FECHNER'S (WIDER) CONCEPTION OF PSYCHOPHYSICS – THEN AND NOW

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Abstract

Three dimensions of Fechner's logarithmic formula are discussed: (1) its methodological character if taken as a measurement formula or as a law of inner psychophysics; (2) the different ways in which the logarithmic law can be interpreted in inner psychophysics; (3) the relation of the logarithmic formula to causality, that is, to the exact nature of the mind-body relation in terms of its causal (or non-causal) meaning. The concluding section argues that Fechner's understanding of his own law merits more sympathy today than 40 years ago because of theoretical and experimental developments in cognitive neuroscience.

Fechner's law stands at the center of Fechner's psychophysics. It is derived from Weber's law, under the assumption that barely noticeable differences in sensation correspond to equal increments in sensation magnitude – regardless of where on the scale of physical intensity they fall. As a result, sensation is conceived as a logarithmic function of external physical stimulus magnitude. If "Weber's law remains the oldest, broadest, and most useful empirical generalization in the behavioral sciences," as D. Algom has recently stated, Fechner's law is the "first explicit, quantitative statement relating sensations to stimuli." (2003, 802)

In the following, I would like to investigate three aspects or dimensions of Fechner's law which are, in my opinion, either neglected or gravely misunderstood in the literature. Explaining them anew from a philosophy of science perspective will, I hope, make Fechner's work appear in a different and more adequate light than usual. Fechner had a clear vision of his science; he is *not* an "inadvertent founder of psychophysics." (E. G. Boring 1961)

The first dimension I would like to deal with concerns the different *methodological status* the logarithmic formula has in inner and in outer psychophysics. (Heidelberger 1993; 2004, ch. 6) In outer psychophysics, it is a statement describing the human perceptual system as a measuring instrument. In inner psychophysics, it outlines a lawful relation between "psychophysical activity" and sensation. The second aspect of Fechner's law treated here relates to the *special interpretation* given by Fechner to his law – namely, the so-called "psychophysical one," which is to be distinguished from the "physiological" and the "psychological" respectively. The third aspect of Fechner's law is its *causal significance*, that is, the way it fits into the causal order of events in the world. Every law of nature is connected to some causal story or other, even if it expresses no causal relation itself. Since the place of causality in the psychophysical relation constitutes

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the essence of the philosophical mind-body problem, to ask for the causal significance of the logarithmic formula is to ask for its philosophical significance. (Heidelberger 2004, ch. 5)

In his *Elemente*, Fechner (1801-1887) defines psychophysics as an "exact doctrine on the functional correspondence or interdependence of body and soul." "Functional correspondence" is there defined as "constant or lawful relation between both [the material and the mental] such that we can infer from the existence and the changes of one the existence and change of the other." (1860, 1:8) Outer psychophysics deals with the relation of external stimuli to psychological phenomena, whereas inner psychophysics is concerned with the relation of "psychophysical activity" or "excitation" – i.e., the nervous activity of the brain parts immediately connected with the mind – to subjective phenomena. The results of outer psychophysics are of an "experimental" nature and meet with many restrictions, complications and exceptions. The results of inner psychophysics are however, as Fechner claims, of a "fundamental" nature, although they are much more "hypothetical" than those of outer psychophysics. Nervous processes in the brain are not directly accessible; thus, their relation to psychophysical excitation can only be inferred from outer psychophysics and the results of anatomy, physiology and pathology. (Fechner 1860, 1:11; 2:378f. & 381; 1877, 13) Whereas outer psychophysics can be experimentally established, inner psychophysics is the result of an inference to the best explanation.

1. The methodological status of Fechner's logarithmic formula

The logarithmic formula appears in both outer and inner psychophysics. The different methodological status of the two fields is reflected in that of the formula. In Fechner's own words, the difference can be expressed as a difference between a "measurement formula/ law" and a "fundamental law." By definition, a natural law expresses an empirical universal regularity in nature, whereas a measurement formula signifies a relation between variables as embodied in a measuring instrument.

Allow me to refer to time measurement as an example. Time is measured by distance as realized in suitable processes – regular repetitive motions such as the movement of the sun, the movement of the hands of a clock, the oscillation of a pendulum or of a crystal, etc. Normally, we set up a time measurement device in such a way that equal units of distance (traveled by the sun, the hands of the clock, etc.) correspond to equal units of time Δt. If we know how much distance the hands of a clock have covered in a given period, we can infer what time it is; from $n \cdot \Delta d$, we infer t. The equality holds that $\Delta t = K \cdot \Delta d$, where K depends on the choice of units. If $K = 1$, we can say that $t = n \cdot \Delta d$. This is the measurement formula as realized in a normal clock with hands. The amount of time elapsed is equal to the number of units of distance traveled by the hands (with n suitably different for the big and the small hand). This is so obvious that we take it completely for granted.

Now, what status does the measurement formula have in this example? It is the result of a *conventional choice*. We cannot say that "$t = n \cdot \Delta d$" is true or false, but at best that "$t = n \cdot \Delta d$" is a more or less useful choice for certain purposes. This means however that the measurement formula cannot be a statement of a natural law. It is true that a statement like "this time measuring device realizes the measurement formula $t = K \cdot \Delta d$" is an *empirical description* of a clock, but it is not a law.

Now we can exploit this example to explicate the measurement of sensation in Fechner. In order for psychophysics to become an exact science, we have to *measure* sensations. Since measurement presupposes a measuring instrument we have to construct or find one. As in the measurement of time with a clock, where distance serves as representative, we have to construct/ find a suitable measuring instrument where the sensation S covaries with a directly observable physical attribute R, such that some measurement formula is reliably realized. We soon learn however that, unlike when we measure magnitudes in physics, we do not have the technological means to construct a device which allows us to infer the magnitude of S from its representative R. It turns out that the only existing device providing a natural process that could be used as a measuring instrument is the living and sensing human body itself. The physical attribute of which we know that it varies with S is the physical intensity of the stimulus that impinges on the human body.

It follows that founding a meaningful psychophysics requires investigation of the naturally implemented measurement formula of the human body. This is exactly the task of outer psychophysics. It is obvious from Weber's law that the measurement formula involved cannot be as simple as in the case of normal time measurement. As we all know, Fechner arrives at his logarithmic solution $S = k \cdot \log R/ R_{0,}$ where R_0 is the absolute threshold. This means that for a given sense modality we have to determine R_0, and also the stimulus increment necessary to produce a just noticeable difference when added to the starting stimulus level R.

All this concerns outer psychophysics. As we stated earlier, however, Fechner claims the validity of the logarithmic formula also, indeed first and foremost, for inner psychophysics – this time not as a measurement formula, but as a fundamental empirical law of nature. This law expresses the relationship of psychophysical activity and the subjective dimension. As we have remarked already, outer psychophysics is for Fechner merely preparation for inner psychophysics.

2. The interpretation of the logarithmic formula

The foregoing discussion showed that the logarithmic function expresses for Fechner above all the lawful relationship of sensation and psychophysical activity of the brain. There is, however, an alternative to the "psychophysical" interpretation of the logarithmic formula's lawful character – namely, the physiological one, which identifies different *relata* for the stated relation. (A choice between these different interpretations does not affect the methodological status of the logarithmic formula in outer psychophysics.)

These alternative interpretations arise from the following reasoning, already present in Fechner's *Elemente*: The process leading from external stimulation of the senses to sensation has to be conceived as two different successive sub-processes – one process leading from the stimulus to psychophysical activity, and another one leading from psychophysical activity to sensation. If one takes the measurement formula as valid for outer psychophysics, and if one of these two sub-processes is regarded as linear, the other one has to be taken as logarithmic. Either the relation of sensation to psychophysical activity – as in the psychophysical interpretation – or the relation of psychophysical activity to the stimulus – as in the physiological interpretation – is logarithmic. Georg Elias Müller (1850-1934) from Göttingen, the sharpest critic of Fechner's *Elemente*, suggested that the

logarithmic formula describes the loss of physical energy from the periphery to the psychophysical substrate. In the words of William James (1842-1910): "Weber's law would thus be a sort of *law of friction* in the neural machine." (1890, 1:548)

Fechner's major argument for the psychophysical interpretation of the logarithmic law rests on another law, which he calls the "parallel law" (i.e., parallel to Weber's law). It states that sensitivity to the differential threshold is independent of absolute sensitivity. If the latter is changed – e.g. by fatigue – the difference between two stimuli is experienced as in the unfatigued state. The parallel law would not hold, says Fechner, if the psychophysical interpretation were not true. The parallel law is thus "one of the bridges leading from outer to inner psychophysics." (1860, 1:302. See also 1860, 1:ch.12 & 2:ch.38; 1882, 221ff.)

Beginning in 1863, Wilhelm Wundt (1832-1920) advocated yet another interpretation of Fechner's (and Weber's) law: the so-called "psychological interpretation." (1863, 1:133; 1885) He argued that the process leading from the physical to the psychological dimension has to be conceived in a tripartite form: The course from stimulus to neural activity and from there to sensation has to be supplemented by a purely psychological process leading from sensation to *judgment* thereof, as manifested in verbal behavior. Holding back this process can only lead to a distorted picture of the true nature of Fechner's experiments. Wundt calls this additional process the "apperception" of sensation. It always involves a comparison, i.e. judgment of one sensation relative to another. Wundt, taking this relativity as the decisive feature of all psychological processes, sees the logarithmic formula as a special case of a general law: the "law of the relativity of the states of consciousness." Fechner's psychophysical methods of measurement, he claims, are in reality purely "psychological." (Wundt 1902-03, 538-553; Heidelberger 2004, 233)

In order to sum up the three interpretations, we can represent the course of events between the external stimulus and the sensory-perceptual dimension with the following figure (Titchener 1905, xci):

R ————> P ————> A ————> S ————> J

where R denotes stimulus, P physiological activity at the periphery, A psychophysical activity, S sensation, J judgment and ‖ logarithmic dependency. We may say, omitting constants, that the three interpretations relate the terms as follows:

The physiological interpretation: P ‖ A = S (= J),
the psychophysical interpretation: P = A ‖ S (= J), and
the psychological interpretation: P = A = S ‖ J.
(The relation between R and P drops out of the psychophysical context.)

3. The causal significance of the logarithmic formula

As noted above, Fechner defines psychophysics with reference to the "functional correspondence or interdependence of body and soul." Both the measurement formula and the logarithmic law in its psychophysical interpretation assert a functional dependency – in the mathematical sense of "function" – between stimulus magnitude and sensation. It should be obvious that the measurement formula must be understood non-causally. It has to be taken in the same way as the relation between time and distance in a clock. The natural law may also express just a functional dependence. There are non-causal laws in science stating interdependency between magnitudes, such that a variation in any of them is

concurrent with variations in the other. Boyle's law for ideal gases is a case in point, as is the law connecting the length and oscillation of a pendulum.

In order to clarify the deeper reasons for Fechner's insistence on the functional and therefore non-causal nature of the logarithmic law, I must delve further back into his thoughts and address his psychophysical parallelism. This doctrine is no piece of speculative metaphysics, but has (at least) a rational core. Although there is some similarity between Fechner's psychophysical parallelism and the parallelism taught by Leibniz, the crucial aspects of Fechner's view are *far from* Leibnizian. It is very unfortunate that Fechner's view was baptized "psychophysical parallelism;" he himself preferred the term "identity view."

There is not just *one* psychophysical parallelism in Fechner; rather, there are *three* different ones, which build upon each other like Russian dolls. The *first version* is to be understood as an empirical and methodological postulate or maxim. Any science dealing with the mind-body relation, it holds, should assume that there is a material basis for every mental phenomenon with which it is correlated. Correlation between magnitudes means that variation in one is concurrent with variation in the other. For a mental phenomenon to be correlated with a physical one means that there is no change of the mental side without a change of its material basis.

Claiming functional dependency of mind from body implies complete neutrality in regard to causality. In researching the mind-body relation scientifically, we simply record this dependency without surmising or presupposing anything about its causal or non-causal character. Therefore, the first version of psychophysical parallelism gives the following advice: "Assume that each mental process has a material correlate on which it functionally depends. Do not interpret functional dependency as a statement of law committing yourself to a causal or non-causal claim. The exact causal significance of the relation should be left open." Fechner abstains from a causal commitment because he wants to keep the foundations of psychophysics free of any metaphysical ingredient. Since philosophers' disagreement about the mind-body problem revolves around the causal or non-causal nature of the mind-body relation, we should keep the foundations of psychophysics free of any causal meaning. Only in this way can we hope that psychophysics will some day be able to give us hints as to the true causal nature of the mind-body relation.

The *second version* of psychophysical parallelism is the attempt to find a strategy by which to clear up the exact causal meaning of the psychophysical law – after psychophysics has laid its foundation. Since Fechner thinks that any *explanation* in science (in contrast to a mere description) implies a causal commitment, a causally uncommitted psychophysics would be scientific, but would not be able to *explain* the mind-body correlation. The goal is to find the minimal causal extension of psychophysics that can claim to explain the mind-body relation without distorting the facts.

Fechner's solution is his second version of psychophysical parallelism, or, as he himself preferred to call it, his "identity view of body and soul." It provides the following philosophical underpinnings for functional dependence: (1) A living human being is not to be considered a conglomeration of two substances but is, rather, a single material entity; (2) the properties of this entity are considered mental when they are perceived inwardly – that is, from the perspective of the entity itself; and (3) the properties of this entity are considered physical when it is viewed externally – that is, from someone facing the entity from an outside perspective. The mental and the physical are therefore two different

aspects of one and the same entity that are intimately related but exercise no causal influence upon each other.

This position is also sometimes called "double-aspect theory." Taking it seriously means viewing the logarithmic law of inner psychophysics as a non-causal law connecting two aspects quantitatively, much the way Boyle's law connects pressure and temperature. By virtue of its non-reductive character, Fechner's position stands apart from any doctrine that assumes the mental to be *caused* by the physical. Indeed, Fechner's position can even be called materialist, since it assumes (at least in his early work) that only matter exists. It does not claim, however, that there are only physical *properties*.

There is nothing mysterious about distinguishing perspectives in the way of Fechner's identity view, as we can demonstrate by considering the example of a bent coin. It would be wrong to say that a dent on the heads side of a coin causes a bulge on the tails side. While both sides of the coin are intimately connected, their joint occurrence has nothing to do with causality; they are merely two sides of one underlying material substrate – two aspects that appear parallel to each other when the coin is damaged or otherwise changed.

Fechner tried to support the identity view form of psychophysical parallelism with several different arguments. Two of them stand out as the most effective: (1) The law of the conservation of energy shows that physical energy can only be transformed into other physical energy. Therefore, the physical and the mental cannot causally affect each other. (2) The identity view form of psychophysical parallelism is the most simple of all possible explanations of the mind-body relation (known so far). All other amendments to the basic empirical fact of the psychophysical relation are metaphysically stronger than the identity view, because they involve more causality, as it were, than the identity version.

In its *third form*, psychophysical parallelism is a cosmological thesis extending beyond the range of the living human organism. It tries to give an answer to the question whether there are other beings in the universe – besides humans and some animals – that have a mental side to them. Fechner is infamous for believing that not only human beings and certain animals, but also plants, the earth, the planets and the sun, indeed even the universe as a whole, have a mental side to them. But this doctrine of panpsychism implying a nesting of different domains of consciousness is not just utter nonsense! It is, I maintain, the result of Fechner's undaunted and provocative attempt to take functionalism in philosophy of mind seriously. It is akin to the influential fashion in contemporary cognitive science of holding that the comprehension of mind calls for the development of purely computational theories, irrespective of their biological implementation. In order to establish the plausibility of panpsychism, Fechner tries to exploit much the same functionalist argument which today allows computational cognitive science to claim that mentality is not bound to the biological details of neural machinery. The functionalist argument is, if correct, an inductive one. It says that the fulfillment of certain criteria in systems other than human beings makes it probable that they have a mental side to them. This is how AI argues that certain robots may have a mental side. So, if functionalism is meaningful, we cannot reproach Fechner for using a similar argument, but only for being overly enthusiastic about the *degree* to which the premises of such an argument support the conclusion. If Fechner's reasoning were not only improbable but absurd, then computational cognitive science would be as well. However, it would be much more effective to criticize Fechner on his own terms: *In light of inner psychophysics*, a merely functional conception of the mind will simply not suffice!

4. Fechner's conception of psychophysics today

It has been an aim of this talk to defend Fechner's viewpoints and to dissolve misunderstandings of some of his concepts and arguments. It has also been a goal to show the sophistication of Fechner's philosophy of science in his development of psychophysics. Above all, however, it was intended to show that inner psychophysics is central to Fechner's reasoning and that the logarithmic law – interpreted psychophysically and conceived as an instance of (the second type of) psychophysical parallelism – is crucial for him.

In conclusion, I would like to consider the question whether the foregoing discussion is to be taken merely as a retrospective bow to the venerable but outdated beginnings of a tradition which this society has carried further? Is it just to "honor Fechner and repeal his law," as S. S. Stevens put it (1961, 80) in the same year in which Boring made the depreciative remark reported above? As I see it, circumstances today are much more sympathetic to Fechner's original intentions than they were 40 years ago, when the behaviorist and operationalist viewpoint largely ruled the day.

The renewed sympathy for Fechner's conceptions is due to two developments. The first general development I have in mind is the new appreciation of consciousness studies in cognitive science, and the move of cognitive science away from the dominance of the computer metaphor toward a more biological outlook. Increasingly, we encounter studies that inquire about the "neural correlate of consciousness." According to Koch and Crick, for example, the NCC "is the minimal (minimal, since it is known that the entire brain is sufficient to give rise to consciousness) set of neurons, most likely distributed throughout certain cortical and subcortical areas, whose firing directly correlates with the perception of the subject at the time." (2001, 2603) This is exactly what Fechner had in mind with his "psychophysical activity" of sensation. The very fact that asking for the neural correlate of consciousness has become legitimate and even popular again shows that the original query that led Fechner to inner psychophysics makes sense after all!

A more specific development has to do with recent experiments linking behavioral and neural data. Nieder and Miller (2003) analyzed behavioral and neural representations of numerosity (numerical information) in the prefrontal cortex of rhesus monkeys. The monkeys were presented with a set of one to five dots, which they were then asked to discriminate from a second set. They made more errors when the numerosities were adjacent and performed progressively better as numerical distance between the two displays increased. Parallel to the task performance, the neural correlate of numerosity was analyzed. It turned out that the neural data mirrored the behavioral ones and that both data obeyed Weber's law. In fact, it turned out that they were truly following Fechner's law as well. (See also Dehaene 2003)

In 1963, MacKay showed that studying behavior alone cannot determine whether magnitude estimations of stimuli depend on neural representations that follow Fechner's logarithmic or Stevens' power law. Because of their dual character, the aforementioned experiments can solve this difficulty and be used to decide between Fechner and Stevens – and also, I think, between Fechner and Wundt. This is an exciting result that shows once again how up-to-date Fechner's intuitions were.

If this impression is correct, we should learn an important lesson from Fechner's outlook. There are strong indications that many advocates of the neural correlate approach believe that the discovery of the true neural correlate of consciousness will finally deliver us a *reductive explanation* of consciousness. (Cp. Koch & Crick 2001, 2600) Fechner tried to show, and I think he thoroughly succeeded in this, that identifying the neural correlate of consciousness is a far cry from proving that it is the *cause* of conscious states. Yet, such a proof would be required in order to show that the neural correlate scientifically *explains* consciousness and that this explanation is *reductive* in character. Fechner would not say that anti-reductionism is true and reductionism false, but that for any reductive explanation of consciousness you can give a non-reductive account in terms of (the second version of) psychophysical parallelism which is equally possible from a logical and empirical point of view, and which has less metaphysical baggage to carry than the reductive one. (See also Fell et al. 2004)

So, in the end, my talk can also be taken as a plea for closer collaboration between mathematical psychophysics and cognitive neuroscience in the spirit of the Fechnerian materialist, yet non-reductive, tradition. Let us build more bridges from outer to inner psychophysics!

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