel's *Blick in Griechenlands Blüte* to be the programmatic image embodying the spirit of Prussian neoclassicism [1]. Du Bois-Reymond's view of the laboratory is in turn emblematic for the link between classicism and the natural sciences typical for his generation. For du Bois-Reymond, modern technology and antiquity were not opposed to one another. While Schinkel's muscled workers use an iron machine in building their temple, the young Greek in du Bois-Reymond's laboratory experimented with the newest tools and instruments.

3. Craftsmanship

In du Bois-Reymonds years as a student, there were around 30 000 Berlin residents who were craftsmen of some kind. Around 200 of these were professionally categorized as 'mechanical artists' (*mechanische Künstler*), highly qualified jacks-of-all-trades in mechanics and optics. But a view of the mechanical artist as the upright citizen with an apron working at the workbench and vice is too limiting, as is shown by the example of Carl Philipp Heinrich Pistor. Du Bois-Reymond commissioned Pistor's workshop in the winter of 1840 with producing his first research instrument, a microscope. In 1816, Pistor had been the first to build a functioning steam machine in Berlin, along with the technician Georg Christian Freund, and in the 1830s provided the technical equipment for the optical telegraph line between Berlin and Koblenz [15]. But Pistor did not limit himself to the city's technical circles. Not only did he host the author Ludwig Tieck, he was also a guest at the literary salon of the publisher Georg Andreas Reimer. Reimer was the publisher of literary romanticism in Berlin, and his program in the 1840s included the writings of E.T.A. Hoffman, Jean Paul, Novalis, Ludwig Tieck, and Grimms' fairy tales [16]. It was also *Reimer Verlag* that published du Bois-Reymond's *Untersuchungen über thierische Elektrizität*.

The study of the contribution of craftsmen to the experimental work of the researchers of the nineteenth century is an issue of comparatively recent interest in the historiography of science [17,18]. In the literature on du Bois-Reymond's *Untersuchungen*, the mechanical artists have only been given a marginal treatment. In this way, over and over again the image of an autonomous experimenter has been conjured up; an experimenter who, at his own whim, relying on his own ability and own intuitions, drove forward his scientific work. But the opposite was the case. Du Bois-Reymond's experimental work on *Untersuchungen* was a shared undertaking, the result of a collaboration between the art of experimentation and the art of mechanics.

Johann Georg Halske was the most important mechanical artist involved in *Untersuchungen*. Better known as the co-founder of telegraphy workshop Siemens & Halske (along with Werner Siemens) in 1847, du Bois-Reymond got to know him at the beginning of his experimental work when Halske worked as an apprentice in the workshop of the mechanic W. Hirschmann in 1841. Between his apprenticeship under Hirschmann and his later collaboration with Siemens, Halske established with F.A. Boetticher a workshop that was located in walking distance from du Bois-Reymond's laboratory. In *Untersuchungen*, du Bois-Reymond expressly emphasized this profitable relationship with Halske and Boetticher. Without the work of the two mechanics, *Untersuchungen* would have been impossible [4 (p. LII)]. This was thus more than just a simple relationship between a customer and a manufacturer. Du Bois-Reymond did not just turn to mechanical artists in order to quickly have an order made, and then again leaving the workshop, returning later to pick up the completed apparatus. He remained in the mechanic's workshop as his instrument was being made, watching and participating in the process. It was in Boetticher's and Halske's workshop, for example, that the galvanometer mentioned above was built. The mechanics took charge of making the instrument's mechanics, while du Bois-Reymond himself took on the task of winding the silk around the copper thread spool [4,6]. *Untersuchungen* was not just an experimenters report on new findings in the area of muscle and nerve physiology. At the same time, du Bois-Reymond presented himself as a mechanical artist who was able to build scientific instruments and was familiar with all sorts of tricks. But this description of the making the galvanometer's copper wire spool only showed one aspect of what was going on in the workshop. In 1847, Hermann Helmholtz reported on the manufacture of the galvanometer in Halske's workshop:

> "*Dr. Dubois was insufferable all day: he was namely working with a mechanic on an instrument that he had himself ordered, carrying out an extremely tedious task, that is, winding copper wire 10000 times around a small wooden frame, because he believed that he would do this with greater care and regularity than the mechanic. He had already winded the entire morning, and wanted to spend the whole next day at it as well. He was so fogged up from his work also in the evening that I could not inform him about what I wanted to speak to him.*" [19 (pp. 6–7)]

4. Draughtsmanship

While Beuth and Schinkel were collecting *Vorbilder für Fabrikanten und Handwerker*, Ludwig Tieck was completing the novella *Der junge Tischlermeister*, also published by *Reimer Verlag* in 1837. A tract against the beginning industrial age, in this novel, the protagonist, the carpenter Wilhelm Leonhard, is a craftsman, an independent autonomous figure who saw himself reflected in his own products, and was repelled by all imitation and the factory-like. Tieck's Wilhelm Leonhard had nothing in common with the models that Beuth and Schinkel had suggested to the craftsman and manufacturer. A master of craftsmanship had to be his own draughtsman. The "relation of art, but without wanting to be art", Wilhelm Leonhard says in the novel, drew him to craftsmanship: "I thus dedicated myself to drawing untiringly" [20 (p. 57)]. Tables, armchairs, and chairs emerged first as 'shapes', as 'things' that floated about in his 'imagination' and were 'turned back and forth', then to be drawn and finally built. From the idea to the drawing, and from the drawing to the final product: in the workshop of the mechanical artists, design and construction before building were at this time still the exception, and considered the latest innovation. Craftsmen working according to plan raised scientific instrument making to a new level. A report by the head of Berlin's observatory, Johann Franz Encke, on the precision mechanic Carl Otto Albrecht Martins describes this modern type of the constructing craftsman:

> "*From the very beginning, Herr Martins made it his approach to make a detailed drawing the foundation of his work, and thus made it possible to form a rational judgement by improving each individual part. As unimportant as it might seem, I do believe it vital to place a great stress on this point, for I learned to treasure in Herr Martins a thoughtful artist who does not just try to discover something by trial and error, but gives his experimentation a sure foundation by making it completely clear to himself what he intends, and thus anticipating the problems that might hinder his intention.*" [15 (p. 41)]

Like Martins or the literary protagonist Wilhelm Leonhard, Halske was a mechanic who also used draughtsmanship in order to explore the mechanics and the operation of the apparatuses that du Bois-Reymond used in his laboratory. Du Bois-Reymond later reported: "Halske was much more than just a talented worker". To a "rare degree", Halske possessed a "constructive talent" and a "sure intuition" for finding the "simplest and best way" to solve the task at hand:

> "*It was a great pleasure that I often enjoyed half the night long to watch him with a pencil in hand approaching step by step the complete perfection of an idea for an experimental set up or a device*." [21 (p. 40)]

The conceptual construction of the laboratory apparatuses with the pencil in hand, in order to anticipate how what was assembled in the workshop would later function in the laboratory, making clear how an instrument emerges and what is intended with a mechanical device or an experimental arrangement, step by step approach, drawing, tinkering, and assembling: du Bois-Reymond's actual laboratory consisted of the triumvirate work bench, drawing table, and experimental table. Like the workers, builders, and artists at Schinkel's construction site, du Bois-Reymond took part in a shared process of construction and growth at Halske's workshop. In the mechanical workshop, du Bois-Reymond assisted in building and conceiving the instrument, got involved, and watched the process of planning, learning how technical things took on shape and form. Step by step over time the apparatuses he needed for the laboratory developed. The development of technical things might well have enthused du Bois-Reymond just as much as nature's own processes of development. The report on Halske's art of draftmanship was thus almost identical sounding to a report on the drawing abilities of his former teacher and mentor Johannes Müller. As du Bois-Reymond remembered, he was a 'master of drawing at the chalkboard': "It was a great pleasure to watch him gradually taking an animal form in the process of development through a series of intermediate steps to the final shape." [22 (p. 272)]

5. Mechanical beauty

The craftsman should not be misguided 'to compose himself', as Beuth and Schinkel warn in their *Vorbilder für Fabrikanten und Handwerker*. Instead, the craftsman should limit himself to internalizing the spirit and taste of historical models and imitating such models. Craftsmen should not seek to be artists. In his novel *Der junge Tischlermeister*, Tieck drew the same dividing line: It was a 'relation to art, but without wanting to be art' that constituted the aesthetic autonomy of craftsmanship. In Tieck's text, Baron Friedrich Elsheim asks the carpenter the question of why he became a craftsman: "I have always been surprised, my friend, that you with your open mind and varied scope of knowledge, your pleasure on all developed things [*allem Gebildeten*], that you did not prefer to chose the status of the artist." Wilhelm Leonhardt answers,

> "*That I did not fit the role of a scholar was something I realized very early, because I was more interested by things than thoughts, words, or formulars. I lack the enthusiasm of the artist, that striving, winged spirit, that can neglect and forget everything, that is at home in strange worlds, but not in our own: in contrast, my own spirit is quite limited, an truly bourgeois; my drive to work, my need to be useful, my pleasure in fixed and practical things; all of this convinced me early on that I was destined to become a craftsman*." [20 (p. 53)]

Wilhelm Leonhard chose craftsmanship over the sciences and art. While scholar, artist, and craftsman are clearly distinguished in Tieck – the scholar is an intellectual, the artist is not of this world, and the craftsman creates useful things – in Halske's workshop, in contrast, craftsmanship, science, and art all mingled with one another. In du Bois-Reymond's view, Halske's creations were far more than just useful things: "Halske's fundamental attitude and goal was to make every piece as consummate an artwork as possible, up to the very last screw." [19 (p. 43)] In the same way, Beuth and Schinkel demanded this for the products of craftsmanship, Halske's instruments united both technical perfection and a consummation of form. Du Bois-Reymond coined his own expression to describe the beauty of Halske's artworks: the scientific instrument possesses a 'mechanical beauty' that 'pleases', since it "rests on the unconscious impression of absolute functionality with the greatest possible simplicity." [11 (p. 32)]

The beauty of Halske's instruments was thus something quite different from the beauty of the use-objects in the *Vorbilder* or those imagined by Tieck. Beuth and Schinkel, just like Tieck, relied on the forms of the past, albeit in a different way. While Beuth and Schinkel related on the aesthetic models of antiquity, Tieck turned to the middle ages. Wilhelm Leonhard wants "to ornament hard straight lines and square corners with flowers and garlands or with light figures that border on the arabesque" – the superfluous and unreasonable is what gives a work of craftsmanship beauty [20 (p. 60)]. Mechanical beauty as understood by Halske and du Bois-Reymond was exactly the opposite: the beautiful is only what looks rational: the impression of beauty arises not by decorating the useful with classical or medieval forms, but by intentionally avoiding any superfluous decoration. There were no instruments placed on classical columns or featuring romantic ornamentation in Halske's workshop and du Bois-Reymond's laboratory. Even Schinkel, the architect of Berlin neoclassicism, had by now taken another route. Berlin's *Bauakademie*, built in the 1830s, was no Greek temple. The new functional building was built to fulfill its purpose, a modern, factory-like red brick building with iron window frames. By the 1840s, the aesthetics of industrialization [23] had thus also arrived in the laboratories of the natural sciences.

Acknowledgement

The author wishes to thank Brian Currid for English translation.

References

[1] A.M. Vogt, Karl Friedrich Schinkel, Blick in Griechenlands Blüte: ein Hoffnungsbild für Spree-Athen, Frankfurt a. M., 1985.
[2] A. Haus, Karl Friedrich Schinkel als Künstler, München, Berlin, 2001.
[3] Vorbilder für Fabrikanten und Handwerker. Auf Befehl des Ministers für Handel, Gewerbe und Bauwesen herausgegeben von der Königlich Technischen Deputation für Gewerbe, Berlin, 1863.
[4] E. du Bois-Reymond, Untersuchungen über thierische Elektricität, Berlin, 1848–1884.
[5] C. von Camphausen, Elektrophysiologische und physiologische Modellvorstellungen bei Emil du Bois-Reymond, in: G. Mann (Ed.), Naturwissen und Erkenntnis im 19. Jahrhundert, Emil du Bois-Reymond, Hildesheim, 1981, pp. 79–104.
[6] G.W. Finkelstein, Emil du Bois-Reymond: The Making of a Liberal German Scientist, 1818–1851, Diss. Phil., Princeton, NJ, USA, 1996.
[7] G.W. Finkelstein, M. du Bois-Reymond goes to Paris, Br. J. Hist. Sci. 36 (2003) 261–300.
[8] D. von Engelhardt, Der Begriff der Bildung und Kultur bei du Bois-Reymond, in: G. Mann (Ed.), Naturwissen und Erkenntnis im 19. Jahrhundert, Emil du Bois-Reymond, Hildesheim, Germany, 1981, pp. 173–186.
[9] M.N. Wise, Bourgeois Berlin and Laboratory Science (in preparation).
[10] E. du Bois-Reymond (Ed.), Jugendbriefe von Emil du Bois-Reymond an Eduard Hallmann, Berlin, 1918.
[11] E. du Bois-Reymond, Über tierische Bewegung. Im Verein für wissenschaftliche Vorträge zu Berlin am 22. Februar 1851 gehaltene Rede, in: E. du Bois-Reymond (Ed.), Reden von Emil du Bois-Reymond, Leipzig, Germany, vol. 2, 1912, pp. 27–50.
[12] E. du Bois-Reymond (Ed.), Zwei große Naturforscher des 19. Jahrhunderts. Ein Briefwechsel zwischen Emil du Bois-Reymond und Karl Ludwig, Leipzig, Germany, 1927.
[13] T. Lenoir, Laboratories, Medicine and Public Life in Germany 1830–1839: Ideological Roots of the Institutional Revolution, in: A. Cunningham, P. Williams (Eds.), The Laboratory Revolution in Medicine, Cambridge, 1992, pp. 14–71.
[14] S. Dierig, Die Kunst des Versuchens. Emil du Bois-Reymonds *Untersuchungen über thierische Elektricität*, in: H. Schmidgen, P. Geimer, S. Dierig (Eds.), Kultur im Experiment, Berlin, 2004, pp. 123–146 & 384–391.
[15] J. Zaun, Instrumente für die Wissenschaft. Innovationen in der Berliner Feinmechanik und Optik 1871–1914, Berlin, 2002.
[16] D. Reimer, Passion & Kalkül. Der Verleger Georg Andreas Reimer (1776–1842), Berlin, New York, 1999.
[17] M. Jackson, Spectrum of Belief. Joseph von Fraunhofer and the Craft of Precision Optics, Cambridge, 2000.
[18] H.O. Sibum, Experimentalists in the Republic of Letters, Science in Context 16 (1/2) (2003) 89–120.
[19] R.L. Kremer (Ed.), Letters of Hermann von Helmholtz to his Wife, 1847–1859, Stuttgart, Germany, 1990.
[20] L. Tieck, Der junge Tischlermeister, Frankfurt am Main, Germany, 1996.
[21] E. du Bois-Reymond, Johann Georg Halske, Verhandlungen der Physikalischen Gesellschaft zu Berlin 9 (1890) 39–44.
[22] E. du Bois-Reymond, Gedächtnisrede auf Johannes Müller. Gehalten in der Leibniz-Sitzung der Akademie der Wissenschaften am 8. Juli 1858, in: E. du Bois-Reymond (Ed.), Reden von Emil du Bois-Reymond, Leipzig, Germany, vol. 1, 1912, pp. 135–317.
[23] M.N. Wise, Architectures of steam, in: P. Galison, E. Thompson (Eds.), The Architecture of Science, Cambridge, 1999, pp. 107–140.