FECHNER'S INNER PSYCHOPHYSICS VIEWED FROM BOTH A HERBARTIAN AND A FECHNERIAN PERSPECTIVE

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Abstract

Following brief summaries of the overlapping lives of Herbart, E. H. Weber, Fechner, and Helmholtz, it is shown that Herbart and Fechner agreed about the nature of mental science in three particular ways. First, both adopted ideas about force and energy from the physical sciences; Herbart's interplay of Vorstellungen assumed that equilibrium states were attained when opposing forces balanced out, while Fechner's notion of brain oscillations was based on the idea that to every action there corresponded a reaction. Second, both assumed that Vorstellungen could be assigned magnitudes, but Fechner was far more concerned than was Herbart with the problem of how to measure those magnitudes. Third, the threshold of consciousness was defined in mathematical terms by Herbart, whereas the absolute threshold associated with a sensation magnitude was speculated about in physiological terms by Fechner.

In order to show both how Herbart and Fechner tried to base their respective theories of mind on the physics available to them, it will be useful first to outline their respective biographies, along with those of E. H. Weber and of H. von Helmholtz. This will enable us to gain an overview of how the lives of these pioneer psychologists overlapped, and, more important, to relate their life-stories to one of the most important innovations in the history of physics, namely, the enunciation of the principle of the conservation of energy.

Johann Friedrich Herbart (1776-1841) spent his childhood in Oldenburg, and showed precocity in music and in philosophy. He studied with Fichte at Jena, where he expressed dissatisfaction with Fichte's view that the 'self' could be considered to be a primitive unit in the construction of a scientific psychology; for Herbart, the self was a product of the laws determining the formation and interactions of *Vorstellungen*. He became a successful educator, both as a private tutor in Switzerland, and as a faculty member at the University of Göttingen. In 1809, at the age of 33, he was awarded the Chair of Philosophy at Königsberg that had once been occupied by Kant. In 1811 and 1812, he wrote several articles that presented the foundations of his mathematical psychology; it was presented as a full system in Part 1 of his as yet untranslated *Psychologie als Wissenschaft* [Psychology as science] (Herbart, 1824/1890). In 1832, disappointed at not having been awarded the Chair of Philosophy at Berlin (following Hegel' s death), Herbart returned to Göttingen, where he resumed the lectures on educational psychology (pedagogy) whose reputation had not diminished during his absence (Flügel, 1905/2001).

Ernst Heinrich Weber (1795-1878) had two famous brothers, Wilhelm Weber, the physicist, and Eduard Weber, the physiologist. In 1820, Ernst Heinrich obtained a teaching position at Leipzig, where, among his students in physiology and anatomy, was to be found Fechner. Wilhelm and Ernst Heinrich made their joint reputation by the first demonstration of inhibition in the nervous system; then Ernst Heinrich made an individual reputation for himself by becoming the undisputed expert on the sense of touch and related cutaneous and kinesthetic sensations. In the course of comparing the sensitivity of various senses, he discovered Weber's Law. He retired from the Chair of Physiology in 1866 and from the Chair of Anatomy in 1871. The most useful life of Weber in English is that of Kruta (1976), while Weber's two books on the touch sense have been translated by Ross and Murray (Weber, 1834, 1846/1996).

Gustav Theodor Fechner (1801-1887) studied medicine at Leipzig before teaching physics there from 1824 to 1839. He had to resign due to illness but recovered in 1843. His views on his invented science, psychophysics, were formulated in the two volumes of his *Elemente der Psychophysik* (Fechner, 1860/1964), of which only the first is available in English, as *Elements of psychophysics* (Fechner, 1860/1966). He continued to write on psychophysics until the end of his life, and also made important contributions to experimental esthetics and to statistics. Heidelberger (1993a) has provided an account of Fechner's career as a scientist.

Hermann von Helmholtz (1821-1894) studied medicine in Berlin under Johannes Müller and formed part of the so-called "1847 school" of physiology that also included Karl Ludwig, an expert on circulation, and Ernst Brücke, who later taught Freud. At the age of 26, Helmholtz produced the article on the principle of the conservation of energy that made him famous. He moved to Königsberg in 1849, to Bonn in 1855, to Heidelberg in 1857, and finally to Berlin in 1870. The years at Bonn and Heidelberg saw the publication of the three volumes of his *Handbook of Physiological Optics* (1856-1867/1924-5) and of his *Sensations of Tone* (1863/1954). He spent his final years studying theoretical physics, notably thermodynamics, and one of his students, H. R. Hertz (1857-1894), was a pioneer in the study of radio waves.

Herbart and Fechner were in basic agreement that the study of mental science had to be modeled on physical science. In Herbart's time, the Newtonian principles of mechanics, as enunciated in his *Principia* (Newton, 1687/1999), had been applied to cosmological events with great success and Herbart explicitly stated his ambition to adapt Newton's theory to the explanation of the risings and fallings of *Vorstellungen* into consciousness (Boudewijnse, Murray, & Bandomir, 1999). The concept of the conservation of mechanical energy would have been familiar to him, and so would the principle of the conservation of mass; the latter had been discovered by A.L. Lavoisier (1743-1794) in 1774, and stated most explicitly in 1789.

During Herbart's lifetime, heat generation by the mechanical motions of engines had been studied by Sadi Carnot (1796-1832). After Herbart's death in 1841, James P. Joule (1818-1889), in 1847, demonstrated that an electric current generated equal amounts of heat and work. Also in 1847, Helmholtz, following his studies of the heat generated by contractions of muscles, and linking his work with that of Joule and other physicists as well as that of K.F.W. Ludwig (1816-1895) and other physiologists, formulated the general principle of the conservation of energy. Later, Helmholtz acknowledged the priority of J.R. Mayer (1814-1878), who had announced the law, unheralded, in 1842.

Herbart and Fechner, therefore, agreed insofar as they thought that mental activity (and its underlying brain activity) took place with constraints determined by the total forces (Herbart) or energy (Fechner) involved. They differed as to what should be the first step towards a psychological science, with Herbart favouring a purely mathematical approach based on the evidence of mental experience, and Fechner favouring a more physiological approach. They also agreed that, when psychological entities (*Vorstellungen*) were the subject of scientific discourse, *Vorstellungen* could be considered to vary in magnitude. And, finally, they agreed that there were constraints such that the word 'threshold' was an appropriate descriptor of the conditions determining a boundary state. We now elaborate on these three topics of agreement.

1. 'Energy' in mental science

In Newton's physics, changes of location are described in terms of movements that are the result of forces (usually, mechanical or gravitational) acting on material bodies in such a way as to cause the movements. When a mechanical force is applied to a body A by a body B, the force on A is described as being given by the mass of B multiplied by B's acceleration, which in turn is most easily described as being a rate of change of the rate of change of location with time. Newton and Leibniz developed the differential calculus that describes such rates of change.

When a number of forces act in concert on a few bodies, all the bodies are set in motion but chaos is prevented by the fact that some forces balance the effect of others and a state of equilibrium is arrived at. The solar system is an example of a number of bodies (planets) held in equilibrium with respect to the sun because its gravitational force has balanced the mechanical forces that had initially determined the paths and velocities of the planets.

Herbart adopted Newton's terminology unabashedly. In one's mind at any moment, there coexist a small number of *Vorstellungen* that can be co-experienced mentally. As soon as a new *Vorstellung* enters the mind, it sets up a disruption that is resolved when all the *Vorstellungen*, including the new one, arrive at an equilibrium state which, nearly always, is fleeting in duration because more new *Vorstellungen* enter the system to disrupt it once again. Each *Vorstellung* is ascribed a magnitude and each pair of *Vorstellungen* is ascribed a number between zero and one inclusive that indicates the degree of opposition between the two *Vorstellungen*. The energy released when two or more *Vorstellungen* clash was stipulated to constitute an 'inhibition sum' that was then distributed among the involved *Vorstellungen* proportionally (an 'inhibition ratio'). The inhibition sum weighed down on all the involved *Vorstellungen* like a burden [*Last* in German]. One or two *Vorstellungen* might be driven down in magnitude by the burden to such a low level that, even though the struggle continued, and the contending forces could be described as sustaining a state of 'tension' or 'striving', the *Vorstellungen* themselves could no longer be consciously experienced

But they were not erased. They could once again be consciously experienced. One way in which this could happen (the 'unmediated' way) was for the burden to lift so rapidly that the proportion that they received of that burden was so light that they resurfaced into consciousness. Another way (the 'mediated' way) was for a *Vorstellung* (currently not consciously being experienced) to have been fused in the past with another *Vorstellung* (currently in consciousness); the former could then be pulled up into consciousness by the latter.

Herbart used the word 'statics' to refer to the processes involved in arriving at an equilibrium state and he used the word 'mechanics' to refer to the processes whereby *Vorstellungen* rose above, or fell down to, a magnitude level such that they could no longer be consciously experienced. This level would be just above or at zero and Herbart called it a threshold level [*Schwelle*]; he actually defined more than one kind of threshold. The risings and fallings were like movements [*Bewegungen*] in Newtonian terminology. But Herbart's system differed from that of Newton insofar as acceleration had no analogue in Herbartian terminology, because Herbart's *Vorstellungen* lacked inertia (Drobisch,1850/1972, pp. 136-7)

Fechner (1860/1964, Vol. 2, Chapter 42) seized on one particular law of Newton, the law that to every action, there is an equal and opposite reaction. Fechner maintained that any mental exertion necessarily involved an expenditure of energy that would be compensated for by a mental relaxation. But, because mental states depended on brain states, these alternations of exertion and relaxation could be thought of as caused by physical oscillations taking place in brain matter.

2. Measuring the magnitude of *Vorstellungen*

Heidelberger (1993a) has traced in detail the fate of Fechner's suggestion that mental magnitudes could not only be *quantified*, as Herbart had suggested, but also be *measured* (by the various psychophysical methods). There was great resistance in Europe to this notion, but one result of the controversy was that Ernst Mach (1838-1916) brought considerable clarity into that branch of mathematics now known as measurement theory. But the problems of measurement had been recognized by scientists well before Fechner's time; one of the most interesting early treatments of the topic was that of Whewell (1847/1967, vol. 1, pp. 319-322), who had distinguished between extended magnitudes (such as spatial distance or time elapsed) and intensive magnitudes (such as degrees of warmth or shades of redness). Even Kant had expressed scepticism that mental magnitudes could be measured (Leary, 1980).

Herbart evaded the question of how *Vorstellungen* could be measured; in fact, in his article on the dark side of pedagogy, Herbart (1812/1888) had confessed that he could not see how a mathematical theory that successfully predicted the rise and fall of *Vorstellungen* in and out of consciousness over the course of a few seconds could ever be applied to the long-range forecasting of a student's future performance as a scholar. He himself did no experiments because he suspected that there were no psychological laws (other than those of his statics and mechanics) that would always be valid (Boudewijnse, Murray, & Bandomir, 2001).

On the other hand, Fechner (1860/1964, Vol. 2, Chapter 36) sharply distinguished between the quantification problem and the measurement problem. He specified that there was a distinction between inner psychophysics and outer psychophysics. The problem of measuring sensation magnitude was a matter for outer psychophysics, where the experimenter could control the stimulus intensity, and the participant would provide an overt response. The obtained measurements could be thought of as contaminated by 'constant errors'; in judgments of the heaviness of lifted weights, for example, there was a 'time error' (the undesired effects of the time elapsing between the presentation of the standard stimulus and the comparison stimulus) and a 'space error' (artifacts arising from left-handed versus right-handed lifting).

His quantification of sensation magnitude applied to inner psychophysics, where a neurelectric response gave rise to a consciously experienced sensation. He believed that the logarithmic transformation whereby stimulus magnitude was transmuted to sensation magnitude took place at the brain interface between the neural and the mental. Heidelberger (1993b) has shown how what we call 'Fechner's Law' was not thought of as a scientific law by Fechner himself; it is a 'measurement formula' (*Massformel*) that talks about how one magnitude (neurelectric) can be mapped onto another magnitude (sensation).

Both Herbart and Fechner clearly understood that almost all sensory and mental experiences involve two or more *Vorstellungen*. Herbart stressed that, when one *Vorstellung* opposed another, the other resisted the opposition; no *Vorstellung* became zero when only one opposed it. The total energy involved in the struggle was determined by the magnitude of the smaller *Vorstellung*, much as a smaller boy has to exert far more energy than a bigger boy in a fight between the two. So, for Herbart, the possibility that a single *Vorstellung* could even exist was a fiction, although a fiction frequently resorted to for teaching purposes only.

For Fechner, the exposition of his measurement formula demanded that the magnitude of the sensation being studied be measured with relation to a particular starting point, the so-called 'absolute threshold.' This was mathematically necessary because, if a stimulus has a strength of 0.5, the logarithm of 0.5 is a negative number; Fechner struggled all his life against critics who thought that his theory implied the existence of 'negative sensations.' But if a stimulus has a strength greater than 1, the problem is avoided; and since a perceptible stimulus intensity is necessarily greater than its corresponding absolute threshold intensity, so-called negative sensations cannot arise. The connected story of how psychologists came to recognize, over the course of the late nineteenth century, that a reported 'sensation magnitude' might better be termed a 'sense distance' has been told by Nicolas, Murray, and Farahmand (1997).

3. The concept of 'threshold' in Herbart and Fechner

It was noted above that, in Herbart's theory, the inhibition sum engendered by three *Vorstellungen* can be so strong that the weakest of the three can have its magnitude reduced to zero or just above. When this happens, that *Vorstellung* can be said to have reached what is Herbart called a statical 'threshold of consciousness'. He distinguished this from a lower-valued 'mechanical threshold', both thresholds having positive values (Drobisch, 1850/1972, pp.174-5).

Herbart also described the exact relationship that the weakest *Vorstellung* would have to bear to the other two *Vorstellungen* if the weakest were indeed to be driven as low as the statical threshold. He called this the 'threshold equation' and separate threshold equations have to be provided for separate situations. For example, the equation for three *Vorstellungen* is different from that for four *Vorstellungen* or for situations where *Vorstellungen* are fused.

The point is that, for Herbart, a threshold is essentially a value on a mathematical continuum that may be labeled '*Vorstellung* magnitude'. Its value is close to or at zero (but is not negative); whether or not an individual *Vorstellung* will ever fall as far as that value depends on the *Vorstellungen* and fusions of *Vorstellungen* currently co-existing in consciousness. Hence, for Herbart, a threshold is defined in terms of mathematics only.

According to Fechner (1860/1964, Vol. 1, p. 238), the word 'threshold' was adopted from Herbart, but Fechner used the word mainly for referring to sensation magnitudes and, because he needed a unit value that would ensure that any scale of sensation magnitude did not incorporate negative values, he distinguished between a basic unit (the 'absolute threshold') and a numerical value on the scale that expressed how many just noticeable differences comprised that value. Fechner's attitudes to Herbart's research have been summarized by Wolters (1988) and by Boudewijnse, Murray, and Bandomir (2001). But Herbart (1824/1890, p.294) himself admitted that, in order to explain why there should be limits on how much one could process in one act of attention, recourse to physiological explanations might be necessitated and added to the mentalistic explanations that were central to his theory of *Vorstellungen*.

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