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The graphic strategy: the uses and functions of illustrations in Wundt's *Grundzüge*

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ABSTRACT

Illustrations played an important role in the articulation of Wundt's experimental program. Focusing on the woodcuts of apparatus and experimental designs in the six editions of his *Grundzüge der physiologischen Psychologie* (published between 1873 and 1911), we investigate the uses and functions of illustrations in the experimental culture of the physiological and psychological sciences. We will first present some statistics on the increasing number of illustrations Wundt included in each new edition of his handbook. Next we will show how Wundt managed to introduce the material and literary technologies of physiology into the 'new psychology'. The distribution of Wundt's material technology will be further demonstrated by highlighting the crucial role of technicians and instrument-makers. We will use Shapin and Schaffer's notions of the 'three technologies' and 'virtual witnessing', combined with Latour's concept of 'immutable mobiles', as analytical tools to explore the strategic aspects of Wundt's illustrations.

Key words experimental apparatus, experimental psychology, scientific illustrations, virtual witnessing, Wundt

In 1873 and 1874 the Leipzig Verlag Wilhelm Engelmann published the first edition of Wilhelm Wundt's two-volume *Grundzüge der physiologischen*

Psychologie. The adjective '*physiologischen*' referred both to the origin and the methodological orientation of the new science. The methods and techniques of experimental physiology had to supply the instruments for the investigation of psychological subjects. Wundt, at that time professor of physiology at the University of Heidelberg, had already begun this research and after his arrival at Leipzig in 1875 he initiated a series of research programs on reaction times and psychophysics. In 1880 the growing corpus of new findings from Leipzig and elsewhere was included in an expanded edition of the *Grundzüge*. In the following decades Wundt prepared four more editions of his textbook. The sixth and final edition appeared between 1908 and 1911. By then the *Grundzüge* had nearly tripled in size.

In the preface to the first edition Wundt indicated that his book was an effort 'to mark out a new domain of science'.[1] It should serve this purpose by presenting an overview ('*Überblick*'), as this, Wundt felt, was the best way of 'discovering the blanks that our ignorance has left in the subject-matter of a developing science'. The idea of an overview might tempt one to compare the *Grundzüge* with one of those magnificent circular panoramas which were in vogue in the latter half of the 19th century, as if Wundt had found himself a high vantage point in the landscape of psychology, made a slow turn around his axis, and produced a painted copy of what he saw. The metaphor is seductive – but not for its suggestion of verisimilitude. Rather the opposite: Wundt's overview of psychology was the result of an intricate process of choice and selection. Like a true landscapist, he left out much of what he saw. Some parts of psychology were considered theoretically irrelevant. Sometimes findings were rejected because they had been gathered with methods that fell short of his stern standards of precision.[2] Still other sections appeared as mere background. Some of the material he did include seems to occupy a disproportionate amount of space.

It is precisely for this reason that subsequent editions of the *Grundzüge* are such a wonderful source of information for historians of science. They offer glimpses into the development of Wundt's preferences, his plans and programs, his blind spots and aversions. They show, to mention but a few examples, how Wundt kept expanding his paragraph on the methods and instruments for the measurement of reaction times to threefold its original length, while research on judgment received only scant attention (Benschop and Draaisma, 2000: 12). Wundt included lengthy chapters on sensory psychology; applied psychology never gained full admittance, nor did the psychology of individual differences. The *Grundzüge* was a panorama indeed: it reflected both the perspective and appreciations of its creator.

We shall discuss a prominent – if neglected – feature of the *Grundzüge*: its illustrations. In the first edition, Wundt included no fewer than 155 illustrations. This number grew with each new edition of the *Grundzüge*, up to 399 in the final one. These illustrations were executed using the most advanced

and minute technique available: woodcuts. They were accompanied by extensive captions and explanations in the text. Clearly, illustrations served an important purpose in Wundt's literary technology and are therefore worthy of historical investigation. What did they illustrate? What did Wundt hope to gain by including them? Did he follow particular pictural conventions, or perhaps create them? How did they fit Wundt's program for psychology? In sum, what is the historical narrative behind this multitude of visual material in Wundt's textbooks?

We first present some statistics on the number of illustrations in the six editions of the *Grundzüge*, along with a global categorization scheme. We then discuss Wundt's illustrations against the background of textbook illustration conventions of his time. After this general introduction we focus on illustrations of apparatus and experimental set-ups. We next introduce several concepts adapted from the sociology of science. From Shapin and Schaffer (1985) we will borrow the tripartite scheme of 'three technologies' and their notion of 'virtual witnessing'. Latour (1986, 1990) will provide us with the concept of 'immutable mobiles'. The combination of these notions, we argue, helps explain why Wundt went to so much trouble to secure detailed and precise drawings.

'A SOMEWHAT SUSPECT BORDERLAND BETWEEN PHYSIOLOGY AND PHILOSOPHY'

Writing to his fiancée Sophie Mau in 1872, Wundt announced that he had decided to direct his aspirations to 'a somewhat suspect borderland between physiology and philosophy'. The qualification 'suspect' was perhaps a romantic exaggeration, but it is certainly true that when the first edition of the *Grundzüge* appeared, the 'new psychology' was little more than a heterogeneous collection of findings on psychophysics and reaction time, gathered mainly by physiologists. By the time the fourth edition appeared, in 1893, there were psychological textbooks and professional journals, laboratories and instruments. In these two decades psychology witnessed the emergence of an experimental culture of its own, embedded in academic institutions (Danziger, 1990). Psychology had become an established science. Subsequent editions of the *Grundzüge* played a constitutive part in this process of discipline formation.

As shown in Table 1, the number of illustrations increases proportionally with the number of pages; all six editions contain approximately one illustration every five pages. Most of these illustrations are *anatomical drawings*: different types of nerve cells, layers in the brain, the anatomy of the senses, etc. Wundt's woodcuts were original; they were not copied from anatomical textbooks, even if Wundt often referred to publications which served as

Table 1. W. Wundt, *Grundzüge der physiologischen Psychologie* (Leipzig: Engelmann)

Edition	*Pages*	*Illustrations*	*Apparatus*
1st (1873–4)	863	155	6 (4%)
2nd (1880)	963	180	8 (5%)
3rd (1887)	1098	210	17 (8%)
4th (1893)	1248	237	35 (15%)
5th (1902–3)	2035	384	64 (17%)
6th (1908–11)	2317	399	68 (17%)

examples: '*nach Meynert*' or '*nach Carus*'. A second category of illustrations depicts *curves*: the conduction of the nerve impulse, the irritability of muscle tissue. Fechner's Law appears both as a formula and as a curve. A third category consists of *diagrams*, explaining binocular perception, the demonstration of the blind spot, the separation of white light in prisms, etc. A fourth category presents *visual illusions* like those published by Zöllner, Poggendorf and Hering (Figure 1). Wundt carefully kept his illustrations up-to-date; the fourth edition of 1893, for instance, contains a discussion of the Müller-Lyer illusion, published in 1889, with eight new figures.

The relative sizes of these first four illustration categories remain roughly constant in subsequent editions. There is a significant shift, however, in *what*

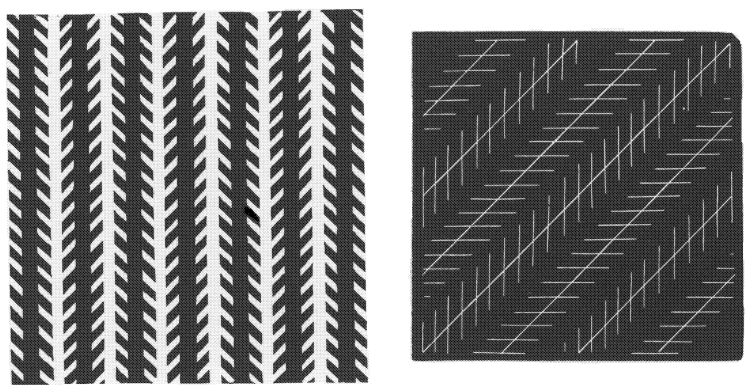

Figure 1 In the first three editions of the *Grundzüge* Wundt included Zöllner's own version of the illusion named after him (left). In the fourth edition, in the context of a discussion of experiments on factors influencing the force of visual illusions, Wundt replaced Zöllner's version by a more powerful version published by Hering (right).

the illustrations show: in the first edition the curves and diagrams depict predominantly *physiological* processes, whereas in later editions representations of *psychological* processes – like the relation between time and forgetting or changes in concentration – gain prominence. The new science had to acquire an autonomous collection of methods, theories and findings; the gradual, but accelerating, shift from physiological to psychological representations was at once the expression of this program and a forceful support for it.

In addition to anatomical drawings, curves, diagrams and visual illusions, there is a fifth category of illustrations: *experimental apparatus*. The first edition has woodcuts of the stereoscopes designed by Wheatstone and Brewster, experimental set-ups for reaction time measurement, Wundt's famous *Pendelapparat* (pendulum apparatus) for complication trials; all in all, 6 illustrations. This number expanded quickly in subsequent editions, between some editions even exponentially, up to 68 in the last edition. Why so many? And to what purpose?

First it should be noted that the inclusion of illustrations in a handbook of 'physiological psychology' was exceptional. The table below presents a chronological list of the main monographs and handbooks on the 'new psychology', sampled from the period between 1872 and 1893.[3] The first four editions of Wundt's *Grundzüge* are marked in bold.

Table 2. Illustrations in the main monographs and handbooks on the 'new psychology', 1872–93

Author	*Illustrations*	*Apparatus*
Horwicz (1872)	0	0
Wundt (1873–4)	155	6
Brentano (1874)	0	0
Hartsen (1874)	17	0
Volkmann (1875)	1	0
Wundt (1880)	180	8
Lotze (1881)	0	0
Lipps (1883)	15	0
Höffding (1887)	0	0
Ladd (1887)	113	0
Wundt (1887)	210	17
Sergi (1888)	40	6
Sully (1889)	0	0
James (1890)	94	2
Baldwin (1890–1)	20	0
Ziehen (1891)	21	0
Sully (1892)	0	0
Wundt (1893)	237	35

About half the authors included no illustrations whatsoever; those who did, presented illustrations of one particular type. During the first 10 years, Hartsen (1874) stands out as an exception: his monograph contained lithographs, mainly of curves. The 15 illustrations in Lipps (1883) are almost all visual illusions; those in the handbooks by Ladd (1887) and Sergi (1888) are mainly anatomical drawings. Thus, both the *number* and the *diversity* of Wundt's illustrations are exceptional. The author who most resembles Wundt is, surprisingly, William James, who in 1890 included 94 rather diverse illustrations in his *Principles of Psychology*. By then, Wundt was preparing an edition of the *Grundzüge* which was to contain 237 illustrations.

Second, and even more remarkable, is that practically none of Wundt's colleagues in psychology included illustrations of experimental apparatus. Sergi (1888) has six drawings of instruments, James (1890) has merely two. In this respect the first edition of the *Grundzüge* was a glaring exception. And so was the second, and the third, and the fourth. In the 'new psychology', one is forced to conclude, Wundt had no conventions to guide or inspire him.

How do we come to grips with these somewhat anomalous woodcuts? One way to answer this question is to set Wundt against a background in which he does *not* appear as an exception. The following is a sample of *physiological* textbooks, dealing with such domains as optics, sense organs, the nerve system, metabolism, etc.[4]

Physiological textbooks from the period routinely contained a sizeable number of illustrations, invariably woodcuts, and a majority of these featured illustrations of apparatus and experimental set-ups. There were a few textbooks dealing exclusively with experimental techniques (e.g. Cyon, 1876; Gscheidlen, 1876), but most physiologists preferred, with good reason, to include descriptions of their methods and instruments in their own textbooks. The establishing of novel techniques and the creating of new instruments were defining characteristics of superior work in experimental physiology. These innovations were described in articles as important discoveries and named after their author: Brücke's dissection glasses, Du

Table 3. Illustrations in physiological textbooks, 1867–96

Author	*Illustrations*	*Apparatus*
Helmholtz (1867)	213	29
Fick *et al.* (1879–80)	144	3
Hermann and Mayer (1879)	41	8
Voit and Hensen (1881)	48	0
Heidenhain *et al.* (1881–3)	113	2
Ellenberger (1887–92)	822	38
Helmholtz (2nd edn, 1896)	254	47

Bois-Reymond's induction apparatus, Helmholtz's ophthalmoscope. Contributions to the technical conditions of experimental research added significantly to a physiologist's professional prestige.

This is the very convention, we argue, that Wundt was following in the *Grundzüge*. The space he reserved for descriptions and depictions of experimental machinery was the expression of a style of professionalization that was directed at the new domain of psychology, but it originated from the science in which he was educated and which shaped his early professional career (Turner, 1982). The paradox to emerge from this is that Wundt, writing his thick tomes on the new psychology, resembled his *former* colleagues more than his present peers.

EYE-WITNESSES AND ALLIES

If we have accurately located the origin of this convention, what *functions* did these illustrations serve? What were their effects and consequences, intended or unintended? Woodcuts, we must remember, were an expensive technique. First a drawing had to be made, and this was then copied on wood by a professional engraver. For large editions – such as the *Grundzüge* – the woodblock was used to manufacture a 'galvano', the copperplate from which the engraving could be printed (Enschedé, 1924).[5] Considering production costs and labour, no publisher would permit an author to include hundreds of illustrations unless there was a compelling reason to do so. Before we shift our attention to the more strategic aspects of what Wundt requested be engraved in wood, we should briefly discuss two notions which will facilitate the analysis of Wundt's treatment of illustrations.

In their classic study of the Hobbes–Boyle controversy on the nature of the void, Shapin and Schaffer have described how Robert Boyle went about securing a collection of 'matters of fact' (Shapin and Schaffer, 1985). The production of these facts, they point out, demanded the use of three 'technologies': a material, a literary and a social technology.[6] We will single out the first and the second of these technologies as the most relevant to the present discussion, postponing a brief discussion of Wundt's social technology till the final paragraph.

Material technology refers to the machine with which Boyle gathered his facts, the Pneumatick Engine or air-pump. The details of this machine and its operation need not detain us here; suffice it to say that it was an extremely elaborate instrument, demanding endless preparations and adjustments. It was also very costly to build, which may explain why there were so few air-pumps available. This created both a methodological and a social problem. According to Boyle, each member of the community of 'natural philosophers' should have the opportunity to witness the experiments with his own

eyes. In practice, however, experiments were performed for audiences of limited size. Those who were granted access to the semi-public space of the laboratory, mostly members of the Royal Society, were assigned the role of eye-witnesses and the credibility of their testimony depended – as in court – upon its multiplicity and agreement. For this reason Boyle requested that his guests sign a register as 'Witnesses of all the said Proceedings, who, by Subscribing their Names, will prove undoubted Testimony' (Shapin and Schaffer, 1985: 58).

In principle, the number of witnesses could also be increased by encouraging other investigators to conduct their own experiments. The emphasis is on 'in principle', since outside the wealthiest researchers, only a few had the financial or technical resources to build an air-pump. A more realistic way to reach the same goal was the mobilization of what Shapin and Schaffer have called 'virtual witnesses'. This mobilization was to be achieved by employing a *literary* technology. To convey a clear image of what had happened, Boyle presented his narrative of the experiments as graphically and circumstantially as possible. He also offered visual assistance in the form of naturalistic engravings to give each reader the distinct impression of witnessing the experiments in person. One of the engravings shows a dead mouse in the receiver of the air-pump, others depict the experimenters themselves. These realistic representations, Shapin and Schaffer argue, 'served to announce, as it were, that "this was really done" and that "it was done in the way stipulated"; they allayed distrust and facilitated virtual witnessing' (Shapin and Schaffer, 1985: 62). By including illustrations, Boyle ensured that the actual witnesses were joined by virtual witnesses – a community that increased in size each time a reader took up the written report.

The notion of witnessing is equally essential in Latour's analysis of visual material in the dealings of scientists. In an essay on visualization and cognition, Latour introduced the notion of 'immutable mobiles' (Latour, 1986). Immutable mobiles are representations, usually on paper, which may be transported, copied, exchanged and distributed, while at the same time guaranteeing a certain stability and constancy. An explorer who draws a profile of some foreign shore to take back home is creating an immutable mobile. Photography is a potent manufacturer of immutable mobiles: all copies are identical, while the great number allows for distribution and circulation. Photographs offered neurologists the opportunity to circulate their histological preparations in print and gave psychiatrists the means to demonstrate the phenomenology of hysteria outside the confines of the clinic (cf. Luys, 1873; Bourneville and Régnard, 1876–80). Latour singled out technical drawings as a species of immutable mobiles with a significant rhetorical force, especially when they are associated with precision and objectivity. For this reason, Latour suggests, mobilization processes in science have become intimately connected with metrology, a branch of science dealing

with the design of instruments and methods for measurement and the development of standards. All attempts at measurement and standardization *ipso facto* support the production and distribution of immutable mobiles.

In science, Latour argues, immutable mobiles serve to find allies. If it is inconvenient or impossible to show the thing itself – an eclipse of the sun, an island, an instrument – immutable mobiles may represent it. Thanks to immutable mobiles such as drawings and photographs the brittle skull of the Neanderthaler could remain safely in the quiet depot of the Neanderthal Museum and still be engaged in the mobilization of allies in the international community of paleontologists (Reybrouck, 1997). Scientific changes are not a direct consequence of new discoveries, theories, methods, or inventions – rather the reverse: the acceptance of something as a discovery or an invention is the result of a successful mobilization process. Visual representations are often essential to this process.

THE EXPORT OF BRASS, MAHOGANY AND PSYCHOLOGY

Returning to the scientific culture that shaped Wundt – mid-19th-century experimental physiology – we may recognize several elements from the analyses of Shapin and Schaffer, and Latour, although in a different configuration. The public nature of science, initiated by Boyle, has become an obvious, self-evident value. The way this openness is given shape in a literary technology, however, has changed. The authority of experiments no longer depends on something as personal as the testimony of trusted witnesses, much less on the convictions of those who, by reading the report, got the *impression* they had witnessed the experiments. The validation of facts is now organized by publishing the relevant experimental details in one of the many *Annalen* or archival publications available to physiologists. The virtual witnesses in *this* culture are of an altogether different kind: they are fellow researchers who may use the specifications in the report to repeat the experiments. In the literary technology to serve this new type of witnesses, illustrations are still essential. They show experimenters how to conduct the trials, how to handle the instruments, how to manipulate and measure. Illustrations have become visual instructions in a text which should guarantee the replicability of the experiment. This change of function called for a change of style. Illustrations now had to be 'realistic' in a different sense: they should depict the instrument as exactly as possible, in a schematic and unadorned way. No dead mice, no experimenters, no people at all, just the hardware, in suitable scales and proportions. In this new technique for the 'multiplication of the witnessing experience', immutable mobiles were indispensable. They should indicate to researchers in other laboratories how to create a

satisfactory resemblance between their own experiments and the original ones, a resemblance, indeed, of a sufficient degree to secure that the results of the replication were relevant to the reported experiments. Illustrations had become means to facilitate the re-creation of experiments.

Such were the material and literary technologies of physiology in Wundt's formative years – and he managed to introduce and distribute these in psychology. In Latourian parlance, Wundt succeeded in mobilizing allies in the scientific community, psychologists who were prepared to subscribe to his observations, findings, discoveries, inventions, theories, prescriptions and methods. As a token of assent they placed their signatures, not, as in the days of Boyle, as 'Witnesses of all the said Proceedings', but as authors of dissertations, articles and books in which the results of Wundtian experimental research were established as facts. Once underway, this process of distribution could be seen to have a wonderful self-perpetuating quality. But how was one to get it *started*?

As the head of an official psychological laboratory, Wundt was in a position to supervise graduate students and assign research projects. In this way at least two generations of psychologists received a thorough instruction in Wundtian psychology. They learned how to set up and manipulate the instruments, how to subject the results to statistical analysis, how to report the findings. This immersion in Wundtian methods and manners contributed much to the distribution of experimental psychology *à la* Wundt. The Leipzig laboratory attracted students from all over the world. It has been calculated that Wundt supervised 116 doctoral dissertations in psychology, most of these in the first decades of his Leipzig career (Woodward, 1982). Among the first 20 or 30 young doctors were many who became founders of laboratories themselves. Cattell, who finished his Leipzig dissertation in 1886, founded the psychological laboratories of Pennsylvania (1887) and Columbia University (1888). Scripture, who received his Leipzig PhD in 1891, became head of the Yale laboratory. In 1900, 12 of the 43 new laboratories in America had been founded by pupils of Wundt (Garvey, 1929). Many of these laboratories were virtual replicas of the Leipzig lab.

A second way to start the process of distribution was connected to Wundt's passion for the technology of measurement. One of the pivotal ideals in his experimental program was the refinement of the standards for precision measurement. This ideal led Wundt to a relentless pursuit of the smallest fraction of a second to be measured and registered reliably. Psychological metrology demanded considerable efforts, of the most diverse nature: calibrating and checking instruments, standardizing experimental procedures, developing conventions for notation, disciplining experimenters and subjects (Coon, 1993; Benschop and Draaisma, 2000). One of the ways to reduce a potential source of error – human intervention – was the rigorous 'electrification' of the experimental set-up. Typically, even an experiment on 'simple reaction

time' involved at least four instruments (*Fallapparat*, reaction key, Hipp chronoscope and control-hammer, plus such accessory tools as batteries and rheostats), all electrically operated (Figure 2). The production of the stimulus and the registration of the reaction were both fully automated electromechanical processes. The result was a form of experimentation directed at a special type of objectivity, to which Daston and Galison (1992) have given the name 'mechanical objectivity'. The instruments designed by Wundt and his collaborators were links in a metrological chain demanding only a minimum of human intervention.

The development of this material technology dovetailed wonderfully with Wundt's literary technology. Each new instrument was described, explained, shown and patented, first in articles, often in the *Philosophische Studien*. Then the next edition of the *Grundzüge* would include a full description of the new invention, securing its place in the standard equipment of a psychological laboratory. The accompanying illustrations acted as immutable mobiles, facilitating distribution. Hence they had to be exact, clear and minute, each line as fine as possible. All suggestion of artistry was shunned; Wundt's woodcuts were, if one may use so paradoxical an expression, emblems of functionality. As in technical drawings, sometimes a part of the instrument was omitted in order to expose parts that would otherwise lie behind it. Still other parts were drawn in the form of a diagram or to a more convenient scale

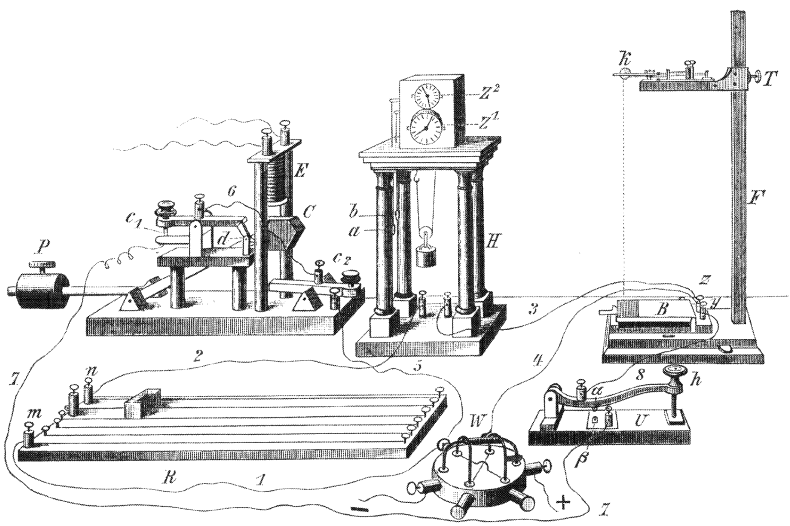

Figure 2 The rigorously electrified experimental set-up.

(Figure 3). Combined with lengthy explanations, such illustrations instructed the reader how to handle the instrument or how to build a replica.

That the illustrations in the *Grundzüge* were actually intended to facilitate replication is confirmed by Wundt's preface to the fourth edition (1893). There he states that psychology has developed its own independent methods and techniques, and that these are illustrated in 'carefully drawn woodcuts'. Hopefully, he writes, 'this expansion will be appreciated by those readers

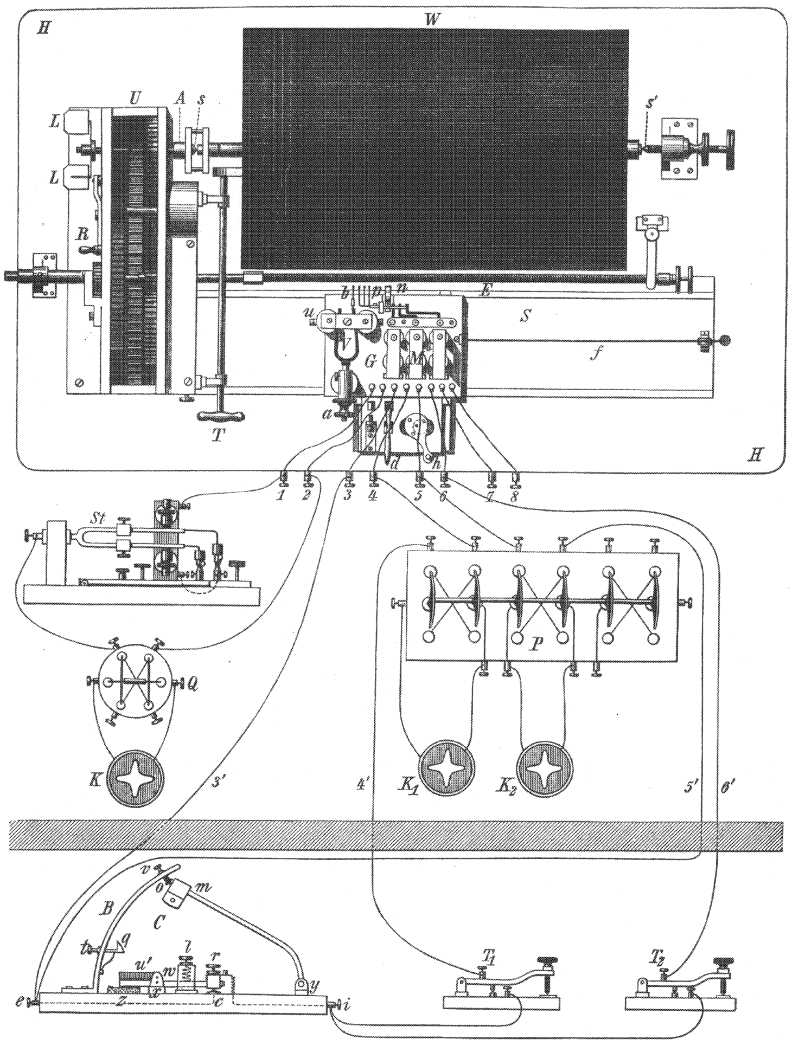

Figure 3 Wundt's woodcuts were functional.

who are conducting psychological research themselves' (Wundt, 1893: viii). The detailed verbal and pictorial instructions articulated the codes and conventions Wundt sought to convey.

ERNST ZIMMERMANN, *PRÄCISIONSMECHANIKER*

The fact that the distribution of Leipzig experimental culture was closely connected with instruments implied a crucial role for a group of professionals often neglected by historians of science: technicians and instrument-makers (cf. Shapin, 1989). In the earlier editions of the *Grundzüge*, Wundt mentions the laboratory's technician, Carl Krille, and his contributions to the Leipzig armamentarium. In 1887, a second instrument-maker set up his workshop in Leipzig: Ernst Zimmermann (Gundlach, 1986). He offered his services both to the physiological and the psychological laboratory, but over the years experimental psychology became his main market. Wundt and Zimmermann worked closely together, to the benefit of both. Often Zimmermann would construct instruments after a design by Wundt; Wundt, in his turn, agreed to test Zimmermann's prototypes in his laboratory. Once the new instrument worked to his satisfaction he included its description in the *Grundzüge*, inviting the scientific community to replicate the experiments with the instruments supplied by Zimmermann. Within a decade, Zimmermann had taken the majority of Wundt's instruments into serial production. They were shown and described in the now famous *Preisliste* or catalogs. Page after page of each catalog exhibits apparatus '*nach Wundt*', with code-like references to the relevant literature. The very first instrument in the 1903 catalog, for instance, is a '*Demonstrations-Opthalmotrop nach Wundt* (Wdt. II. 534)', meaning that information on this instrument was to be found in Volume II of the *Grundzüge* (Zimmermann, 1903). In fact, such references as these were so numerous that there was little point in consulting the catalog without having the appropriate edition of the *Grundzüge* at hand.

Around the turn of the century, the distribution of Leipzig material technology had assumed many of the characteristics of commercial export. Laboratories all over the world ordered their instruments from Zimmermann or asked local instrument-makers to copy them from the woodcuts in the catalog or the *Grundzüge*. From the fifth edition on, the mutuality in the relationship between Wundt and Zimmermann received its final (and pictorial) expression when Wundt included illustrations supplied by Zimmermann, with the firm's name engraved sharply in the base of the instrument (Figure 4).

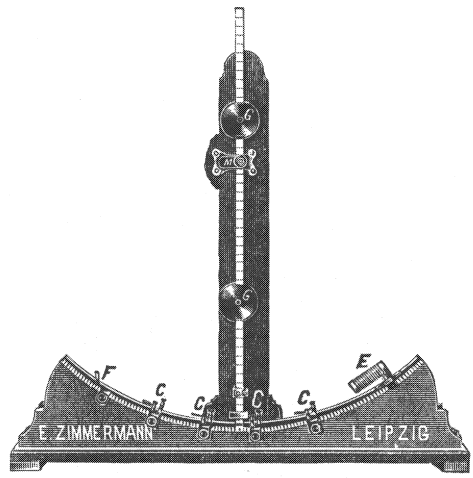

Figure 4 Instrument supplied by Ernst Zimmermann.

WUNDT'S CONTROL-HAMMER

Neither mobilization nor distribution, however, should be understood as a fast and frictionless process. The construction of an independent technology for psychology demanded time, money and ingenuity. As a rule, several years and in some cases even decades elapsed between the initial stages of sketches and prototypes, and the final adoption of the instrument in regular experimental practice. The history of one such instrument, an apparatus known as 'Wundt's control-hammer', offers a concise illustration of these efforts; at the same time it presents a nice pictorial recapitulation of what was involved in manufacturing immutable mobiles.

Around the middle of the 19th century the German physiologist Pflüger constructed a *Fallhammer* (Figure 5). This device had to regulate as accurately as possible the opening and closing of an electric circuit. It was used in experiments in which stimuli had to be presented during sharply defined intervals. In Pflüger's apparatus the start of the interval was marked by switching off the current. This caused the electromagnet at the top of the instrument to drop the head of the hammer. The head then hit a handle which closed the circuit. This terminated the interval. The sequence of events took just a fraction of a second. The experimenter could lengthen the interval by adjusting the height of the magnet.

In 1886, one of Wundt's students, Gustav Oscar Berger, reported on a series of experiments on the calibration of the Hipp chronoscope (Berger,

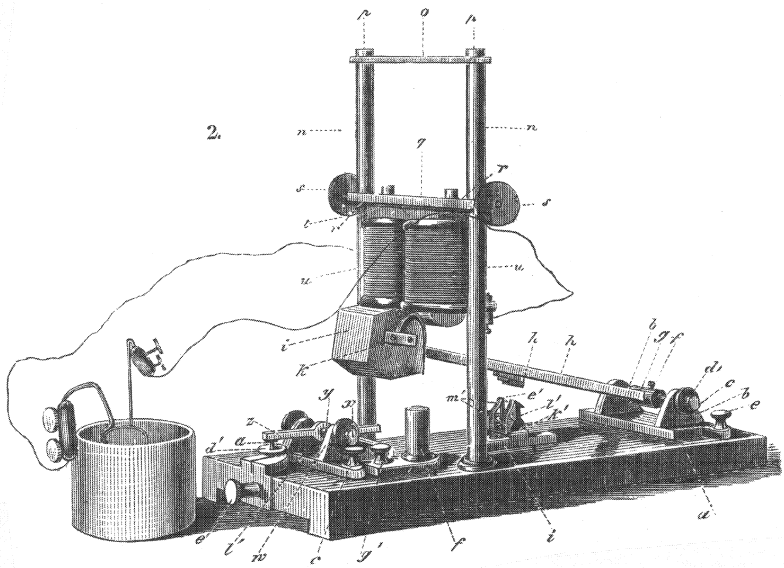

Figure 5 Fallhammer by Pflüger.

1886). To check the accuracy of the chronoscope, Berger used (as he put it) 'a fallhammer which happened to be at hand' (Berger, 1886: 45). By taking the interval of the fall as the standard to be compared with the time indicated by the chronoscope, Berger hoped to calibrate the latter instrument. Profiting from Berger's work, Wundt published a detailed description of the fallhammer in the third edition of the *Grundzüge* (1887[1873]). This description makes it clear that Pflüger's instrument had been adapted. It now had a counter-weight attached to the shaft of the hammer to slow down the fall. But the main transformation was its new *function*: instead of determining the duration of a stimulus, the fallhammer now checked a time measurement device. This turned the fallhammer into an altogether different instrument.[7] Wundt did not refer to Pflüger (or to Berger, for that matter) and called 'his' apparatus a *Kontrollhammer*. In a note he announced that the control-hammer, like other pieces of the Leipzig equipment, could be supplied by Herr C. Krille, and in a 'superb construction' at that (Wundt, 1887[1873]: 276). The fourth edition of the *Grundzüge* (1893[1873]) showed the first illustration of the control-hammer (Figure 6). A little later Zimmermann began producing control-hammers. Zimmermann's 1903 catalog has a beautiful woodcut of a control-hammer, with an indication of the proper source for detailed information concerning its function, purpose and handling: of course, this source was the *Grundzüge* (Figure 7). By then the

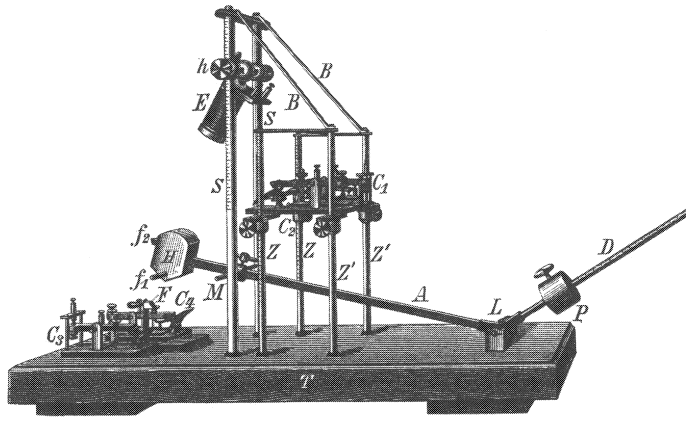

Figure 6 Wundt's control-hammer, 1893.

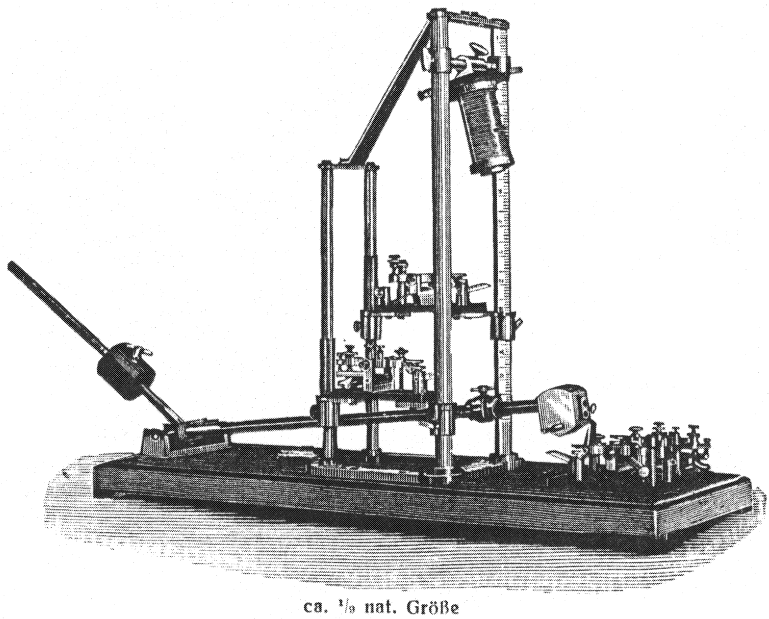

Figure 7 Control-hammer featured in Zimmermann's catalog, 1903.

control-hammer had become a standard tool in psychology's experimental arsenal. In his four-volume manual on laboratory practice Titchener mentions the control-hammer as a convenient apparatus to check chronometrical instruments (Titchener, 1901–5: Vol. 2, 343). For a full description he referred to the *Grundzüge*; his own manual presented a simplified drawing of the hammer (Figure 8).

This quartet of hammers presents a graphic chronicle of some of the agents and factors in the distribution of Wundtian psychology. For Berger, Pflüger's fallhammer may have 'happened to be at hand', it was no coincidence either to find a physiological instrument in a psychology lab, nor to achieve its subsequent transformation into an instrument for psychological experimentation. The changes in the apparatus, both physical and functional, marked its entrance into a new network of mutual references. The descriptions and illustrations of experiments involving control-hammers in the *Grundzüge* instructed psychologists in other labs in how to replicate the Leipzig experiments or to devise variations. The commercial availability of control-hammers helped the spread of this particular experimental practice. Thus immutable mobiles were at once condition and consequence. Condition: the design, construction and supply of instruments facilitated the distribution of

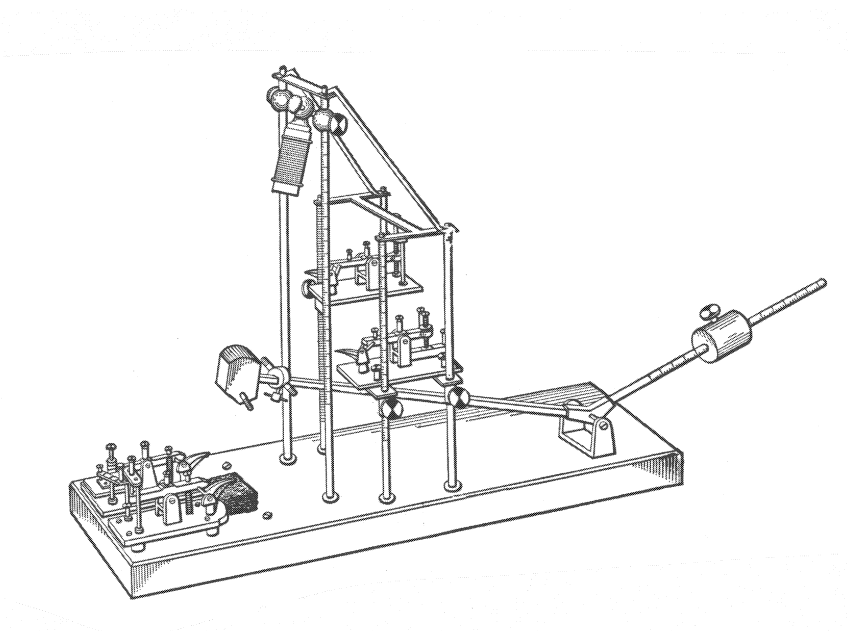

Figure 8 Titchener's drawing of a control-hammer, 1901–5.

methods of measurement; consequence: once gaining momentum, distribution created an increase in demand. With every apparatus prepared for export in the workshops of Krille and Zimmermann a part of the Leipzig experimental culture was made ready to depart for foreign countries as well.

THE RISE AND DECLINE OF WUNDTIAN PSYCHOLOGY

Illustrations were a quintessential element in Wundt's literary and material technologies. Their vital position in a configuration of textbooks, instructions, technical descriptions and catalogs made them effective weapons in what Latour has called a 'proof race'. A proof race shares its dynamics with an arms race: the means to produce evidence provokes the adversaries to deploy more forceful means (Latour, 1990: 35). The party which succeeds in supporting its position with convincing immutable mobiles compels the other party to exceed these efforts. Thus the costs of a rival theory, method or technique may make it unprofitable to compete. If an experimental psychologist should want to develop an alternative to – say – Wundt's apparatus for checking chronoscopes, he was faced with a control-hammer which already had a secure position in experimental practice, effectively protected by a network of references in textbooks and laboratory manuals. In many cases the prospects for producing a rival technology must have looked grim enough to prevent the project altogether. Part of Wundt's success in producing and distributing a material technology seems to have been due to the advantage of a 'first strike'. At an early stage Wundt had created favourable conditions for the design, use and marketing of experimental machinery. He hired skillful technicians, supported the research of collaborators with an interest in metrology, and finally teamed up with an instrument-maker who proved to have a keen eye for commercial opportunities.

Much the same advantage applied to Wundt's literary technology. The first edition of the *Grundzüge* appeared when there was hardly such a thing as experimental psychology. New editions appeared at regular intervals and were carefully kept up-to-date. Each edition featured illustrations of the highest quality. Even if we refrain from speculating on the intentions behind Wundt's dealings, there is no doubt about their consequences – and these were most discouraging for potential competitors. In the full 38 years between its first and last edition, the *Grundzüge* remained without serious rivals. It is telling that the instruments in the Zimmermann catalogs *not* '*nach Wundt*', are mostly in psychological domains which were not very much '*nach Wundt*' either. Memory research is a case in point: the score of *Mnemometers* and *Gedächtnis-Apparate* featured such names as Hempel, Ranschburg, Wirth, Ach, Müller, or Pilzecker.

In a more general discussion of the dissemination of Wundtian psychology we think it is wise to invoke the third type of 'technology' indicated by Shapin and Schaffer, a 'social technology', dealing with – in the case of Wundt – the relations between researchers, students, experimental subjects and society at large. That Wundt did indeed deploy a social technology may very well be one of the best-documented assertions in the historiography of psychology. The work of Danziger, Coon, Kusch and recently Benschop and Draaisma has made it clear that Wundt set up his laboratory as an intensely hierarchical institution. The interaction between subjects and experimenters was regulated by a strict system of social constraints, dictating the kind of behaviour appropriate for the various roles in experimental research (Danziger, 1990: 49). The new psychology demanded discipline and rigorous training, resulting in a standardization of the subject which paralleled contemporary technoscientific ideals of replicability and quantification (Coon, 1993: 766–7). Wundt's 'two-tier hierarchy of the mind' – with an experimentally accessible, 'lower' substratum of processes, such as sensation and perception, and a 'higher' level of processes, such as thinking or language – was reflected in the hierarchical division of labour in Wundt's institute (Kusch, 1995: 427–8). Taking the Cattell–Berger experiments on mental chronometry as their case study, Benschop and Draaisma have pointed out that Leipzig experimenters made strenuous efforts to bring themselves and their subjects under a regime of control and calibration, even outside the immediate experimental context (Benschop and Draaisma, 2000: 15–20). We may safely assume that laboratory life, under Wundt, was a highly disciplined type of social interaction.

Part of the success of Wundt's social technology was due to the fact that he managed to enlist recruits and that some of them turned into partisans. Several of his foreign students, upon returning to their home countries, championed the Wundtian cause. Scripture, for instance, established a Leipzig-like regime in the Yale laboratory, summoning his colleagues to observe the Leipzig standards of accuracy (Scripture, 1893). Scripture also copied Wundt's treatment of illustrations: his manual for experimental psychology contained 129 illustrations, 49 of them illustrations of apparatus (Scripture, 1897). His name on the title page is followed by 'Ph.D. (Leipzig)'. Another student of Wundt's, Titchener, became a professor of psychology at Cornell, where he presented, to all accounts, a perfect imitation of Wundt. His *Experimental Psychology* featured no fewer than 251 illustrations, including 168 that were of instruments (Titchener, 1901–5). Titchener even replicated Wundt's connection to Zimmermann, casting the Chicago instrument-maker Stoelting in Zimmermann's role. Closer to home, Wundt's handling of illustrations began to be copied as well. Textbooks by Höfler (1897) and Ebbinghaus (1902) each sported numerous illustrations. Even the *Zeitschrift für die Psychologie und Physiologie der Sinnesorgane*, founded in 1890 by

Ebbinghaus with the veiled intention to counterbalance Leipzig psychology, adopted the same policy for illustrations as the *Philosophische Studien*.

Wundt's material, literary and social technologies, firmly interlocked, were forceful weapons. Yet even this ponderous armamentarium did not result in an absolute hegemony for a Leipzig-like style of psychology. Some of the counterforces were more or less provided by the limits of each of these technologies: one may export Leipzig instruments, distribute illustrations and explanations, provide rigorous training, even certify some of the former students as 'Ph.D. (Leipzig)', but all of this does not guarantee that research elsewhere will really be a copy of the Leipzig original. Benschop and Draaisma have argued that even for psychologists aspiring to be as Wundtian as they can – certainly Scripture would be a case in point – it was virtually impossible to construct true replicas of experiments (Benschop and Draaisma, 2000: 24–5). There were simply too many circumstances and conditions left unspecified. In the practice of research, each laboratory developed its own conventions.

This relativistic note should help us understand that Wundt's illustrations – like the three technologies they were part of – are best seen as facilitating factors in the distribution of a Leipzig-like psychology, certainly not as sufficient conditions. Even at the height of his influence, Wundt was only one among several directors of psychological laboratories. Kusch (1995) has argued convincingly that Külpe (Würzburg) and Müller (Göttingen) ran their laboratories on radically different lines. Well before the decline of Wundtian psychology it was clear that there were a number of ways of conducting investigations and each of these variants had its own pattern of practices and conventions. This also had implications for the different uses and functions of illustrations.

After the turn of the century, Wundt's grand experimental programs visibly began to lose momentum. There were reasons and causes for this, of course, but to discuss these would involve us in a new story. It would be a story of decline, though, rather than of a sudden fall. With the possible exception of the imageless thought controversy (Kusch, 1995: 420), there were no specific battles lost, no decisive defeats suffered. The closing decade of classic Leipzig psychology is best described as the waning of an era. For one thing, Wundt's own interests had shifted to non-experimental areas of psychology; he had little personal involvement in the preparation of the sixth edition of the *Grundzüge*. The contents of the *Grundzüge* also began to look outdated. Its heavy emphasis on sensory psychology was clearly out of balance with contemporary psychology. The programs which had served for decades as paragons of precision and cutting-edge science – psychophysics, mental chronometry – were now seen as out of touch with modern developments. The *Grundzüge* had become a panorama of a landscape which no longer existed. Engelmann Verlag never published a seventh edition. Even the

illustrations began to look old-fashioned. Woodcuts, once an advanced technique, gave the book a distinctly 19th-century look. The newest textbooks featured photographs or even stills from films. By the time the last edition of the illustrious *Grundzüge der physiologischen Psychologie* appeared, in 1911, the tide for the 'new psychology' had run out. Its 399 woodcuts presented a graphic monument for a bygone era in experimental psychology.

NOTES

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1 Quotation taken from Edward B. Titchener's translation of the *Grundzüge*: Wundt, *Principles of Physiological Psychology* (London: Swan Sonnenschein, 1904).
2 Cf. Wundt's reservations concerning Gabriele Buccola's findings in reaction time experiments, formulated in a note in the third edition of the *Grundzüge*, Vol. II, p. 274.
3 Full titles in the Bibliography.
4 Full titles in the Bibliography.
5 Even if the actual procedure for printing illustrations changed over the course of time, the illustrations were still called 'woodcuts'. We will follow this convention.
6 In an article on the dissemination of psychoanalysis, Frank Sulloway (1991) has demonstrated the productivity of this scheme for the analysis of a topic from the history of psychology.
7 Taking the tachistoscope as an example, Benschop (1998) has argued convincingly that a change of function creates a new instrument, even if its name stays the same.

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