



Time and noise: the stable surroundings of reaction experiments, 1860–1890

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Received 11 February 2002; received in revised form 14 August 2002

Abstract

The ‘Reaction experiment with Hipp chronoscope’ is one of the classical experiments of modern psychology. This paper investigates the technological contexts of this experiment. It argues that the development of time measurement and communication in other areas of science and technology (astronomy, the clock industry) were decisive for shaping the material culture of experimental in psychology. The chronoscope was constructed by Matthäus Hipp (1813–1893) in the late 1840s. In 1861, Adolphe Hirsch (1830–1901) introduced the chronoscope for measuring the ‘physiological time’ of astronomical observers. Hirsch’s observatory at Neuchâtel (Switzerland) served to control the quality of clocks produced in the nearby Jura mountains. Hipp provided the observatory with a telegraphic system that sent time signals to the centers of clock production. Time telegraphy constituted the stable surroundings of the reaction time experiments carried out by both astronomers and psychologists. This technology permitted precise measurements of short time intervals and offered to Hirsch, as well as to Wilhelm Wundt (1832–1920), a useful metaphor for conceptualizing their respective ‘epistemic objects’. But time telegraphy also limited the possibilities of the experimental work conducted within its framework. In particular, noise from outside and inside the research sites at Neuchâtel, Leipzig and elsewhere disturbed the precise communication of time.

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Keywords: Wilhelm Wundt; Adolphe Hirsch; Psychology; Astronomy; Time

Simon Schaffer’s 1988 ‘Astronomers mark time’ was a brilliant contribution to the deconstruction of the narratives with which scientists shape their disciplinary

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histories. Schaffer showed how historical fragments from other contexts are ‘colonized’ by teleological accounts, using as an example a 1961 paper on the history of psychology by Edwin G. Boring. Boring situated the astronomer’s problem of individual observational error in the pre-history of psychology, as did many of his contemporaries—psychologists and historians of psychology alike. In the course of his description of the ‘personal equation’ problem, Boring ascribed a ‘puzzled incomprehension’ to astronomers of the nineteenth century—an incomprehension only clarified by the research of physiologists and psychologists such as Hermann von Helmholtz (1821–1894), Franciscus Donders (1818–1889) and Wilhelm Wundt (1832–1920). In this view, not only did these scientists ‘solve’ the problem of the personal equation, they also seemed to offer psychology ‘its finest chance for disciplinary growth’.¹

Schaffer argued that Boring’s account demonstrates gross ignorance of the means by which astronomers accounted for individual observational error, not to mention that they did so utilizing scientific procedures whose cast and development differed considerably from that of academic psychology. Taking the Greenwich Observatory under George Airy as a case study, Schaffer clarified how the introduction of disciplined organization coordinated the activities of astronomers, assistants and instruments and contributed to guarantee a broad interchangeability of observers. The ‘coordination of self-registration, prompt and accurate reduction of observation, and a rigid time table for assistants’ work, including the practice of clocking on introduced by Airy for all his subordinates’ brought the personality factor under control within astronomical practice by the second half of the nineteenth century. By means of this virtually ‘panoptic’ regime, the observatories established values of objectivity and precision that clearly differed from those in psychological laboratories. Following Schaffer’s general argument, precise measurement is only given ‘its meaning when situated in specific contexts of styles of work and institutions’ (Schaffer, 1988, pp. 120, 115).

As brilliant as this deconstruction of Boring’s history of psychology was, it concealed some very real links between astronomy and the emerging discipline of psychology.² These links exist not only at the discursive level, but also and more importantly at the level of material culture. Schaffer failed to mention, for example, that some of the physiologists and psychologists he dealt with carried out their research on time at observatories. Such was the case of Rudolph Schelske, who measured the speed of the propagation stimuli in human nerves with the instruments he had at hand at the Utrecht observatory in the early 1860s. In contrast to Helmholtz, who had invented a ‘frog tracing machine (*Froschzeichenmaschine*)’ for the same purpose, Schelske made use of a Krille registration apparatus that he modified slightly for psycho-physiological purposes.³

In the case of Wilhelm Wundt, the often referred to founding father of physiologi-

¹ Schaffer (1988), p. 117. See Boring (1961), p. 116. On Boring, see O’Donnell (1979).

² On this topic, see also Canales (2001).

³ See Schelske (1862). See also Helmholtz (1850, 1852). On Helmholtz’s work in this context, see Brain and Wise (1994), Olesko and Holmes (1993).

cal psychology, the links between astronomy and psychology are even more obvious.⁴ Wundt's interest in the connection between thought and time dates to the early 1860s, and brought him back repeatedly to the problem of the personal equation.⁵ Also, the psychological instrument that Wundt initially developed for investigating the 'time and thought' question was concretely modeled after a situation in which astronomers of the mid nineteenth century used to work. The so-called 'pendulum apparatus (*Pendelapparat*)' provided simultaneous acoustic and optical stimuli, thereby imitating the 'eye-and-ear' method employed by astronomers to determine time: the audible ticking of a pendulum clock had to be coordinated with visible star passages. Wundt's pendulum apparatus was designed to measure the subjectively experienced time differential between objectively simultaneous optical and acoustic stimuli.⁶

The acceptance and application of this instrument by other psychologists was, however, limited, particularly in comparison to the spread of another experiment whose design Wundt took directly from the astronomical context. Wundt first presented this experimental set-up—later to enjoy an international career as the 'Reaction experiment with Hipp chronoscope'—in his *Grundzüge der physiologischen Psychologie* (1874). Similar to the pendulum apparatus, the experiment was devised to psychologically probe the 'the succession and association of representations', here via the operation of a telegraph key by the test subject upon hearing a sound caused by a ball hitting a piece of wood. An electromagnetic precision time measurement instrument, the Hipp chronoscope, permitted accurate measurement of the time between the sound made by the ball hitting the wood ('stimulus') and the activation of the telegraph key ('reaction') to within a thousandth of a second (Fig. 1) (Wundt, 1874, pp. 726–800).

The first attempt to conduct this experiment was made by Adolphe Hirsch (1830–1901), director of the Neuchâtel observatory. The 'Chronoscopic experiments on the speed of various sensory impressions and of the nerve conduction' which Hirsch carried out in October and November 1861 at his observatory were motivated by efforts to determine and, consequently, to reduce individual error in astronomical observations. Wundt referred to a corresponding publication of Hirsch's which no doubt came to his attention easily as it had appeared not in an astronomical, but a physiological periodical. Following Hirsch, Wundt's *Grundzüge* recommended the use of the Hipp chronoscope in experimental psychology as, in comparison to astronomical registration instruments and to the pendulum apparatus, it had the advantage that 'it is quite easy to use and the read out on both faces immediately displays the absolute time'.⁷

Adoption of Hirsch's experimental set-up helped Wundt to take a decisive step toward the concrete realization of his ultimate goal: to establish a scientific psy-

⁴ On Wundt, see Danziger (1990), Robinson (1987), Bringmann and Tweney (1980).

⁵ See, for example, Wundt (1863a), pp. XXVII, 335, 382; also Wundt (1863b), pp. 25–40, 365–377.

⁶ Wundt (1863b), pp. 38–39. Wundt provides information on the everyday background of his construction in Wundt (1862a). A more technical description can be found in Wundt (1874), pp. 777–780.

⁷ Wundt (1874), p. 772. See also Hirsch (1865a). The initial publication of the latter is Hirsch (1862).

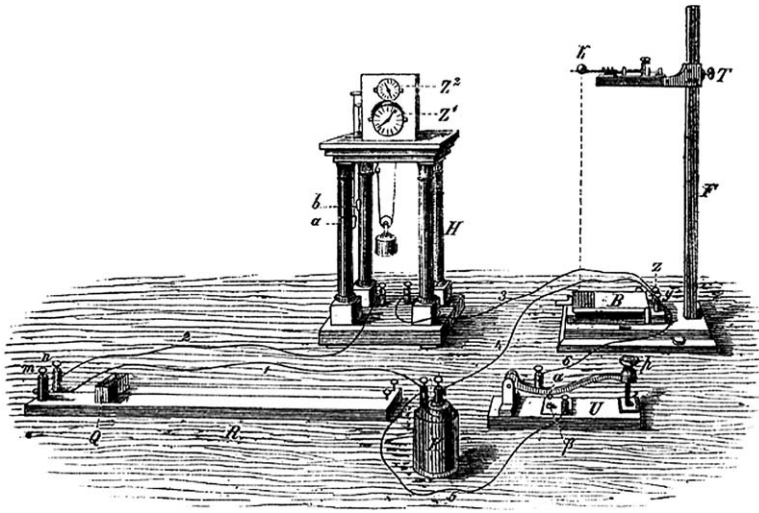


Fig. 1. Reaction experiment with Hipp chronoscope (from Wundt, 1874, p. 770).

chology. With the chronoscope reaction experiment, Wundt was able to make time—in the idealist philosophy of Immanuel Kant an *a priori* form of intuition and consequently not accessible to concrete empirical investigation—a subject for scientific research. The reaction experiment simultaneously served as Wundt's vehicle to extend research in the realm of sensory physiology into a domain that he saw as genuinely psychological. Differing in technique from Fechner's 'psychophysics' or Helmholtz' 'physiological optics', as well as from Wundt's own research on binocular vision, the reaction experiment investigated 'representations', that is ideas, not sensations and perceptions. That is, the experiment concerned conscious phenomena which Wundt believed to be independent from elementary physiological events, and which operated according to a specific, 'psychological causality'.

Wundt owed this particular position on the reaction experiments to his structural view of psychological processes and his 'apperception theory'. The goal of experimental psychology for Wundt was the 'analysis (*Zergliederung*)' of complex psychological phenomena into their most simple physiological and psychological components. Wundt was convinced that the *physiologically* determined elements of experience (i.e., sensations and perceptions) were only transformed into representations, that is, *psychological* phenomena, when entering the visual field (*Blickfeld*) of consciousness and the visual point (*Blickpunkt*) of attention, that is when being 'perceived' and 'apperceived'. One of the first problems the former Helmholtz-assistant hoped to solve with the reaction experiment was thus to determine the time needed to apperceive perceptions, for example, acoustic stimuli. In addition, Wundt assumed (like Johann Friedrich Herbart and Johannes Müller before him) that the entry of sensations and perceptions into consciousness took place in a specified succession. Wundt's 1860 'law of the unity of representation (*Gesetz von der Einheit der Vorstellung*)' stated that 'one representation always follows another and that

every arrival of new representations presumes the disappearance of those which are present' (Wundt, 1863b, p. 364). Consequently the second problem which he hoped the reaction experiment would solve was that of measuring the length of time a single representation remained in consciousness and, as a corollary, the length of the time between representations.⁸

In his early experiments with the pendulum apparatus, Wundt proceeded from the premise that the time differential between two representations was a 'psychological constant' whose value he determined at one-eighth of a second. At this time, Wundt was also convinced that he had found this 'psychological measure', a sort of natural entity or unit of time.⁹ Following the introduction of the reaction experiment, however, Wundt was forced to relativize this conviction considerably. After 1879, the experimental research carried out in his Leipzig laboratory indicated that time measured by the chronoscope was highly variable—not only between test subjects, but also in relation to the given stimulus. These results did not lead Wundt and his students to any principle objections to conducting reaction experiments, however. Rather the breadth of the results was taken by the growing community to be productive.

From 1880 to 1920, researchers such as Emil Kraepelin, James Cattell, Edward Titchener, Hugo Münsterberg and Théodore Flournoy made use of the chronoscope to measure reactions toward optical, visual, tactile and other stimuli in various constellations and contexts including other psychologists and students of psychology, school children, those seeking employment, and psychiatric patients. The swift spread of the reaction experiment can be accounted for by virtue of the multiplicity of its possible applications and evaluations, as well as by the fact that the chronoscope and its related equipment were easy to acquire and completely mobile. Physically and metaphorically, the chronoscope then traveled from the Neuchâtel observatory to Wundt's psychological laboratory in Leipzig, and from there to Paris, Cambridge (Mass.), or Toronto: to laboratories, clinics, factories, etc. A network of research institutes and instrument manufacturers, held together by textbooks and trade catalogues, secured the precision of this psychological research. Emblematic images of the chronoscope in textbooks emphasized the central place of the reaction experiment for the emergent discipline.¹⁰

1. Local contexts and the technological background of the reaction experiment

In this paper I reconstruct the local context in which Hirsch carried out his chronoscopic experiments in the early 1860s. The focus will thus be on the clock industry

⁸ See Wundt (1863a), pp. VII–XXXII; Wundt (1863b), pp. 365–377; Wundt (1906 [1882]).

⁹ See Wundt (1862a, 1866).

¹⁰ On the history of the reaction time experiment, see Robinson (2001). See Gundlach (1997) and Evans (1998) for information on the use of the chronoscope and other psychological time measuring instruments. On the history of other psychological instruments, see Benschop and Draaisma (2000), Caudle (1983), Gundlach (1996), Popplestone (1980), Popplestone and McPherson (1980), Traxel, Gundlach, and Zschuppe (1986).

in the Swiss canton of Neuchâtel, the observatory in the city of Neuchâtel, and the Neuchâtel factory for telegraphs and electric equipment headed by the ‘inventor’ and manufacturer of the chronoscope, Matthäus Hipp (1813–1893) since the early 1860s. I simultaneously describe the impact of this context on the work of those psychologists who worked with the chronoscope—in Leipzig and elsewhere. I will first briefly describe the economic background of the Neuchâtel observatory; thereafter I will comment on some of the technological aspects of the observatory’s functioning. This will help clarify that the technological milieu within which Hirsch’s experiments were carried out was dedicated to the telegraphic communication of time.

In contrast to the observatories in Greenwich, Paris or Vienna, the Neuchâtel Observatory was constructed almost exclusively to serve time. Built at the behest of the clock-makers in the Jura, it was designed to act as a control for the marine chronometers and pocket watches made in the Swiss canton of Neuchâtel. Furthermore, a telegraphic apparatus sent a daily timing signal from the observatory to the clock- and watch-makers’ workshops in the Jura mountains. Postal and telegraph offices in Neuchâtel were also served by this timing signal from the observatory. In the early 1860s, this time service was extended to all telegraph offices in Switzerland. In the Swiss context, this function of the Neuchâtel observatory played an important role in the transition from local to standard time: it ‘established for the first time in Switzerland a standardized and unified time for a larger geographic space’.¹¹

Adolphe Hirsch’s contribution to this development was considerable. As co-founder and secretary of the Swiss Geodetic Commission (1862), as member and secretary of the International Geodetic Association (1866–1900), and as the Swiss delegate to the Rome (1883) and Washington (1884) conferences on the Prime meridian, this astronomer was an active proponent of the unification and propagation of standardized time and measures.¹²

Hirsch received practical support in his efforts to standardize and distribute time from Matthäus Hipp, the former director of the national telegraph offices in Bern. After having moved from Bern to Neuchâtel in the early 1860s, Hipp founded his own telegraph factory as a society of stockholders (*actionnaires*) in April 1863. Hipp supplied the observatory with the telegraph apparatus needed to guarantee the accurate transmission of time. In addition, Hipp assembled electric clock systems designed to make possible the delivery of time—from single buildings (factories, schools, railway stations, town halls) to entire cities, including Zurich and Rome amongst others. As ‘inventor’ and producer of the chronoscope, Hipp also contributed directly to the execution of Hirsch’s experiments on the speed of sensory impressions. Hipp not only made available two chronoscopes to his partner and friend (without which

¹¹ Messerli (1995), p. 74. On the Neuchâtel observatory see *Département de l’Instruction publique* (1912), Guyot (1938). On the introduction of standardized time in other contexts, see Bartky (2000), Stephens (1985, 1989). For a more general account, see Blaise (2001).

¹² On Hirsch, see Legrandroy (1901). On Hirsch as a student in Heidelberg, see Mumm (1992), pp. 86–87. On the role of the ‘International Earth Measurement’ project in the standardization of time and measures, see Bialas (1982), p. 239–273. On the role of astronomy during the internationalization of science, see Cawood (1977), Chapman (1985), Herrmann and Hamel (1975), Headrick (1981).

Hirsch would not have been able to carry out his experiments in their well-known form), but as a member of the Neuchâtel Society of Naturalists he also took part in Hirsch's experiments as a test subject.¹³

Inspired by Hans-Jörg Rheinberger, I recognize time-telegraphy as the 'technical system' that surrounded the reaction experiment; that is as the wider field of 'material cultures of knowledge' (Rheinberger, 1997, p. 29) in which was researched the 'epistemic object' known alternatively as the 'personal equation' to astronomers, as 'physiological time' to those astronomers and psychologists interested in physiological matters, and, finally, as 'reaction time' to the bulk of psychologists. Those astronomers and psychologists who investigated this epistemic object did so, I shall demonstrate, within the same surroundings of time-telegraphy technology.

In their experiments, both Hirsch and Wundt profited from the possibilities created by the fusion of clock mechanics and electromagnetism. Both also constantly sought to perfect the practical uses of the instrument that in a certain sense embodied this fusion: the chronoscope. Seeking to understand and explicate the epistemic objects they investigated within this context, astronomers and psychologists presented it in telegraphic terms: nerves became 'conductors'; nerve impulses, 'signals' or 'messages'; and their propagation throughout the nervous system, 'transmissions'. These conceptions were not simply products of a metaphorical discourse common to nineteenth-century physiologists, philosophers and literary writers. They reflected above all, I suggest, the concrete handling of telegraph technology both at the observatory and in the laboratory. But, as we shall see, the familiarity with telegraphy did not prescribe all the details of transferring this basic technology to scientific discourses. When Wundt set out to describe the *psychological* processes he was most interested in, he left behind the telegraph metaphor.¹⁴

I also follow Rheinberger's position that the technological surroundings of an experimental system simultaneously define its horizons and its borders.¹⁵ This assumption permits me to show that not only did the functioning practice of 'time-telegraphy' leave its mark on the reaction experiment, but also its dysfunctionings were of concern to astronomic and psychological experimenters. Whether at work in an observatory or in a psychological laboratory, environmental disturbances affec-

¹³ On Hipp, see Weber (1893), Keller and Schmid (1961). On the history of electric clocks, see Aked (1976a,b), Hope-Johns (1949), Weaver (1982).

¹⁴ As I shall show, the use of telegraphic terms for physiological phenomena involved not just the 'effect' of use (or only of the mere existence) of a technology, as Friedrich Kittler (1990) probably would argue. In working with 'their' epistemic object, the language of physiologists and psychologists developed via the hybridization of technological and scientific terminologies. This is similar to what, in other contexts, Peter Galison described with the phrase 'trading zone' and Rheinberger as 'blending between discourses'. See Galison (1997), Ch. 9; Rheinberger (1997), Ch. 10. On the use of the telegraph metaphor in nineteenth-century physiological, psychological and literary discourses see Lenoir (1994), Menke (2000), Otis (2001).

¹⁵ See Rheinberger (1997), p. 29.

ted the precise communication of time. In addition to ground vibration and climatic change, noise played an important role.¹⁶

Since astronomers determined time with the ‘eye-and-ear’ method, they were particularly sensitive to distraction by noise, regardless of its distance to the observatory. Experimental psychologists engaged in experiments designed to measure time could also be disrupted by noise from within and without the laboratory. Around 1890, Hugo Münsterberg (1863–1916) and other psychologists complained that environmental noise filtered into their laboratories and disrupted work. In subsequent years, psychologists had to realize that even the noise of their own time measuring instruments could affect the course of an experiment, particularly when it interfered with those qualities being measured. As we shall see, test subjects around 1900 increasingly gave testimony that the ‘sound of the chronoscope’ distracted their attention and even caused ‘feelings of aversion’. Even the test subject became a distraction in this context, as will be shown toward the end of this article. After Edward W. Scripture (1864–1945) had compiled all the various means by which test subjects could be disturbed, he recognized in this subject an ultimate ‘source of disturbance’. With this, the limit of the experimental system with which psychologists worked was demarcated: if Scripture had removed every possible disturbance, he would have simultaneously cut off all access to the epistemic object.

In contrast to Schaffer, who was concerned mainly with the social organization of scientific work at observatories and in psychological labs, I am thus interested in the interaction of ‘human beings’ and ‘non-human beings’—in this case, technical beings—during the process of experimentation in both astronomical and psychological research sites.¹⁷ First, I seek to make clear that the technological objects with which experimenting scientists work are not isolated individuals, at least no more than the scientists themselves. Whether microscope, kymograph or centrifuge, a scientific instrument, as a component of an experimental system, should not be seen as related only to the other components of this system—regardless of whether these are of a more institutional, social or epistemic character—since, at the same time, the technological and other components of an experimental system are also connected to a material culture whose borders extend far beyond the sciences. In reaction experiments, the chronoscope was used in conjunction with the fall apparatus, the telegraph key, galvanic components and other peripherals, as well as with experimenter, text subject, concepts and theories. But, as will be shown, the chronoscope was also linked to the mechanic pendulum clock and the writing telegraph that Hipp had built in the 1840s before he shifted to the production of telegraphs. The chronoscope was bound together with these apparatuses and with the overarching system of time-telegraphy, that was developed by Hipp in the 1860s for the Neuchâtel observatory and that, eventually, was sold internationally with great success.

Second, I want to demonstrate that instruments, not least because of their embed-

¹⁶ On the social history of noise, see Lentz (1995), Krömer (1981), Saul (1996). On acoustic and architecture, see Arns and Crawford (1995), Thompson (1997, 1999). On noise and the environment in general, see Schafer (1977).

¹⁷ On this terminology, see Latour (1993).

dedness in a general material culture, can intervene into the experimental work of scientists in sometimes unexpected ways. The close relations between single components of an experimental set-up and the technical system in which they are bound becomes especially obvious when sudden disturbances affect the course of the experiment.¹⁸ Whether these disturbances are caused by poor instrument functioning, by a researcher's clumsiness or mishandling, or by the surroundings in which the experiment is conducted, I shall argue that it is not the individual component (for example, the chronoscope) that comes to the fore and attracts attention. When a reaction experiment is unexpectedly disrupted, it is not the chronoscope that changes its mode from 'ready to hand' to 'being present', as Martin Heidegger might have said.¹⁹ It is more accurate to say that such disruptions make noticeable the larger system of material culture from which the technological components of the experiment were taken.

It is certainly true that the psychologists of the Wundt School entertained a virtually continuous discussion on the difficulties related to the use of the chronoscope.²⁰ (These discussions, however, often repeated observations made years earlier by users of the chronoscope such as physicists.²¹) Psychologists nevertheless made routine use of this instrument for nearly forty years. What did change during this period was the order of the components of the reaction experiment on laboratory benches and, above all, the distribution of these components within laboratories. In 1890, Wundt recommended that to avoid disturbances in reaction experiments, chronoscope and test subject should operate from separate rooms. He simultaneously suggested making use of the very technical surrounding the chronoscope belonged to since its invention in the late 1840s. Test subject and chronoscope, that is, should be physically separated from each other, yet brought back into communication with the help of telegraphy. It is in this sense that the 'referential totality' of telegraphy came to the fore by temporal breakdowns of the reaction experiment, not the individual instrument. To speak again with Heidegger: 'The disruption is not present as a pure change in the thing, but as a *breach of the familiar referential totality*'.²²

¹⁸ Until this date, the epistemological interest of disturbances, accidents and failures was mainly exploited in studies on the sociology of technological, ecological and medical risks. See, for example, Bosk (1979), Clark (1989), Gieryn and Figert (1990), Hilgartner (1992), Jasanoff (1994), Perrow (1984). For an example from the history of the life sciences, see Dierig (1998).

¹⁹ Winograd & Flores (1988), pp. 36–37, 77–79, 90–91, make use of this Heideggerian terminology in order to analyze disturbances in interactions between humans and computers. The detailed development of the terms in question can be found in Heidegger (1996), pp. 62–81. See also Heidegger (1994), pp. 254–270.

²⁰ See, for example, Cattell (1893), Ebbinghaus (1902), Wundt (1894).

²¹ See Brettes (1853), especially pp. 27–32 (Brettes' text incorrectly refers to Hipp as 'Hill'), and Decher (1852), p. 13. Regarding the fall apparatus, see Schneebeli (1874).

²² Heidegger (1994), p. 255: 'Die Störung ist nicht gegenwärtig als pure Dingveränderung, sondern als ein *Bruch der vertrauten Verweisungsganzheit*'. In this sense, see also Heidegger (1996), p. 70: 'in a *disruption of reference*—in being unusable for . . . —the reference becomes explicit'.

2. The Swiss clock industry at the 1855 Paris ‘Exposition Universelle’

When the Parisian *Exposition Universelle* opened its doors in 1855, the Swiss Confederation was represented by more than 400 exhibitors. More than 10,000 firms represented the host nation, France. England was present with 2500 exhibitors, Prussia with 1300. The French exhibitors took up almost half of the *Palais de l’Industrie*, which had been erected between the Champs Elysées and the Seine. The Swiss were housed in both an *Annexe* of the industrial palace, which extended for 1200 meters along the riverbank, and in the *Palais de l’Industrie* itself, between the Dutch and Spanish delegations (Fig. 2).

Despite the comparatively small number of exhibited pieces, the French found laudatory words for the Swiss contribution to the exhibition: ‘For a nation of two and a half million the Swiss exhibit is rather considerable’ (Tresca, 1855, p. 130), read an official guide to the *Exposition*. Most noteworthy was that the Swiss hand-work industry (*industrie manufacturière*) was obviously not in decline, but rather the opposite: it had developed quite remarkably. Examples of this included muslin, cotton cloth and curtains from St. Gallen, silk from Zurich, ribbon from Basel, and straw articles and wooden sculptures from canton Aargau.

Special attention was given to the wares of the Swiss horological industry. Cantons Neuchâtel and Geneva were, according to the *guide*, the most important centers of the Swiss clock- and watch-production. The workshops in the Jura Mountains alone produced up to 1000 watches daily, ‘at prices from 20 to 1000 francs’ (Tresca, 1855, p. 131). While in canton Neuchâtel the mass production of timepieces and their parts was the order of the day, the horologists in Geneva specialized in the manufacture

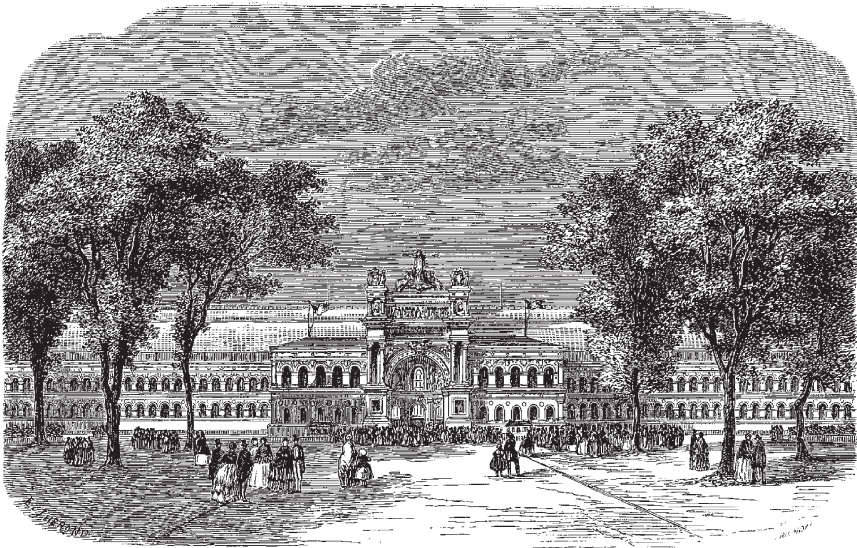


Fig. 2. Main entrance of the *Palais de l’Industrie*, Paris (from Tresca, 1855, frontispiece).

of exclusive clocks and watches: they displayed their ‘delicate’ and ‘decorated’ wares along with miniature watches (Tresca, 1855, p. 131).

Judgment of the exhibits was delegated to an international jury, an illustrious group of politicians, scientists and industrialists responsible for awarding medals to the horological industry, part of the rubric ‘precision arts and crafts related to science and instruction’. In addition to physicists such as David Brewster, Heinrich Wilhelm Dove and John Tyndall, this jury also included the Frenchmen Jean Baptiste Philibert Vaillant, ‘*ministre de la maison de l’empereur*’, and the politician and meteorologist Philippe Mathieu. In his written report on the state of the horological industry, Mathieu wanted to leave no doubt as to the predominance of French and English manufacturers: ‘Nothing surpasses the elegance of the luxury pendulum clocks and the quality of the precision pendulum clocks made in Paris. Chronometers are made in great quantities and with remarkable precision in England . . . The luxurious watches from Paris are superior to those made in Switzerland and England’. Solely in the realm of ordinary watches was Switzerland judged to be leading, because the Swiss had been producing them in enormous quantities for some time (Mathieu, 1856, p. 408).

If Mathieu’s report limited its praise of the merits of the Swiss horological industry to mass production (in fact the main activity in the canton of Neuchâtel), the medals awarded to the Swiss tell another story. Excluding precision watches and large, public clocks, Swiss manufacturers received nearly all the highest marks. Horologists such as Winnerl (Paris) and Fordsham (London), manufacturers of marine chronometers and precision pocket watches, received the expected praise. Yet luxury watches from Geneva and Neuchâtel were awarded more first class medals than the French and English won together. Swiss horologists also completely dominated the realm of simple watches (*montres ordinaires*) to the extent that the jury awarded an honorary medal to the Swiss Federal Department of Commerce in order to praise the entire horological industry in Neuchâtel and Geneva (Mathieu, 1856, p. 420).

The reasons the jury gave for according this prize illuminate what was at stake for the Swiss horologists. As the jury recognized, the Swiss were not only interested in expanding their mass production of clocks, watches and their respective parts, they also desired to significantly improve the quality of their products. It was noted that many Swiss watches with second hands were sold as ‘chronometers’ although their distorted accuracy brought little honor to the name. The exhibition indicated, however, ‘that in this country one really begins to see the construction of true pocket chronometers and even marine chronometers’ (Mathieu, 1856, p. 420). The production of precise pocket watches and marine chronometers was indeed the area in which the Swiss would subsequently become particularly successful.²³

In order to be able to assess the state of the international clock- and watch-industry, canton Neuchâtel sent to Paris a delegation of local entrepreneurs and politicians. This delegation drew rather different conclusions about the exhibition than did

²³ On the history of Swiss horology see Jacquet and Chapuis (1970), Fallet (1995). See Cardinal, Jequier, Barrelet, and Beyner (1991) for the cultural-historical contexts.

Mathieu. It noted curtly that ‘nothing of note’ could be reported on either the French or the English chronometers. The workmanship and the aesthetic design of these chronometers represented ‘nothing exceptional’. The delegates noted that the technical design of English marine chronometers had hardly changed in twenty years. In their eyes, the state of precision clock making outside of Switzerland was even alarming: ‘Given this state of stagnation in the art of such an important industry as precision horology one fears that it, like so many other fields, is decaying into the banal domain of simple speculation’ (Anonymous, 1856, p. 10). On the other hand, canton Neuchâtel could flatter itself with its clock and watch making abilities that, in terms of their craftsmanship as well as in their technical importance, were equal or superior to other manufacturers. ‘The struggle with other nations in possession of the same industry’ could be thus engaged ‘to our own advantage’.²⁴

For this to take place, however, the horologists needed the administrative and organisational support of the State. While still in school, clock workers should be inculcated with a desire for perfection (*désir de perfectionner*) and a sense for the elegant design of clock casings. Above all, however, it was necessary to establish an observatory in Neuchâtel in order to ensure the quality of manufactured clocks:

We have never had any means by which to check the precision of our chronometers. We can only do this ourselves by incurring costs and exceptional work for the mass production manufacturers which, after all is said and done, are only able to serve our own personal satisfaction. Our self-made regulation tables have virtually no value to clients. Even if they do not doubt our good will, they can at least call the accuracy of our observational technique into question. Whereas a chronometer accompanied by a regulation table drawn and backed up by the Director of a public observatory is authoritative and increases the value of the piece as well as the amateur’s trust in it. (Anonymous, 1856, p. 11)

As early as the early 1830s, so-called ‘time trials’ were carried out in other countries, for example at the observatory in Greenwich. Horologists deposited their watches, which were tested and—if they passed—were provided with a certificate of performance. However, in England these trials ‘were reserved for marine chronometers and watches with view to purchase the best pieces by the Royal Navy’.²⁵ The Swiss horologists went about this differently. They wanted to submit also to these tests the clocks and watches for private use. This was the objective of the observatory established in Geneva in 1829, and it was also the goal for building the observatory at Neuchâtel in 1859.

²⁴ Anonymous (1856), p. 10. The Neuchâtel Commission’s report did not go unchallenged. As editor of the *Revue chronométrique*, Claudius Saunier, general secretary of the French *Société des Horlogers*, criticized the polemic tone of the report and answered with a counterproposal in which he detailed the functioning of the French chronometers. See Saunier (1857a,b).

²⁵ Landes (1983), p. 291. More generally, see Landes (1983), pp. 290–307; Jacquet and Chapuis (1970), pp. 171–199.

3. Adolphe Hirsch and the establishment of the Neuchâtel observatory

The first step toward this goal was the solicitation of expert scientific and technological advice to plan the construction of the observatory. At the suggestion of the Neuchâtel physician and politician Louis Guillaume (1833–1924),²⁶ the Neuchâtel state council turned to the Halberstadt-born astronomer Adolphe Hirsch, then working at the Paris observatory.²⁷ In March 1858, Hirsch presented a plan which became the basis for building the observatory at Neuchâtel. Based on this plan, the government of canton Neuchâtel decided on 17 May 1858 to erect an observatory capable of determining precise time.²⁸

For Hirsch, it was clear from the very start that the observatory would be established with an essentially practical goal, namely the exact determination of time for the horological industry. The equipment and organization of the observatory was consequently based on meeting this goal. However, Hirsch disagreed with the Neuchâtel delegation that had been sent to Paris as to how, exactly, this was to take place. His opinion was that it was not sufficient to create a public facility which ‘functioned authoritatively’; the observatory must also have a certain recognition in scientific circles. As he explained to the state council:

Even if it is not the intention that your observatory becomes one of the great centers of astronomy, it must be able to make scientific observations and thereby earn a place within the scientific world of observatories. Without this status the regulation tables issued by the observatory to your horologists will not have sufficient authority for clients (despite having earned it) and you will fail to meet your desired goals.²⁹

Hirsch clarified that the large observatories in Greenwich, Paris, Berlin and Vienna, with which he was personally familiar, were too large to serve as a model for Neuch-

²⁶ On Guillaume, see Buess (1978).

²⁷ Guillaume, only a few years younger than Hirsch, apparently met the latter in the 1850s privately when he studied medicine in Zurich. Guillaume worked with the clinician and pathological anatomist Hermann Lebert (1813–1878) under whom he wrote his *Beiträge zur Lehre der Zuckerausscheidung im diabetes Mellitus* which was presented as his dissertation to the medical faculty in December 1854. See Guillaume (1854). Hirsch, about whose studies little is known, studied astronomy at Heidelberg, Berlin (with Encke) and Vienna. If Guillaume’s recollection is to be believed, he met Hirsch accidentally at one of Zurich’s tourist attractions, the *Uetliberg*. Hirsch found himself then as *précepteur* with a student traveling to Venice to spend the winter. See Legrandroy (1901), pp. 4–5. It is also possible that Hirsch had been interested in studying medicine in Zurich. At any rate, he penned the 1883 article on Lebert, Guillaume’s advisor, for the *Allgemeine Deutsche Biographie* (Hirsch, 1883).

²⁸ See Département de l’Instruction publique (1912), p. 23.

²⁹ Hirsch (1858), p. 3. Hirsch made the same point in a lecture before the Neuchâtel Society of Naturalists in 1859. As he explained, the delegate-commission to the Paris Exhibition indeed correctly referred to the importance of the authority the regulation tables receive with the signature of the director of a state institution; but the official character of these tables is not itself sufficient. Hirsch argued that in principle the observatory must work up to scientific standards, that is, it must achieve a level of accuracy in measuring time required by science. See Hirsch (1859).

âtel. In his suggestions for equipping the observatory Hirsch nevertheless went beyond the original proposal of the members of the delegation. If they wanted to limit the equipment to a meridian telescope and an astronomical pendulum then, in Hirsch's eyes, they would have to add at least a parallactic machine. Although this machine was not needed for measuring time, it would help secure the status of the observatory.

The instruments which Hirsch recommended strongly included 'a meridian circle, an equatorial with two circles, two pendulum clocks, a barometer, and an instrument to test the performance of the chronometer at various temperatures' (Hirsch, 1858, p. 10.). He furthermore recommended the acquisition of a 'telegraphic apparatus to link the observatory to the centers of clock- and watch-making' (Hirsch, 1858, p. 11). As for personnel, Hirsch thought it wise to employ at least one assistant—a suggestion he justified by noting that the observatory in Polkova had twenty-five employees. Finally he made some recommendations as to the most favorable location for the observatory: not in the center but at the edge of the city, with as open a horizon as possible (Hirsch, 1858, p. 5).

The governing authorities did their best to follow Hirsch's recommendations closely. After a geological survey had been conducted, a construction site on the eastern side of the city was found next to an abandoned park, the so-called *Mail*. In constant contact with Hirsch in Paris, Neuchâtel architect Hans Rychner designed and planed the construction of the observatory. In the summer of 1860 the observatory was finally put into service. In January of the following year the state council issued a directive establishing a supervising commission as well as stipulating the particulars of time measurement (Fig. 3).³⁰

The time service provided by the observatory included the determination and distribution of time as well as the observation and assessment of all precision timepieces produced in the canton of Neuchâtel. Manufacturers such as Grandjean, Bertschinger and Breting deposited their watches at the observatory to be systematically tested in various positions and under varying temperatures. After successfully passing these tests the watches received certificates which confirmed their quality. The results of these tests were published yearly by Hirsch, which permitted direct comparison of clocks and encouraged competition between horologists.

In addition, the observatory provided clock- and watch-manufacturers with accurate time. According to Hirsch's plan, the telegraphic time service was primarily meant to offer manufacturers of ordinary watches the possibility to better control the products of their work.³¹ Once per day a time signal was sent from the observatory to the workshops of the Jura horologists. This took place with the help of a telegraph apparatus installed at the observatory and made use of the existing telegraph network without disturbing the ongoing communications. This service was quickly expanded. In 1859 the link from the observatory to the telegraph office in Neuchâtel was established; from there it was broadened to La Chaux-de-Fonds and Le Locle, and then

³⁰ See Département de l'Instruction publique (1912), pp. 26–27.

³¹ See Hirsch (1858), p. 11.

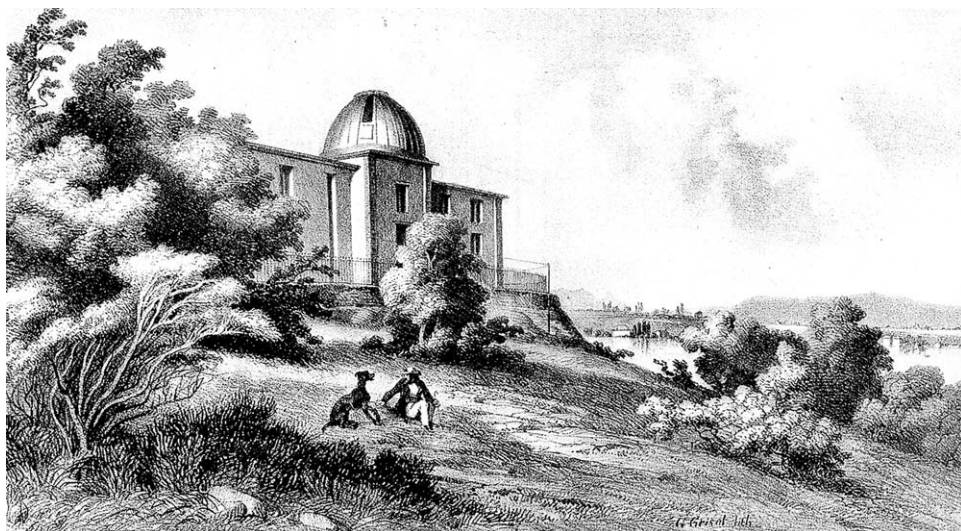


Fig. 3. The Neuchâtel observatory, ca. 1860 (from *Département de l'Instruction public*, 1912, p. 6).

to Les Ponts and Fleurier. The following year the clocks in all telegraph offices in Switzerland were synchronized to the time signal from the Neuchâtel observatory. Shortly thereafter, in certain regions of Switzerland (canton Vaud and the city of Biel, for example) the Neuchâtel time signal was also used for public clocks. It is no wonder then that contemporary travel guides mentioned the observatory with more than a little pride: 'From there, time is distributed throughout Switzerland via electric wire' (Favre and Guillaume, 1867, p. 23).

Hirsch conveyed a more realistic picture of the time service in his annual reports on the observatory's functioning. In 1863, for example, he stated that in the previous year the communication of time had taken place with a regularity that left little to desire. He had to concede however that between April 1862 and April 1863 the signal had failed to make it to La Chaux-de-Fonds and Le Locle about seventy times. This included twenty-eight days during which the signal was not sent at all because of the director's absence or on account of repairs to the various transmission apparatuses. Nonetheless the usefulness of the organization was recognized by all interested—competent horologists as well as the postal and telegraphic offices, each of which praised the regularity of the signal highly (Hirsch, 1864b, pp. 6–7).

4. Matthäus Hipp's activities between clock-making and telegraph technology

The technological prerequisites for the time services of the Neuchâtel observatory were provided by the entrepreneur and 'inventor' Matthäus Hipp. Hipp not only delivered and installed the telegraph equipment used to transmit the time signal, but also installed all the electric components at the Neuchâtel observatory. Hipp's *Fab-*

rique des télégraphes et des appareils électriques was located not far from the city center, in a former warehouse about halfway between the observatory and the post and telegraph office (Fig. 4):

The telegraphs, their batteries and related equipment are assembled in this facility by about sixty workers, some working metal, others wood. There are mechanics of several sorts, clock-makers, carpenters, etc. Two Ericson hot-air engines drive most of the machine tools. These motors are soon to be replaced by a turbine engine brought into service by the high-pressure water provided by the Water Department (*Société des Eaux*). (Favre and Guillaume, 1867, pp. 94–95)

The 1867 travel guide from which this account is taken from makes clear that the production of telegraphs and related equipment was only one aspect of Hipp's operations. According to the *Guide du voyageur à Neuchâtel*, a visitor to the factory could also see electric pendulum clocks whose workings were 'incomparably accurate', barometers, thermometers and limnometers capable of 'self-recording' the values they measured at certain hours. One could also see Hipp's electrically triggered disks used as signals by the railroads. Finally one could marvel at the chronoscope—capable of measuring time to a thousandth of a second and used for scientific purposes.³²

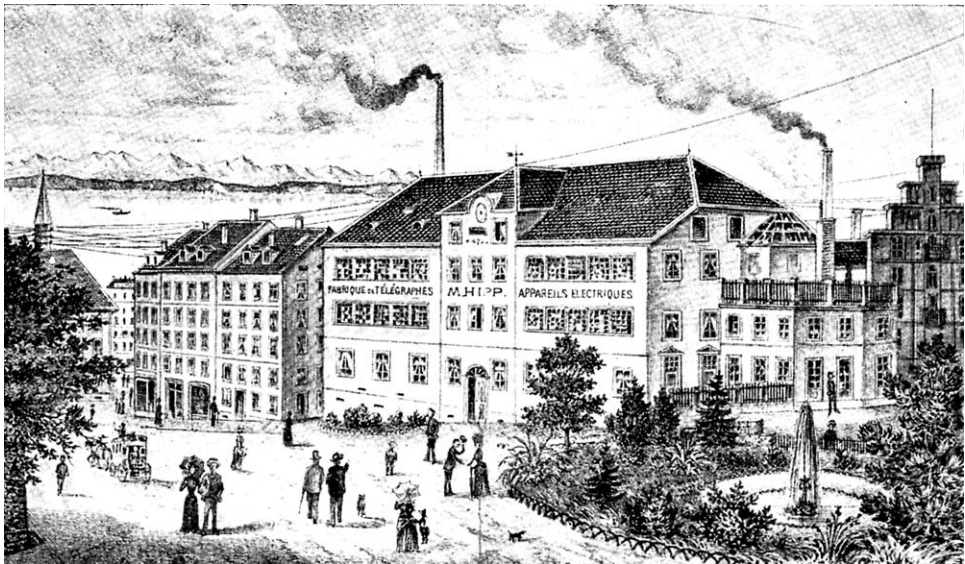


Fig. 4. Hipp's telegraph factory at Neuchâtel, ca. 1875 (from Keller and Schmid, 1961, p. 24).

³² One might further mention that a short time later visitors could be astounded by another attraction from Hipp: an electric piano Hipp invented in the 1860s which he played himself during concerts at the Neuchâtel high school. Hipp's musical instrument was considered so interesting that the local *Société industrielle et commerciale* assembled a commission to more closely explore its other possible uses. This commission concluded that the electric piano is 'a musical instrument of incontestable artistic worth',

The fact that the *Fabrique des télégraphes* had become a tourist attraction in the 1860s testifies Hipp's success as an entrepreneur. Originally from Blaubeuren in south west Germany, Hipp completed his training in watch-making in the 1830s and established himself, with his own manufacture, as maker of large and small time-pieces (*Groß- und Kleinuhrmacher*) in Reutlingen in 1840. Stemming from his horological work Hipp subsequently expanded his activities to applied electricity culminating in the production of telegraphs and electric clocks. While skilled in the innovative construction of fine mechanical and electromagnetic devices, Hipp's true domain became the installation of electric systems for communication and registration of all kinds of data: chronometric, barometric, thermometric, limnometric, and so on.

Indicative of the development of his activities are the three devices with which Hipp made his name in German-speaking Europe in the 1840s. In 1843 Hipp presented his 'self-controlling clock'. The basic principle of this initially purely mechanical pendulum clock consisted in giving a correcting 'impulse' to the bottom of the pendulum if it lost momentum.³³ In the 1850s, Hipp replaced the mechanical impulse working with an electromagnet, thereby creating an electromagnetic pendulum clock. In the 1870s, Hipp developed this pendulum clock to a precision such that it was used at observatories—in Neuchâtel and elsewhere.³⁴

Clock-making and applied electricity were jointly applied again in the chronoscope, which was first presented to the German-speaking public in 1848. In this precision instrument, the clockwork of which was regulated by a *Springfeder* (a sort of miniature tuning fork) capable of 1000 vibrations per second, time was measured with the assistance of an electromagnet. Charles Wheatstone had already presented his similar instrument, also named a chronoscope, in a session of the Parisian *Académie des Sciences* in 1845. As Wheatstone explained, the chronoscope was designed to measure quick movements, particularly the speed of projectiles. Similarly, the Hipp chronoscope was presented as an instrument 'for experiments on the velocity of shotgun bullets' in 1849.³⁵ In contrast to Hipp, Wheatstone had been led to develop the chronoscope by his work on telegraph technology. Regarding his needle-telegraph, the English physicist explained before the *Académie* that the chronoscope could be understood as a 'derivative' of this technology.³⁶

As for Hipp, his initial foray into the realm of telegraphy was incorporated only in the third device he developed during the period in question. In 1852, Leipzig's *Illustrierte Zeitung* published an illustration of Hipp's writing-telegraph constructed 'after the American model'. This machine was a letter-telegraph that permitted the

which will probably enjoy a 'successful industrial future'. On the basis of this judgment the Chamber of Commerce opened a competition to compose a 'series of musical pieces' for Hipp's electric piano. See Anonymous (no date).

³³ See Hipp (1843).

³⁴ Hipp's electromagnetic pendulum clock is described in Favarger (1884–1885), p. 95–96. For contemporary descriptions of Hipp's astronomical precision pendulum clock, see Hirsch (1884a,b, 1891). On Hipp and the history of astronomical precision pendulum clocks, see Erbrich (1978), pp. 21–23.

³⁵ See Oelschläger (1849).

³⁶ See Oelschläger (1848a,b, 1849) as well as Wheatstone (1845), p. 1555. On Wheatstone's contribution to telegraph technology, see Hubbard (1965).

transmission of twenty-four Latin letters. In its most simple form this machine consisted of two parts, the ‘signaling (cause) and writing (effect) components’. When the rotating drums of both parts were correctly synchronized, letters keyed into the sender would be reproduced by the writer at the reception point. Of importance to the functioning of the telegraph was the ‘extraordinary regularity of the clockworks in both the sender and the reception components’. It is not surprising then that Hipp, when synchronizing the rotating drums, returned to the construction of the chronoscope: both drums were activated by clockwork weights controlled by springs producing 1000 vibrations per second.³⁷

Hipp made the transition from timepiece to telegraph manufacture in the early 1850s, and it took a little time for this to impact on his personal career. In 1852 Hipp was offered a job as a machine supervisor (*Maschinenwerkführer*) at the newly established Swiss Federal Telegraph Workshop in Bern and was quickly promoted to Chief of the entire operation. This Federal Workshop was designed to construct, test and repair telegraph apparatuses for use throughout Switzerland. Hipp’s assignment included the ‘care of materials and in particular of galvanic apparatuses’, which were particularly important to telegraph technology. Under his leadership, some thirty workers labored to satisfy Switzerland’s communication technology needs. In addition, Hipp somehow continued to find time for his ‘inventions’. He reported the results of his innovative activities regularly in the *Communications of the Society of Naturalists in Bern* (*Mittheilungen der naturforschenden Gesellschaft in Bern*) and the *Archive of the Physical and Natural Sciences* (*Archive des sciences physiques et naturelles*).³⁸ The fruits of these labors also created a lucrative trade. Between 1855 and 1858 the profits from Hipp’s manufacture and sale of ‘his own apparatuses’ to foreign administrations and individuals surpassed his wages two- or three-fold. A conflict between Hipp’s ‘private’ activities and his official assignment seemed to be inevitable. After a series of arguments regarding the bookkeeping at the Bern workshop Hipp finally decided to submit his resignation in the summer of 1860 and relocate to Neuchâtel as an entrepreneur.³⁹

During his years in Neuchâtel, Hipp established another lucrative business in the production of electric clock systems. After his experience setting up the telegraphic communication of time signals at the Neuchâtel observatory in 1860, he delivered his first electric clock system to the city of Geneva in 1862. Thereafter followed the installation of tailored systems to Neuchâtel in 1864, where it was used both by the

³⁷ Anonymous (1851a). For another description, see Anonymous (1851b).

³⁸ See, for example, Hipp (1854, 1855, 1859).

³⁹ On the Federal Swiss Telegraph workshop between 1852 and 1864, see *Generaldirektion der PTT* (1952), pp. 152–180. The success of Hipp’s Neuchâtel factory can be measured, for example, by the awards which his equipment received at international industrial exhibitions. As early as 1855, at the Paris Exhibition, mentioned above, Hipp’s firm along with Siemens & Halske, Gintl and Breguet was awarded a medal of honor for developments in the construction of telegraphic apparatus. See Anonymous (1856), p. 457. Twelve years later, at the following *Exposition universelle* in Paris (1867) a jury (composed of Siemens and Wheatstone, amongst others) awarded Hipp a gold medal for his telegraphic apparatus. In the class ‘*Instruments de précision et matériel de l’enseignement des sciences*’ Hipp received a cash award for his barometric registering apparatus. See Anonymous (1867), Groupe I, p. 56; Groupe VI, p. 90.

city and by other ‘subscribers’, Zurich in 1865 (of 135 networked clocks), Königsberg and Winterthur in 1869, and so on. He subsequently provided similar clock systems for other cities, including Rome, London and Philadelphia.⁴⁰

Hipp thus provided technological contributions to the unification of time, as propagated in Switzerland by his friend Adolphe Hirsch in the 1880s and 1890s. Hirsch’s program included fixing the zero meridian at Greenwich and introducing an internationally valid ‘universal time’. This universal time, argued Hirsch in his role as secretary of the International Geodetic Association, would be as important for large communication and transport concerns (telegraphy, railroads, steamships, and so on) as for those scientific disciplines which cooperate internationally. Local or regional times would not be superseded however, Hirsch explained in the 1880s to an obviously concerned Swiss public. Rather, local times would be kept and universal time would only find its way into use when society needed it.⁴¹

5. Hirsch’s chronoscopic experiments on ‘physiological time’

When, at the end of October 1861, Hirsch began his ‘Chronoscopic Experiments on the Speed of Sensory Impressions and of the Nerve-Conduction’ at the Neuchâtel observatory, his business partner Hipp made available two chronoscopes. Hipp and other members of the Neuchâtel Society of Naturalists personally took part in the experiments.⁴² Hirsch first tested the accuracy of the chronoscopes by measuring the speed of a falling ball from a given height and comparing this to its calculated speed. To do this Hirsch utilized one of Hipp’s fall apparatuses, thus reinstating an experimental set-up familiar to physicists since the early 1850s.⁴³ This was an experiment Hirsch ‘repeated very often’ and could thereby confirm that in one of the chronoscopes the ‘average error in any case did not exceed two-thousandths of a second’. This was the instrument which Hirsch then used in his experiments on the speed of sensory impressions and nerve conduction (Hirsch, 1862, p. 106).

Hirsch then modified his experimental setup so that it no longer measured the time of the falling ball, but the time an ‘observer’ needed to react to the sound of the ball hitting the board. To this end, a ‘common telegraph-key’ was added to the

⁴⁰ See Anonymous (1881). See also Hipp’s extensive articles on electric clocks (Hipp, 1879, 1880). As with the chronoscope, Hipp was probably not the first to ‘invent’ this technology, but rather he adopted and perfected instruments already being produced in other parts of Europe. Between 1840 and 1852 Alexander Bain developed electric clocks in this way and described this in detail in his *Short history of the electric clock*. See Hackmann (1973). Similar descriptions of electric clocks can be found in Moigno (1852).

⁴¹ See Hirsch (1884–1885).

⁴² In addition to Hipp, amongst others the former secretary and colleague of Louis Agassiz, Pierre Jean Édouard Desor (1811–1882), took part in the research. On Desor, see Carozzi (1981).

⁴³ Physics teachers and physicists such as Friedrich Reusch (1812–1891) were apparently the first to buy the chronoscope. See Weber (1893), p. 324. In the 1850s, Wilhelm Eisenlohr, Professor of physics at the polytechnic in Karlsruhe, recommended the chronoscope to empirically verify the laws of falling bodies known since Galileo’s times. See Schmidgen (2000).

setup and the flow of electricity was correspondingly rewired. The striking of the ball against the board no longer stopped the chronoscope, but rather now began it. The chronoscope would only be stopped by the observer's operation of the telegraph key after hearing the sound caused by the ball. With this small change, Hirsch transformed an experiment for empirically verifying the laws of falling bodies (Fig. 5) into a set-up that would eventually be found in nearly all the emerging laboratories for psychology. Together with the new experimental set-up, the telegraph key made its way onto the laboratory benches of psychologists such as Wundt, Münsterberg and Scripture.⁴⁴ Thus, the telegraph key constituted the tangible link of the reaction experiment to the overarching system of material culture from which the technological components of the experiment came.

But it was not only on the level of material culture that telegraphy left its mark on the reaction experiments carried out by Hirsch, Wundt and others. The physiological and psychological discourses subsequently generated around this experiment were also marked by this technology. In a certain sense, it is ironic that Hirsch labeled his epistemic object not 'personal equation' (as most astronomers would have), but 'physiological time': it was precisely this label which led him to adopt the vocabulary of telegraphy. Hirsch left no doubt that his research sought to increase the accuracy of astronomical time determinations, but, surprisingly, in his article he referred more frequently to the work of experimental physiologists than to that of his colleagues in astronomy (Maskelyne, Bessel or Airy, for instance). Hirsch clearly knew that the experimental investigation of the speed of nerve conduction in living organisms was

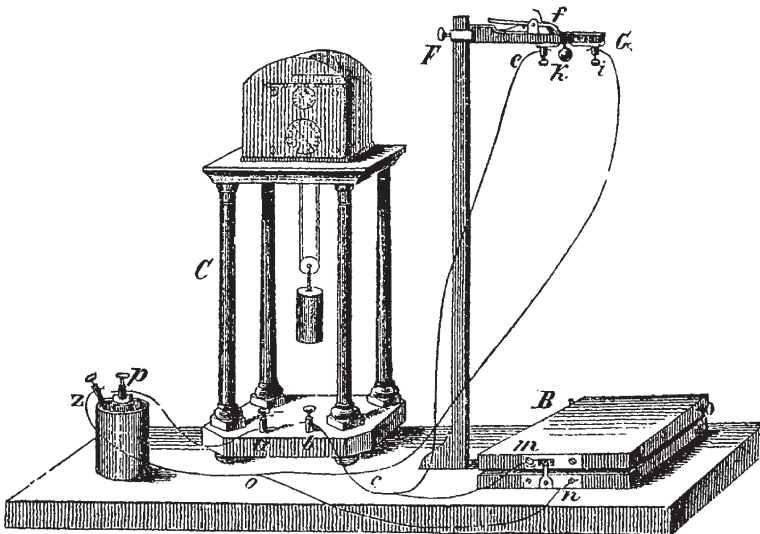


Fig. 5. Experiment with chronoscope for demonstrating the laws of fall (from Eisenlohr, 1860, p. 647).

⁴⁴ Wundt later wrote in his *Grundzüge* that 'American telegraph keys are highly recommended'. See Wundt (1893a), p. 324.

a research subject ‘reserved for physiologists’ (Hirsch, 1862, p. 103), yet he did not hesitate to link his study with the work of Emil Du Bois-Reymond and Hermann Helmholtz.⁴⁵

With a touch of acquired local patriotism Hirsch pointed out that it was a son of Neuchâtel, Emil Du Bois-Reymond, who had laid the groundwork for his chronoscopic experiments.⁴⁶ According to Hirsch, Du Bois-Reymond’s *Investigations into animal electricity* (*Untersuchungen über thierische Elektrizität*) (1848–1849) set out clear reasons that the functions of the brain and the nervous system could be subjected to the methods of physics ‘just like any other natural force’. In Hirsch’s eyes this subjugation was no longer surprising since Du Bois-Reymond had shown that the ‘nervous action is, fundamentally, probably nothing more than an electric phenomenon’ (Hirsch, 1862, p. 102).

The second reference for Hirsch’s investigation was Helmholtz’ research into the speed of nerve impulse propagation.⁴⁷ Helmholtz’ publications on the topic did indeed make extended use of telegraphic imagery.⁴⁸ In a lecture delivered at the Physical-economical Society of Königsberg in December 1851, Helmholtz claimed it ‘not improper’ to compare ‘nerve strings’ with ‘electric telegraph cable’ which would ‘send reports from the furthest borders of a state to the ruling center’. This comparison led straight to the question which motivated Helmholtz’ research: ‘Regardless of whether traveling from the most distant points of the epidermal nerves or from the nerves in the sensory organs to the brain or sent by the will from the

⁴⁵ Hirsch’s interest in physiological problems predates 1860. His notes de cours indicate that only half of his studies were spent with astronomy, physics and mathematics. The other half was devoted to subjects such as law and economics, philosophy, and physiology. Hirsch wrestled not only with Plato’s *Politeia* und Hobbes’ *De cive*, but also with Proudhon, as well as Michelet and Feuerbach. The notes on zoology, anthropology and physiology also indicate that he studied Carl Vogt’s popular *Naturgeschichte der lebenden und der untergegangenen Tiere* (1851). Under the heading ‘Haenle’s physiology’, one further finds notes on General and specialized nerve physiology, as well as on Johannes Müller’s ‘Physiology of generation’. The problem of physiological time, however, is not touched upon in these excerpts. See Hirsch (no date a). On Hirsch’s political activities as a student in Heidelberg, see Mumm (1992), pp. 86–87.

⁴⁶ Emil Du Bois-Reymond had in fact been born in Berlin, but his father, Félix-Henri Du Bois-Reymond (1782–1865), was a Neuchâtelier. The latter had been entrusted since 1831 with leading the Department Neuchâtel of the Prussian Foreign Ministry in Berlin. The historical background for Félix-Henri’s activities can be resumed as follows: In 1648, Neuchâtel became independent of the French house of Orléans-Longueville. In 1707 it chose as its prince a distant claimant (both geographically and genealogically), Frederick I of Prussia. In 1798 the Swiss Confederation collapsed, leaving Neuchâtel to fend for itself. As Napoleon was at war with Prussia, he annexed Neuchâtel. In 1815 the King of Prussia regained his nominal authority over Neuchâtel, but almost simultaneously the province was admitted as a canton to the Swiss Confederation, with which it had been allied since the fifteenth century. This bizarre anomaly led to decades of civil conflict between Neuchâtel royalists and republicans. In 1848 a revolution abolished the monarchy within Neuchâtel, and in 1856 Prussia and Switzerland stood at the brink of war over sovereignty. In 1857 Frederick IV renounced his claim to Neuchâtel. For more general information on this, see Chambrier (1984).

⁴⁷ In particular, Hirsch referred to a report on Helmholtz’s research work given by Otto Ule (1857).

⁴⁸ On this point, see Otis (2001), pp. 68, 73, 120.

brain via the motor nerves to the muscles, does the transmission of a particular message require a specified amount of time?’ (Helmholtz, 1883 [1850], p. 873).

As a consequence of formulating the problem in this way, Hirsch also conceived of his question in terms of telegraphy. The ‘physiological time’ he sought to measure consisted, as he explained, of three parts: ‘1. the transmission of the sensation to the brain; 2. the action of the brain that (so to speak) transforms sensation into will; 3. the transmission of the will via motor nerves to the muscles and the execution of movement by them’ (Hirsch, 1862, pp.103–104). In other words, experiencing an event was understood by Hirsch as the telegraphic transmission of signals from the periphery of the body to the brain and from the brain to muscles. In this context, ‘sensation’ and ‘will’ were conceptualized as ‘sent messages’. Hirsch also applied the term ‘transmission’ to the propagation of these ‘messages’ throughout the body. And that was precisely the word he made use of when describing the sending of time signals in his annual reports on the activities of the observatory: ‘*transmission de l’heure*’ (Hirsch, 1862, p. 113).

In his 1874 *Grundzüge*, Wundt adopted Hirsch’s experimental set-up virtually unaltered. The discourse Wundt developed from and for the reaction experiment was, however, of a more philosophical cast. The Leipzig psychologist was not primarily interested in ‘physiological time’ (although it was exactly this term that he adopted from Hirsch) (Wundt, 1874, p. 730). Wundt’s main focus was on ‘representations (*Vorstellungen*)’, or ideas, and their ‘comings and goings’, that is their entry ‘into the field of consciousness’ (Wundt, 1874, pp. 727–728), and their subsequent exit from it. According to Wundt, the representations performed a ‘spectacle’ before one’s consciousness (Wundt, 1874, pp. 726–727). As he explained, this spectacle was only experienced when placed in the center of attention. In other words, when describing *psychological* phenomena, Wundt took up the theater metaphor known from the English empiricists.⁴⁹

But when turning to the *physiological* processes that, as he presumed, formed the ultimate basis for the emergence of representations, Wundt adopted the telegraph metaphor as he knew it from Helmholtz, Hirsch, and others. Wundt used Hirsch’s notion of ‘physiological time’ to designate the interval between the presentation of a stimulus to a test subject, the ‘signal’, and his or her operation of the telegraph key, the ‘reaction’. And, similarly to Hirsch, Wundt divided this interval into single entities. Thus he spoke of ‘the conduction from the sensory organs to the brain’ and ‘the conduction of . . . motor excitation to the muscles’. Wundt saw both these processes, which Hirsch listed as 1 and 3, as ‘purely physiological’. Only where Hirsch spoke of the ‘action of the brain’ did Wundt refer to ‘representations’ and their ‘comings and goings’.

A theater stage encircled by telegraph cables: that is how Wundt conceived of the

⁴⁹ See, for example, Hume (1992), p. 534: ‘The mind is a kind of theatre, where several perceptions successively make their appearance; pass, re-pass, glide away, and mingle in an infinite variety of postures and situations’.

relationships between the psychological and the physiological with respect to the reaction experiment.

6. Noise as a disturbing factor at observatories and in psychological laboratories

If Hirsch and Wundt differed in the way they unfolded their respective discourses about experienced time, they nevertheless shared a similar relationship to the material culture of time. For both, the astronomer and the psychologist, the sound of the functioning timepieces was an important factor in executing their precision work. Hirsch had to listen carefully to the ticking of his astronomical pendulum clock in order to coordinate it with the star passages he observed. In a similar vein, Wundt paid much attention to the sound of the vibrating spring that regulated the chronoscope's clockwork. These acoustical aspects of material time made both Wundt and Hirsch quite receptive to environmental disturbances.

Already in 1858, when giving his recommendations regarding the construction of the Neuchâtel observatory, Hirsch drew attention to this problem. With respect to the choice of the observatory's location, Hirsch explained to the state council that it was not only important to ensure the widest possible horizon possible, but also to guarantee that the observatory's building was insulated from all forms of shocks and vibrations, as these could disturb the delicate astronomical instruments. But above all, a 'deep tranquility (*tranquilité profonde*)' was required so that the astronomer was 'always able to hear his pendulum clock':

One must therefore avoid clock towers, busy sections of town and above all major roads so that the *noise of the bells*, the circulation of cars, and the whistling of the locomotives do not disturb observation and to prevent ground vibrations from traveling to the building foundations and the observatory's instruments.⁵⁰

In other words, Hirsch saw his efforts to precisely determine and communicate time

⁵⁰ Hirsch (1858), p. 5 (my emphasis). Such environmental concerns were not Hirsch's alone. When plans began in the mid-1840s to build a railway line from Woolrich to Greenwich, astronomers of the Royal observatory reacted immediately. Concerned that the vibrations of passing trains might affect astronomical work, Airy charged his assistant Edwin Dunkin to carry out experiments with which the 'practical inconveniences' of passing trains could be assessed. Conducting his experiments near an existing railway line, Dunkin's alarming results were ultimately sufficient to prevent the construction of a line through Greenwich Park. See Hingley and Daniel (1999), pp. 86–87. The Royal Observatory of Scotland, established in 1817 on Canton Hill in the heart of Edinburgh, also struggled with environmental disturbances. In contrast to Greenwich it was not the consequences of modern transport, but rather atmospheric conditions of the industrial city, which affected the astronomers' work. In fact, Edinburgh's industrial smoke was so troublesome that a new observatory south of the city was begun in the late 1880s. See Donnelly (1973), pp. 89, 119.

threatened by another, more ancient system for communicating time.⁵¹ The ‘noise of the bells’, he feared, could disturb the concentrated coordination of eye and ear required for the coordination of the astronomical pendulum clock and the star passages.

These concerns reflected some of the experiences Hirsch had had during his work with Urbain-Jean Joseph Le Verrier at the Paris observatory. As successor to Arago, Le Verrier became director of the observatory in 1853. Besides intensifying the research work in stellar physics, one of his main goals was to improve the precision of astronomical time measurements, to install devices for the telegraphic distribution of time, and to carry out, in cooperation with other observatories, longitude determinations.⁵² The Paris observatory was located in the center of the city. This context was not entirely favorable to carrying out Le Verrier’s projects. He and his colleagues appreciated the proximity of other Parisian scientific institutions and the instrument makers residing in the French capital. But the ground vibrations due to public traffic near the observatory, dust and mist in the air of the city center, as well as city lights, were experienced as environmental obstacles to accurate work in astronomy.⁵³ As to the astronomical determination of time, this aspect of Le Verrier’s work was threatened by the bells of the religious establishments close to the observatory. Only in the 1860s were these bells synchronized so that, as a contemporary commentator observed, ‘an astronomer will never again hear the same hour tolled by various clocks over half an hour’ (Bourdeline, 1862, p. 71).

Against this background, one understands why Hirsch, in his chronoscopic experiments, was particularly interested in exploring questions of acoustics. Time determinations relying on the ‘eye-and-ear’ method could be disturbed by noise, in particular by the noise of time itself. The fall apparatus in Hirsch’s experimental set-up offered a way to investigate this problem more closely. It was as if constructed for the presentation of acoustic stimuli. But its simple construction also limited the options to present different kinds of stimuli. Disappointed, Hirsch noted: ‘I would have liked to have investigated [physiological time] as influenced by the kind of noise or sound one hears, for example when it is more or less crisp and sudden. But the nature of the apparatus and the kind of experiments conducted aren’t well suited for this’ (Hirsch, 1862, p. 109).

Through his interest in noise, Hirsch anticipated a problem that experimenting psychologists saw themselves confronted with in later times. As a matter of fact, in the 1880s and 1890s disrupting environmental noise, and the noise of time in particular, also became problematic for experimenters in psychological laboratories, threatening their accurate work. Wundt’s model institute lay protected in an inner-courtyard of the large Leipzig University building. Hence, Wundt himself complained less about noise than did his students who had still to struggle to conquer

⁵¹ On one side there is a ‘sound net’, orientated toward the midday sun and providing regional time, on the other there is an electric net, regulated by astronomers’ gazing and providing supra-regional time. On the ‘language of bells’, see Corbin (1994).

⁵² See Le Verrier (1855).

⁵³ See Aubin (in press).

space for their own institutes. Shortly after his arrival at Harvard University, when Hugo Münsterberg presented his newly established psychological laboratory, noise was an aspect that he paid special attention to. In Münsterberg's eyes (and ears), the instrumentation of his lab left little to desire, but the location of it was quite unfavorable: '... whoever has undertaken psychological investigations on the corner of Harvard Square, at a place where the electric cars cross from four directions, and where the hand-organs of the whole neighborhood make their *rendezvous*,—out of his soul will not vanish the wish that a new laboratory may some time arise at a more quiet spot'. Ten years later this 'quiet spot' was found, in the form of the impressive Emerson Hall building on Harvard's campus, and complaints about disturbing noise ceased.⁵⁴

In subsequent years, the noise within the laboratories became a major problem with which psychologists were occupied. As was noted earlier, the functioning of the chronoscope was accompanied with a clearly noticeable sound. This working sound was not only due to mechanical clockwork and electromagnets clicking, but also to the spring which regulated the clock and made a clear, whistling tone. This tone served to control the accurate working of the instrument. Already Hirsch had recommended to check the tone of the spring against a tuning fork making 1000 vibrations per second (Hirsch, 1865a, p. 187). But it would not be long before psychologists noticed that the sounds made by chronoscope had a disturbing impact on precisely those phenomena that they wanted to research with this instrument.

Published complaints by test subjects about how distracting the chronoscope was increased at the turn of the century. Thus, the Leipzig psychologist Paul Bader reported in his 1912 experimental study on 'The effect of the question (*Die Wirkung der Frage*)' on the difficulties caused by the experimental setup in his research. In some subjects, the chronoscope aroused a 'feeling of aversion', particularly when they had the impression that they were not responding quickly enough to a stimulus. In such cases, Bader wrote, the sound of the chronoscope had an unpleasant effect on consciousness, appearing as a 'loud reminder (*lauter Mahner*)'. As evidence for this observation, he cited numerous comments by test subjects including: 'Distracted by the noise of the apparatus. Whistling tone distracting'; 'Clear auditory representation of the running clock—painful'; 'Just before [the stimulus] I hear the sound of the chronoscope, I can't get rid of it. I'm not averse to it right away, but I'm also not unaware of it. I hear it constantly' (Bader, 1912, pp. 6–7).

Already in his 1905 study on the *Activity of the will and the thought process (Die Willenstätigkeit und das Denken)* Narziß Ach had reported similar, if less explicit, observations: 'After just a few experiments test subjects adjust to the sound of the chronoscope; when concentrating on the experiment itself, it is completely ignored' (Ach, 1905, p. 28). In their 1898 *Psychological investigations into reading, based on experiments (Psychologische Untersuchungen über das Lesen auf experimenteller Grundlage)*, Benno Erdmann and Raymond Dodge also presented the focussing of attention on the given task, along with habituation to the experimental set-up, as the

⁵⁴ Münsterberg (1893), p. 206. Emerson Hall is described in Münsterberg (1906).

decisive strategies in carrying out undisturbed experiments: ‘We were able to establish that the numerous and varied small sounds made by the functioning apparatus were indeed perceptible, but remained unnoticed as long as they flowed normally. But if a change occurred in their flow, the test subjects’ attention was immediately drawn to it and the distraction was experienced as a disturbance’.⁵⁵ The precondition for successful psychological experiment thus became, as a Münsterberg student put it, the test subject’s ability ‘not to think of the experiment’ (Solomons, 1899, p. 377).

However, Wundt School psychologists did not want the individual ability of a test subject to be the decisive element in determining whether the experiment was successful. They tried to prevent the test subject from distractions by means of concrete measures. Edward Scripture addressed this specifically when he referred to the ‘errors of surroundings’ in his address to the second annual meeting of the American Psychological Association in 1893: ‘Disturbing sounds are probably the worst sources of error’, he confirmed. Scripture was convinced that the only remedy was the architectural separation of the test subject from the disturbing instruments. It was obvious to him that ‘the experimenter, the recording apparatus and the stimulating apparatus [must be located] in a part of the building distant from the person experimented upon’ (Scripture, 1893, p. 429). In the early 1890s Wundt himself had spoken out in favor of the isolation of the test subject from disturbing instruments. In the early years of the Leipzig Institute’s reaction experiment test subjects saw only their telegraph key, ‘all other apparatus being hidden’ (Wundt, 1874, p. 771). By 1893 Wundt deemed this purely optical precaution no longer sufficient for chronoscope use. Although the illustration of the reaction experiment remained principally the same in subsequent editions of the *Grundzüge*, in the fourth edition Wundt made an important change to the accompanying text: ‘... in order to see clearly, all apparatuses are depicted in direct connection, while *when carrying out the experiments* it is urgently recommended the experimenter and the observer [i.e., the test subject] are placed *in completely separate rooms*’.⁵⁶ In other words, fall apparatus, telegraph key and test subject had to be imagined ‘in another room’ than chronoscope, galvanic element and *Rheochord*, which were ‘only of interest to the experimenter’.⁵⁷ Wundt further explained that in order to be able to distribute the experiment over two or more rooms, additional technological facilities were required: ‘in addition to the cable needed to connect the apparatus, telegraphic communication between the experimenter and the observer by means of an agreed-upon signal is required’ (Wundt, 1893a, p. 324). Test subject, fall apparatus and telegraph key should thus be *architecturally* removed from experimenter, chronoscope, battery and *Rheochord*.

⁵⁵ Erdmann and Dodge (1898), p. 325. In contrast to Ach, Erdmann and Dodge used a self-constructed chronograph. See Dodge (1895).

⁵⁶ Wundt (1893a), p. 324 (original emphasis).

⁵⁷ Wundt (1893a), p. 324. In a similar vein, Tigerstedt and Bergqvist (1883) had argued earlier in favor of a separation of the experimental set-up. In 1920, the Jena-based psychiatrist Theodor Ziehen argued: ‘The reacting test subject and the registering experimenter should, if in any way possible, be in separate rooms. I recommend mistrusting all experiments, where this condition is not fulfilled’. See Ziehen (1920), p. 488.

Simultaneously, however, they had to be *technologically* reconnected by telegraphic equipment.

The Leipzig Institute was first able to accommodate these requirements after it relocated in the autumn of 1892 from the old university buildings into a building on the *Grimmaische Steinweg*. There the Institute had at its disposal eleven rooms lined up one after another. Originating at an ‘electronic central station’, composed of sixty large *Meidinger* batteries, twenty cables ran through the Institute by which individual laboratories were serviced. These cables were laid out such that the rooms could also be connected to each other in any way desired.⁵⁸ Wundt explained the purpose of the multiple electric cables as follows: it permits the set-up of ‘the chronoscope and its attendant control and other equipment in one room’ and the device for presenting stimulus and for recording the reaction ‘in another, preferably distant, room’ (Wundt, 1893b, p. 454). It was thereby not only possible to control the experiment from a distant room, but also ‘observer and experimenter are always able to communicate by means of telegraphic signals or, if necessary, via telephone’ (Wundt, 1893b, p. 454). In psychological labs telecommunication thus took place not only between test subject and experimenter, but the psychologist’s work also entailed ‘tele-stimulation’ by the experimenter (i.e., the stimulus would be generated in a distant room) as well as ‘tele-reactions’ by the test subject (i.e., the response to the stimuli would be given in a different room). In other words, psychologists coped with auditory disturbances during reaction experiments within the framework of the very technology that constituted the surroundings of the chronoscope since the 1850s: telegraphy.

Scripture’s attempt to avoid auditory disturbances went one step further. In his laboratory at Yale, he devised an isolation room meant to keep all possible disturbances at bay. In a cramped room, the test subject sat at a table with a telegraph key, linked to a chronometer in another room, upon it (Fig. 6). There was also a telephone on the table, to speak with the experimenter, just as Wundt had described. Scripture commented that ‘to be rid of all distraction, the person experimented upon is put in a queer room, called the “isolated room”, whose thick walls and double doors keep out all sound and light. When a person locks himself in, he has no communication with the outside except by telephone’—and of course via the telegraph key, connected as it was to the recording instruments of the experimenter.⁵⁹ Similar installations, sometimes described as a ‘room within a room’, were subsequently installed in the psychological laboratories of the universities of Princeton, Cornell and Texas. Here too, wall and ceiling isolation was circumvented to a certain degree by a system of cables. As we shall finally see, these efforts at isolation were nonetheless insufficient

⁵⁸ Wundt (1893b), p. 452–453. Another description of these localities can be found in Henri (1893), pp. 609–618.

⁵⁹ Scripture (1895), p. 41. On Scripture, see Sokal (1980). The similarity between the isolated room and a telephone box is hardly accidental. In the construction of such rooms, designers and architects were indeed inspired by the model of these boxes. At least this is what the Dutch physiologist and psychologist Hendrik Zwaardemaker (1857–1930) claims was the case. He constructed a *camera silentia* in his laboratory at the University of Utrecht in 1904. See Zwaardemaker (1930), p. 505.

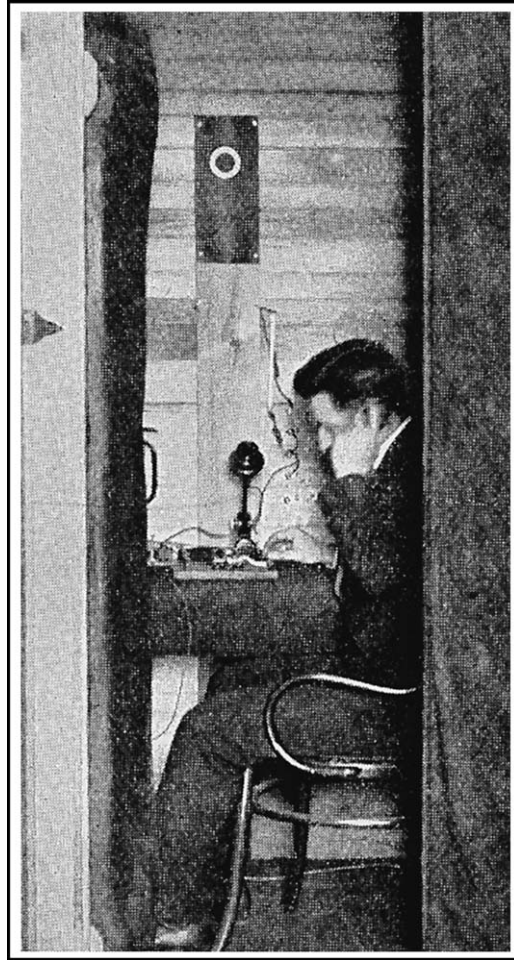


Fig. 6. Test subject in isolation room, Psychological Laboratory, Yale University, ca. 1895 (from [Scripture, 1895](#), p. 41).

to eliminate all potential sources of disturbance to psychological experiments ([Dallenbach, 1931, 1953](#); [Langfeld, 1926](#)).

7. Astronomical and psychological consequences of noise

Despite his interest in physiological problems, Hirsch did not forget that his chronoscopic experiments were motivated by quite practical concerns: to guarantee the necessary precision of astronomical time determinations. But when the director of the Neuchâtel observatory began to tackle the task of determining and correcting the individual observation error, he did not use the experimental set-up which later

was found in psychology laboratories. Taking concrete steps to determine his own personal correction in May 1862, Hirsch once more made use of the chronoscope. But instead of again employing an acoustic stimulus, as he had with the fall apparatus, Hirsch opted this time for an optical stimulus. Before the threads of the meridian telescope ‘artificial stars are pulled past, attached to a kind of pendulum which moves with such speed that the artificial stars appear to the viewer to have the same movement as the stars in their passages’ (Hirsch, 1864a, p. 65). Again, this apparatus was made by none other than Matthäus Hipp. Some months later Hirsch began using this apparatus to determine his personal correction. The new experiment, which was more similar to the actual observation situation of the astronomer, ran as follows: the pendulum with the artificial stars was started and, by its swinging, it disconnected an electric current at a given point. This set the chronoscope in motion. ‘The observer sees moving the bright point before the net of threads in his telescope. The very moment he sees the point in the middle position of the net, he shuts the current down. The chronoscope stops’. The instrument then displayed the elapsed time.⁶⁰ In subsequent years, Hirsch determined with this experimental set-up his own personal correction as well as those of his colleagues in Swiss astronomy Émile Plantamour in Geneva and Rudolf Wolf in Zurich.⁶¹

Within the context of his astronomical work, Hirsch thus handled the observational error pragmatically. After numerous calculations of his own and his colleagues personal equation he came to the conclusion that the ‘best’ astronomical observers are not those who require the smallest correction, but those whose corrections are the most constant. Instead of further exploring the physiological basis for individual observational error (as he had done in the article quoted by Wundt) Hirsch now turned to experiences from astronomical practice. The decisive factor in personal error correction, he explained, was a mixture of discipline and routine: ‘The result of exercise is less to reduce time [i.e. the individual observational error], it is more to make it more constant’. In turn this meant that only a great number of measurements could put things right because only in this way could the ‘normality’ of the phenomenon be established (Hirsch, no date b, p. 13). As with the practice of some experimental psychologists, habituation of the subject thus became the factor that guaranteed accurate work.

In everyday astronomical work the consequence was that, as a *physiological* problem, the ‘problem of physiological time’ was de-emphasized. For time measuring psychologists, however, the question of physiological time remained where it always had been: in the foreground. But eventually the research work carried out in psychological laboratories made clear that the physiological, the psychological and the temporal were so interwoven that an undisturbed measurement was hardly possible. The ‘isolation room’ in any case did not bring about the desired silence, but led back to the problem of time—and noise. Describing his experience in the isolation room, Scripture notes:

⁶⁰ Hirsch (1864c), pp. 367–368. See also Hirsch (1865b).

⁶¹ See, for example, Plantamour and Hirsch (1875), pp. 107–136.

My clothes creak, scrape and rustle with every breath; the muscles of the cheeks and eyelids rumble; if I happen to move my teeth, the noise seems terrific. I hear a loud and terrible roaring in the head; of course, I know it is merely the noise of the blood rushing through the arteries of the ears . . . , but I can readily imagine that I possess an antiquated clock-work and that, when I think, the wheels go round.⁶²

Distanced from every obvious source of disturbance, an encounter with the intimate interrelation of body, thought and time took place. In the solitude of the isolation room, the test subject was confronted with an inescapable inner clock. The result was that the test subject eventually revealed itself as a disturbance in time measurements. Scripture wrote of this paradox: ‘all the sights and sounds can be shut out, all disturbances of touch can be made small by comfortable chairs, but, alas! we have let in a sad source of disturbance, namely, the person himself’ (Scripture, 1895, p. 42).

The time measuring efforts of psychologists thus reached a limit at the very object of their study. This was perhaps not as surprising as one might think. To a certain degree, Wundt had anticipated this result some thirty years earlier. In 1862, that is only one year after Hirsch had carried out his initial chronoscopic experiments, the then *Privatdozent* for physiology at Heidelberg published a short piece with the succinct title ‘Time’ in the popular journal *Conversations Around the Home Fire* (*Unterhaltungen am häuslichen Herd*). Time, Wundt explained here, invades the life of the individual in a way not easily compatible with freedom: ‘The first clock was the first policeman, a policeman that thought itself instituted and to which all subsequent limitations of personal freedom became connected’. Wundt opposed this reflection with certain conviction: ‘No one can get his own time wrong’. As he explained, ‘time is a property no one else knows about. Nobody can tell me if I am hungry or thirsty; and hence nobody can prescribe me a measure of time’ (Wundt, 1862b, p. 591).

If Wundt had thereby addressed the inescapability of individual time, psychologists (including Wundt) did not find it absurd to investigate this time experimentally. If one takes Scripture’s remark seriously, then this kind of psychology could be considered a science only when it had freed itself from the ultimate source of disturbance, namely human beings. But such an enterprise only began in the 1960s, when Herbert A. Simon (re-)founded psychology as a ‘science of the artificial’. As a consequence, empirical questions of time hardly played any role.⁶³

8. Conclusion

The reaction experiment with chronoscope that contributed so vitally to the growth of experimental psychology in the late nineteenth and early twentieth centuries func-

⁶² Scripture (1895), p. 42. A similar experience is reported in Zwaardemaker (1930), p. 506.

⁶³ Simon (1969). On Simon, see, for example, Thorpe and Turner (1993).

tioned against the technological background of time telegraphy. The development of the central technical component of the reaction experiment set-up, the chronoscope, stemmed from the work of two pioneers in the business and technology of telegraphy: Charles Wheatstone and Matthäus Hipp. Together with some of the peripherals used in reaction experiments, especially the telegraph key, the chronoscope constitutes the tangible link between the reaction experiment and the technology of telegraphy in general and time telegraphy in particular. In other words, astronomers investigating individual observation errors by means of the chronoscope around 1860 worked within the same technical surroundings as psychologist studying the course and association of representations by means of same instrument in the late 1870s. Although, as Simon Schaffer has convincingly shown, different scientific practices emerged from the respective experiments of these scientists, astronomers and psychologists were thus closely related to each other at the level of material culture.

The telegraphy of time defined the horizon as well as the borders of the various experiments carried out with the chronoscope. On a practical level, telegraphy not only made it possible for Hirsch to send time signals from his Neuchâtel observatory to more or less remote places; telegraphy also allowed test subjects in psychological laboratories to sit in their isolated rooms and to send reaction time messages to the experimenter placed in some other room. In addition, telegraph technology offered a powerful metaphor, used by astronomers as well as by psychologists, to conceptualize their respective epistemic objects, albeit to different degrees. As far as the *physiological* aspects of individual time were concerned, this object was understood in telegraphic terms, both in the astronomical and psychological context. No matter whether a star passage or the sound made by a ball hitting a piece of wood, the use of this metaphor transformed the experience of events into a ‘transmission’ or ‘conduct’ of ‘messages’ from the periphery of the human body to its brain. Wundt and his students further conceptualized the *psychological* aspects of these processes. What Hirsch had generally addressed as ‘the actions of the brain’ was spelled out by these scholars as the ‘coming and going of representations’ on the inner stage of consciousness. To them, time telegraphy provided the technological and metaphorical framework for continuing to do empiricist philosophy by other means. Meanwhile, astronomers using the chronoscope had begun to handle pragmatically the individual time phenomena they had been confronted with in the early 1860s. Hirsch, Wolf and others responded to the problem of physiological time by turning it into the routine practice of measuring the personal corrections.

Time telegraphy thus opened and secured new fields of scientific activity for both astronomers and psychologists. But, at the same time, this kind of telegraphy, constituting the hardly altered background of reaction experiments, defined the borders of experimentations undertaken by means of the chronoscope. From a technical point of view, the telegraphic transmission of time signals was acknowledged to be relatively unproblematic since the mid-1860s. Despite this fact, the accurate transmission of time remained precarious as long as human beings functioned as the ultimate senders of time signals. This threat was experienced at the observatory as well as in the psychological laboratory. In Neuchâtel, time could not be send if the director of the observatory was absent. More importantly, the control of the pendulum clock at the

observatory displaying the time transmitted by Hirsch to the subscribers of his service was amenable to disturbances, especially in cases where the astronomer was distracted when observing star passages. Above all, noise entering the observatory was apt to complicate the human coordination of the pendulum clock with the observed star movements. From this point of view, the problems encountered by psychologists in their laboratories did not significantly differ. There too, noises from inside and outside the research site disturbed the accurate communication of time. Interestingly enough, the noise problem became especially explicit when astronomers and psychologists felt themselves distracted by the noise of time. In this sense, the sound of chronoscopes distracting test subjects inside the psychological laboratory echoed the disturbing sounds of bells tolling outside the observatory.

In the cases discussed here, the handling of the noise problem was not primarily a question of social organization, as Schaffer perhaps would have argued. What was at stake in Neuchâtel, Leipzig and elsewhere was, so to speak, the ‘agency’ of material culture itself, or, to be more precise, the interactions between ‘human beings’ and ‘non-human beings’—in this case, technical ‘beings’. Astronomers such as Hirsch and psychologists such as Wundt aimed at coping with the disturbances of their timing work primarily on the very level of material culture: by constructing their sites far away from the sources of noise and other possible disturbances and by changing existing constructions in such a way that they were protected against surrounding noise. The architectural distance and isolation was technologically compensated for by reconnecting the separate spaces with the help of telegraphy. As a result, we find a striking similarity between the situation of the astronomer who, from his observatory situated at the edge of the city, sent signals to its center and other places, and the situation of a test subjects placed in the isolated room of a psychological laboratory, yet connected with the experimenter by means of telegraph technology. In both cases, the ultimate aim was to communicate time in an undisturbed manner.

Despite this material resemblance, the scientific practices cultivated at the observatory and in the psychological laboratory differed in significant ways. Whereas Hirsch routinely determined his personal equation and that of his Swiss astronomer colleagues by means of a changed experimental set-up (chronoscope and artificial stars), psychologists kept on working with a set-up from which they felt time fled in all directions: from the electro-magnets of the chronoscope, the current source, the falling balls, and so on. Psychologists even saw the experimental subject contributing to this flight of time. After each and every possibly disturbing time measuring instrument had been removed and every pocket and wrist watch had been taken from them, the test subjects encountered, in the isolation room far from the chronoscope, in the dark silence, their proper time: the time of their bodies, their organs. In contrast to astronomy, time in experimental psychology thus proved to be so multifarious and individual that its measurement was forced to remain a precarious undertaking.

Acknowledgements

This paper was written in the context of a research project on the ‘Experimentalization of Life’. The project group is located at the Max-Planck-Institute for the History of Science (Department III: Hans-Jörg Rheinberger), Berlin, and receives funding from the VolkswagenStiftung, Hannover. I would like to thank Dr. Hartmut Petzold and ‘Herrn Ellinger’ from the *Deutsches Museum von Meisterwerken der Naturwissenschaft und Technik* (Munich) for offering me the possibility to see and, above all, to hear a chronoscope at work. I also thank the Archives of the State of Neuchâtel (Jean-Marc Barrelet) and the Library of the City of Neuchâtel for permission to use and quote unpublished sources. I thank Hans-Jörg Rheinberger, David Aubin and one of the anonymous referees for their helpful comments on an earlier version of this paper. Thanks finally to Eric Francoeur and especially to David Lee for ‘improving my English text life’.

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