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Consciousness and Neural Force Fields

Abstract: *This article compares Wolfgang Köhler's pioneering field theory of the consciousness–brain relation with Benjamin Libet's conscious mental field theory and Karl Popper's mental force field hypothesis. In the discussion of Köhler's theory we devote special attention to his analysis of problems of sense perception and to his explanation of figural after-effects. Both Libet and Popper take consciousness to causally interact with the brain, and we argue that even Köhler presupposes an interactionist interpretation of the consciousness–brain relation. We argue that nothing necessarily rules out that consciousness as something subjective may causally interact with the brain as something objective. We discuss an evolutionary argument for the theory that consciousness causally interacts with the brain, and we consider some arguments for consciousness having had a survival value.*

1. Introduction

During the last twenty years a number of elaborate field theories of mind have been proposed (for a review, see Jones, 2013). In many of these theories electromagnetic fields of the central nervous system are taken to be crucial to the explanation of conscious experiences. Though often vaguely described, in the different theories different

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components of the brain's electromagnetic field are understood to be relevant to consciousness, and in fundamentally different ways — e.g. as being identical with or being the substrate of consciousness. Susan Pockett (2000) suggests that consciousness is identical with certain spatio-temporal patterns in the electromagnetic field. She (2011) seems to assume that it is extracellular potential fields (mean fields) having a dipole character that are identical with consciousness. Mostyn Jones (2010) suggests that consciousness is a certain 'electro-chemical substance'. He seems to assume that even fundamental particles and their fields are conscious. Similarly, Colin Hales (2014) enquires into the possible molecular sources of electromagnetic fields in the brain, and suggests that certain virtual bosons are identical with certain qualia components ('qualeons'). Johnjoe McFadden (2013) suggests that extracellular electromagnetic fields, caused by synchronous firing neurons, independent of frequency, are the substrate of consciousness. There are also some important field theories of mind that are more remotely connected with the problems of our discussion — e.g. the theories of Fingelkurts, Fingelkurts and Neves (2010), Freeman (1999), and John (2001).

In the following we shall focus on the pioneering field theory of the consciousness–brain relation proposed by Wolfgang Köhler (1929; 1938; 1942; 1960) and we will compare this theory with Benjamin Libet's conscious mental field theory (Libet, 1993; 1994; 2004) and with an interpretation (Lindahl and Århem, 1994) of what we will call *Popper's mental force field hypothesis* (Popper, Lindahl and Århem, 1993). Köhler's, Libet's, and Karl Popper's analyses are of particular interest because they explicitly presuppose that consciousness is *distinct* from the activities and states of the brain. Köhler, Libet, and Popper take into consideration the fact that consciousness is subjective whereas the activities and states of the brain are not subjective. And due to this epistemic fact consciousness cannot be identical with any activity or state of the brain. (The assumption of such an identity would be illogical; it would violate the principle of the indiscernibility of identicals.)[3] Köhler's and Libet's field theories of mind are of interest also because they are supposed to be empirically testable.

[3] The principle of the indiscernibility of identicals states that 'if A is identical with B, then every property that A has B has, and vice versa' (Blackburn, 1994, p. 191; *cf.* Mautner, 1996, p. 206). For an illuminating discussion of this principle, see Maunu (2002).

Popper's mental force field hypothesis supplements these theories by calling attention to certain important similarities between mind and physical forces. Popper's philosophy of mind is of interest also more generally because of its evolutionary biological perspective on the problem of how consciousness is related to the brain (the consciousness–brain problem). We agree with Popper in that the consciousness–brain problem ought to be seen largely from a biological point of view.

The fact that Köhler, Libet, and Popper take consciousness to be distinct from the activities and states of the brain raises several questions: (1) In what sense, then, is consciousness distinct from the activities and states of the brain, according to Köhler, Libet, and Popper? (2) How, more exactly, do they take consciousness to be related to the activities and states of the brain? (3) To the extent that this relation is understood to be causal, are Köhler's, Libet's, and Popper's respective views of this relation tenable? And since they analyse the consciousness–brain relation in terms of fields, one may also wonder: (4) Does the reference to field properties contribute to making this relation comprehensible? We will try to answer these questions.

In Section 2 we examine some of the key notions in Köhler's conceptual framework, in an attempt to explicate his notion of consciousness. We also comment on some aspects of Libet's notion of consciousness. In this connection we discuss how Köhler and Libet distinguish between consciousness and the activities and states of the brain. We call attention to the fact that, whereas Libet's theory is clearly interactionistic, Köhler's theory is less explicit about how consciousness is related to the brain. In the discussion of Köhler's theory we devote special attention to his analysis of certain problems of sense perception and to his explanation of figural after-effects.

In Section 3 we distinguish between an ontological and an epistemological interpretation of Popper's distinction between consciousness and the brain, and we apply the epistemological one. We discuss Popper's interactionist understanding of the consciousness–brain relation and the role he takes certain neuronal electromagnetic fields to play in this interaction, and we argue that, given the epistemological interpretation, nothing necessarily rules out that consciousness may causally interact with the brain in the way Popper suggests.

In Section 4 we argue that Köhler in his experiments on visual after-effects presupposes an interactionist interpretation of the consciousness–brain relation. We discuss an evolutionary argument for the theory that consciousness causally interacts with the brain, and we consider some arguments for consciousness having had a survival value. In this discussion we focus on certain aspects of the problem of perceptual binding.

In Section 5 we sum up the main points of our analysis.

2. The Theories of Köhler and Libet

Köhler distinguishes between *the physical world* and *the phenomenal world* and defends what he calls 'the theory of psychophysical isomorphism' (Köhler, 1938, pp. 142, 223). A fundamental element of this theory is that when we observe an object, say an elephant, there is an isomorphism between the cortical organization and the perceptual structure: 'If an image of the animal is projected upon my retina, cortical processes within a circumscribed region of my brain are immediately segregated as a particular macroscopic unit, which is my "psychophysical elephant"; and one phenomenal thing, the elephant-percept, appears in my visual field' (*ibid*., p. 218). Köhler discusses the isomorphic relation in terms of mere *correlations*, however. Libet's theory is somewhat bolder than Köhler's theory. Libet makes it clear that he takes activities of nerve cells in the brain to be physical and conscious experiences to be non-physical, and that he takes brain activities to *causally interact* with conscious mental activities (Libet, 2004, pp. 2–3, 14, 138).[4]

Libet (*ibid*.) objects to the attempts that have been made to distinguish between different kinds and levels of conscious experience, and argues that the common feature is awareness and that the differences lie in the *contents* of awareness. He further contends that awareness is an *emergent* result of certain neuronal activities (*ibid*.). Libet suggests that conscious experience may be viewed as a field, and that a feature of this *conscious mental field* (CMF) would be that of 'a unified or unitary subjective experience' and that another feature would be 'a causal ability to affect or alter neuronal function' (Libet, 1993, p. 394; 1994, p. 120; *cf*. 2004, p. 168). According to Libet (1993; 1994), the CMF is produced by brain activity. Libet emphasizes that the CMF is not in any category of known physical

4 Libet (2004) does not explicitly define what he means by 'physical' and 'nonphysical'. But he states that the non-physical phenomena of conscious subjective experiences include 'sensory awareness of the external world, thoughts, feelings of beauty, inspiration, spirituality, soulfulness, and so on' (*ibid*., p. 3).

fields, but is in a *phenomenologically* independent category — not in the category of a Cartesian substance (Libet, 2004, pp. 169, 182). In a similar way, Köhler (1938, p. 371) suggests that there are *phenomenal fields* with corresponding *fields of cortical processes*. Köhler argues that we do not have direct access to the physical world, but only to the phenomenal world; that our approach to the physical world consists of inferences and constructions, and that if the perceptual and the physical structures were not isomorphic, physics would not be possible (*ibid*., chapter V; *cf.* 1929, chapter I).

We need here to make a few conceptual clarifications. In *Gestalt Psychology* Köhler points out that instead of talking about consciousness it may seem more cautious to talk about what he calls 'direct experience', and that for some people 'consciousness is rather a function by or in which we become aware of "immediate experience"' (Köhler, 1929, p. 8). In *The Place of Value in a World of Facts* (1938) Köhler discusses what he refers to as 'phenomenal experience', and he almost never uses the terms 'conscious' or 'consciousness'. Köhler (1929) uses 'direct experience' and 'immediate experience' synonymously. And he distinguishes between direct experiences in their *external* and in their *internal* aspects — those of the external kind he calls 'objective experiences' (i.e. sensations and sensory perceptions) and those of the internal kind he calls 'inner experiences' (e.g. emotions) (*ibid*., pp. 8, 21–7, 261–2). According to Köhler (*ibid*., pp. 23–6) the properties of physical reality can be discovered only by objective experiences, and similarly he maintains (1938, pp. 142, 376) that the physical world — or, rather, what we perceive as the physical world — is constructed by phenomenal experiences. Thus, for Köhler at least some phenomenal experiences play the same epistemic role as objective experiences in our contact with the physical world.

How, then, should what Köhler calls 'direct experience' be understood to be related to consciousness? Before we try to answer this question we need to get a clear idea of what is meant by 'consciousness' here. Unfortunately, Köhler (1929; 1938) is not clear on this point. The situation is further complicated by the fact that 'consciousness' has been used in a variety of senses over the years. *Oxford English Dictionary* (1987) defines six main senses of consciousness. *A Comprehensive Dictionary of Psychological and Psychoanalytical Terms* (English and English, 1958, p. 113) concludes: 'Because of stubbornly persistent confusions, the term ["consciousness"] has lost usefulness and should be replaced in technical discussion.' If we look up 'consciousness' in a psychological dictionary from about the time of Köhler (1929; 1938) we find three main senses: '1. the distinguishing feature of mental life, variously characterized as (*a*) awareness, (*b*) the central effect of neural reception, (*c*) the capacity of having experiences, (*d*) the subjective aspect of brain activity, (*e*) the relation of self to environment; 2. the sum-total of an individual's experiences at any given moment; 3. the capacity of the individual to know external objects and to influence them' (Warren, 1935, p. 57). Let us for a moment dwell upon the second sense, which we may call 'consciousness$_{W2}$'.

Suppose you are drinking coffee. You will then have objective experiences — sensations as well as sensory perceptions — involving several sensory modalities, and you might even have an inner experience, say, an emotional experience. If we take 'experiences' in Warren's (*ibid.*) second definition of consciousness to be referring to what Köhler (1929) counts as objective and inner experiences, the sum-total of your direct experiences would then make up your consciousness$_{W2}$ at the moment when you are drinking the coffee. Given this interpretation of 'experiences' in Warren's (1935) second definition, and given that Köhler is understood to use 'consciousness' as referring to consciousness$_{W2}$, a direct experience would be related to consciousness$_{W2}$ as a part of a whole. Let us assume that this is how Köhler uses 'consciousness' and how he takes direct experience to be related to consciousness.

Is direct experience something other than what Köhler (1938) calls 'phenomenal experience'? This is not easy to tell. As we have noted, according to Köhler at least some phenomenal experiences contribute in the same way as objective experiences to our apprehension of the properties of physical reality. Whether or not 'phenomenal experience' covers also inner experiences is not clear. Of interest in this connection is Köhler's idea of phenomenal fields. In English and English (1958, p. 207) the concept of phenomenal field is defined as 'everything, including itself, experienced by an organism at any moment' — and they add that the emphasis is upon 'the external world *as experienced*'. Köhler (1938, p. 354) even includes emotions in the phenomenal field. So if Köhler by 'phenomenal experience' means any experience being a part of the phenomenal field, 'phenomenal experience' would cover at least some inner experiences. Let us assume that for Köhler phenomenal experience is the same as direct experience. We may then also note that in Andrew Colman's *A Dictionary of Psychology* (2001, p. 552) the concept of phenomenal field is defined as 'The sum total of consciousness at a given moment'. Given this definition and provided that phenomenal experience is the same as direct experience and that phenomenal experiences are what the phenomenal field consists of at a given moment, *the phenomenal field may be understood to be equivalent to consciousness$_{W2}$* at that moment. This will be our interpretation of Köhler's notion of phenomenal field.

In order to see how Köhler may be understood to take consciousness to be distinct from the brain we may think of his example of the observation of the elephant — where the animal, the image on the retina, and the cortical processes all exist in the *physical* world, whereas the elephant-percept exists in the *phenomenal* world. And we should then also note that Köhler (1938, p. 142) takes the physical world to be 'transphenomenal'. So from this point of view the line between the processes in the visual cortex (on which the visual percepts depend most directly, according to Köhler) and the elephant-percept is *epistemic* — a line between what is transphenomenal and what is phenomenal. And this epistemic distinction holds for the relation between the brain and *all* of the phenomenal experiences that would make up the phenomenal field (i.e. consciousness$_{W2}$). Thus, in his view of how the distinction between the phenomenal field and the brain should be understood, Köhler may be said to embrace a form of dualism — epistemological dualism.

Whether or not Köhler in his theory of visual experience takes the visual percepts and the processes in the visual cortex to be also *temporally* distinct is more difficult to say. Köhler points out that 'particular visual percepts as they appear in the visual field depend directly on particular corresponding processes in the visual cortex' (*ibid*., p. 138) — 'certain things, the visual percepts, exist, disappear or change in correlation with the occurrence, the disappearance or the alteration of corresponding brain-events' (*ibid.*). Does this mean that the changes in the visual cortex precede the changes of the visual percepts or are they contemporaneous? Popper, in an analysis of Köhler (1920), understands Köhler to subscribe to a parallelistic idea of the mind–brain relation (Popper and Eccles, 1977, pp. 532–3). In two of his later works (1938, pp. 412–3; 1960, p. 23), Köhler explicitly declares that he prefers to reserve judgment on the question of how the phenomenal events and the brain processes are related. Köhler (1960) calls attention to the fact that when dealing with this question and assuming that the phenomenal events appear only in brains we seem to come up against a problem of *emergence*. To use the example of visual experience, even if the changes in the visual cortex and the changes of the visual percepts are strictly parallel, the *origin* of the visual percepts remains to be explained. And once we admit — as in the example of the observation of the elephant — that the visual percepts are caused by physiological processes, initiated by the nerve impulses from the retina, we have a case of *something phenomenal emerging as a consequence of something transphenomenal*. It is not easy to see how Köhler could avoid this conclusion.

In *Dynamics in Psychology* (1942) Köhler develops his field theory of mind further. He (pp. 40–3) contends that every psychological fact has a brain-correlate, and that it is only by our knowledge of the brain-correlates that we can understand how one psychological fact is related to another psychological fact. Köhler discusses how the appearance of the spatial distance between two stimuli may change if they are simultaneously given, compared with if they are given in succession. He gives an account of such results from studies of touch, vision, and hearing. Köhler argues that these phenomenal experiences of the spatial distance between the stimuli cannot be sufficiently understood in mere psychological terms, and that we have to assume that there is an interaction between the brain-correlates of the perceptual facts. In the case of the touch impressions, Köhler (*ibid*., p. 52) suggests that it is this interaction among the brain-correlates which 'alters the localization of the points in phenomenal space'. The interaction among the brain-correlates, Köhler maintains, is an interaction of *fields*. Köhler (*ibid*., p. 46) postulates what he calls the 'field theory of perception', by which he means 'that the neural functions and processes with which the perceptual facts are associated in each case are located in a continuous medium; and that the events in one part of this medium influence the events in other regions in a way that depends directly on the properties of both in their relation to each other'.

As Köhler (1938, p. 335) points out, the term *field* in one sense refers to things like areas, and in another sense it refers to 'dynamic vectors that extend from an object into its environment'. It is in the first sense, he explains, that we speak of the field of vision and of the phenomenal field. And, clearly, when Köhler (1942) discusses the field theory of perception, he is using 'field' in the second sense. From now on, we will call fields in this sense 'force fields'. We take what Köhler (1938, p. 371) calls 'fields of cortical processes' to be force fields. (In Section 4 we will come back to the question of the causal role of phenomenal fields.)

Libet (2001, p. 59) maintains that in Köhler's theory 'unification of a subjective experience is mediated by an electromagnetic field that spans large areas of the cerebral cortex'. Libet refers to Köhler, Held and O'Connell (1952), a study that questions the so-called *Leitungslehre* (the conduction doctrine). According to this doctrine basically all neural functions, including the cortical, can be accounted for in terms of 'conduction in the fiber of a given neuron and, at its end, events which start conduction in a further neuron' (Köhler, Held and O'Connell, 1952, p. 290). Köhler *et al*. (*ibid*., pp. 292–3) argue that the conduction doctrine cannot account for certain facts in the psychology of perception — that the doctrine can neither explain 'the splitting of visual fields into molar objects and their background', nor deal with 'the consequences of this phenomenon in overt action, and in the distortion of subsequent perception'. Earlier, Köhler and Wallach (1944) had by a series of experiments on visual perception developed a *theory of figural after-effects*. In the experiments the subject observed a number of figures (e.g. squares, rectangles, circles, angles, or lines) on a screen. Some of the figures were used as inspection objects (*I*) and some as test objects (*T*), and there was a fixation mark (×) on the screen. After a certain inspection period, during which the *I*-objects were shown without the *T*-objects, the *T*-objects were shown without the *I*-objects and, contrary to what could be separately observed, in some of the experiments one of the *T*-objects appeared smaller, further back, and/or paler than another *T*-object on the screen, and in other experiments the distance between some of the *T*-objects appeared shorter, and in further experiments a *T*-object appeared distorted (e.g. changed from a square to a trapezium). For example in Figure 1, where first the *I*-object is supposed to be shown without the *T*-objects, and then the *T*-objects without the *I*-object, the right *T*-object will appear smaller, further back, and paler than the left *T*-object.

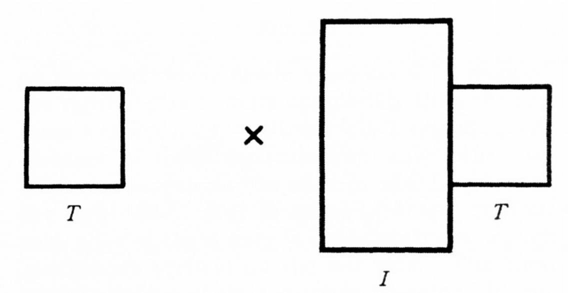

Figure 1. Objects of an experiment demonstrating a figural after-effect (reproduced from Köhler and Wallach, 1944, Figure 4, with permission). The experiment starts with the subject being shown the *I*-object without the two *T*-objects, fixating the gaze at the cross. Subsequently the subject is shown the two *T*-objects without the *I*-object, still fixating the gaze at the cross, and, contrary to what could be separately observed, the right *T*-object will appear smaller, further back, and paler than the left *T*-object.

In order to explain the figural after-effects, Köhler and Wallach invoke an idea of what they call 'electrotonus', implying that *a constant current in nervous tissue will affect the nervous tissue by decreasing the currents in regions close to the cortical object and increasing the currents in regions more distant*.[5] Köhler and Wallach (1944, p. 276) describe the effect that the constant current of a cortical *I*-object has on the nervous tissue as a lingering 'satiation' of the tissue in the area of the cortical *I*-object and its close environment — 'the fact that the prolonged presence of a given figure causes the "depressed" condition of the medium'. The theory of figural after-effects may be understood to assume (i) that for each visual object — *I*-object as well as *T*-object — there is a corresponding local process

5 Köhler and Wallach explain: 'Immediately after its onset the current begins to weaken. At the same time its distribution is changed inasmuch as a conservable flow appears outside the stretch which offers the most direct connection of the electrodes. The current seems to withdraw from those parts of the nerve's surface which lie directly under, or very near, the electrodes and to prefer a detour around these places' (1944, p. 321).

Originally 'electro-tonic state' was used by Faraday (1832) for a certain electric state of a metal in a magnetic field. Later, however, 'electrotonus' has mainly been used for a certain electric reaction of a nerve when a constant current is injected into it (see e.g. Rosenberg, 1937; and Katz, 1939). The mechanisms of these neuroelectric effects are still poorly understood, but an increase in the resistive properties of the most adjacent tissue regions as well as an introduction of an electromotive force — possibly by a polarization-like process, opposing the current through the electrode — have been suggested.

(a 'cortical object') in the visual cortex, (ii) that each cortical object induces electric currents (i.e. acts as an electromotive force), (iii) that the currents of each cortical object pass through the tissue at right angles to the visual cortex, (iv) that the currents of each cortical object return to the respective object through its environment, (v) that the currents of each cortical *I*-object have electrotonic effects, (vi) that the electrotonic effects involve an obstruction of electric currents, and (vii) that the electrotonic obstruction of electric currents, which the satiation of the nervous tissue in the area of a cortical *I*-object and its close environment gives rise to, causes a figural after-effect (*ibid.*, especially chapters 6 and 7; Köhler, Held and O'Connell, 1952, pp. 293, 294, 300, 310, 317–8).

So in the example illustrated by Figure 1 the explanation of the figural after-effect would be that the inspection of the visual *I*-object caused a satiation of the nervous tissue in the area of the cortical *I*-object and its close environment, which resulted in a reduced conductivity (i.e. increased the resistivity) of the affected area, and this in turn influenced the currents of the right cortical *T*-object, which caused the right visual *T*-object to appear smaller, further back, and paler than the left visual *T*-object.

To sum up, Köhler may be said to embrace an epistemological dualism, according to which something phenomenal (consciousness$_{W2}$/the phenomenal field) is distinct from something transphenomenal (the brain). Similarly, Libet maintains that the CMF is in a phenomenologically different category than any known physical field. But he does also take conscious experiences to be non-physical and the brain to be physical. Whereas Libet takes awareness to emerge from neuronal activity, and conscious experiences to be able to causally influence neuronal functions, Köhler wants to keep open the question of how the phenomenal events are related to the brain processes. In practice, however, Köhler presupposes that certain phenomenal entities — the percepts — may be *caused* by brain processes. This means that Köhler allows of something phenomenal (the percepts) to emerge as a consequence of something transphenomenal (the brain processes). According to Köhler's theory, perception involves fields of two different kinds, phenomenal fields and fields of the brain-correlates of the perceptions. Fields of the latter kind, Köhler seems to maintain, may causally influence phenomenal experiences. According to Libet's theory, brain activity may produce a CMF, and this field may in turn causally influence neuronal functions.

Let us now examine Popper's mental force field hypothesis, and enter into the question of the tenability of an interactionist interpretation of the consciousness–brain relation.

3. Popper's Mental Force Field Hypothesis

In *The Self and Its Brain* (Popper and Eccles, 1977) Popper expounds and defends an interactionist mind–body theory. In this work, Popper addresses only briefly the problem of detecting neural activities related to consciousness (*ibid*., pp. 117–20). He speculates about the possibility of there being a one-to-one relationship between certain conscious experiences and certain brain processes, e.g. in cases of *Gestalt* switches, but he does not specify this further. Popper concludes that 'it seems that the whole brain must be in high activity to be linked with consciousness — a teaming process of unimaginable complexity' (*ibid*., p. 120). In *Knowledge and the Body–Mind Problem*, Popper suggests that both in the phylogeny and in the ontogeny of humans *self-consciousness* appears with the higher functions of language, and that the self interacts with the speech centre of the brain (Popper, 1994, pp. 115, 131–2). In 1993 Popper adds two new elements to his philosophy of mind (Popper, Lindahl and Århem, 1993). One is a mind–force analogy, the other is an idea of how mind is related to the brain. Taken together these two elements constitute Popper's mental force field hypothesis. The mind–force analogy is an attempt to demystify somewhat the existence of mind. Popper argues that minds have at least six properties — minds are '(i) located, (ii) unextended, (iii) incorporeal, (iv) capable of acting on bodies, (v) dependent upon body, and (vi) capable of being influenced by bodies' (*ibid*., p. 168). And, he reasons, many people would object that something with all these properties could not exist. But, Popper maintains, these are properties that minds have in common with *physical forces*. According to Popper there are also two additional properties that minds and physical forces have in common — '(vii) they are intensities' and they have '(viii) extension through a span of time' (*ibid*., p. 168). The mind–force analogy concerns all these eight properties.

Popper further suggests 'that the complicated electro-magnetic wave fields which, as we know, are part of the physiology of our brains, represent the unconscious parts of our minds, and that the conscious mind — our conscious mental intensities, our conscious experiences — are capable of interacting with these unconscious physical force fields, especially when problems *need* to be solved that *need* what we call "attention"' (*ibid*., p. 179). According to Lindahl and Århem (1994) this may be understood to mean that there are two levels of causal interaction: the first between a certain spatio-temporal pattern of action potentials and a specific electromagnetic field (a field that is identical with the unconscious part of mind[6]); the other between the electromagnetic field and the conscious mind. This is the interpretation on which we will here base our discussion of Popper's mental force field hypothesis. Let us examine more closely the two levels of interaction.

The action-potential pattern–electromagnetic field interaction

The brain may be seen as a dynamic configuration of molecules embedded in an electromagnetic field. According to the received view of electrodynamics, the field is caused by electric charges and magnetic dipoles, and other electric charges and magnetic dipoles are in turn affected by the field. Thus all electric activity in the brain causes and is influenced by electromagnetic fields.

At first it might be difficult to accept that the fields produced by a brain neuron may in turn influence the activity of another, adjacent, neuron. It takes a potential change over the membrane of at least 20 mV to excite a *resting* neuron (Hodgkin, 1964; Hille, 2001). Consequently, even under the most favourable conditions, an electric field of at least 0.5 V/cm would be necessary (Lindahl and Århem, 1994). This is many times stronger than the electric field around a nerve cell, induced by a normal impulse activity. However, Popper's mental force field hypothesis seems to imply that electromagnetic fields do not have to trigger *resting* neurons to affect the impulse activity (Lindahl and Århem, 1994). By affecting spontaneously active neurons even a weak field can trigger impulses in neurons close to a certain threshold potential; the field could be understood to sculpture *ongoing* neuronal activity.

The investigation into the non-synaptic action ('distance action') between nerve cells in the brain may be traced back to the 1930s (Gerard, 1936; 1937). Katz and Schmitt (1940) demonstrated that activity in invertebrate axons can influence neighbouring axons. Recent work has extended the tests to cortical networks of mammalian

6 For a discussion of this identity, see Libet (1996; 1997); Lindahl and Århem (1996a).

brains. Fröhlich and McCormick (2010) showed in the visual area of ferret brains that weak sinusoidal and naturalistic electromagnetic fields enhance and entrain physiological neocortical network activity with an amplitude threshold within the range of in vivo endogenous field strengths. Thus, it is clear that an extracellular electromagnetic field caused by a neuron can modulate the activity of a neighbouring neuron in mammalian cortices.

The electromagnetic field–consciousness interaction

In his analysis of the consciousness–brain problem, Popper distinguishes between three 'Worlds' — World 1, the world of physical objects, World 2, the world of subjective experiences, and World 3, the products of the human mind (Popper and Eccles, 1977, pp. 16, 36–50). We shall here focus on World 1 and World 2. The neuronal activities and their electromagnetic fields belong to World 1 and the conscious experiences belong to World 2. There are two ways of understanding Popper's distinction between World 1 and World 2. The one is ontological and takes Popper's characterization of World 1 as point of departure and understands 'physical' to be synonymous with 'material', and World 2, therefore, as the world of something immaterial. The other understanding is epistemological and takes Popper's characterization of World 2 as point of departure and understands World 1 as the world of something objective (for a discussion of these interpretations, see Lindahl and Århem, 1994). We will apply the epistemological interpretation. A reason for this is that we know through introspection that consciousness is something subjective. We may leave the issue of whether or not consciousness is material an open question. It also happens to be the case that the epistemological interpretation of Popper's distinction closely resembles Köhler's phenomenal–transphenomenal distinction.

Is it, then, possible, *in principle*, for something objective, say a change in a certain neuronal electromagnetic field in the brain, to cause something subjective, say an occurrence of an unpleasant sensation, and for something subjective, say the occurrence of the unpleasant sensation, to cause something objective, say a change in a certain neuronal electromagnetic field in the brain? In order to be able to give a relevant answer to this question we need to know what may count as a *cause* in this context. Just for the sake of argument, let us suppose that the notion of cause that Konrad Marc-Wogau (1962) defends is relevant here. This notion may be understood in the following way: an individual event α is a cause of another individual event β, if and only if (i) α precedes β in time, and (ii) there is a class γ of individual events δ_1, δ_2, … δ_n, such that (a) each event in γ is a minimal sufficient condition for β and (b) δ_1 or δ_2 or … δ_n is a necessary condition for β, and (iii) δ_1 is a necessary condition *post factum* for β, and (iv) α is a moment in δ_1.[7] This will be our interpretation of Marc-Wogau's notion of cause. Central to this interpretation is the idea that a certain antecedent may be a cause of a given effect, despite the fact that the antecedent is not itself sufficient for the effect and the effect could have occurred even if the minimal sufficient condition of which the particular antecedent is a part had been replaced by some other minimal sufficient condition. Clearly, nothing in our interpretation of Marc-Wogau's notion of cause rules out that the antecedent is something subjective and the consequent is something objective or that the antecedent is something objective and the consequent is something subjective.

In this connection it is of interest to consider Jones's (2013) analysis of Popper's mental force field hypothesis. Jones applies the ontological interpretation of Popper's distinction between World 1 and World 2. And Jones raises the question of 'how the mechanics of energy transfers work when non-physical minds move our bodies, and when non-conscious brains create conscious minds' (*ibid*., p. 134). What Jones wants to call attention to here seems to be the argument that a dualistic mind–brain interaction would violate the first and/or second law of thermodynamics.[8] Popper has dealt with various aspects of this argument. Regarding the first law, Popper argues (i) that the law holds only with (more or less) good approximation for organisms, since they are never closed (Popper, 1984); (ii) that there might exist 'purely mental forms of energy, convertible into electrochemical

7 This notion of cause resembles John Mackie's (1974) well-known, but more problematic, idea of a cause as an individual instance of an *inus* condition — an *insufficient* but *non-redundant* part of an *unnecessary* but *sufficient* condition. For a discussion of Mackie's notion of cause, in this sense, see Lindahl (2009, Appendix).

8 In the history of physics both the first and the second law of thermodynamics have appeared in different forms. Rudolf Clausius has been understood to formulate the first law as stating that 'in any closed system (a steam engine, for example) the total amount of energy is constant' and the second law as stating that 'heat cannot pass from a colder to a hotter body on its own accord; for this to happen some external cause must come into operation' (Ronan, 1983, p. 447). In *The Open Universe*, Popper calls the first law 'the law of conservation of energy' and the second 'the law that asserts that entropy can only increase' (Popper, 1982, p. 172).

forms' (*ibid*., p. 21);[9] (iii) that according to some interpretations of de Broglie's particle-wave theory, 'there seem to be empty pilot waves that can interfere with non-empty (energy-piloting particles and energy-carrying) waves', and this would suggest 'the possibility of non-energetic influences upon energetic processes' (Popper, 1984, pp. 21–2).[10] Regarding the second law, Popper argues (i) that the law is refuted by Brownian movement (Popper, 1992, p. 165; see also 1998, pp. 180–1); (ii) that the law does not hold for open systems, and that every living system is an open system (Popper, 1982, pp. 172–3). In *The Self and Its Brain*, Popper speculates about the possibility that for the relation between World 1 and World 2 the first law might turn out to be valid only statistically, and that an interaction between World 1 and World 2 would after all not violate the second law (Popper and Eccles, 1977, p. 541).[11]

Jones (2013, p. 134) finds it untenable to treat causality as just perceived correlations. Events cannot be causally explained, Jones reasons, unless they are actually produced by underlying forces. In fact, even David Hume (1978, p. 168) seems inclined to allow that in certain objects there may be some unknown qualities that might be called 'power' or 'efficacy'. Without going further into Hume's analysis, one may wonder whether we can *know* that a certain event has been produced by a force. And if such knowledge is possible, how can it be achieved? Jones (2013) does not enter into these issues. However, David Fair (1979) defends a notion of causation that implies that a cause is a source of energy and momentum that flows to the effect. Fair discusses several problems in the application of this notion. One of the problems is the fact that in ordinary language causal relations may involve mental states — e.g. 'Bill's slamming a door in John's face caused the latter's anger' (*ibid*., p. 233). Fair

9 Popper considers such forms of energy 'perfectly possible', but adds that 'I do not think much of this possibility' (Popper, 1984, p. 21).

10 Popper makes it clear that this idea of non-energetic influences upon energetic processes has not been 'corroborated by the experiments going on at present' (Popper, 1984, p. 22).

11 In a commentary on Popper's mental force field hypothesis, Beck (1996) suggests, as a way to make an interaction between consciousness and the electrochemical brain dynamics compatible with the strong conservation laws of physics, that this interaction would involve an intermediate field of probability amplitudes. Lindahl and Århem (1996b) reject this suggestion, partly because it presupposes an unnecessary ontological interpretation of Popper's distinction between World 1 and World 2, and partly because the suggestion is based on a subjectivist interpretation of quantum theory.

argues that we must then 'reduce this ontology so described to an ontology of physical objects described in terms of physical magnitudes in order to be able to apply the physics' (*ibid*.). Fair discusses also how we may come to know that there is an energy-momentum flow between two objects. As evidence of such a flow that may also serve as evidence of causation he suggests (i) contiguity, (ii) motion, and (iii) past causal regularities (*ibid*., pp. 241–2). Fair emphasizes that his proposed analysis of causation is not complete. And, indeed, it is far from convincing. A particularly problematic part of Fair's analysis is the reductive requirement. If the reduction implies that the conscious mind (consciousness) is identical with some brain activity or state it is not achievable. As we have noted, since consciousness is subjective and the brain is not subjective, consciousness cannot be identical with any activity or state of the brain.

So it is not difficult to agree with Jones (2013) that we have to distinguish between causation and mere perceived correlations. But a notion of causation that would imply that consciousness is identical with some brain activity or state will not do.

It should be noted that in the account of his mental force field hypothesis (Popper, Lindahl and Århem, 1993), Popper does not explicitly suggest that the *conscious* mind (consciousness) is a field, and, clearly, he does not suggest that this part of the mind is a *physical* force. (The *un*conscious mind, however, Popper seems to take to be a physical force field — see Lindahl and Århem, 1994, p. 115.) It is due to the fact that the conscious minds belong to World 2 and the physical forces belong to World 1 that Popper's mind–force analogy about the eight properties, mentioned earlier, is an *analogy*. So, according to the epistemological interpretation of Popper's distinction between World 1 and World 2, the eight properties of the physical forces are objective, whereas the eight properties of the conscious minds are subjective.

To sum up, Popper's mental force field hypothesis seems to presuppose two levels of causal interaction. On the first, neuronal electric charges and magnetic dipoles generate electromagnetic fields, and these fields in turn influence not only other electric charges and magnetic dipoles of the same neuron, but also electric charges and magnetic dipoles of other, adjacent, neurons. On the second level, certain neuronal electromagnetic fields interact with the conscious mind. Whereas the interactions on the first level take place within World 1, the interactions on the second level take place between something in World 1 (the electromagnetic fields) and something in

World 2 (the conscious mind). We interpret Popper's distinction between World 1 and World 2 as a division into the world of something objective (World 1) and the world of something subjective (World 2). As the interpretation of Marc-Wogau's notion of cause illustrates, nothing necessarily rules out that something subjective (the conscious mind) may causally interact with something objective (certain electromagnetic fields in the brain).

4. Discussion

A merit of Köhler's analysis of the consciousness–brain problem is the distinction between what is phenomenal and what is transphenomenal, and the theory of figural after-effects. By emphasizing the phenomenal–transphenomenal distinction Köhler avoids getting into the fruitless ontological discussion of whether or not consciousness is material. And by stating the theory of figural after-effects, based on experiments on visual perception, Köhler and Wallach (1944) and Köhler, Held and O'Connell (1952) make it possible to discuss concretely what the neurophysiological causes of the visual perceptions might be. The explanatory value of the theory of figural after-effects has been questioned by M.K. Malhotra (1958; 1960). We will not go into this issue here, however.

We have noted that Köhler presupposes that something transphenomenal (brain processes) may cause something phenomenal (the percepts). But it may also be argued that in the experiments on visual after-effects he even presupposes that the percepts cause, partly, the bodily movements involved in the reports of the subjects. In fact, the validity of the experiments depends on the percepts having played such a causal role. Thus Köhler implicitly embraces an *interactionist* interpretation of the consciousness–brain relation.

Is, then, the interactionist consciousness–brain theory tenable? We have already argued that nothing necessarily rules out that consciousness as something subjective may causally interact with the brain as something objective. But is there really any good reason to assume that consciousness causally interacts with the brain rather than always occurs as a mere epiphenomenon or as something supervenient on brain activity?[12] Since consciousness appears in animals — in humans,

12 Several authors question the causal efficacy of consciousness (see, for example, Wegner, 2002; Haggard, 2005; Pockett, 2006; Roediger, Goode and Zaromb, 2008; Searle, 2004).

and probably also in other vertebrates — it is of interest to deal with this question from an evolutionary biological point of view. The problems of the origin, evolution, and possible survival value of consciousness have been much discussed (see e.g. Allen and Bekoff, 1997; Århem *et al*., 2008; Butler *et al*., 2005; Edelman and Tononi, 2000; Griffin, 2001; Macphail, 1998; Rial *et al*., 2008; Roth, 2000). And, as William James (1879) seems to have been the first to point out, the theory of evolution by natural selection may be understood to speak in favour of an interactionist interpretation of the consciousness–brain relation. James (*ibid*., pp. 3, 18) reasons: 'Consciousness, namely, has been slowly evolved in the animal series, and resembles in this all organs that have a use'; and 'if it [consciousness] is useful, it must be so through its efficaciousness'. Popper (1977; 1978; Popper and Eccles, 1977) develops a similar evolutionary argument for the theory that consciousness causally interacts with the brain. (For a discussion of James's and Popper's evolutionary arguments, see Lindahl, 1997.)

James (1879) does not enter upon the problem of defining different forms of consciousness in biological evolution. But one may here think of Gerald Edelman's (1992) distinction between primary consciousness (which he suggests that probably most mammals and some birds have) and higher-order consciousness (which he argues that humans have in addition to primary consciousness).[13] And it is even conceivable that some animals are sentient, without having a primary consciousness (Lindahl, 1997).[14] It may be argued, however, that the assumption that consciousness has evolved by natural selection *need* not rule out an epiphenomenalist or supervenienist interpretation. A

13 Edelman (1992, p. 112) states: 'Primary consciousness is the state of being mentally aware of things in the world — of having mental images in the present. But it is not accompanied by any sense of a person with a past and future… In contrast, higher-order consciousness involves the recognition by a thinking subject of his or her own acts or affections. It embodies a model of the personal, and of the past and the future as well as the present.'

14 A major challenge in the study of the origin and evolution of consciousness is to find appropriate cognitive-behavioural and physiological-anatomical characteristics that may serve as empirical markers of consciousness (see Århem *et al*., 2008; Roth, 2000; Seth, Baars and Edelman, 2005). The principal, currently competing, theories of the neural basis of human consciousness vary considerably as to which brain areas and activities are suggested to cause conscious experience (Butler *et al*., 2005). A special problem of importance for the question of the role of consciousness in biological evolution is to explain the ability to selectively attend to perceived as well as imagined objects. For suggestions of neural activities that may be involved in such abilities, see Fingelkurts and Fingelkurts (2015); Noack (2012).

question here is, therefore, whether there is any evidence indicating that consciousness may have had a survival value. There are several suggestions. One is the fact, which James (1879) calls attention to, that pleasures are generally associated with what is beneficial, and pains with what is detrimental, to us. And, in a similar way, this might have influenced the behaviour of organisms far back in the evolution. James also speculates about the possibility that consciousness might be needed for steering a nervous system that has grown too complex and unstable to regulate itself (*ibid.*). It has further been suggested that consciousness might have contributed to the evolution of innate behavioural predispositions (Lindahl, 2001). And Popper argues that the conscious mind makes it possible to 'let our theories die in our stead' (Popper and Eccles, 1977, p. 210). An additional argument is 'economic': since the brain uses more energy during wakefulness than during non-REM sleep (e.g. Madsen *et al*., 1991; Maquet, 1995) and waste of energy would be disadvantageous in biological evolution, it is unlikely that consciousness would have been preserved in evolution unless consciousness contributed to an adaptive overt behaviour. Of course, even taken together, these arguments for consciousness having had a survival value are not conclusive. But they do at least make an interactionist interpretation more plausible than the idea that consciousness is a mere epiphenomenon or something supervenient on brain activity.

When discussing the role of consciousness in biological evolution it is important to consider the problem of *perceptual binding* — that different units of perceptual information are tied together into a unified conscious experience. A distinction should here be made between what may be called *cross-modal* binding (e.g. when visual and tactile information are tied together) and *intramodal* binding (e.g. when visual information of, say, colour and shape are tied together). The ability to achieve perceptual binding varies among vertebrates. Interestingly, when a snake catches its prey, the striking is governed by sight or heat sensation, the subsequent following of the prey is governed only by smell, and the swallowing by touch (not sight or smell) (Sjölander, 1997). Thus the snake has, if any, a very limited capacity for cross-modal binding. Nevertheless, the snake manages to behave in an adaptive way.

An influential theory of how perceptual binding is achieved is the theory of *re-entry* — 'a process of ongoing parallel and recursive signaling between separate brain maps along massively parallel anatomical connections, most of which are reciprocal' (Edelman and

Tononi, 2000, pp. 105–6). (Brain maps are assemblies of connected cerebral areas — *ibid*., p. 42.) The theory of re-entry covers both cross-modal and intramodal binding (*ibid*., pp. 106, 114, 211). The perceptual binding is understood to make a coherent overt behaviour possible. The theory does not deal with the problem of *how* the unified conscious experience may influence the overt behaviour.[15] But we may here think of Köhler's and Libet's ideas of conscious experience as a field, and — as an analogy — of how neuronal electric charges and magnetic dipoles generate electromagnetic fields, which in turn influence other electric charges and magnetic dipoles of the nervous system. In fact, Libet (2004, p. 169) suggests that the CMF may be thought of as analogous to physical force fields, and he illustrates this with how an electromagnetic field is related to an electric current.

Köhler's (1938) idea of phenomenal fields and his assumption that we have direct access only to the phenomenal world clearly have a bearing on the problem of perceptual binding.[16] To think of consciousness as a field makes it possible to picture not only how different units of perceptual information may form a unified conscious experience, but also how this unified experience may be brought about and be maintained by the joint activity of different parts of the central nervous system. Even the snake, when he strikes his prey, say a mouse, might have a phenomenal field, representing different aspects of the transphenomenal mouse and its background. A human being, due to her capacity for cross-modal binding, is then able to have a more complex representation of the same transphenomenal object. From an evolutionary biological point of view, the human ability to have a more complex representation could then be seen as a result of natural selection. The difference in the capacity for perceptual binding

15 It is not quite clear how Edelman and Tononi (2000) take consciousness to be related to the brain. On the one hand Edelman and Tononi emphasize that conscious experience is *subjective* (*ibid*., pp. 10–2), on the other hand they maintain that the 'sensation of red is a particular *neural* state' (*ibid.*, p. 167, our emphasis) and they refer to consciousness as a 'physical' process (*ibid*., pp. 12, 14, 207). They argue that consciousness is efficacious (*ibid.*, pp. 14, 217–8), but in their discussion of their metaphysical and epistemological assumptions (*ibid.*, p. 215) they refer to *The Remembered Present*, which presupposes a mind–brain supervenience (Edelman, 1989, p. 260).

16 It should be noted that in the sense we take Köhler to use 'phenomenal field' (as referring to consciousness$_{W2}$), a phenomenal field may at various moments of the individual's life constitute not only a unified conscious experience of sensory perceptions, but also emotions. For a discussion of the unity of consciousness, see Chalmers (2010, chapter 14).

between the species would then be explained by the difference that this capacity would make for the overt behaviour of the individuals.

5. Concluding Remarks

To sum up, in our analysis of Köhler's field theory of the consciousness–brain relation, Libet's CMF theory, and Popper's mental force field hypothesis, we have discussed the tendency to contrast consciousness as *subjective* with the brain as *physical*. As we noted in the discussion of Popper's distinction between World 1 and World 2, the contrast between *physical* (belonging to World 1) and *subjective* (belonging to World 2) is ambiguous. We have taken Popper's characterization of World 2 as point of departure, and have understood Popper's distinction as a division into the world of something *objective* (World 1) and the world of something *subjective* (World 2). And we noticed that in this epistemological interpretation Popper's distinction closely resembles Köhler's phenomenal–transphenomenal distinction. We have also noted that both Libet and Popper take consciousness to causally interact with brain activities, and we have argued that even Köhler presupposes an interactionist interpretation of the consciousness–brain relation. In two ways we have defended the idea that consciousness causally interacts with the brain: we have argued that nothing necessarily rules out that consciousness as something subjective may causally interact with the brain as something objective, and we have called attention to arguments for consciousness having had a survival value. We have further noted that, whereas Libet clearly refers to consciousness as a field (the CMF) and Köhler refers to the phenomenal field (consciousness$_{W2}$), Popper does not explicitly suggest that consciousness is a field. So, whereas Libet's and Köhler's theories are field theories of mind with respect to the *conscious* mind, Popper's mental force field hypothesis, as we have noted, seems to be a field hypothesis regarding the *un*conscious mind. We have argued that the idea of consciousness as a field makes it possible to imagine how different units of perceptual information may form a unified conscious experience and how this unified experience may depend on the joint activity of different parts of the central nervous system. And we have also argued that the fact that an electromagnetic field may influence neuronal activity may serve as an analogy for an influence of a conscious field on the activity of the brain.

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