THE COMPLEX DYNAMICAL SYSTEMS APPROACH TO INNER PSYCHOPHYSICS

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Abstract

Most interest in Fechner's work went to the law of outer psychophysics, which relates external stimulus intensity and sensory experience. Yet, according to Fechner's own conviction the validity of this law depends entirely on inner psychophysics' prescription that brain activity and experience are different aspects of the same entity. This means there must be lawful connections between the two that can be expressed as type-identity. This implication of Fechner's work seems to be of considerable significance today, in setting the agenda for psychophysical, neuroscientific, and interdisciplinary investigations. I suggest that the identity is to be found between dynamic activity patterns in the brain and the time course of perceptual experience. In this perspective, the evolution of coherence in brain activity relates to the micro-evolution of a perceptual experience and the duration of coherence corresponds to the psychological present. I discuss an approach to model these phenomena, based on complex systems dynamics.

A romantic undercurrent in 19th century German science, often addressed as *Naturphilosophie*, has been seeking resource to an overarching concept of "spirit" in an attempt to overcome an overly static image of nature. Lacking the present-day insight in evolution as well as the active, self-organizing capacities of the physical world, materialism was thought to imply the exclusion of goal-directedness from scientific study, leaving the material world passive and inert. The romanticists sought to restore a notion of anima, or active growth into this world.

Fechner in Zend-Avesta (Zoroaster; living word) adopted a panpsychism of nature (cf presocratics), which, in a similar vein, was promoted against static materialism. His approach differed in important respects from the romantic *Naturphilosophie*, and is more consistent with today's concept of selforganization. This is an *intrinsic* rather than overarching capacity of nature's components, and is realized as they engage in mutual interaction. Fechner himself described the difference as one of methodology. Naturphilosophie takes the *allgemeine Beseelung* as its starting point for speculation on die individuelle Seele. Fechner's empiricist attitude, however, militated against such speculation. We reach an understanding about the general concept of spirit only by using methods of induction and analogy, taking the individual mind as a starting point. The empiricistic attitude combined with a rejection of outward materialism is a distinctive mark of Fechner's intellectual pedigree, most notably Lorenz Oken, and connects him with later authors such as Wundt and Mach (Üner, 1998).

Although far less known than the "Elemente der Psychophysik" (1860) the Zend-Avesta (1851) are more than just an undergrowth of Fechner's thinking that needs to be cut back in order to reach to the scientific part. In fact, this work contains the conceptual foundation for later scientific developments. The active character of the system is reflected in its *Teleologie*. It is about self-organizing behavior, resulting into a structure, in which the components at different levels of a part-whole hierarchy take a functional role in the behavior of the whole. Fechner's psychophysics, therefore, could be understood from today's point of view as a unique blend of mind/brain identity and dynamic functionalism.

Fechner wanted to express the living, evolving, active aspect of nature that he attributes to Seele, or mental life as it is immanent to material beings. Die Sache ist die: es gibt eine auessere sichtbare Seite der Natur, und ich fusse darauf, dass es auch eine unsichtbare oder nur sich selbst sichtbare Seite derselben gibt (p. XIV). Yet, we will not reach an understanding of it through speculation. Induction, analogy, and history are the methods by which the concept of 'allgemeine Seele' is won. In other words, the principles of the world can be understood in analogy to the phenomena that occur in our own mind. Their dynamics are manifest to ourselves only. Following the empiricist principle, rather than to speculate about its being, we much see to describe its phenomena and subsume them under some principle, or law.

The quantitative expression of this principle is addressed by Fechner as, das "neue Prinzip mathematischer Psychologie, welches zugleich das einer mathematischen Behandlung der gesamten Beziehungen von Koerper und Seele ist"… p XIII . This principle connects, with necessity by law of nature, a quantified experience and a quantified bodily state, through the symbol "=". With this scientific postulate, the existence of this connection is claimed, not its precise form. Existence rather than precise form provides the necessary underpinning of empirical laws such as Weber/Fechner's, and any claim beyond that would be speculation. The precise form was unknown in Fechner's time and is still largely unknown today.

Failure to observe this leads to the dismissal of internal psychophysics as being speculative. Consequently, in many of today's textbooks psychophysics is habitually defined as "-quantification of the way in which psychological experience varies as a function of changes in physical stimulus properties" (Ryan, 1997, p. 105). Reducing psychophysics thus implies dogmatism. The family of Weber/Fechner laws implies log-linear scaling of stimulus intensity. Stevens proposed a power law, and psychophysics was drawn into an ultimately pointless debate over the "right" law (cf. Krueger, 1989). Outer psychophysics, however, is (mere) inductive and analogical expression of the laws of inner psychophysics. "It must be remembered that the stimulus does not cause sensation directly, but rather through the assistance of bodily processes with which it stands in more direct connection. The dependence, quantitatively considered of sensation on stimulus, must finally be translated into one of sensation on the bodily processes which directly underlie the sensation -- in short the psycho-physical processes; and the sensation, instead of being measured by the amount of the stimulus, will be measured by the intensity of these processes". (Fechner, Elemente der Psychophysik). This means that the laws that govern outer psychophysics only apply by approximation. On Fechner's own terms, log-linear scaling, therefore, can neither claim universal validity, nor uniqueness on account of the data. Gregson (1995) and others have shown many instances where stronger forms of non-linearity govern outer psychophysics.

One way to proceed from here is to take far more serious the dynamic aspects of Fechner's functionalism. Insofar classical psychophysics depends on measurement in equilibrium conditions, dynamic variability is a nuisance which needs to be controlled experimentally and discarded theoretically. This leads to the experimental elimination of Hysteresis and Enhanced Contrast (Hock, Kelso, & Schöner 1993), and them being discarded as error, respectively of habituation and anticipation. Once the focus is on the system characteristics of the mind/brain, the significance of these phenomena as hallmarks of nonlinearity become more obvious. More generally these observations may inspire a reconsideration of sequential effects. Sequential effects that extend across trials, yield evidence for deterministic chaos in system responses (Kelly, Heathcote, Heath, et al. 2001).

Such investigations would put an end the systematic underrepresentation of context-dependency in psychophysics. We have seen contextual effects being either reduced to a decision process (Swets, Tanner, & Birdsall, 1961 or, alternatively, to passive scale adjustment, as in adaptation-level theory (Helson, 1964). We can observe context influence effecting psychophysical judgment in a manner that is neither a cognitive decision, nor a passive adaptation. Constancy phenomena (Epstein, 1977) are a case in point.

We could go further still: Fechner in his time was still confined to infer the law of inner psychophysics by analogy to that of outer psychophysics. What we know today, is sufficient to claim that system dynamics, rather than being a source of error, has a central, constitutional role on experience. This means that we should make the comparison between experience and the brain, not one between signals, but between *dynamic patterns*.

Ongoing research work in my own laboratory is focused on the computational characterization of the dynamic patterns that arise in visual information processing, both in awareness and the brain. We are choosing a level of description for these phenomena which is optimized for allowing identity-statements. This means that without reservation we can place our work in the tradition of Fechnerian inner psychophysics.

A starting point for our work is that in a first-person perspective, perceptual experience is poised between a microscopic and macroscopic orders. The perspectival limit of its micro-dynamics is its *Aktualgenese*, or emergence of a visual experience. The upper limit is its duration, or persistence in time. The lower and upper limits I have called elsewhere: hologenesis and coherence interval and their roles have been studied in, among others, perceptual priming, interference, perceptual switching, search, and serial learning (van Leeuwen, 1998).

To answer the question of inner psychophysics, what are the counterparts in the brain of these experiential phenomena, we need to have a model of the brain that is optimal for identity. A functional isomorphism between brain tissue and experience is required. For this, a level (or grain size) has to be identified that connects to the patterns of experience as identified in hologenesis and coherence interval. Instead of the macroscopic isomorphism originally stipulated by Wolfgang Köhler and the microscopic ones that may exist in the dendritic arborizations, (Pribram, 1984) we would like to propose a mesoscopic level, corresponding anatomically to the layers of brain areas such as V1 and V2 (see also Freeman, Kozma, & Werbos 2001).

The activity at this level is likely to be highly nonlinear. To gain an understanding of the behaviour of these systems we started from components that are maximally simple, and have chosen Coupled Maps (CM; Kaneko, 1990) as a convenient mathematical modelling tool. CM are complex dynamical systems, which produce hyperchaotic dynamic patterns of activity, of which Figure 1 provides an illustration. Spontaneous synchronization occurs through the connections between CM network units. These are both lateral and feedback connections, but lateral diffusion processes are emphasized.

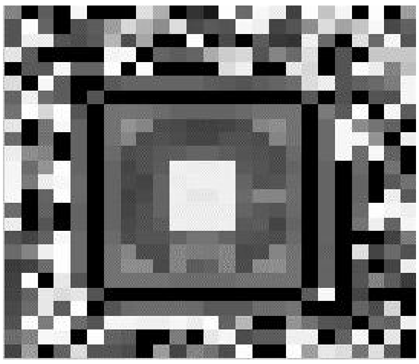
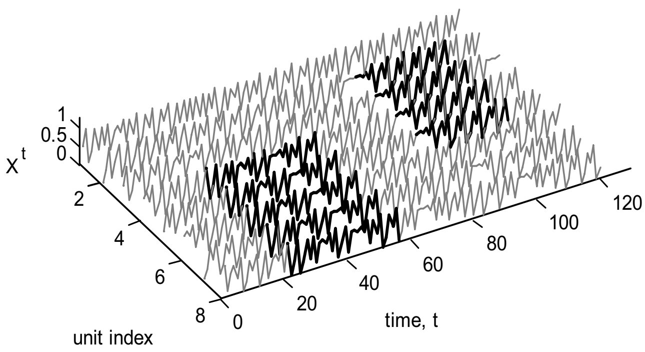


Figure 1. Synchronization can be modulated by stimulation (in the example above, modulation with a square-shaped pattern). Results in global context influence by diffusion through the local, lateral connections in the network. (from: van Leeuwen & Raffone, 2001).

With respect to hologenesis, these models show interesting properties such as invariant pattern creation (van Leeuwen, Verver, & Brinkers, 2000) for memory, iconic encoding, medium and long-term storage, spontaneous rehearsal (van Leeuwen & Raffone, 2001). With respect to coherence intervals, these were observed as dwelling times for certain perceptual interpretations. These have traditionally been modelled as gamma distributions (Borsselino, DeMarco, Alazetta, et al. 1972). The present approach could model these distributions without stochastic assumptions (van Leeuwen, Steyvers, & Nooter, 1997; van Leeuwen, Simionescu, & Raffone, 2001).

(a) A cluster is a set of coherent trajectory segments



(b) Clusters often show drifting limit cycle behavior

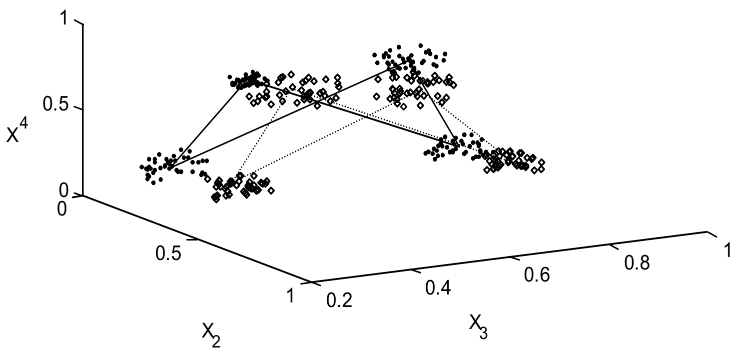


Figure 2. **Dynamic Clustering**. (a) In many dynamical systems units tend to synchronize for certain intervals of time. (b) A drifting limit cycle of period 4. (from: van Leeuwen, Simionescu, & Raffone, 2001).

Dynamic patterns in these models are observed as clusters of synchronized activity (Figure 2). Clusters are formed and annihilated rapidly, in accordance with its immediate character in experience (hologenesis). Clusters are meta-stable, which means that they have an intrinsic life-cycle (coherence interval).

The current approach is still far removed from a realistic model of the brain. Our strategy is to gradually incorporate into the model evidence about the connectivity structure of the brain, activation regulation and learning. By doing so, we hope to make these models increasingly realistic implementations of Fechner's identity postulate.

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