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The CEMI Field Theory

Gestalt Information and the Meaning of Meaning

Abstract: *In earlier papers I described the conscious electromagnetic information (CEMI) field theory, which claimed that the substrate of consciousness is the brain's electromagnetic (EM) field. I here further explore this theory by examining the properties and dynamics of the information underlying meaning in consciousness. I argue that meaning suffers from a binding problem, analogous to the binding problem described for visual perception, and describe how the gestalt (holistic) properties of meaning give rise to this binding problem. To clarify the role of information in conscious meaning, I differentiate between extrinsic information that is symbolic and arbitrary, and intrinsic information, which preserves structural aspects of the represented object and thereby maintains some gestalt properties of the represented object. I contrast the requirement for a decoding process to extract meaning from extrinsic information, whereas meaning is intrinsic to the structure of the gestalt intrinsic information and does not require decoding. I thereby argue that to avoid the necessity of a decoding homunculus, conscious meaning must be encoded intrinsically — as gestalt information — in the brain. Moreover, I identify fields as the only plausible substrate for encoding gestalt intrinsic information and argue that the binding problem of meaning can only be solved by grounding meaning in this field-based gestalt information. I examine possible substrates for gestalt information in the brain and conclude that the only plausible substrate is the CEMI field.*

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Introduction

Consciousness is notoriously difficult to define, but awareness of information[1] (either about the outside world or the self) is certainly associated with most, if not all, conscious states. It follows that the substrate of consciousness must be capable of encoding information. David Chalmers has proposed that version of dual aspect theory in which information has two aspects, a physical one and awareness. Awareness then becomes a property of information in much the same way as mass is a property of matter or frequency is a property of a field (Chalmers, 1995). In earlier papers, I outlined the CEMI field theory (McFadden, 2002a,b; 2006; 2013), which similarly claims that consciousness is a property of the information, in this case, the information encoded by the brain's electromagnetic (EM) field that is downloaded (through various neural pathways, including those involving memory) into motor actions such as speech. Equating consciousness with information (including information encoded in EM fields) has many problematic implications, including pansychism, since information (either matter- or field-encoded) is not limited to human brains or even living matter but is potentially found everywhere in the universe wherever correlations between physical systems exist. Indeed, it has been claimed that information is the fundamental property of the universe that underpins the physical reality of both matter and energy (*it from bit*, as John Wheeler. 1990, claimed). Equating consciousness with information can therefore have the undesirable consequence of failing to account for the phenomenon at all — if consciousness is everywhere then its existence in human brains is no longer problematic; the problem instead becomes one of understanding why objects other than the human brain fail to exhibit the characteristics we would expect for conscious entities. A more fruitful approach is to equate consciousness with information that exists only in certain dynamic states. This can be compared with life, which is a property of matter, but only in certain dynamic states. Life may be made of matter but not all matter is alive. Similarly, consciousness may be made of information, but not all information is conscious. The problem then becomes one of understanding the dynamic features of information that give rise to the property of consciousness. Neural identity theory (Feigl,

[1] Information is also a notoriously difficult concept to define. I here use the Shannon concept of information as that part of a message that is transmitted between a sender and receiver. In this sense, information exists whenever there exists a correlation between the degrees of freedom of the message and those of the receiver (Shannon, 1949). For the purpose of this paper the message is considered to be objects in the external world and the receiver is the brain. The concept of information is discussed in more detail in Section B.

1967; Place, 1956) claims that mental states correspond to physical states, so a search for the physical substrate of consciousness amounts to a search for a physical substrate that has the expected informational dynamics for a substrate of consciousness. A productive approach would be to identify the constraints that the properties of consciousness impose on the information dynamics underlying consciousness. In this paper I examine one of these constraints — the requirement that the informational substrate underlying consciousness must be capable of encoding meaningful information — and examine the consequence of this constraint for our understanding of the physical nature of consciousness.

Section A: The Nature of Meaning

A1. The Binding Problem of Meaning

Meaning is of course a fundamental problem that has challenged philosophers for more than two millennia. I have no intention here of attempting to resolve any of the deep philosophical issues associated with the concept, but only to tackle what I would call the *binding problem of meaning*.

The binding problem is familiar in consciousness studies but is often framed in terms of perception, particularly visual perception (Crick, 1994; Treisman, 1996). We know that visual information falling on the retina is captured by sensory cells and converted into electrical signals that travel along nerves and are processed (mainly in the visual cortex) to eventually generate an output in terms of a motor action. There is no problem in accounting for the functionality of the system, but there is a problem in accounting for its phenomenology. Whereas the visual information arriving at the retina is immediately dissected, distributed, and then processed along parallel neuronal paths, we do not perceive dissected units of information but whole objects with informational content bound into unified percepts. This is the binding problem (Hardcastle, 1994). In my earlier papers outlining the CEMI field theory I proposed that a solution to the binding problem is to propose that the substrate for the phenomenology of consciousness is the brain's electromagnetic (EM) field which integrates and thereby binds distributed neuronal information. Here I intend to show that the *phenomenology of meaning* — how a conscious being experiences meaning — similarly suffers a binding problem, and its solution is again to be found in the CEMI field theory. I next highlight five properties of meaning that highlight its binding problem.

Unity. The meaning of the concept of an object, such as a chair, is the whole object and cannot be reduced to a collection of its parts. This can be illustrated with reference to Figure 1. The image demonstrates how our percepts tend to be meaningful whole objects, however unlikely, rather than a collection of meaningless lines and shades. Meaning (in this case, the sense of believing that this object is an impossible triangle rather than a collection of lines) has already intervened between sensory input and percept to undermine our experience of the parts (the lines) in favour of perception of meaningful whole objects. Note that the impossible*ness* of the triangle is a property of the whole object, rather than its parts. A key question for consciousness research is: where in the brain is this impossible object represented? We know from neurobiology that different aspects of this object (the lines, the corners, etc.) will have been detected by independent neurons located in widely-separated regions of the brain, and will have been processed along independent neural pathways. Each neuron encodes (in its firing rate) just a tiny fraction of the information in the image and can only *know* at most a few bits of that information at a time. Even if we imagined there was some kind of 'triangle neuron' that fired only in response to complex inputs corresponding to triangular shapes; that neuron would only really *know* its own firing rate; it could not be a plausible substrate for the complex percept of the impossible triangle (including our knowledge that it is impossible).

The problem is that the neural pathways of our brain are adept at dissecting and processing information in order to generate a response (which they do very efficiently); but our conscious mind deals not with meaningless data and disconnected parts but with meaningful (even if impossible) whole objects. The problem is also exemplified in the familiar vase-face illusion where the visual input remains the same but the percept is constantly switching between whole objects already laden with their contrasting meanings. Where in the brain are the percepts corresponding to these meaningful whole objects represented?

The insight that conscious minds deal with meaningful whole objects rather than their meaningless parts goes back to the gestalt psychologists who first studied the holistic properties of perception, not only for visual objects but for all forms of perception. For instance, the gestalt psychologists pointed out that musical notes get their value by being perceived as part of a whole melody, just as a beat gets its value only as part of a whole rhythm. Similarly, words are perceived as holistic percepts, laden with the meaning of the objects they represent, not as a collection of letters or sounds; so that the meaning of structurally similar words (like car and care) is never confused.

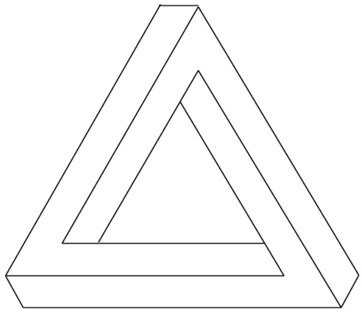

Figure 1. The impossible triangle.

Context dependence. Meaning depends on context. This is clear in simple sentences such as 'the ink is in the pen' or 'the sheep is in the pen'. The word 'pen' has two completely unrelated meanings, either as a writing implement or an enclosing structure for livestock. Which meaning applies in this particular sentence is clear to any English reader but cannot be derived from the syntax of the sentence. Instead it requires knowledge of the world and in particular the mechanism of writing implements and the structure of sheep enclosures. The meaning of the word 'pen' is therefore not a property of the individual letters that make up the word but of the context of the whole sentence and indeed the larger context of the entire human world. It is only in this larger context that the meaning of the word becomes apparent. Considering these issues, the linguist Anthony Oettinger (1968, p. 239) observed that 'Perhaps… the phenome comes after the fact, namely… it is constructed, if at all, as a consequence of perception not as a step in the process of perception itself'. He goes on to conclude that 'This drives me to the unpopular and perhaps unfruitful notion that maybe there is some kind of Gestalt perception going on… and somehow the meaning of what I am saying comes through to you all of a piece'. How does information in discrete neurons generate holistic meaning?

Meaning can *enter* perceived objects from their context to alter their experiential characteristics. This can be illustrated in the optical illusion in Figure 2 (best seen by quickly turning the next page and turning back after only a moment to note your perception). In this case our perception seems to wrestle with the meaningless set of characters 3ALL and the more meaningful interpretation of the characters as BALL. The meaning of the entire word seems to be primary to our perception of its first letter. As the gestalt psychologists pointed out, we tend to perceive objects with meaning, objects with *good gestalt* (objects with meaning), in preference to meaningless, bitty, or disconnected figures. This is apparent when comparing Figure 2 with Figure 3 where there is no longer any figure with good gestalt to grasp so the number 3 is seen in isolation, rather than as a component of a meaningful word. Note, however, that meaning and percept are not identical. The word 'BALL' may be considered to have the same or a very similar meaning to that of a picture of a ball; but their percepts are clearly very different. The key point is that meaning is inherent in all percepts.

3ALL

Figure 2. A gestalt illusion.

The primacy of meaning over perception is even more apparent in the condition of synaesthesia. Subject with synaesthesia will often experience letters and numerals as associated with particular colours. For instance, the number 5 may be associated with the colour red whereas the letter S may be associated with an experience of greenness. But then the same character, e.g. the numeral 5, will be experienced as a red number when it is within an appropriate numerical context (3 + 2 = 5); but as a green letter when it is embedded within a word, such as CON5CIOUSNESS, where it may be mistaken for the letter S (Ramachandran and Hubbard, 2001a,b). Meaning of the entire word or phrase is, in these subjects at least, primary to perception of the component letters.

This primacy of meaning is also apparent in sentences with ambiguous words, such as *pen* in the above sentences, whose precise meaning depends on context. Deciding which meaning is appropriate to either sentence requires what is often termed *common-sense knowledge* — knowledge of the human world. But common-sense knowledge is knowledge that, like meaning, depends on context, and any attempt to encode it suffers from the same infinite regress problems that beset any definition of meaning (pen has meaning in terms of types of writing implement, which has meaning in terms of the activity of writing, which has meaning in terms of the purposes of human communication, etc. etc.). Each item of common-sense knowledge conceals a vast tree of information about the human world, but the entire tree appears to be grasped in that flash of understanding in which we comprehend the word's meaning. Although, in his *Tractatus Logico-Philosophicus* (Wittgenstein, 1922), the early Wittgenstein attempted to deal with this by reducing knowledge to a set of atomic facts about the world ('The world is the totality of facts, not of things'), the later Wittgenstein abandoned this approach, asking 'What lies behind the idea that names really signify simples?… Both Russell's "individuals" and my "objects" were such primary elements. But what are the simple constituents of a chair?… It makes no sense at all to speak of the "simple parts of a chair"' (Wittgenstein, 1972). Just as 'pen' cannot be defined simply, so chair, or the parts of a chair such as the 'leg', yield to no simple definition. Instead the later Wittgenstein claimed that the meaning of a word is embedded in its *use*, which although understood by the user, admits to no simple definition. Thus 'We are unable clearly to circumscribe the concepts of use; not because we don't know their real definition, but because there is no real definition of them' (*ibid.*).

3TLL

Figure 3.

Compression. Wittgenstein pointed out that, despite the fact that the use of a word is extended in time, its meaning is grasped in a flash: 'But we understand the meaning of a word when we hear or say it; we grasp it in a flash, and what we grasp in this way is surely something different from the "use" which is extended in time!' (*ibid.*). This compression of complex information into a singular thought that can be grasped in a flash was noted more than a century earlier by Mozart when he described how an entire musical composition may be 'finished in my head though it may be long. Then my mind seizes it as a glance of my eye… It does not come successively, with various parts worked out in detail, as they will later on, but in its entirety…' (Hadamard, 1945).The meaning of words, music, art, or indeed any concept is complex but is grasped in a flash. And just as visual information is dissected and processed along parallel neuronal pathways, so the informational content of a word, a piece of art, or a musical score — with all their associations and meanings — must be encoded by the firing of very many neurons in different regions of the brain. How is all this distributed information bound into a single meaningful percept? That is an aspect of the binding problem of meaning.

Emergence. The meaning of a whole cannot be reduced to the meaning of the parts. This is apparent in the meaning of the word 'chair' which, as Wittgenstein argued, is far more than a collection of legs, seat, etc. but encompasses both the form and use of a chair. The properties of a whole cannot thereby be derived (at least not in any simplistic way) from consideration of the properties of the parts. This holistic character is true for perceptual objects, such as the impossible triangle in Figure 1. A triangle has quite different properties from the lines from which the triangle was constructed. Similarly, a musical chord (e.g. C minor) has a quite different perceptual feel than a collection of its individual notes perceived separately (as Ella Fitzgerald sang, 'how strange, the change, from major to minor'); just as the perception of a chair is very different from the perception of a wooden pole (its leg).

Interdependence. A feature of interdependence is that modification of one part of an object modifies the entire percept of that object. This can be easily seen in visual illusions, such as the familiar Kanizsa triangle in Figure 4a. In Figure 4b, only a *part* of the triangle is altered but its effect on perception is global.

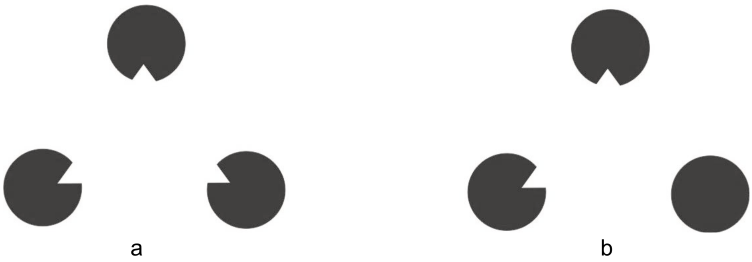

Figure 4. The Kanizsa triangle.

Another characteristic of interdependence is that a change in any part of an holistically perceived object affects all its parts instantaneously. This is apparent when viewing ambiguous objects, such as the familiar vase-face illusion. The entire object is two faces or a vase, never a mixture of the two. A semantic version of the vase-face illusion may be the turning over in our mind the two meanings of the word 'pen'. The word is either a writing implement or a farm enclosure; it is never some mixture of the two options.

These five properties constitute the binding problem of meaning: how is holistic meaning encoded within a neural brain that fragments information? However, just as the visual binding problem has been criticized under the grand illusion hypothesis as a *pseudoproblem* (Blackmore *et al.*, 1995), so similar criticisms may be levelled at the binding problem of meaning. Perhaps we don't grasp all the information encoded within the meaning of a word *in a flash*, but we only think we do. I argued in my earlier papers (McFadden 2002a,b) that although the stream of consciousness may be better described as a dribble, each object of attention consists of complex information and must be encoded by the firing of many neurons. Similarly, when applied to meaning, we may understand far less than we think, but we understand far more than could be encoded within a single neuron. The grand illusion may reduce the bandwidth of the binding problem but it does not eliminate it.

A2. Gestalt Isomorphism

The features of meaning described above have much in common with the characteristics of perception identified by the gestalt psychologists a century ago. Gestalt psychology emerged in opposition to the contemporary atomist movement, which claimed that perceptual experience is merely the sum of simple sensory inputs. The gestalt psychologists instead emphasized the holistic nature of perception which they claimed was more akin to fields rather than particles. In this they were influenced by the ideas coming out of the newly emerging science of quantum mechanics (indeed, Wolfgang Köhler, one of the gestalt pioneers, studied with Max Planck, the founder of quantum mechanics). Fields share the holistic qualities of perceptual fields described by the gestalt psychologists but the gestalt psychologists went on to propose that physical fields exist in the brain that are *isomorphic* to the objects they represented, in the sense that they had the same shape as the represented object: 'In fact, we are inclined to assume that when the self feels in one way or another referred to an object there actually is a field of force in the brain, which extends from the processes corresponding to the self to those corresponding to the object. The principle of isomorphism demands that in a given case the organization of experience and the underlying psychological facts have the same structure' (Köhler, 1947).

It was the proposal that the brain contains real physical fields that correspond to perceived objects (as Köhler described it, that the brain acts as a 'physical Gestalt') that led to the virtual abandonment of gestalt psychology in the late 1950s. Modern neurobiology defined the neuron as the fundamental computational unit in the brain and there didn't appear to be any way of forming isomorphic gestalt fields out of static neurons. Yet it is hard to dispel the notion that — at least for visual perception — there is isomorphism between our perception of objects and their actual structure. For instance, the time taken for subjects to perform mental rotations of imagined 3D objects varies according to the degree of actual rotation of the objects in real space (Kebeck and May, 1991; Pinker, 1980).

Despite the successes of neuroscience, its inability to provide a unifying theory of consciousness has led to several attempts to incorporate gestalt ideas into modern neurobiology. For instance, Palmer (1978) extended the gestalt notion of isomorphic representations to distinguish between intrinsic and extrinsic representation; arguing that representation is intrinsic 'whenever a representing relation has the same inherent constraints as its represented relation…[whereas] representation… is extrinsic whenever the inherent structure of a representing relation is totally arbitrary and that of its represented relation is not'. In this sense, a model motorcar, or even a detailed plan of a motorcar, are intrinsic representations of an object whereas the word 'motorcar' is an extrinsic representation of the same object. Steven Lehar (2003) went further to argue that the visual world is represented in the brain as an explicit volumetric spatial model of external reality — a kind of virtual world inside our heads. However, neither in the original work of the gestalt pioneers nor in the theories put forward by Palmer or Lehar is the physical nature of the substrate that encodes isomorphic representations in the brain defined. In the following sections I explore the possibility that the physical substrate that encodes gestalt representations is the brain's EM field.

Section B: The Nature of Information

Information, like consciousness, is notoriously difficult to define. Gregory Bateson's 'A difference that makes a difference' is probably one of the most succinct but, as 'difference' remains undefined, it doesn't lend itself to further analysis. Claude Shannon was the first to clearly define information in its scientific sense in terms of a communication or correlation between structures: 'The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point' (Shannon, 1949). System A is said to encode information about system B if particular aspects of the structure of system A are correlated with aspects of the structure of system B. System A could for instance be the alphanumeric characters, 2, written on paper whose structure is correlated with system B which might be the number of goals scored in a football match. In this case, the particular geometric configuration of black ink particles (the foreground) on a white paper page (background) are correlated with the number of times a leather ball passed through the goalposts within a particular football stadium. However, the problem comes in knowing what is actually encoding the information in system A. If it is the ink particles then it is certainly not any individual ink particle since, on its own, a single particle or droplet of ink cannot encode anything. It is instead the geometric pattern formed by millions of ink particles against the background of the white page. But if the information is not in the ink particles, where is it? Perhaps each ink particle encodes just a small bit (in both senses of the word) of the complete information concerning the football scores. But this will not work either, since without changing the structure or arrangement of the ink particles we can remove all their informational content simply by replacing the white paper background with a background of identical ink particles so there is no longer any distinction between foreground and background. The structure of the original ink particles hasn't changed but they no longer encode any information (about the football match). The information is therefore not encoded within the ink particles alone, but in the arrangement of both ink particles and the cellulose fibres that make up the white paper: the foreground and background. This kind of information is therefore not intrinsic but depends (like meaning) on context. This becomes problematic if we claim that awareness (or consciousness) is a property of information because there are usually no internal cues that define where the context ends. For a written ink message, the context is the white paper which must be sufficient to make the message legible. But this would depend on the visual acuity of the reader of the message, his/her distance from the message, etc. The claim that awareness is a property of information (Chalmers, 1995) is therefore a very different category of claim than, for instance, the claim that mass is a property of matter or frequency is a property of a field. Whereas it is uncontroversial to ascribe properties to real physical systems (such as matter) that exist independently of observers (ignoring for a moment the *Copenhagenist* interpretation of quantum mechanics), it is not at all clear whether it is legitimate to ascribe properties to abstractions, such as the informational content of matter, which depend not only on context, but also on the properties of an observer.

B1. Intrinsic and Extrinsic Information

To resolve this dilemma I will, following Palmer (1978), draw a distinction between intrinsic and extrinsic information. Intrinsic information is the stuff of physical reality. It is the information that is encoded within the solutions of Maxwell's wave equations that describe classical fields and the information in the solutions to quantum wave functions that describe matter at the quantum level. More prosaically, it is the information encoded within measurable properties of matter and energy such as the frequency of EM waves, or the energy of electrons in atomic orbitals. That field properties encode information is apparent from the use of EM waves (usually radio) to encode and transmit information in television and radio signals. But what is often not appreciated is that all the properties of matter and energy can also be seen as a form of information coding. Any particle — photon, electron, proton, etc. — can be completely described by a finite set of numbers (information). In quantum theory, particles with the same set of quantum numbers are, in principle, indistinguishable. Distinguishable particles (e.g. photon and proton) differ only in the value of these numbers. The physicist John Wheeler went on to claim that it is information, rather than matter or energy, which is the ultimate reality of the universe (*it* from *bit*). He wrote, 'Every it — every particle, every field, every force, even the spacetime continuum itself — derives its function, its *meaning* [my italics], its very existence entirely, even in some instances indirectly — from the apparatus-elicited answers to yes-or-no questions, binary choices, bits' (Wheeler, 1990). In this view, physical reality *is* information written into the various fields (electromagnetic, gravitational, etc.) that fill the universe: intrinsic information.

By analogy with Palmer's definition of intrinsic representation (see above), I now define intrinsic information.

> *Intrinsic information exists whenever aspects of the physical relationships that exist between the parts of an object are preserved — either in the original object or its representation.*

Intrinsic information is the information that underpins physical reality but also exists in representations whenever they are isomorphic with the original object. All the properties of matter — charge, mass, etc. — that are associated with objects are properties of intrinsic information encoded within the fields that encode matter. In a sense, all these properties are *aspects* (in the sense of Chalmers' use of the word) of intrinsic information.

An incomplete representation of an object as intrinsic information may be a model, such as a model motorcar, which possesses physical information (e.g. the relative dimensions of its parts) that is isomorphic with the full-sized car. In a sense, the *meaning* of the representation (in the limited sense of the referent of the encoded information) is the motorcar but because there is a fixed mapping between the structure of the object and its representation, it is possible to deduce some properties of the object — some of the meaning of the information — simply from examination of the structure of its representation. The *meaning* of intrinsic information is thereby intrinsic to the encoding system. Yet the structure of an object need not be conserved for it to be an isomorphic representation (and thereby encoding intrinsic information). For instance, the height of a set of objects may be represented by the weight of another set of objects. In this case, the same physical relationships that existed between the parts of the represented objects (the ratio between their heights) are transformed (into a ratio between weights) but preserved in their representation. Similarly, a contour map that represents geographical contours as a continuous colour range also bears an isomorphic relationship to the object it represents: it is intrinsic information.

A complete representation of an object as intrinsic information possesses all the original object's properties: it is *for all intents and purposes* (FAPP, as the physicist John Bell used to describe the situation) the original object. This is of course the principle of quantum teleportation: transmitting all the (intrinsic) information encoding a particle from one place to another amounts to teleporting the actual particle (Zeilinger, 2000). However, an incomplete representation of an object encoded as intrinsic information may share some of the properties of the original object. For instance, a model car possesses real physical properties (e.g. its ability to roll along a surface) that are shared with the object it represents (which is why models are used in simulations). However, when the medium of the information is changed (as, for instance, from height to weight) then the properties of the representation will be a kind of isomorphic transformation of the properties of the represented object. For instance, the properties associated with the height of a tower (such as its tendency to topple) may be isomorphically transformed into properties associated with the weight of its representation. This isomorphic transformation may allow a system to process the transformed information more easily or more effectively that it could process the original information. For instance, adding up the heights of a large number of objects may require a lengthy computation, but if the heights are transformed into weights then a simple mechanical weighing scales may instantly perform that computation. This is of course the principle of analogue computing. An isomorphic representation of an object may thereby look very different from the object it represents but, so long as there is some mathematical transformation that can recover the original form of the object from its representation, then it is isomorphic with the object and thereby intrinsic information.

An example of information that is not intrinsic would be the representation of an object, such as a motorcar, by a word, such as 'motorcar'. In that case, the structure of the representation bears only an arbitrary relationship to the structure of the object it represents. The word 'motorcar' written on a page possesses none of the properties of the object it represents. Its relationship to the object it represents is arbitrary and depends on the mind of the observer (whether, for instance, they understand the English language). This kind of representation is extrinsic information.

> *Extrinsic information exists when the physical relationship between the parts of an object are not preserved in its representation.*

B2. Meaning and Information

Classical messages (Shannon information), such as written messages, Morse code, or telegraphy, are usually forms of extrinsic information. Their structure correlates with the original information but has no structural resemblance to it. This does not in any way detract from the ability of extrinsic information to describe a system. Any object may, in principle at least, be completely described by a finite set of numbers recorded on ink and paper, but those numbers share none of the object's properties. The *meaning* of a list of motorcar component may be a motorcar or the parts of the motorcar, but the representation possesses none of the properties of the represented objects. Both types of information may be substrates for information processing. However, whereas the word 'motorcar' may be efficiently processed by a conventional digital system in which the information is dissected and digitized; intrinsic information must be processed by some sort of analogue system (for example, a weighing scales) that maintains (or transforms) the holistic properties of the original information through the information processing process.

Another way of describing the meaning of classically written extrinsic information is that it is *symbolic*. In contrast to intrinsic information, which is the same to all observers (a model car looks like a motorcar to any observer), extrinsic information (such as numbers written on paper) requires a reader who knows the code and must decode the message to extract its meaning: it is symbolic information. Without the code, the ink particles of a message are just scattered atoms and molecules with no more physical relationship to each other than they have with any other atoms or molecules in the world. In a very real sense, the symbolic information is not only written on the paper but is also written in the mind of the decoder. Of course the decoder could be replaced by a machine — a robot — programmed to decode the message and perform certain operations on the basis of that decoding. However, this does not change the fact that the message requires knowledge of code — it is just that that knowledge must now be written into the robot's programs. The important point is that the decoding information needs to be stored somewhere outside of the message. The *meaning* of extrinsic information is therefore extrinsic to the message and thereby requires a decoder. This contrasts with intrinsic information whose meaning is indeed intrinsic to the physical system (the cognitive agent or receiver) that encodes the information and does not require a decoder.

The difference between intrinsic and extrinsic information can be illustrated by imagining that we wished to transfer the description of a motorcar to an alien race who had no experience of human civilization. We could send them a car manual that provided a detailed description (in text) of the car and its components. This would be a perfectly acceptable form of information in the Shannon sense, and an example of extrinsic information, but it would be completely useless to the aliens because they would not possess the code needed to decode the text. In contrast, sending them a model car, or even a picture of a car (both examples of intrinsic information), would convey sufficient information for the aliens to reproduce at least the form of a motorcar and investigate its properties. The meaning of intrinsic information is intrinsic to the physical system that encodes it so it does not require external decoding.

B3. Grounding Meaning in the Brain

The central tenet of cognitive science is that the brain is an information processing device that manipulates symbols (extrinsic information) about the real world. This claim has often been questioned, most famously in Searle's Chinese room argument (Searle, 1990) where he demonstrated that a system that is capable of manipulating symbols to generate appropriate responses might nonetheless lack understanding of what it is doing. The problem is to understand why understanding is lacking in this symbol-manipulating system but is so obviously present in the human mind. However, consideration of the above distinction between symbolic and intrinsic information makes the problem clear. Symbolic information is a form of extrinsic information that may be functional (in the sense that it may be processed to yield an appropriate response) but, to acquire meaning, it must always be decoded. Considering the human mind as merely an instrument to manipulate symbols then involves us in either a potentially infinite regress of meaning-providing decoders, or the requirement for a Cartesian homunculus who must witness and decode the symbols — as Dennett (DATE?) describes it, the spectator in the Cartesian theatre.

Returning to the question of encoding meaning in the brain, it is now clear that to avoid the necessity of placing a homunculus in the brain, the meaning of conscious information must be intrinsically encoded within the physical substrate of consciousness as gestalt information.

B4. Why Don't Computers Understand Meaning?

The distinction between intrinsic and extrinsic information also clarifies why computers fail to handle meaning. In his famous critique of artificial intelligence (AI), 'What Computers Can't Do' (Dreyfus, 1992), the philosopher Hubert Dreyfus argued that meaning is always holistic and can never captured by a digital information processing system. Whereas a computer might attempt to analyse a situation in terms of facts and rules for dealing with those facts, for the human mind 'the situation is organised from the start in terms of human needs and propensities which give the facts meaning, make the facts what they are, so that there is never a question of storing and sorting through an enormous list of *meaningless, isolated* [Dreyfus's italics] data' (*ibid.*, p. 262). Similarly to the gestalt psychologists, Dreyfus argued that whereas computers process meaningless nuggets of digital information, even our immediate perceptions are already loaded with meaning that depends on context.

Making computers that can understand common-sense knowledge is a major problem for artificial intelligence (AI). Even Marvin Minsky, champion of AI and cofounder of MIT's Artificial Intelligence Laboratories, complained, 'There is no computer that has common sense. We're only getting the kind of things that are capable of making an airline reservation. No computer can look around a room and tell you about it' (Minsky, 2003). Computers must always dissect and digitize information and thereby suffer an inevitable loss of understanding because they can only process extrinsic (symbolic) information rather than intrinsic information. The meaning of their programs is encoded in the mind of the programmer.

Section C:
The Properties of the Substrate of Consciousness

The main conclusion arrived at thus far is that the meaning of conscious information must be intrinsically encoded within the physical substrate of consciousness in the brain. We can consider the neural representation of an image, such as illustrated in Figure 5. The object, a face, is represented initially as an image on the retina (region A in Figure 5). There is a clearly a one-to-one mapping between the shape of an object and its representation on the retina, so the retinal image can be considered to be encoding intrinsic information. The next step in the information processing pathway is when the retinal image is translated, by photoreceptors, into a pattern of neuron firing (region B in Figure 5, firing and non-firing neurons are represented by filled and unfilled cell bodies respectively) which, since it bears a roughly one-to-one correspondence with the image, similarly encodes intrinsic information as a kind of field of neurons within the retina. However, it is at this stage the image is also converted from intrinsic to extrinsic information. If we take the simplistic assumption that neurons fire only if they *see* the image of the face falling on the retina then the image is effectively translated into a sequence of numbers such as: 0001111000. This sequence is clearly an example of extrinsic information since it has no structural similarity to the original information nor can the original image be reconstructed, by any kind of isomorphic transformation, from this sequence. The sequence could be written on a page of paper, input into a computer, encoded in some other form of extrinsic information (a verbal report 'three zeros followed by four ones followed by three zeros'), or further processed by downstream neurons. Each neuron involved in encoding the sequence encodes just one digit and can be said to *know* just one bit of the complex information encoding the entire image. Yet, as discussed above, the pattern of neuron firing on the retina is isomorphic with the object. So at this stage the image of the face can be said to be encoded as both intrinsic information (the geometric pattern of neuron firing) and extrinsic information (neural firing rates).

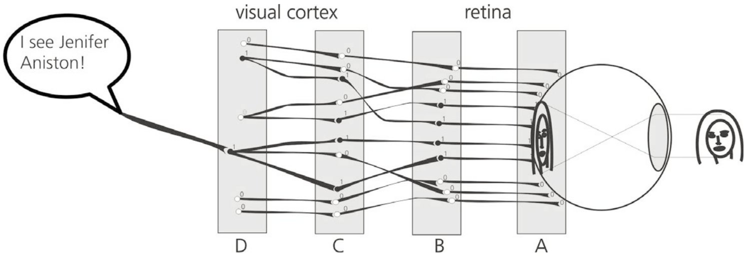

Figure 5. Isomorphism in neural representation. The image of Jennifer Aniston is generated on the retina and information encoding that image is then transmitted to the brain via the optic nerve. Standard neural processing will generate an appropriate response, such as a speech report, but the neurons generating this response have very limited information content and cannot represent the image to the conscious mind. However, as the image is processed in the visual cortex the configuration of neurons processing the image retains a distorted but isomorphic information relationship with the original image and its object.

The next stage of information processing takes place when the information encoded in the neural firing rate in the retina is transmitted to the primary visual cortex where it generates a pattern of neuron firing in receiver neurons in the cortex (C in Figure 5) that may be further processed in the higher areas of the visual cortex (D in Figure 5). These neurons can be said to *read* the information in their input neurons to generate a response in terms of their own firing rate. The neural connections may simply transmit the information (as going from B to C) or perform some kind of information processing (as going from C to D) involving a sequence of logical operations acting as logic gates. In this way the extrinsic information encoded in the neurons entering the visual cortex may be processed along parallel pathways such that precise form of visual input is eventually recognized by a highly selective (cardinal, gnostic, or grandmother) neuron to generate some kind of motor output, such as the statement ‘I see the face of Jennifer Aniston’ (Quiroga *et al.*, 2005). This single neuron registering the image of Jennifer Aniston is clearly an example of extrinsic information: external knowledge is needed to recreate any aspect of Jennifer Aniston from the firing rate of that neuron. There is no problem with this form of neural processing being entirely functional. It can perform highly complex computations to generate highly specific outputs. But the information read by, or encoded within, the highly selective neuron is merely a firing rate. It bears no relationship to the target input and the target input cannot be recovered by any isomorphic transformation of the neuron's firing rate. It is a symbol of the face. Any signal generated by the neuron can be further processed by any symbol-manipulating machine to generate more complex outputs but it cannot correspond to our conscious percept of the face of Jennifer Aniston.

But what has happened to the intrinsic information that was encoded in the pattern of neurons at the retina? At C (Figure 5), it is certainly still present but it has undergone numerous isomorphic transformations as the information at the retina, distributed amongst thousands of neurons, is transmitted along sometimes parallel but often non-parallel routes to the visual cortex. The pattern of nerve firing at the visual cortex will be very different from the pattern of firing at the retina but it will be an isomorphic transformation of that pattern. Essentially each point of the image at the visual cortex is connected to some point on the retina by a tangle of hard-wired deterministic connections so it is just a question of topology to reverse those causal connections and thereby recreate the image on the retina from the image on the cortex (each connection can be represented by a mathematical operation). So the pattern or ensemble of Aniston-induced neural firing in the visual cortex will encode a highly distorted image of Jennifer Aniston but it will remain an intrinsic representation of her face.

The situation becomes more complex at region D in Figure 5, representing higher areas of the visual cortex. At this stage of the computation, synaptic connections are represented as performing several logical operations such that there is no longer any one-to-one correspondence between neuron firing at B and at D. Nevertheless, because the information corresponding to the image is transmitted along a causal chain of neural pathways there will exist some pattern of neuron firing in the higher cortex that represents all of the information encoded in the original image (information is not erased in the brain). Because this ensemble or pattern is hard-wired to the input image (via a tangle of neurons), it (the ensemble, not the individual action potentials) will once again be an isomorphic transformation of the information encoded in the original image. Jennifer Aniston's face will be represented in the visual cortex as a pattern of neuron firing: intrinsic information.

But the question now arises: how is this intrinsic information *read* and experienced in the brain to generate our conscious percept? The brain has no problem reading the extrinsic information encoded in the firing rate of a single Jennifer Aniston neuron to generate an output, but the encoded intrinsic information is denuded of all the richness of the original image (it is just a firing rate) and cannot correspond to our conscious perception. All of the original visual information is encoded in the firing rates of many thousands of neurons distributed right across the brain, a form of intrinsic information. But these neurons are not physically unified. This can be seen by the fact that, in principal at least, the neurons could be separated to arbitrary distances and still possess exactly the same neurobiological functionality. Yet it is very difficult to see how such widely separated neurons could generate a unified percept: how would one neuron even *know* that another neuron existed? If we are to avoid a Cartesian Theatre in the brain (Dennett, 1991) we need some means of experiencing these large-scale patterns — the brain's intrinsic information — that isn't grounded solely in the firing rates of separated individual neurons.

The brain's EM field provides a plausible answer. Neural firing patterns will generate patterns of EM field perturbations that, like the neural firing patterns themselves, will be isomorphic transformations of the original image. Place the seat of consciousness in the brain's EM field and the richness of experience is recaptured. Since neural firing inevitably generates EM field perturbations, all of the spatial information encoding in the pattern of neuron firing encoding Jennifer's Aniston's face will also be encoded as spatial information within the EM field of the brain. Awareness associated with the brain's EM field will experience all of the richness of the world as a unified field or perception.

These EM field-encoded representations can be detected by numerous techniques. For instance, EEG and voltage-sensitive dyes have been used to demonstrate that particular visual stimuli (e.g. the orientation of a line) generate correlated two dimensional patterns of neural activity in the cortex (Shoham *et al.*, 1999; Wang *et al.*, 2003).[2] Spontaneous emergence of these cortical representations of visual attributes has even been detected in the absence of any sensory data (Kenet *et al.*, 2003), leading the authors to suggest that these dynamic cortical states represent the brain's 'internal context' that is capable of influencing memory, perception, and behaviour. Similarly, the perception of familiar objects, such as faces, is correlated with particular

[2] The electrical source of EEG and MEG remains unclear (Grech *et al.*, 2008), but may be primarily generated by dendritic potentials and currents rather than action potentials. However, dentrites receive synaptic inputs generated by action potentials so the structure of dendritic fields will be correlated with the fields generated by those action potentials and may therefore be considered to be a surrogate of those fields.

configurations of the brain's EM field, as detected by magnetoencephalography (MEG) or EEG (Liu *et al.*, 2002), and even facial affect (demonstrating happiness or disgust) generates characteristic MEG changes (Lewis *et al.*, 2003). Also, EEG recordings made with a high density array of EEG electrodes demonstrate that the perceptual switching that occurs when viewing ambiguous illusions (in this case both the vase-face illusion and also a face figure that allowed perception of a sad or happy face) is correlated with topographic features of the brain's electromagnetic field (Keil *et al.*, 1999). More recently, researchers have been able to recognize and categorize EEG patterns generated by human subjects viewing visual scenes such that they were able to successfully predict what type of objects (e.g. a happy or sad face) the subjects were experiencing (Schyns *et al.*, 2011) from examination of the EEG pattern.

The tendency for the brain to generate EM field configurations that are isomorphic with the represented object (gestalt information) may be true not only for visual information but all sensory perception. For instance, neurons that respond to touch receptors on the skin have distinct receptive fields that map to defined areas of the skin surface. Adjacent neurons generally have receptive fields that map to adjacent areas of the body surface, creating the familiar somatotopic map (the homunculus) of the body surface in the somatosensory cortex and the motor cortex. Indeed the entire neocortex is largely organized into numerous feature maps. Even sound is represented in the cortex as spatial patterns since the cochlea converts sound frequencies into spatial representations that are retained in the auditory cortex.

Firing of neurons within each of these topological maps can be considered to be isomorphic representations of sensory information — gestalt information — that can be detected by brain scanning techniques. For instance, in classic experiments on rabbit olfaction Freeman (1991; Freeman and Schneider, 1982) demonstrated changes in the spatial patterns of EEG activity in the cortex of rabbits in response to particular odours. In this case the pattern of firing neurons encoding olfactory information in the cortex must be some kind of isomorphic representation of information falling on the olfactory epithelium. Even more interestingly, these patterns changed according to the animal's conditioning (for instance, whether or not the animals expected a reward associated with the stimulus), leading Freeman to conclude that the *meaning* of neural information (for the animal) was encoded in these patterns. Similarly, in humans, EEG/MEG signals can be detected that correlate with the emotional content of stimuli such as facial expressions (Luo *et al.*, 2009; Peyk *et al.*, 2008), indicating that the emotional 'meaning' of stimuli for humans is also encoded in the brain's EM field. Artistic experience may also be reflected in the brain's EM field. A study using functional magnetic resonance imaging (fMRI) (Janata *et al.*, 2002) of subjects listening to western tonal music demonstrated that the tonal structure of the music was maintained as a dynamic topography of active neurons in the cortex (and will thereby be reflected in the EM fields generated by those neurons). Similarly, several studies have demonstrated that motor actions can effectively be *decoded* from EEG and MEG measurements (Waldert *et al.*, 2008), demonstrating that the configuration of the underlying EM fields encode information corresponding to these actions. These and similar studies are of course the basis for efforts to design EEG and MEG-driven brain–machine interfaces (Lebedev and Nicolelis, 2006) whose premise is the ability to read the mind from spatial, power, and frequency encoded information written into the brain's endogenous EM field.

Even abstract information may be encoded by some kind of isomorphic field representation in the brain. For instance, magnetoencephalography (MEG) has been used to monitor brain activity during language processing and shown than EM field modulations are correlated with word processing (Wang *et al.*, 2000). A recent study (Pulvermuller *et al.*, 2001) has demonstrated that the earliest detectable MEG responses to word recognition (recorded about 100 ms after visual stimulation) respond to word semantics (the meaning of a word) rather than the sound or syntactic properties of the word. Gestalt information encoded by EM fields appears to accompany the 'meaning' of sensory information, in all its manifestations in the brain.

Section D: Grounding Meaning in the Field-Encoded Gestalt Information in the Brain

I now return to the problem of meaning and argue that the binding problem of meaning, outlined above, is solved if meaning is grounded in an EM field-based consciousness.

Unity. The problem alluded to above was the question of where an object such as the impossible triangle illustrated in Figure 1 could be represented in the brain. The answer I propose is the brain's EM field where all the information describing the triangle will be unified. Fields are always unified. That is what physicists mean by a field. Any field-based system must be described by a single unified wave equation. However, in quantum electrodynamics EM fields are considered to be a kind of sea of virtual photons that pop in and out of existence. But how big is each photon? The question makes no sense because photons have no fixed position outside of a measurement when they may be absorbed or emitted at a single point. In the absence of that measurement, photons may be considered to exist at all spatial points in the field simultaneously. Each *photon* thereby encompasses the entire volume of space in which the EM field has significant effect. Thus, if a photon is absorbed by a neuron in the brain, then the 'size' of the photon prior to its absorption by another neuron is simply the volume of space within which this phenomenon can occur. The *volume* of each photon in a field will thereby overlap with the *volume* of every other photon comprising the field and the information encoded by these photons (their frequency) will similarly overlap. Each point in the space of the field is thereby potentially receptive to the information encoded by the entire field. This fact is of course utilized in telecommunications where an antennae located at a single point may download information distributed over a vast area of space. In a very real sense, the field unifies the distributed information at the point of absorption such that a change in the firing state of any neuron in the network will be communicated to all neurons that are influenced by the brain's EM field. The field integrates and unifies the information encoded in the firing rates of all neurons to which it is causally connected.

So triangles, musical chords, words, and other whole objects will be represented in the brain by EM field perturbations that are isomorphic with the target object. This is where the meaning of these objects is grounded in consciousness. Once again I emphasize that I make no attempt here to resolve any of the deep philosophical issues associated with the relationship between percept and referent, but only to tackle what I call the *binding problem of meaning* and how it is grounded in the brain. This can be illustrated by considering the meaning of the word 'clone'. Thirty years ago the term would have been associated with terms such as 'genetically identical' or 'twin'; but since 2005 the term is invariably associated with the word 'Dolly' and the image of a sheep. My argument is that brains that now consider the word 'clone' generate EM field perturbations that are also generated by seeing or considering a sheep and are thereby isomorphic with a sheep. The gestalt information previously encoding the concept 'genetically identical' has, since 2005, become physically unified with gestalt information encoding sheep to cause the word 'clone' to acquire its sheepy meaning in human brains.

Context dependence. Fields are always context dependent. This can easily be seen by the fact that the value of the EM field strength at any point in space is a product of all the charges in its vicinity. Also, the value of the field at any point in space may simultaneously be a component of the representation of many nested and overlapping objects by the same field. So the field configuration that represents, say, a letter may also represent aspects of other objects, such as the word in which the letter is embedded as well as colours, sounds, or indeed any percept. Remarkably, recent research demonstrates that brain EEG patterns can represent several different objects in different frequency bands (Schyns *et al.*, 2011). For instance, when subjects were shown a picture of a face, beta EEG oscillations encoded two eyes whereas theta oscillations encoded the mouth. These field oscillations cannot be entirely independent so context will always influence the experience of field-encoded objects. This is very different from a neural representation the information encoding complex objects is dissected into numerous independent *bits* encoded within the firing rates of thousands of widely separated and independently functioning neurons.

Compression. Although from the viewpoint of an external observer the brain's EM field may be considered to be distributed throughout its volume, if we shift our frame of reference to the photons that comprise the field (where I claim awareness is located) then the situation looks very different. Photons travel at the speed of light, and since, according to general relativity, time slows down to stop at this speed, then from a photon's resting frame (and I am aware that considering a photon to have its own frame of reference is itself problematic), it takes no time at all to travel from its point of creation to its point of annihilation: 'the "time" that a photon experiences (if a photon could ever have experiences) has to be zero!' (Penrose, 2004). The photon exists at all points in the field simultaneously — it is everywhere at once. All information in a field is therefore instantaneously available to all points of the field that are causally connected. Meaning encoded in a field may indeed be 'grasped in a flash' by the photons that comprise that field. So the impossible triangle illustrated in Figure 1, or the image of Jenifer Aniston illustrated in Figure 5, will be grasped in a flash if the seat of awareness is the brain's EM field.

I should point out that although a photon may not 'experience' time in the normal sense of the word, the field generated by the brain will be continually remodelled by neural firing so that its informational content, and the information being downloaded from that field into neurons, will be constantly changing *in time*.

I should also like to emphasize that, just as in quantum electrodynamics where photons are treated as components of a coupled system of emission and absorption, so in the CEMI field theory consciousness is both a product of the neurons (photons emitted by neurons) and is *absorbed* by the neurons (through absorption of photons). Consciousness, like photons, is a strongly coupled system that does not exist independently of the emitters and absorbers in the brain.

Emergence. Emergence can be seen as the natural consequence of the context dependence of field encoding, as described above. Singular objects such as individual letters or musical notes can be represented by field configurations but, if the field simultaneously represents several such objects to form, for instance, words or musical chords, then the representation of the singular objects will be altered. Complex objects will thereby possess properties that cannot be predicted from a consideration of their parts.

Interdependence. If a field parameter is changed at one point in space then the entire field is instantaneously modified (although from an external frame the perturbation will be propagated at the speed of light). So any field-based representation of a part of an object will be dependent on the field-based representation of all other parts or indeed other objects represented by the same field.

Section E:
Application of the Theory to Consider Perceptual Illusions

The theory that meaningful percepts are associated with EM field-based isomorphic representations in the brain could be seen to be problematic when dealing with perceptual illusions where the percept is clearly not entirely isomorphic with the actual object. Consider the familiar Necker cube which spontaneously switches between two contrasting percepts, yet the visual input is the same. How can two different percepts, which according to the theory must be represented by two different EM field configurations in the brain, both be isomorphic with the same visual data?

However, this problem disappears when we realize that the isomorphism isn't necessarily with the actual object but with an idealized perceived object (just as the sheepiness in the word 'clone' is isomorphic with an idealized sheep not an actual sheep). In the case of the Necker cube, the actual object that is the source of the visual input is a collection of lines on two dimensional paper. That those lines are perceived as a cube indicates that the neural firing patterns associated with that visual input generate a particular EM field (gestalt information) that is isomorphic with a cube in the sense that it overlaps with the EM field that is generated by seeing an actual cube. Switching between percepts is also unproblematic: presumably the EM field perturbation generated by the lines on paper overlaps with the fields generated by seeing either forward or backward facing cubes. The dynamic system of the neurons is assumed to be bistable and capable of instantaneously flipping between either of the alternative states that are compatible with the visual input. The theory is also consistent with perceptual illusions, such as the Kanizsa triangle, where the percept includes features (edges and a triangle) that are not present in the visual input. In this case, the neurons processing the visual information are proposed to generate an EM field configuration that overlaps with EM field configurations generated by seeing an actual triangle, despite the fact that the edges and triangle are not present in the visual data.

Shifting awareness from the neurons to the field thereby provides a novel and illuminating perspective on the source of visual illusions. I propose that most are generated by discordance between the EM field configuration associated with the perceived object (which is isomorphic to an imagined real object) and the actual object. It is the conflict between these alternative viewpoints — the isomorphic representation in the brain and the actual visual data — that is the source of the illusion.

Conclusions

The conventional approach of western philosophy to the problem of meaning has been to claim that truth and meaning must be grounded in simple propositions whose truth is 'self-evident'. The problem for neurobiology is to discover how a physical structure in the brain can encode a truth that is 'self-evident' from the frame of reference of the encoding structure (rather than from an external frame, such as a decoding homunculus). In this paper I claim that conscious meaning is grounded in informational structures in the brain's electromagnetic field — gestalt information — that are isomorphic to the objects they represent. It is this analogue relationship, represented by some level of isomorphism between objects and their representation, which ultimately bestows information with its 'self-evident' meaning. Meaning is, however, meaningless unless it can be communicated. I therefore add that meaning must be grounded in gestalt information that can be communicated to a third party. The only known physical substrate capable of achieving this is the brain's EM field.

Processing information by harnessing an isomorphism between an object and its representation is the principle of analogue computing. Claude Shannon, the founder of the science of information, wrote in 1962, 'Efficient machines for such problems as pattern recognition, language and translation and so on, may require a different kind of computer than we have today. It is my feeling that this will be a computer whose natural operation is in terms of patterns, concepts and vague similarities, rather than sequential operations on ten-digit numbers' (Shannon, 1962). Similarly, John von Neumann, the inventor of the 'von Neumann architecture' that underpins all digital computers, wrote in 1963 of neural computation, 'The available evidence, though scanty and inadequate, rather tends to indicate that the human nervous system uses different principles and procedures [than digital computers]. Thus message pulse trains seem to convey meaning by certain analogue traits…' (von Neumann, 1963). Both these pioneers of the digital revolution recognized that the human mind was unlikely to operate like a conventional digital computer, but was more akin to an analogue computer.

Analogue computers were built alongside the first digital computers, with machines like the *differential analyser* developed by Vannevar Bush at MIT in the 1950s, which performed mathematical operations by converting equations into a configuration of rotating shafts and gears (an isomorphic transformation). Despite their success in efficiently performing the operations for which they were designed, they were rapidly superseded by their digital counterparts. This was primarily because, compared to digital computers, they were so hard to program. The logic of their calculations was built into their structure (as intrinsic information) so changing the program amounted to rebuilding them. For the differential analyser, this meant that each calculation needed a different arrangement of shafts and gears, obviously a much more cumbersome transformation than reprogramming a digital computer.

However, the architecture of the brain is far less rigid than a mechanical device and its structure is constantly changing under the influence of both individual experience and evolutionary pressure. It may not be easy to engineer a flexible analogue computer, but it may be possible to evolve one. I propose that our conscious mind is such a device — a flexible analogue computer evolved out of the neuronal architecture of the brain that uses the brain's EM field or CEMI field (McFadden, 2002a,b) to process gestalt information. In reality, only remnants of the informational content of a perceived object will be captured in the brain's EM field. Yet the field integrates these aspects into a single physical system — a gestalt — whose structure is isomorphic with aspects of the original object (or at least its impression on sensory receptors) and thereby encodes its meaning.

The ability of the CEMI field to integrate distributed information effectively converts extrinsic information encoded in neurons into intrinsic information — a kind of virtual object — in the CEMI field. I propose that it is these gestalt virtual objects that are manipulated by the conscious mind, both in visual imagery (Pinker, 1980) but also in all conscious thought which requires manipulation of meaningful data, such as the use of language. And just as in the above example where the combined height of a set of objects was (analogue) computed (by a set of weighing scales) after transforming heights into weights, so the conscious mind may be capable of performing holistic analogue computational operations on objects represented as gestalt information in the brain's EM field. Indeed, MacLennan (1999) has proposed that the brain is capable of field computing (which has many of the attributes of quantum computing) that may perform some operations with greater efficiency, or with fewer resources, than can be achieved in a digital system. In a similar way, optical holograms can perform convolution, deconvolution, and Fourier transforms at the speed of light, acting on massively parallel data sets. Conversely, I suggest that it is their inability to process gestalt information holistically that accounts for the failure of digital computers to handle meaning, understanding, or common-sense knowledge.

Moreover, since isomorphic intrinsic information may, like the objects they represent, possess properties, so it is reasonable to ascribe properties to the gestalt informational objects encoded in the brain's EM field. As proposed in my earlier paper, awareness may be a property of information experienced from the frame of reference of the physical substrate encoding information. Just as magnetic and electrical forces are properties of the same system (electromagnetism) experienced from different frames, so awareness and information may be two aspects of the same system, gestalt information, experienced from an inner or outer frame of reference. Our only access to the inner frame of reference (and thereby the *experience* of gestalt information) is to experience it from the inside (since any other experience of gestalt information is from an external frame of reference). However, this experience is only observable if the gestalt information is capable of manipulating a motor system that is capable of communicating its experience, as in the CEMI field theory. Consciousness, as a scientific concept, is thereby limited to systems that encode gestalt information and have access to a motor system: the human brain (and possibly the brain of higher animals). Panpsychism is thereby avoided and consciousness is understood as a dynamic property of gestalt information.

However, it is important to emphasize that the CEMI field theory does not propose that the whole brain is involved in this type of information processing. There is little doubt that most of what the brain does — all of the unconscious operations that are performed by the brain — is achieved through the actions of neurons, action potentials, and synaptic transmission — digital and symbolic computing. But, as argued in my earlier papers, such a system, although functional, cannot account for consciousness; and, as argued in this paper, meaning cannot be grounded or bound in such a system. The information underpinning meaning, understanding, and common-sense knowledge is holistic and gestalt in character. This gestalt information can only be encoded in a physical field: the CEMI field.

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