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Bergson and the holographic theory of mind

Stephen E. Robbins

Abstract Bergson's model of time (1889) is perhaps the proto-phenomenological theory. It is part of a larger model of mind (1896) which can be seen in modern light as describing the brain as supporting a modulated wave within a holographic field, wherein subject and object are differentiated not in terms of space, but of time. Bergson's very concrete model is developed and deepened with Gibson's ecological model of perception. It is applied to the problems of consciousness, direct realism, qualia and illusions. The model implies an entirely different basis for memory and cognition, and a brief overview is given for the basis of *direct* memory, compositionality and systematicity.

Key words Bergson · holography · time · perception · memory · cognition · qualia

Introduction

That Merleau-Ponty acknowledged his early debt to Bergson, I am sure is well known in the phenomenological community. I think it safe to say that Bergson was the proto-phenomenologist. His entire philosophy was born in the moment of his absorption in the concrete experience of time.

> Below homogeneous time, which is the [spatial] symbol of true duration, a close psychological analysis distinguishes a duration whose heterogeneous moments permeate one another; below the numerical multiplicity of conscious states, a self in which succeeding each other means melting into one another and forming an organic whole. (Bergson, 1889, 128)

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But this model of time presents a very real alternative to both the symbolic manipulation and neural net models current today. It was made, even then, as concrete as possible given then-current physics. Despite what might appear to be, on the basis of current expositions of Bergson, an exotic philosophical theory of mind, there dwells within it a model that is far more specific for cognitive science than is realized. It became my goal, on first reading Bergson, to translate this haunting theory into the current language and concerns of cognitive science (Robbins, 1976). But to do so with any effect means that one must offer something as concrete as the current metaphors of that discipline.

This is not to say that the model I am about to present is as concrete as possible. There is far more work for neuroscience to do. But the case can be made that Bergson's model can be made sufficiently detailed, when updated with the work of recent science, to provide the outlines of a dynamic mechanism. Gibson's ecological perception, we shall see, is a particularly important contributor to this project.

What type of 'device' then was Bergson trying to paint with both his abstractions and his beautiful metaphors?

Bergson's model of perception

Everything begins with the problem of perception. Without solving the problem of perception, one has no base for a theory of memory or cognition. Perception is another name for *experience*. If you do not know what experience actually is, how can you have a theory of its 'storage'? If you do not know how experience is stored, how can you have a theory of cognition, the essence of which is to use stored elements of experience in thought? Such a theory inherently rests upon symbols that are derived from this experience. As such, you cannot know what 'symbols' actually are. Indeed, your theory of perception may reveal, as we shall see, that experience is not something that can be stored, and the notion of a symbol, defined upon this experience, may obtain a far different meaning from that envisioned by a science rooted in the computer metaphor. This has been the sin, so to speak, of cognitive science. It has presumed it can proceed without having solved the problem of perception. This is sadly not the case.

What do I mean by the problem of perception? I will be concrete. We are asking how the white-china coffee cup on the table before you, with wisps of steam rising and cream-brown liquid surface being stirred, is seen as external, in volume, in depth, in space. Yes, to solve this problem, you must solve all the modern problems of consciousness as they are understood. You must solve the problem of qualia, the explanatory gap, the homunculus.

Bergson clearly understood these problems. His solution is powerful and elegant. It rests in this passage on the problem of perception. In addressing the origin of the image of the external world, and denying that the brain produces a 'photograph' (or representation) of this world, he argued:

> But is it not obvious that the photograph, if photograph there be, is already taken, already developed in the very heart of things and at all points in space. No metaphysics, no physics can escape this conclusion. Build up the universe

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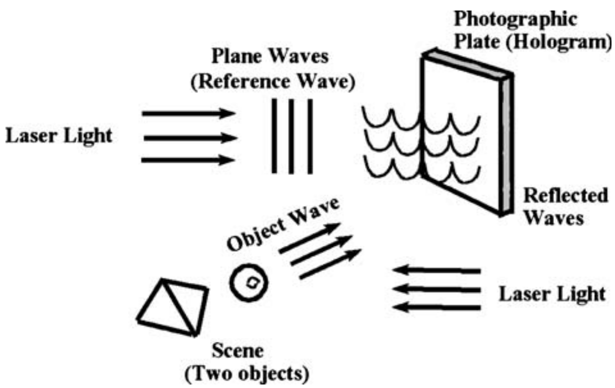
> with atoms: Each of them is subject to the action, variable in quantity and quality according to the distance, exerted on it by all material atoms. Bring in Faraday's centers of force: The lines of force emitted in every direction from every center bring to bear upon each the influence of the whole material world. Call up the Leibnizian monads: Each is the mirror of the universe. Only if when we consider any other given place in the universe we can regard the action of all matter as passing through it without resistance and without loss, and the photograph of the whole as translucent: Here there is wanting behind the plate the black screen on which the image could be shown. Our 'zones of indetermination' [organisms] play in some sort the part of that screen. They add nothing to what is there; they effect merely this: That the real action passes through, the virtual action remains. (1896/1912, pp. 31–32)

By the 'photograph developed in the very heart of things and at all points in space', Bergson was envisioning the matter-field as a dynamic interference pattern—a holographic field. This was 50 years before Gabor discovered the principles of holography. Yes, others such as Pribram (1971) have attempted to use holography in a theory of mind, but none as did Bergson. To understand the significance of this passage and the way in which Bergson's model of perception works, we must review several things: the principles of holography, J.J. Gibson's theory of perception as 'direct specification' and the role of invariance laws, and some implications of current physics.

Holography

The 'hologram' was discovered by the British-Hungarian scientist Dennis Gabor in 1947. Holography is defined as *the process of wave front reconstruction*. In considering one of the several methods of constructing a hologram, the principles we require for understanding the process are simple. Figures 1 and 2 illustrate both the process of construction and the nature of a hologram. It can be seen from these figures that a hologram is essentially the record of the interference pattern of two light waves. The *reference* wave is usually emitted from a source such as a laser (Figure 1) which provides our very 'coherent' form of light. Coherence refers to the

Figure 1 Holographic construction.



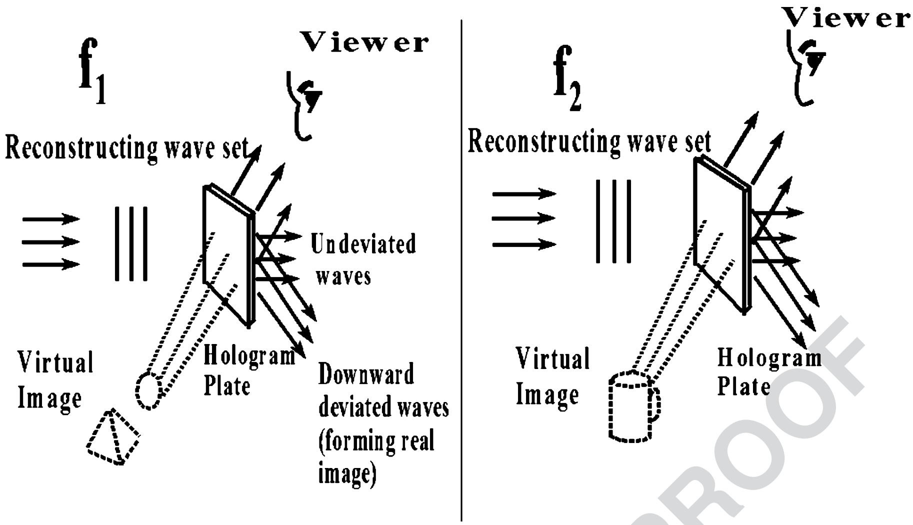


Figure 2 Holographic reconstruction. The reconstructive wave, modulated to frequency 1, reconstructs the stored wave front (image) of a pyramid/ball. The reconstructive wave, modulated to frequency 2, now reconstructs the wave front of the cup.

purity of frequency. A light wave containing only a single frequency of light is perfectly coherent. The *object* wave arises from light reflected off the object of which we intend to make a hologram.

When a *reconstructive* wave – a wave of the *same frequency* as the reference wave – is beamed on the photographic emulsion containing the interference pattern of the two waves, the original wave front is reconstructed (Figure 2, left). The reconstructive wave is diffracted as it passes through the plate, analogous to what happens to water waves as they flow through a line of barriers and bend around them, though in this case the 'barriers' are the loci of constructive (+ +) and destructive (+ −) interference. Figure 2 shows that one set of waves travels downwards while yet another set passes through undeviated. A third set travels upwards in the same direction that the complex object wave in Figure 1 would have been moving. A viewer in the path of these upward waves then believes himself to see the source which generated the wave-set located in depth behind the hologram and in three dimensions. We might say then that the upward traveling waves 'specify' the nature of their source of origination, namely a pyramid form with a globe in front of it. These waves specify what is termed the *virtual* image.

There are two major properties of holograms we should review. Firstly, we can consider each point of an illuminated object as giving rise to a spherical wave which spreads over the entire hologram plate. Thus we can consider the information for each point to be spread over the entire hologram. This implies, conversely, that *the information for the entire object is found at any point in the hologram*. In fact, we can take a small corner or 'window' of the hologram of the pyramid scene in Figure 1 and reconstruct the image (wave front) of the entire scene with a reconstructive wave. In principle, any point of the hologram carries sufficient information to reconstruct the whole scene.

Secondly, it is possible to record a multiplicity of wave fronts on the same holographic plate. We can do this by changing the frequency value of the reference wave. Thus we could make a hologram of a pyramid and ball, a chalice, a toy truck, and a candle successively, using reference waves of frequency f1, f2, f3, and f4 respectively. By *modulating* the reconstructive wave, i.e., changing its frequency appropriately from frequency f1 through f4, we could reconstruct the successive wave fronts which originated from each object (Figure 2, left/right). The degree of resolution of image separation is a function of the coherence of the reference and reconstructive waves. The more finely we can modulate these waves to a single frequency, the more distinctly separate and clear will be the reconstructed wave fronts. If, however, we were to illuminate the plate with a diffuse, non-coherent wave, we would reconstruct a composite image of all the recorded scenes.

Let us begin to consider the subject of perception. We seek the principle by which the perceived external image – in volume, in depth – can be the result of a process that is as physical as the image generated by holographic reconstruction. The nature of this image, we shall see, is transformed under considerations of time. But it is external *events* that we perceive. The coffee cup on the table before us is simply a special case of an event. The coffee cup, with its coffee being stirred, the surface swirling, the steam rising, the spoon clinking, is a dynamic event. It is simultaneously an experience. We are about to define the elements of this experience.

Gibson and invariance

Gibson's (1950) fundamental insight came in recasting the problem of depth perception. When considered from the viewpoint of Newtonian space, as stated by Berkeley, a single static eye could not give any information about the third dimension since the latter consisted of the line of sight itself, a line represented by only a single point on the retina (Figure 3, line ABCD). There is nothing to indicate whether the point is near or far, for the point remains invariably the same on the retina. Thus, according to Berkeley, "distance of itself, and immediately, cannot be seen". This led to a history of attempts to account for the perception of distance in terms of 'depth cues', and ultimately to 'judgments' and mental operations for *inferring* depth. Gibson, however, turned to the notion of the 'ground', and the problem was reformulated such that it became how the continuum of distance across the ground in all directions is visually perceived. Thus the problem became how the different distances, w, x, y, z on the ground line G_1G_2 are perceived (Figure 3). Note that when the eye is put in motion, something varies on the retina in this situation, while in the older formulation the distances always project to the same point. Note also that the relative distances zyxw are preserved under the projective transformation indicated, i.e., they are projectively invariant. This projective invariance is the basic grounding of the mathematics characterizing an event. Let us consider an event—'coffee stirring'.

The common event of stirring coffee is immensely mathematically rich. If the cup rests on a placemat on a tiled table, it rests on a texture density gradient (Figure 4). The tiles are our texture 'units' and have a decreasing horizontal separation (S) as a function of the distance, $S \propto 1/D$, and vertically as $S \propto 1/D^2$. These gradients are ubiquitous—beaches, fields of grass, tiled floors, rugs, etc. If the cup is moved

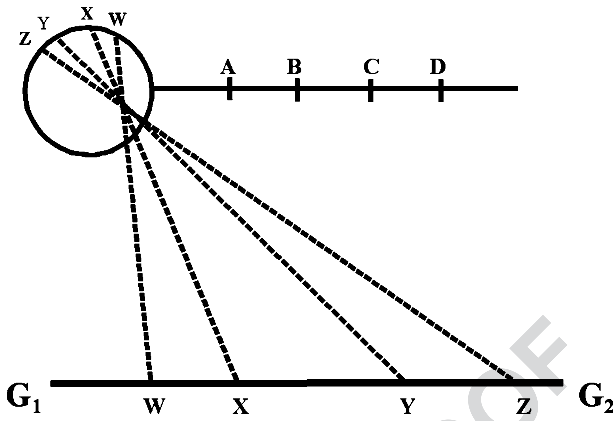


Figure 3 The 'ground' (after Lombardo, 1987).

towards us across this gradient, the size constancy of the cup as it moves is being specified, *over time*, by the invariant proportion, S∝1/N, where S is the (increasing) vertical size of the cup on the retina, N the (decreasing) number of texture units it occludes (SN=k).

When the gradient itself is put in motion, as the subject moves towards the table, it becomes an optical flow field—a gradient of velocity vectors where there is an increasing point velocity as the distance from the eye decreases, $v \propto 1/d^2$, all radiating from a single point, the point of optical expansion (Figure 5). Let us suppose further, that the cup is cubical in structure. If the cup is rotated, then as a side rotates into view, an expanding flow gradient is defined, and as the side rotates away, a contracting flow gradient is defined (cf. Domini, Vuong & Caudek, 2002). The top surface becomes a radial flow field. The cup's edges are sharp discontinuities in these flows. If the cup is static (it can never truly be so given the saccadic motion of the eye), and the spoon is stirring the coffee, another form of radial flow field is created. When we poured the coffee into the cup, the rate of increase of the pitch of the sound as the cup fills with liquid is an invariant specifying the (visual) time it will take for the cup to fill to the brim (Cabe & Pittenger, 2000). There are other symmetry or invariance laws, we shall see, supporting the *form* of the cubical cup (cf. Robbins, 2004a).

The stirring motion of the hand is a complex of forces. The use of the spoon is a form of 'wielding'. The moments of force here are described (cf. Turvey & Carello,

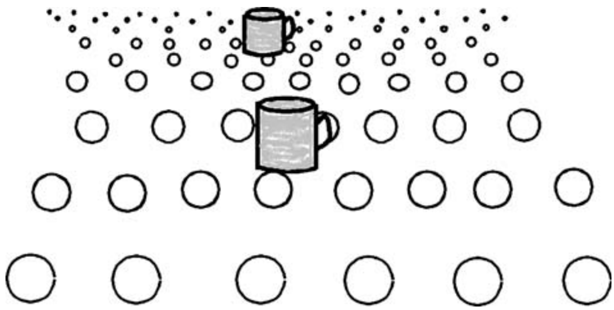


Figure 4 Texture density gradient (Gibson, 1950). The horizontal separation, S, is proportional to the distance, or S∝1/D, the vertical separation as $S \propto 1/D^2$. The cups on the gradient can be viewed as the same cup in two different positions.

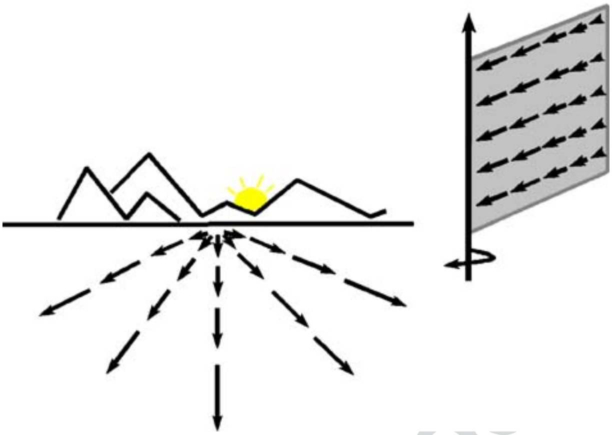


Figure 5 Optical flow field. A gradient of velocity vectors is created as an observer moves towards the mountains. The flow field 'expands' as the observer moves. *At right*, the flow as a flag rotates towards the observer (after Robbins, 2004a).

1995) under the concept of the 'inertia tensor'. Over the periodic motion of the stirring spoon, there is likewise a haptic flow field defined, and within this, there is an adiabatic invariant—a constant ratio of the energy of oscillation to the frequency of oscillation: Energy of Oscillation/Frequency of Oscillation=k. (Kugler & Turvey, 1987).

This is the beginning of what we can term the *invariance structure of an event*, which we can define as a specification of the transformations and structural invariants defining an event and rendering it a virtual action. The transformations define the information specifying the form of the change—rotating, swirling, flowing. The structural invariants define the information specific to that undergoing the change—a cup, a liquid, a field of grass or stretch of gravel. Let us begin to relate this to action. Over this flow field a value, τ, is defined by taking the ratio of the surface (or angular projection) of the field at the retina, r(t), to its velocity of expansion at the retina, v(t), and its time derivative. This invariant, τ (or tau), specifies time to impending contact with an object or surface, and has a critical role in controlling action (Kim, Turvey & Carrelo, 1993). A bird coming in for a landing, must use this τ value to slow down appropriately to land softly. As the coffee cup is moved over the table towards us, this value specifies time to contact and provides information for modulating the hand to grasp the cup (Gray & Regan, 1999; Savelsbergh, Whiting & Bootsma, 1991).

Gibson's direct specification

For Gibson, the world is 'directly specified' by this information; there is no 'code' for the world created in the brain for a homunculus to unfold, no theatre of consciousness. To unfold a code, the homunculus would already have to know what the world looks like. Three dots in your neural matrix so to speak, '...', can stand for an 'S' in Morse code, the number three, the three blind mice or Da Vinci's nose. The domain of this code mapping must already be known. This is the 'coding problem'; it is the problem of representation at its most essential, and its solution is critical to the problem of perception (Bickhard & Ritchie, 1983; Robbins, 1976). For Gibson

(1966), then, the brain merely 'resonates' to this richly structured information. His 'resonance' is now understood as prefiguring the attractors of a dynamic system.

Suppose, then, the event of stirring coffee, and to appreciate the full dynamics that might be involved, let the cup be rotating, successively presenting its flow field-sides and simultaneously moving towards us across the table's gradient surface. When stirring this (moving) cup of coffee, we are involving multiple areas of the brain—visual areas, motor areas, auditory areas, haptic areas. Even the action-goal of 'stirring' must be supported by the pre-frontal areas. Over these, we have a resonant feedback from the multiple re-entrant projections between all areas which supports a dynamical pattern occurring over time. For practical purposes, we have a near-global, time-extended pattern supported over the brain. The pattern (attractor) in some form must support the ongoing invariance structure of the coffee-stirring event being specified in perception.

With this conception we have the following picture: On the one side, we have the *image* of the rotating coffee cup, moving across a gradient. On the other side, we have the brain—a dynamically transforming neural network supporting, we can posit, an attractor. The form of the attractor has some structural relation to the information defining this rotating cubical cup, including its symmetry period. But the attractor can look nothing like the transforming cubical cup; this dynamic pattern can look ultimately nothing like the phenomenal experience. The pattern is 'specific' to the environment, but this environment, as optic array, and especially at the micro-scale of time – the time-scale at which we deal with the life-span and death of mesons and vastly less – looks nothing like our phenomenal experience either. We have perhaps the worst of 'codes'. We do not know how the transition step is effected. There is a gap between our picture of what is going on in the brain, and the experience of the world-out-there. We face the infamous 'explanatory gap'.

Gibson had tried to cross the gap by arguing that the attractor or resonance is 'specific' to precisely what is going on in the field external to the brain, i.e., specific to the structure of the field over a time-extent. But to be more precise, the attractor must be specifying precisely what *was* going on in the external field. As the brain is inherently reacting to or processing information over some period of time, the attractor it supports must be specific to a *past* time-extent of the field at a given scale.

Rather than unpacking a code, Gibson was trying to locate his extremely dense and highly structured perceptual content within the equally highly-structured, external matter-field, in fact, within a past time-extent or portion of the transformation of this field. But how can this be done? At this point, Gibson ceased theorizing.

Extending Gibson

How, we are asking, can there even be an *image* arising from this 'specification' via the dynamical, 'resonant', codeless pattern (or attractor) supported over the dynamics of the brain? Well, in fact, we have seen a process like this already described, namely holography. What if, we can ask, the brain were *within* a hologram? The hologram, as Bergson envisioned, would need be formed by the matter-field itself. Physics itself has come to view this matter-field nearly routinely as a vast dynamic interference pattern (cf. Beckenstein, 2003). Let us take this as a postulate. Then, we can ask, what if the brain were a *modulated reconstructive wave* passing through this hologram? The information in the field-wide, dynamic interference pattern the wave is picking out and specifying would be precisely the invariance laws or invariance structures described by Gibson. The wave would be ‘modulated’, the modulated pattern being a function of the invariance structure of the dynamically changing event, e.g., our rotating flow field-coffee cup moving towards us across a texture gradient.

Viewing the brain as supporting a wave is quite realistic. Yasue, Jibu and Pribram (1991) argue for the evolving brain states in terms of complex valued wave flows, where constraints on the brain’s (state) evolution are elegantly represented by Fourier coefficients of the wave spectrum of this formulation. Glassman (1999), for example, attempts to account for the limited capacity of working memory by viewing the brain, globally, as a set of waves whose frequencies are confined to a single octave. When considering the near-global, time-extended, feedback- resonant pattern supported over the brain, it is not a great leap to construe this as a wave, and holographically, as a reconstructive wave. In essence, we are saying that this resonant neural activity, which we have tended to view as simply supporting an abstract set of *computations*, may well be intended for a far more concrete purpose, as concrete as the dynamics of an AC motor. The motor has as its purpose the generation of a field of force; the dynamical brain is intended to generate a very concrete waveform, a wave which supports a broader form of computation, broader than Turing’s narrow definition, but consonant with his larger vision (cf. Copeland, 2000; Robbins, 2002).

This is, in part, how Gibson’s ‘specification’ could be conceived, and how it could give rise to an invariance-structured, external image, an image precisely where it appears to be, in the external world, without recourse to unpacking a code for this world. The brain is a *decoder*; it is the reconstructive wave that is unpacking the ‘code’ in the holographic field. But there are three major areas we must yet address. I have stated that the specification is to the *past*, i.e., to a past form of the motion of the matter-field. How is this possible? Let us approach this together with another element of the problem, the homunculus. The difficulty is in Figure 2. Who ‘sees’ this image? We hope not a small viewer seated in a control room in the brain. We need to remove the ‘viewer’. This is where we need to bring in Bergson’s yet larger framework. Finally, we wish to relate all this concretely to action, for in Bergson’s succinct phrase, *perception is virtual action*.

The wobbly cube

To understand how perception is of the past motion of the matter-field, it is profitable to embed the question in the problem of the perception of form. Let us consider a demonstration discussed by Shaw and McIntrye (1974) with a cube constructed of wire edges and rotating at a constant speed. Every such object has a symmetry period. If we consider rotational symmetry, the period is given by the number of times the object is mapped onto itself or carried into itself in a complete rotation of 360°.

If the room is dark and we strobe the cube periodically, the form that is actually perceived is totally dependent on whether or not the periodic strobes preserve this symmetry (invariance) information! Suppose the cube rotates fully, 360°, every second. If we strobe in phase with or at an integral multiple of this period, for example 4, or 8, or 12 times/s, an observer would see, as we might expect, a cube in rotation (Figure 6). But if the strobe is out of phase, what is perceived is not a rigid cube in rotation, but *a distorted, plastic, wobbly object*.

Why does the rigid cube become a plastic-like, wobbly object? Why does the out-of-phase strobe cause the brain to perceive a non-rigid object? Do we not consider the *form* of something – a table, a chair, a cube – utterly set, static, completely given at a glance? The strobe is essentially taking snapshots of the cube. Why are these snapshots not sufficient to specify the rigid cubical form we would expect? Why are they not sufficient to specify the straight lines, straight edges, corners or vertices—the standard 'features' of a cube? The strobe occurs over time. What is there about the brain and time that makes even *form* a function of time?

Flow fields and form

Current perception theory sees perceived form as derived from velocity fields (Figure 5) in conjunction with Bayesian constraints. The models (known as 'energy' models) are built upon arrays of elementary spatiotemporal filters, and such filters, because of their limited receptive fields, are subject to the aperture problem (Figure 7). As such, the estimate of velocities is inherently uncertain, forcing a probabilistic approach (Robbins, 2004a for a review). The fundamental constraint used by Weiss, Simoncelli and Adelson (2002) is 'motion is slow and smooth'. The energy model/constraint explains many illusions. Applied to the velocity fields defining a narrow rotating ellipse, the 'violation' of this constraint ends in specifying a non-rigid object if the motion is too fast (Mussati's illusion; Mussati, 1924; Figure 8). If we were to consider a 'Gibsonian' cube, this becomes a partitioned set of these velocity fields. As each side rotates in to view, an expanding flow field is defined. As the side rotates out of view, a contracting flow field is defined. The top of the cube is a radial flow field. The 'edges' and 'vertices' of this cube are now simply sharp discontinuities in these flows.

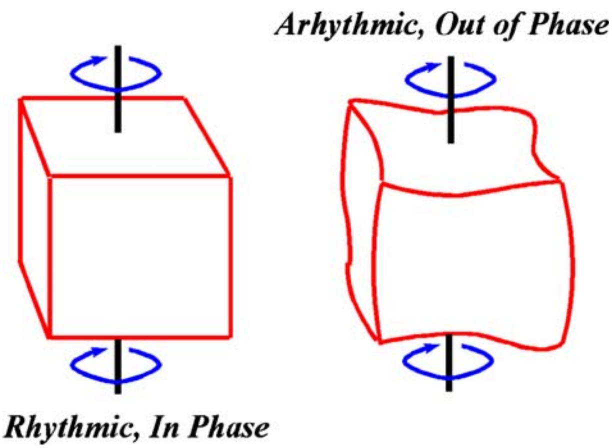


Figure 6 Rotating cubes, strobed in phase with, or out of phase with, the symmetry period (after Robbins 2004a).

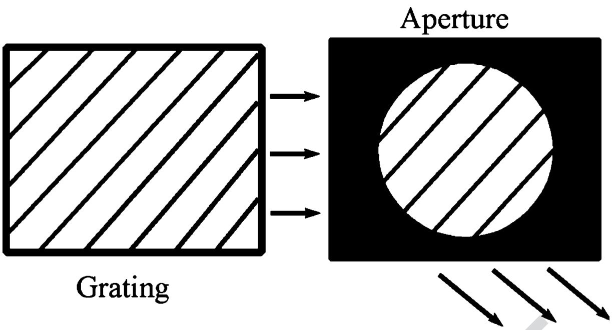


Figure 7 The aperture problem. The card with the grating is moving to the right, and passes beneath the card with the circular aperture. The ends of the moving lines are now obscured, and only the downward motion of the lines is seen in the aperture.

All form, then, from the energy model perspective, is an optimal specification given the inherent uncertainty of information. We must now approach a fundamental problem noted by Bergson (1896/1912, pp. 266–277), the importance of which is essentially ignored—the origin of the *scale* of time imposed by this dynamical or ‘resonant’ brain. For, as we shall see, *scale implies quality*.

Dynamic systems and time

The cube, rotating at a certain rate, and perceived as a cube in rotation, is a function of a scale of time imposed by the dynamics of the brain. Let us take our rotating cube and gradually increase the velocity of the cube’s rotation. With sufficient increase, it will become a serrated-edged figure, and at a higher rate, a figure with even more serrations. Finally, it becomes a cylinder surrounded by a fuzzy haze. Each of these figures is a figure of 4n-fold symmetry—8-edged, 12-edged, 16-edged..., with the cylinder a figure of infinite symmetry (Figure 9). In total, this transitional series

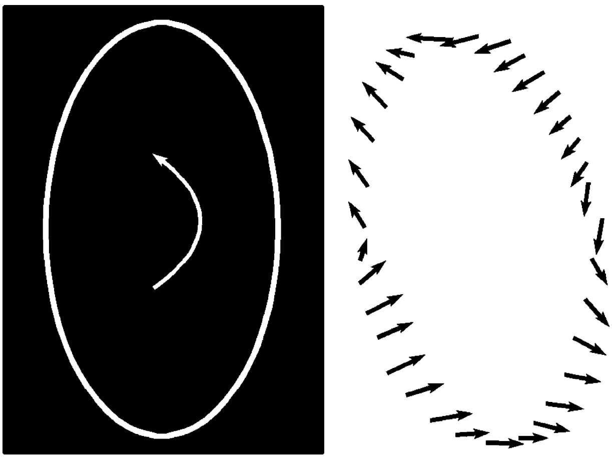


Figure 8 The normal velocity vector components (*right*) of the edge of the rotating ellipse (*left*). These tend to induce non-rigid motion (after Weiss & Adelson, 1998).

of forms reflects the scale of time in which we normally dwell. Each form is a different quality. While never in the standard lists of qualia exemplars – 'pains', 'reds', 'the taste of cauliflower' – nevertheless, form *is* qualia.

Let us perform a thought experiment. We have considered increases in the velocity of the cube's rotation. Symmetrically, we can consider increases in the velocity of processes underlying the dynamics of the brain.

This dynamics rests upon a hierarchy of scales—the electron, molecular, chemical, neural. It is a *coherent* system—a change at any hierarchical 'level' affects the whole. At bottom then, this dynamics rests utterly on its lowest 'level'. Again, arbitrarily, we can focus on the chemical level where processes are proceeding with a certain chemical velocity or rate of flow. Below this level we know that all is dependent on the appropriate orientation of certain bonds, on the properties of electron shells, the availability of orbits to occupy, etc. Let us ask a 'what if' question. What if we were to change the chemical velocities underlying this entire system and its dynamics? What if, as Hoaglund (1966) suggested, we introduce a catalyst (or catalysts)? The effect of a catalyst is simply to promote a reaction that would not begin at all at normal body temperature, or which would occur and continue only if supplied by a large amount of energy available only at a high temperature. An enzyme, as a catalyst, by orienting appropriate bonds, enables a reaction to proceed at body temperature, reducing the energy of activation normally required to initiate the process.

I am asking an *in principle* question here. It is not material at this point if we know exactly what this catalyst or set of catalysts is, though in point of fact, as Hoaglund notes, even temperature can change chemical velocity. We are asking about an in principle possibility, and if it is possible in principle, we are also asking if nature can have failed to allow for it. Let us remember then, if we introduce this catalyst(s) into our chemical level, that the system is coherent, that there are no preferred levels, and thus the system as a whole – the global dynamics – must be affected.

Scale and invariance

Let us suppose a catalyst that *increases* the chemical velocities. As a shorthand, in keeping with the nature of a catalyst, we can say that we are raising the 'energy state' of the system. What might be the effect on our rotating cube? Suppose that the system is in its normal state, and that the cube is spinning at sufficient velocity to be perceived as a cylinder. Now we begin gradually increasing the strength of our catalyst (or catalysts). We would expect the cube to transition, in reverse order from Figure 9, from a cylinder through figures of 4n-fold symmetry (where n decreases) until we arrive at the cube in slow rotation, and beyond to a motionless cube. The

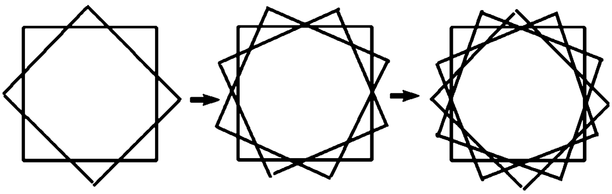


Figure 9 Successive transformations of the rotating cube (2-D view) through figures of 4n-fold symmetry as angular velocity increases.

form of the cube is again specified by an invariance law. Invariance (or conservations) under scale transformations is termed *gauge* invariance (cf. Kugler & Turvey, 1987, on invariance laws).

To borrow from physics, we would say that we are gradually changing the 'space–time' partition. In the relativistic version of these partitions, the space–time partitions correspond to measures of distance and time taken with respect to the states of motion of observers. It is only invariance laws ($d=vt$, $d'=vt'$) that hold across such partitions. Each observer obtains a value for distance in his system by the same law (distance equals velocity×time), though the measure of time used by each is different due to their relative motion. It is only the invariants that are the realities of Einstein's relativistic universe.

Imagine that we are watching a fly 'buzzing' by. The fly's wings are oscillating at roughly 200 cycles/s. The 'buzzing' fly, his wings a-blur, represents this 'history' of oscillations summed as it were in a single visual display. The dynamics of the system at normal scale are not sufficiently fast to show the fine grain of the events. But as we increase the chemical velocities underlying the dynamics, we are increasing the system's ability to specify the fine grain of the event. With sufficient strength of catalyst, we can posit that the fly could now be perceived as slowly flapping his wings—like a heron. And again, a new quality.

Consider the aging of the facial profile. Normally, this is an extremely slow event. Yet we recognize easily a face that has aged many years since our last observation. Pittenger and Shaw (1975) have shown that this transformation is specified by a strain transformation applied to a cardioid, where the cardioid is centered roughly on the temple (Figure 10). (A cardioid is a heart-shaped geometric figure with a precise equation.) Were the event sped up, the dynamically transforming head would be specified by the same law.

In general, then, the structure of experience is determined by the form of *information* (read law) 'processed' by the brain that, (a) holds across these possible space–time partitions and, (b) determines the form or event structure of the scaled external image. The significance of this should be re-emphasized: if the dynamics of the brain is indeed subject to this potential variability, then nature, in respecting this, can only be responding to invariance laws as the only form of information valid across space–time partitions. Such information is inherently four-dimensional.

We can think about this in terms of a ratio. We have numbers of elementary events occurring in the external environment. Call this E. Let us suppose E here is defined by the 200 cycles/s of the wing beats of the fly. We also have numbers of elementary processing events occurring in the brain or the organism. Call this O. At normal scale, for the sake of simplicity of example, we shall suppose these elementary processing events, however we might define them, happen to be 10/s. Our E/O ratio is thus 200/10 or 20/1. This ratio corresponds to, or underlies, the 'buzzing' fly of normal scale. Let us say, when we administer our catalyst, we speed up the chemical velocities such that now the number of elementary processing events in O is 50/s. The E/O ratio is now 200/50, or 4/1. Perhaps this ratio corresponds to the scale of the heron-like fly, barely moving his wings. The dynamics of the brain then implies this ratio or *proportionality* upon the elementary events of the external matter-field.

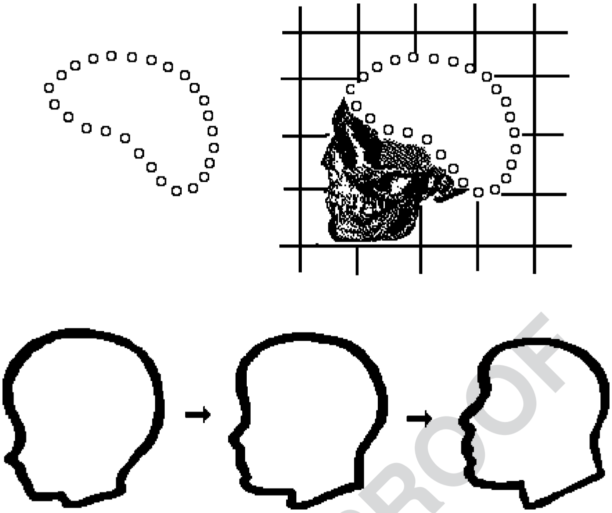


Figure 10 Aging of the facial profile. A cardioid is fitted to the skull and a strain transformation is applied. (Strain is equivalent to the stretching of the meshes of a coordinate system in all directions.) Shown are a few in the sequence of profiles generated (adapted from Pittenger & Shaw, 1975).

Consider then Messrs. A and B. Let B have increased chemical velocities. The razor-thin instant or ‘present’ of the transforming matter-field is the same for both. A sees the ‘buzzing’ fly—hundreds of wing beat cycles forming A’s ‘present’. For B, the fly’s wings are barely ‘inching along’. For B, a wing-position ‘a few seconds of an arc ago’ is in the vastly far past. The hundreds of cycles comprising the ‘buzzing’ perceived by A as his ‘present’ are vastly in B’s past. Does B have the right to say all these are *non-existent*, being preserved only by A’s memory? Yet we could imagine a being C, at even higher process velocity and yet smaller scale of time, arguing the same of B’s minute changes of wing position.

In essence, we have introduced a ‘relativity principle’ that makes it extremely problematic to assign a function to some ‘primary memory’ by which the ‘past’ is preserved from non-existence and the perception of time-extended form is enabled. It what sense is this a ‘memory’? In what sense, if we can simply attribute a change of the extent of its retention of the past (the number of events stored) to a change in the underlying dynamics? The basis for the memory which supports these extents in perceptions and the forms of these perceptions is a far from simple concept of a ‘memory’.

The problem of time-extent—primary memory

Scale implies extent. Some form of memory is required to support the time-extended experience of ‘rotating’ cubes or ‘buzzing’ flies. I am appropriating the term ‘primary memory’ here. I mean a form of memory even more fundamental than the sense in which James (1890) used the term. What is the nature and origin of this memory?

Let us put the question more concretely: how does the brain support the perception of a rotating cube? It is a natural theoretical tendency to model this as samples or snapshots of the event, where the snapshots are stored in a short-term or immediate memory medium, or ‘iconic’ store, etc., allowing the motion to be reconstructed. The event of the rotating cube would be parsed into a series of slices, each consisting of a frozen, static snapshot comprised of the static features of the cube – edges, vertices, surfaces – at some position along the imagined circle of the rotation.

The 'sampling model' of the memory supporting the perceived event is inherently flawed. Each sample is only a static state. A series of such states is simply a series of static states. We have lost the motion. Do we introduce some sort of 'scanner' within the brain to scan the stored samples? Then we must explain how the scanner perceives motion. We begin the temporal form of the (homuncular) infinite regress.

There are other difficulties. For Shaw and McIntyre's wobbly non-cube, a strobe in-phase with the cube's symmetry period allowed the brain to specify a cube in rotation, while an out-of-phase strobe specified a plastic, wobbly object. The strobe flash is equivalent to a sample. A brain-driven sampling mechanism, to allow the specification of a cube-in-rotation, would have to be pre-adjusted to the symmetry period of the cube—a form of pre-cognition. And if there were two or three cubes rotating at different rates?

The sampling model also implies a set of static features within each sample—edges, vertices. But we have seen that these are only ephemeral constructs to the brain—sharp discontinuities in velocity fields, features which themselves, in the global specification of the form, are functions of Bayesian constraints. Destroy or change these constraints, the 'features' disappear.

Sampling provides no answers. But why bother to invoke sampling in the first place? We need only to imagine the continuous processes underlying the neural firing as the support for the ongoing perception. Taylor (2002), for example, notes:

> The features of an object, bound by various mechanisms to activity in working memory, thereby provide the content of consciousness of the associated object... In these [neural activity loops], neural activity 'relaxes' to a temporally stable state, therefore providing the extended temporal duration of activity necessary for consciousness... (Taylor, 2002, p. 11)

The 'temporal extension' of neural processes provides the support here for the time-extended perception of the rotation. This is a gratuitous assumption. By what right do we grant this temporal extension to the material world, including the brain? If we can so easily grant it, how do we place a limit upon it? Why should the limit not extend for our entire lifetime? Or to the entire history of the matter-field? And why would the limit apply only to the brain? On the other hand, we intently pursue the method whereby the brain *stores* experience. Why? Because our implicit model of matter is tied to the classical model of time. This model sees matter as existing only in the 'present' instant.

Consider the buzzing fly, wings beating at 200 cycles/s. For the sake of choosing a scale, assign each wing beat to a 'present' instant. As each present instant arrives (with its wing beat), the previous moves into the past. The past, to us, is the symbol of *non-existence*. Therefore, to preserve the instant, it must be stored in the ever-'present' brain (matter), which is to say, in some brain-instantiated memory. The 'buzzing' fly perception is comprised of a series of these 'presents' that have long since come and gone. By this logic, each must be stored in the brain, i.e., in matter, else it is lost to non-existence.

But if we are not willing to grant infinite time-extension to the present instant, what is the time-extent? In fact, we view the classical 'instant' as infinitely divisible. Being such, the best we can say is that the classical, 'present' instant of time's evolution is the most infinitely minute amount of time imaginable. If the lifetime of the shortest lived micro-particle is say, 10^{-9} ns, then the present instant of the time-evolving matter-field is even less than this. This is the best we are allowed to say for the actual time-extent of the neurological processes.

I am forcing a decision here. If we are storing experience in the brain because the brain is matter, and matter is always that which is present, therefore existent, as opposed to non-existent, then we must face the implications of this logic. Declare the actual time-extent of this present. If your model of time is a series of instants, what is the time-extent of an instant? If the answer is 'infinitesimal', it goes without saying that the notion of 'extended' neurological processes is a convenient, but invalid myth. And it goes without saying that the time-extension of these processes cannot then be invoked to support the perception of something even so simple as a 'rotating' cube.

Abstract space and time

How did we get to this state of affairs? The source lies in an *abstract* space and time. Bergson (1896/1912) argued that abstract space is derived from the world of separate 'objects' gradually identified, ironically enough, by our perception. It is an elementary process, for perception must partition the continuous, dynamic field which surrounds the body into objects upon which the body can *act*—to throw a 'rock', to hoist a 'bottle of beer', to grasp a 'cube' which is 'rotating'. This fundamental perceptual partition into 'objects' and 'motions' – at a particular scale of time we should note – is reified and extended in thought. The separate 'objects' in the field are refined to the notion of the continuum of points or positions. As an object moves across this continuum, as for example, my hand moving across the desk from point A to point B, it is conceived to describe a *trajectory* – a line – consisting of the points or positions the hand traverses. Each point momentarily occupied is conceived to correspond to an 'instant' of time. Thus arises the notion of abstract time – the series of instants – itself simply another dimension of the abstract space. This space, argued Bergson, is in essence a 'principle of infinite divisibility'. Having convinced ourselves that this motion is adequately described by the line/trajectory the object traversed, we can break up the line (space) into as many points as we please. But the concept of motion this implies is inherently an infinite regress. To account for the motion, we must – between each pair of static points/positions supposedly occupied by the object – re-introduce the motion, hence a new (smaller) trajectory of static points—ad infinitum.

Motion, Bergson argued, must be treated as *indivisible*. The paradoxes of Zeno, he held, had their origin in the logical implications of an abstract space and time; they were Zeno's attempts to force recognition of the invalidity of this treatment. When Achilles cannot catch the hare, it is because we view his indivisible steps through the lens of the abstract trajectory or line each step covers. We think of the abstract space traversed. We then propose that each such distance can be successively halved—

infinitely divided in other words. Achilles never reaches the hare. But Achilles moves in an indivisible motion; he most definitely catches the hare.

In the abstraction, neural processes can have no time-extent, and it is not possible to appeal to such without implicitly violating the logic of the model by which we store experience in the brain in the first place. This argument is to force exactly the same recognition as that which Zeno attempted. The classical abstraction – time as a series of instants – forces us to clarify our notion of matter. If matter is only that which is 'present', else it is consigned to non-existence, then we are forced to ask, "what is the extent of the present instant?" Then, since we are committed to 'instants', we are committed to abstract space with its principle of infinite divisibility. We end by taking any 'instant' or extent of time and dividing it unto its ultimate component—an abstract mathematical point. This is the inherent extent of the instant, the time-extent of matter, the time-extent of the brain and the time-extent of all neural processes. In truth, at the mathematical point, there is no time at all. If we accept abstract space and time, then it is on this logical and metaphysical basis that we must explain the perception of rotating cubes, buzzing flies, and singing notes of violins—all experience, all qualia.

But rarifying the abstract conception of space continues. The motions are now treated as *relative*, for we can move the object across the continuum, or the continuum beneath the object. Motion now becomes *immobility* dependent purely on perspective. All *real*, concrete motion of the matter-field is now lost. Thus, Bergson argued, there must be *real* motion. He would insist:

> Though we are free to attribute rest or motion to any material point taken by itself, it is nonetheless true that the aspect of the material universe changes, that the internal configuration of every real system varies, and that here we have no longer the choice between mobility and rest. Movement, whatever its inner nature, becomes an indisputable reality. We may not be able to say what parts of the whole are in motion, motion there is in the whole nonetheless. (1896/1912: 255)

He would go on to note:

> Of what object, externally perceived, can it be said that it moves, of what other that it remains motionless? To put such a question is to admit the discontinuity established by common sense between objects independent of each other, having each its individuality, comparable to kinds of persons, is a valid distinction. For on the contrary hypothesis, the question would no longer be how are produced in given parts of matter changes of position, but how is effected in the whole a change of aspect... (1896/1912, 259)

In the global motion of this whole, the 'motions' of 'objects' now are seen as changes or *transferences of state*. The motion of this whole, this 'kaleidoscope' as Bergson called it, cannot be treated as a series of discrete states. Rather, he argued, this motion is better treated in terms of a melody, the 'notes' of which permeate and interpenetrate each other, the current 'note' being a reflection of the previous notes of the series, all forming an organic continuity, a 'succession without distinction' (Bergson, 1889), a motion which is indivisible. From this perspective, 'primary memory' becomes a property of the field itself and of its melodic motion.

Abstract space/time is a projection frame for our thought, derived from the necessity for practical action. Imported into the problem of consciousness, it is a barrier. For physics, the effort to break from this projection frame has been very real. If for physics itself it is true that, "*...a theory of matter is an attempt to find the reality hidden beneath...customary images which are entirely relative to our needs...*" (Bergson, 1896/1912, 254), the abstraction has been the ultimate barrier.

Physics and the abstraction

First to go was the concept of a trajectory of a moving object. This no longer exists in quantum mechanics. One can determine through a series of measurements only a series of instantaneous positions, while simultaneously renouncing all grasp of the object's state of motion, i.e., Heisenberg's famous principle of uncertainty. As de Broglie (1947/1969) would note, writing his comparison of Bergson to current concepts of physics, the measurement is attempting to project the motion to a point in our continuum, but in doing so, we have lost the motion. Thus Bergson noted, over 40 years before Heisenberg, "In space, there are only parts of space and at whatever point one considers the moving object, one will obtain only a position" (Bergson, 1889, p. 111).

Nottale (1996) simply notes Feynman and Hibbs'(1965) proof that the motion of a particle is continuous but not differentiable. Hence, he argues, we should reject the long held notion that space–time is differentiable. He opts for a fractal approach—indivisible elements which build patterns. The essence of differentiation is to divide (say, a motion from A to B, or the slope of a triangle) into small parts. This operation is carried out with smaller and smaller parts or divisions. It is understood that the divisions can be infinite in number, infinitely small. When the parts or divisions have become so minute, we envision 'taking the limit' of the operation—obtaining the measure of say, 'instantaneous' velocity, or slope, etc. To speak of non-differentiability is to say—'non-infinite divisibility'. We have something—indivisible. To state that space–time is non-differentiable another way, we may say the global evolution of the matter-field over time is seen as non-differentiable; it cannot be treated as an infinitely divisible series of states.

Lynds (Foundations of Physics Letters, 2003) now argues that there is no precise static instant in time underlying a dynamical physical process. If there were such, motion and variation in all physical magnitudes would not be possible, as they would be frozen static at that precise instant, and remain that way. In effect, such an instant would imply a momentarily static universe. Such a universe is incapable of change, for the universe itself could not change to assume another static instant. Consequently, at no time is the position of a body (or edge, vertex, feature, etc.) or a physical magnitude precisely determined in an interval, no matter how small, as at no time is it not constantly changing and undetermined. It is by this very fact – that there is not a precise static instant of time underlying a dynamical physical process or motion – that variation in magnitudes is possible; it is a necessary tradeoff—precisely determined values for continuity through time. It is only the human observer, Lynds notes, who imposes a precise instant in time upon a physical process. Thus, there is no equation of physics, no wave equation, no equation of motion, no matter how complex, that is not subject to this indeterminacy.

With this view, there can be no static form at any instant, precisely because this static instant does not exist. The brain cannot base its computations on something that, to it, does not exist. The brain is equally embedded in the transforming matter-field, i.e., it is equally a part of this indeterminacy. It can only be responding to invariance over a non-differentiable, indivisible flow or change.

Non-differentiable time-motion

The brain, and the reconstructive wave it supports, is embedded within this field and its non-differentiable motion. The rotation of the cube is equally part of this motion. Due to the hierarchical dynamics of the brain, the dynamical pattern (or attractor) it is supporting is in a certain *proportionality* relative to the micro-events of the matter-field, and therefore the image of the cube is specific to a scale of time—a spinning, fuzzy cylinder-cube, or a barely rotating cube. This dynamical pattern can equally be viewed as being 'specific to' an indivisible, variable (scaled), time-extent of this field—a spinning 16-edged cylinder-cube, or a static cube, or according to the invariance laws constraining this dynamical pattern, a non-rigid, wobbly cube. We have noted that the 'specification' supported by this dynamics is to the *past*, i.e., to past 'states' of the transforming matter-field. The external events the brain is processing – the wing-beats of the fly, the motion-cycles of the cube, and all the micro-events comprising these motions – have long since come and gone. Yet the relativity principle we have discussed in the context of Messrs. A and B, the non-differentiable or melodic motion of the field, the fictional status of present 'instants' that cease instantly to exist—all tell us that this past-specification is possible. We have at least the foundations for the solution to the temporal variant of the homunculus regress. If we can rely on the 'primary memory' of the matter-field itself, we do not need a memory storing samples of the event, nor yet another observer scanning the samples.

This is a concrete realization of Gibson's abstract 'direct specification' of events or of dynamic forms. It is a 'direct' realism that is not simply a naïve realism. The image is always an optimal function of the invariance information available in the field in conjunction with invariance laws (constraints) built into the brain's design. It is a specification of the past motion of the field given the best available information within the field and given the intrinsic uncertainty of 'measuring' this field due to its temporal motion. Being a specification of the past, it is always, as Bergson argued, already a *memory*, a memory based in the primary memory supported by the non-differentiable time-evolution of the matter-field itself.

The quality of color

A long-standing view of color is that there is no type of objective, physical property suitable for identification with our experience of color. Nothing is actually colored.

The (white) coffee cup resting before us possesses no color. Colors only exist as *subjective* qualities. For representationalism, color experience is a vast illusion for us all. Objects (better, 'objects') are *represented* as colored in the dark, quiet brain, yet there are no properties of the physical world that the representations are reflecting. Note that these last statements can be equally said of form. Form too is not a primary property; it must be an illusion. As per the wobbly cube, objects are represented as having a form, yet there are no simple properties of objects that this representation of form is reflecting.

The matter-field, at the null-scale of time, must be conceived as being itself intrinsically qualitative. The concept that matter does not have 'secondary' qualities, that nothing is truly colored, is a function of an atomistic, mechanistic model—abstract billiard balls in abstract 'motions' denuded of quality. A field of abstract, homogeneous 'objects' (e.g., particles, electrons, quarks) in equally abstract (and relative) 'motions' introduces an impassable gap between these objects/motions and quality (or qualia). At the null scale of time, the matter-field may indeed be near the homogeneous state envisioned by classical mechanics in its particles with their abstract motions. But as we impose scale, this changes:

> May we not conceive, for instance, that the irreducibility of two perceived colors is due mainly to the narrow duration into which are contracted the billions of vibrations which they execute in one of our moments? If we could stretch out this duration, that is to say, live it a slower rhythm, should we not, as the rhythm slowed down, see these colors pale and lengthen into successive impressions, still colored no doubt, but nearer and nearer to coincidence with pure vibrations? (Bergson, 1896/1912, p. 268)

Color, just as form, is an optimal specification of properties of the external matter-field. Byrne and Hilbert (2003) show that the 'representation' of color, e.g., the redness of the tomato, is in terms of proportions of hue-magnitude—legitimate properties of the tomato as part of the matter-field. This 'representation', we have seen, is better understood as specification.

The external image, subject-object and time

We need to defeat the natural companion of the coding problem, the homunculus. We cannot have (as in Figure 2) a little viewer or mystical eye in the brain viewing the virtual image. How can this dilemma be avoided? Both Bergson (1896/1912) and Bohm (1980) called attention to real properties of the holographic field, the implications of which must be considered. If the state of every element reflects the whole, if the motion of the whole is indivisible (or non-differentiable) and therefore again, the state of every element reflects the history of the whole field, it is difficult to avoid the concept that an elementary awareness is implicit within this field at the null scale. That is, if the state of each 'element' of the field is reflective of, or carrying information for, the whole, it is in a very elementary sense, 'aware' of the whole. This view will be taken as a form of panpsychism, but note, this is the *null* scale of time. Hitherto, when panpsychism speaks of 'consciousness' in the field,

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what scale is meant? Does it refer to the scale of consciousness as we know it? Nor is there any form of 'mentality' being ascribed to the field, to its 'particles', to virtual photons, etc. Again, in the case of the model discussed here, the whole dynamical apparatus supporting the brain as a reconstructive wave is required to impose a time-scale upon this field in order to support consciousness as we (or even frogs or chipmunks) know it.

The point here then is that initial considerations of the properties of the holographic field lead to postulating a limited, elementary property of awareness – call it a limited form of panpsychism – over the matter-field. Deeper quantum considerations lead to better arguments. But how does such a (panpsychic) property help the homunculus aspect of the coding problem? It is only useful in this way: at the null scale of time, there is no differentiation within the matter-field between body and field, or subject and object. Let us suppose our body and a fly external to the body within this field. At the null scale, there is no differentiation—both are simply 'phases' of the field. If we run a little gedanken experiment, letting the dynamics of the brain gradually impose a scale of time, the fly transforms gradually from an ensemble of vibrations, to a motionless creature, to the heron-like fly, to the 'buzzing' being of our normal scale. *Subject is differentiating from object*. The specification of the brain's reconstructive wave, as noted, is to increasing extents of the past, but we can see that the specification is also simultaneously to a (time-scaled) form of the elemental awareness defined throughout the field. There is no homunculus looking at the image. This is the essence of Bergson's principle: "*Questions relating to subject and object, to their distinction and their union, must be put in terms of time rather than of space*" (1896/1912, p. 77).

The relativity of virtual action

> [Objects] send back, then, to my body, as would a mirror, their eventual influence; they take rank in an order corresponding to the growing or decreasing powers of my body. The objects which surround my body reflect its possible action upon them. (1896/1912, pp. 6–7)

So Bergson would begin his argument that perception is virtual action. He stated that we must accept the obvious, like it or not, about the function of the brain. The brain, he argued, should be regarded as "an instrument of analysis with regard to movement received, and of selection with regard to movements executed 'and' (The higher centers of the cortex) do but indicate a number of possible actions at once, or organize one of them" (1896/1912, p. 20). Thus the essential function of the brain (as with Sperry, 1952) was viewed as the preparation of an array of appropriate motor acts relative to the surrounding environment. Significantly missing, as we saw, is the function so usually sought, i.e., the representation and generation of the image of the external world. Highly related to Gibson's notion of the perception of 'affordances', the perceived world thus becomes the reflection of an array of action possibilities.

The *order* being carved out of the ambient energy flux (Bohm's 'explicate' order) is a particular order defined relative to the action capabilities of the organism. The regularities of the world, the shared commonalities across observers that save us from pure idealism, derive from the invariance laws (in the realist's field) to which these systems can respond. As we earlier considered the effects of introducing a catalyst into the dynamical makeup of the body/brain, we already previewed the relativistic aspect of this principle. Let us complete the implications, for the time-scaling of the external image is not a merely subjective phenomenon—it is objective, and has objective consequences realizable in action.

Consider a cat viewing a mouse traveling across the cat's visual field (Figure 11). Focusing on the Gibsonian structure of this field and its complex projective invariance, we note the texture density gradient, the size constancy of the mouse as it moves specified by the invariant proportion, $S \propto 1/N$, the value, τ, specifying the impending time to contact with the mouse, with its critical role in controlling action, implicitly defined in the brain's 'resonance' state. This entire structure (and much more than described) is supported, over time, by the 'resonant' or dynamical pattern of the brain.

Within this dynamical pattern, there are 'tuning' parameters for the action systems (cf. Turvey, 1977a). Turvey described a 'mass-spring' model of the action systems, where, for example, reaching an arm out for the fly is conceived as in releasing an oscillatory spring with a weight at one end. 'Stiffness' and 'damping' parameters specify the end-point and velocity of such a system. Time is necessarily another parameter. Note that we can translate the mouse and his track towards or away from the cat, and yet the horizontal projection (h) on the retina is the same, any number of such mice/tracks projecting similarly. Therefore h/t is not enough information to specify unambiguously the mouse's velocity and the needed information required for a leap. The needed muscle-spring parameters must be realized *directly* in the cat's muscular or coordinative structures via properties of the optic array, e.g., the texture density gradient across which the mouse moves and the quantity of texture units he occludes.

At our normal scale of time, we can envision a function relating the minimum velocity of leap (V_{min}) required for the cat to leap and intercept the mouse at D as the mouse moves along his path. But how is the velocity of the mouse specified by the body? A physicist requires some time-standard to measure velocity. He could use a single rotation of a nearby rotating disk to define a 'second'. But were someone to surreptitiously double the rotation rate of this disk, the physicist's measures of some object's velocity would be halved, e.g., from 2 ft/s to 1 ft/s. But the body must use an internal reference system—a system equally subject to such changes. This system must be an internal chemical velocity of the body, a velocity it was argued, that can be changed by introducing a catalyst (or catalysts)—an operation that can be termed, in shorthand, modulating the body's energy state. If I raise this energy state, the function specifying the value of V_{min} for the cat must change. This is simply to say, with reference to our example, that the perceived velocity of the object (mouse) must be lowered, for its perceived velocity must be a reflection of the new possibility of action at the higher energy state. There is a new (lower) V_{min} defined along every point of the object's trajectory, and therefore the object, *if perception is to display our possibility of action with ecological validity*, must appear to be moving more slowly. If the fly is now flapping its wings slowly, the perception is a specification of

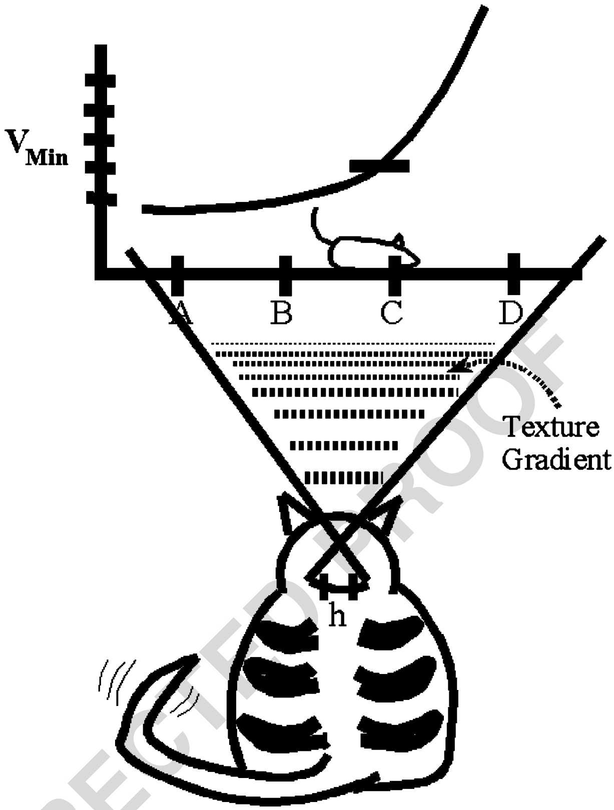

Figure 11 Hypothetical function describing the minimum velocity required for the cat to intercept the mouse at D (after Robbins, 2000; 2001).

the action now available, e.g., in reaching and grasping the fly perhaps by the wing-tip. In the case of the rapidly rotating cylinder with serrated edges (once a cube), if by raising the energy state sufficiently we cause a perception of a *cube* in slow rotation, it is now a new specification of the possibility of *action*, e.g., of how the hand might be modulated to grasp edges and corners rather than a smooth cylinder.

This dynamic system, then, composed of environment and organism, undifferentiated at the null scale, is truly a tightly coupled, reciprocally causal system. It is a symmetric system, and as Shaw and McIntyre (1974) had pointed out, referencing Ernst Mach (1902), such a system is in equilibrium. A change in one half of the system demands a corresponding change in the other to maintain equilibrium. In this case, we have a *cognitive* symmetry, maintaining the equilibrium between the organism's psychological states and the information states of the environment. The relativity viewed here is an implication of this symmetry. It is now a cognitive 'relativity', obtained when we leave the classical abstraction of space and time behind.

Situatedness and time

There are no representations in this system, i.e., there are no internal symbols within the brain carrying the weight of semantics. The objects of perception, located externally in depth, in volume – the buzzing fly, the transforming cube – are the ‘symbols’. The meaning of these ‘symbols’ is inherently grounded in the body itself, for they are reflections of the possibility of action. The system is embedded in time, in the melodic flow of the matter-field.

This embeddedness, not only in time but in the physical environment, has become an important concept in the theory of robotics. In their early argument for situatedness, Winograd and Flores (1987) rejected the view of cognition as symbolic manipulation of representations that are understood as referring to objects and properties in the ‘external’ world. Following Heidegger’s (1927) philosophy of being-in-the-world they noted:

> Heidegger makes a more radical critique, questioning the distinction between a conscious, reflective, knowing ‘subject’ and a separable ‘object’. He sees representations as a derivative phenomenon, which occurs only when there is a breaking down of concernful action. Knowledge lies in the being that situates us in the world, not in reflective representation (pp. 73–74).

Heidegger was certainly aware of Bergson. Cassirer (1929/1957) was straightforward, noting, “It is the lasting achievement of the Bergsonian metaphysic that it reversed the ontological relation assumed between being and time.” The relationship of subject and object in terms of time constitutes the fundamental framework within which ‘situatedness’ truly lies. Q2

Practically, in terms of constructing a conscious situated ‘device’, as I have noted elsewhere (Robbins, 2002, 2004a), it means the following:

(1) The total dynamics of the system must be proportionally related to the events of the matter-field such that a time-scale is defined upon this field.
(2) The dynamics of the system must be structurally related to the events of the matter-field, i.e., reflective of the invariance laws defined over the time-extended events of the field.
(3) The information resonant over the dynamical structure (or state) must integrally include relation to/feedback from systems for the preparation of action (to ensure the partition of a subset of field events related to action).
(4) The operative dynamics of the system must be an integral part of the indivisible, non-differentiable motion of the matter-field in which it is embedded.
(5) The dynamical structure must globally support a reconstructive wave.

In (4) the term ‘operative’ dynamics is employed. This is to sharply differentiate this ‘device’ from the syntactic (or symbolic manipulation) model, where the operative ‘dynamics’ is in syntactic operations, and where it is felt that these syntactic operations can ride atop a real dynamics, e.g., atop the real electromagnetic flux of a computer, and still account for mind (e.g., Prinz & Barsalou, 2000).

Indirect vs. direct

There is a large array of ‘how-would-this-work?’ questions such a model opens up, from the operation of memory to the nature of thought, language and cognition. I have approached some of these elsewhere (Robbins, 2000, 2002, 2006). The indirect realist immediately demands an explanation of illusions. A brief indication might suffice and throws light on the possibilities of specification as an approach. Several experimental findings that appear to support indirect realism center around saccades. When we first look at a room, the eye darts from point to point over the area, in zigzag fashion, taking in information. During the movement itself, between the points, the eye is apparently blind, picking up no information. Under such conditions, objects presented during a saccade are actually invisible. The visual system appears to be shut down for an instant, but the brain 'computes' what we would have seen during the saccade. Smythies (2002) notes that it would be most implausible to suggest, per direct realism, that we see directly only when our eyes are not in saccadic movement. The response is that the perception is as direct as ever. During the motion of a clock hand relative to a receptive eye (as in Yarrow, Haggard, Heal, Brown & Rothwell, 2001), the always dynamic velocity flow information from the field is taken in, the optimal percept computed, and the reconstructive wave/specification is, as ever, to the past motion of the field. During the saccade, the brain-supported reconstructive wave does not cease. Just as for the rotating cube, this 'wave' continues to specify a transforming field based on the information available and the probabilistic algorithm employed by the architecture.

O'Regan (1992) is similar in this respect. He noted that an entire page of surrounding text can be changed without notice during a saccade while someone is reading as long as the 17–18 character window the eye is focused upon is undisturbed. This observation would lead to his treatment of 'change blindness' (O'Regan & Noë, 2001). He opted to conceive of the environment as an 'external memory store' to explain the persistence of the perceived world during saccades. He is one of the few that hold that perception is not 'within', in some strange internal mini-world. But what is the scale of time of such an external memory store (i.e., world)? Certainly nothing like the scale of our 'buzzing' fly (cf. Robbins, 2004b). We can better say that the reconstructive wave and/or the pattern supporting it within the brain is not affected by a substitution of the surrounding text during a saccade with its minute information gathering capacity (one estimate has this at 44 bits of information), the brain's specificatory wave yet being to the same (time-scaled) form of the past motion of the matter-field.

Direct memory

This model of perception implies an entirely new theory of memory and cognition. For the sake of a view of the implications, I intend here to give a very brief overview. If Gibson's model of direct perception is in effect Bergson's, perception is not solely occurring within the brain. Experience, then, cannot be exclusively stored there. Bergson (1896/1912) visualized the brain, embedded in the 4-D matter-field, as a form of 'valve' which allowed experiences from the past into consciousness depending on the array of action systems activated. In updated terms, we say again that the brain, embedded in the 4-D holographic field, again acts as a modulated reconstructive wave. Loss of memories – amnesias, aphasias, etc. – would be due, as

Bergson (1896/1912) in essence argued, to damage that causes inability to assume the complex modulatory patterns required.

This does not mean that no form of memory is stored in the brain. Sherry and Schacter (1987) described two general forms of memory, labeled 'System I' and 'System II'. The two systems correspond exactly to the distinction Bergson made in *Matter and Memory*. 'System I' can also be termed the 'procedural'—stored mechanisms or procedures for unrolling an action at will. It is amenable, at least partially, to the connectionist net, and is obviously brain-based. 'System II' holds experiences. It corresponds to the memory Tulving (1972) termed 'episodic'. It is the difference, in Bergson's example, between a series of piano practice sessions on Chopin's Waltz in C# minor as events (System II, experiences or 'episodic') and the series resultant—the neural mechanism (System I) that unrolls the practiced waltz at will. This System I includes the sensorimotor 'schemas' of Piaget, where, for example, an object such as a cup becomes embedded as it were in a matrix of possible actions – lifting, drinking, pouring – which are initially overtly acted out when a cup is perceived and with age, ultimately inhibited. These become a basis for triggering wave-modulation patterns. The relation between these two forms of memory – that based in the brain and that which is not – is a complex one and a subject for much further theory.

The essential operation of direct memory is 'redintegration', termed so by Wolff in 1732. Examples of this phenomenon abound in everyday experience. Thus the sound of thunder may serve to redintegrate a childhood memory of the day one's house was struck by lightning. Perhaps, for example, we are walking down a road in the summertime and suddenly notice a slight rustling or motion in the grass along the embankment. Immediately, an experience returns in which a snake was encountered in a similar situation. Klein (1970) notes that these remembered experiences are "structured or organized events or clusters of patterned, integrated impressions," and that Wolff had in effect noted that subsequent to the establishment of such patterns, the pattern might be recalled by reinstatement of a constituent part of the original pattern. Ignored to this point, with relatively few exceptions, has been the significance of Gibson. Yet the characterization of Wolff's "structured or organized events or clusters of patterned, integrated impressions," or event-patterns that can be recalled by reinstatement of a constituent part of the original pattern, is exactly Gibson's theory.

Imagine a drive up a mountain road. The road curves back and forth, sinusoidally, rising at a particular grade. We have then a certain gradient of velocity vectors lawfully transforming as a function of the radius of the curves and the velocity of the vehicle. Our driver can rely directly on the τ value to modulate his velocity to avoid possible impacts with structures along the road. There are other components such as the contour and texture density gradients peculiar to a mountain terrain. An integral part of this transforming field (E) is the organism (O). The transformation specifying the flow field is also that defining the values of tuning parameters for the action systems. The velocity of field expansion/directional change is specific to the velocity of the car and to the muscular adjustments necessary to hold it on the road. Therefore the state of the body/brain with respect to future possible (virtual) action as well as that actually being carried out constitutes an integral component of the E–O event pattern.

I believe it is quite common for people to have past experiences redintegrated by this form of flowing, road-driving, invariance structure. My wife tells me that every time we drive along a certain curving section of the freeway near Milwaukee, she feels she is in an area of California where she once lived. Why is this? The brain, I have already argued, is a modulated wave within the holographic matter-field. The reason that the experience is reconstructed is that the brain is thrown by the invariance structure of the present event into the same reconstructive wave pattern as that which defined the original event. This is the entire principle of redintegration. We can state it thus:

> A present event E' will reconstruct a previous event E when E' is defined by the same invariance structure or by a sufficient subset of the same invariance structure.

The more unique this invariance structure, the easier it is to reconstruct the event. It is exactly as if a series of wave fronts were recorded upon a hologram, each with a unique frequency of reference wave, as when we imagined storing the wave fronts of a pyramid, chalice, toy truck and candle (Figure 2). Each wave front (or image) can then be reconstructed uniquely by modulating the reconstructive wave to each differing frequency.

Imagine a series of perceived events, for example, a man stirring coffee, a baseball hurtling by one's head, a boot crushing a can. Each has a unique invariance structure. To create the reconstructive wave for these, i.e., to evoke over the brain the needed modulation or dynamic wave pattern, I might use as a 'cue' respectively—a stirring spoon, an abstract rendering of an approaching object capturing the tau value of the baseball event, and an abstract rendering of one form descending upon and obscuring another. But these events are multi-sensory (multi-modal) and the four-dimensional extent of experience is multi-modal. There are auditory invariants as well defined over the events. The steady 'looming' of the approaching baseball, with its radial, expanding flow field, is proportional over a range of frequency values to the change of sound inherent in the Doppler effect. Our cues could become respectively—the whoosh of the passing baseball, the swishing or clinking sound of stirring, the crinkling sound of collapse of a tin structure. Even the dynamics of the muscular (or haptic) component of the event has a mathematical structure we could employ to re-cue the event—the 'inertia tensor', and its mathematical specification of the forces and moments of inertia in three dimensions that describe the motion. We could cue our stirring event by wielding a 'tensor object'. that captures this inertia tensor (invariant) specific to spoon-stirring.

In the heavily studied memory context employing verbal materials such as paired-associate learning, we can imagine learning a pair (among many pairs in a list) such as SPOON–COFFEE. SPOON is now used as the 'cue' to test recall of COFFEE. Let us suppose that the subject at least imagined an event, namely himself stirring coffee. Nevertheless the abstract SPOON is very non-specific, corresponding to a very unconstrained wave capable of reconstructing many events. We need to constrain the reconstructive wave and we can do so by placing successively richer dynamics upon the spoon. The subject can imagine a spoon in a stirring motion, or actually use a concrete spoon, moving it in a stirring motion. Greater constraint would add a liquid medium with the resistance similar to coffee. Each corresponds to a finer tuning of the reconstructive wave defined over the brain. Such concrete, ecological constraint would allow retrieval of lists in such technically difficult verbal paradigms as the A–B, A–C, where the same cue/stimulus word appears in both lists, for example SPOON–COFFEE in list 1, SPOON–CAKE BATTER in list 2. Now, for the CAKE BATTER, the stirring must be constrained by the diameter appropriate to a bowl versus a cup, or by the resistance appropriate to a batter-like medium as opposed to coffee. In fact, ecological constraint of the reconstructive wave will support a technically impossible verbal paradigm, such as lists where every stimulus word is SPOON, e.g., SPOON–COFFEE, SPOON–BATTER, SPOON–SOUP, etc. As the research field of Subject Performed Tasks is now demonstrating (cf. Engelkamp, 1998; Robbins, 2006), this ecological dynamics for direct memory is prior, and the laws of verbal learning are derivative.

Cognition and the compositional

This fundamental memory operation lies at the basis of cognition. If the 'concept' is the basic 'unit' of cognition, the concept becomes a function of a wave of lesser coherence sent through 4-D memory. For example, consider a series of experienced events of coffee stirring. The events have an invariance structure as we have seen. Over repeated events, other invariants emerge. There are, for example, what can be termed structural invariants. Required to move the liquid is an instrument of sufficient length, rigidity and width. Conversely, a liquid with density and viscosity capable of being (easily) moved is always required. A container is required with depth, volume and height sufficient to both hold and spatially constrain the liquid. There are force invariants: a force needed to move the spoon, forces needed to hold the cup on the table and in place as it is stirred. Gelernter (1994) envisioned an operation of taking a 'stack' of events across which the invariants stand out, just as Galton's (1883) example of an abstract face derived over multiple superimposed photographs. One may conceive of the basis for a 'concept' as a wave of less than perfect coherence supported by the dynamics of the brain (e.g., a composite of f_1 and f_2 in Figure 2) reconstructing a composite of images or wave fronts (stirring-events) across 4-D memory, over which the invariants across the images/events stand out. 'Stirring' itself, as a *concept*, is an invariant across multiple stirring events in 4-D memory as defined by this operation. In this sense, the operation of redintegration or direct recall is the basis of abstraction and, in turn, of the 'compositionality' (or compositional elements) Fodor and Pylyshyn (1995) insist upon as the basis for representative thought.

'Systematicity' is the second essential component required by Fodor and Pylyshyn. I have argued elsewhere (Robbins, 2002, 2006) that Piaget's 'operations' are in fact the essence of systematicity, and that Piaget's stages, now seen as the natural bifurcations of a dynamic system (cf. Molenaar & Raijakers, 2000), describe the dynamical trajectory underlying the development of this capacity. Consider the task of predicting the order in which three colored beads on a wire, call them ABC, will emerge after entering a little tunnel and the tunnel is given n 180° rotations. (One 180° turn or semi-rotation=>CBA, two semi-rotations=>ABC, three=>CBA, etc.) The dynamic trajectory the children follow requires years to represent these bead/tunnel rotations as images, images which grow increasingly schematic, i.e., 'operational', until the odd-even 'rule' (invariance) securely emerges (Piaget, 1946).

The children in fact come to a stage where they can predict the results of three or four semi-rotations, but literally exhaust themselves trying to represent (imagine) the results of additional semi-turns, failing then on the general rule. Piaget's theory of operational thought is above all a theory of *explicit* thought, where images become increasingly schematic symbols of potential actions.

> Operations, one might say, are nothing other than articulated intuitions rendered adaptable and completely reversible since they are emptied of their visual content and survive as pure intention... In other words, *operations come into being in their pure state when there is sufficient schematization*. Thus, instead of demanding actual representation, each inversion will be conceived as a potential representation, like the outline for an experiment to be performed, but which is not useful to follow to the letter, even in the form of performing it mentally. (1946, p. 30, emphasis added.)

Beneath Piaget's theory of operations lies Bergson's 'device'. The less-than-coherent waves driven through its 4-D memory and reconstructing abstract, composite versions of past events support the phenomenon of mental images—so problematic for both the symbolic-computer model and the neural net model. The higher the order of invariance, the more abstract and context-free the images become. The phrase "a utensil is moving a liquid medium," for example, represents a higher order of invariance across a far wider set of events bearing the same general structure, as opposed to the more 'concrete' phrase, "a spoon is stirring coffee." So in the course of the child's progress on Piaget's tasks, the more schematic the dynamic event-images eventually become (e.g., of rotating objects), until they become the abstract 'operations' of his theory. But these schematic forms are always founded in invariance defined over concrete experience. The abstract and the concrete are reciprocal. A (4-D) 'device' that can 'store' this concrete experience, allowing for this definition of invariance, is required for Piaget, his operations, imaginal reconstructions, and thought.

Conclusion

The framework for cognition and memory that Bergson's model establishes is rich, powerful, and worthy of a much larger treatment (cf. Robbins, 2002, 2006). The above is simply enough to provide the vision that indeed a theory of cognition/memory is implied in Bergson's model of perception. It all rests, of course, on a vision of the role of the brain that neuroscience has yet to consider. But it should be understood that neuroscience is far from understanding how experience is 'stored' in the brain. It is currently confounded by the fact that everywhere one looks, 'processing' site and 'storage' site seem to be equivalent. In fact, this 'storage' has never been more than a hypothesis, though one with the force of a dogma.

We have focused on Bergson's theory of perception, and of course his natural ally, Gibson. It should be clear that it harbors considerations on time that simply are not discussed anywhere in the current literature on the 'hard problem' of consciousness. This alone should cause theorists to consider if the framework in which the problem has been approached is sufficiently wide. It is my hope that this exposition of the concrete key to Bergson will give his remarkable philosophy of mind the greater attention it should deserve.

References

Beckenstein, J. (2003). Information in the holographic universe. *Scientific American, 289*(2), 58–66.

Bell, J. S. (1987). Beables for quantum field theory. In B. J. Hiley & F. D. Peat (Eds.), *Quantum implications*. London: Routledge and Kegan-Paul. Q4

Bergson, H. (1889). *Time and free will: An essay on the immediate data of consciousness*. London: George Allen and Unwin Ltd.

Bergson, H. (1896/1912). *Matter and memory*. New York: Macmillan.

Bickhard, M. H., & Richie, D. M. (1983). *On the nature of representation*. New York: Praeger.

Bohm, D. (1980). *Wholeness and the implicate order*. London: Routledge and Kegan-Paul.

Cabe, P. A., & Pittenger, J. B. (2000). Human sensitivity to acoustic information from vessel filling. *Journal of Experimental Psychology: Human Perception and Performance, 26*, 313–324.

Cassirer, E. (1929/1957). *The philosophy of symbolic forms, vol 3: The phenomenology of knowledge*. New Haven: Yale University Press.

Copeland, B. J. (2000). Narrow versus wide mechanism: Including a re-examination of Turing's views on the mind-machine issue, XCVI. *Journal of Philosophy, 1*, 5–32.

Craig, C. M., & Bootsma, R. J. (2000). Judging time to passage. In M. A. Grealy & J. A. Thomson (Eds.), *Studies in perception and action V*. New Jersey: Erlbaum. Q4

De Broglie, L. (1947/1969). The concepts of contemporary physics and Bergson's ideas on time and motion. In P. A. Y. Gunter (Ed.), *Bergson and the evolution of physics*. University of Tennessee Press.

Domini, F., Vuong, Q. C., & Caudek, C. (2002). Temporal integration in structure from motion. *Journal of Experimental Psychology: Human Perception and Performance, 28*(4), 816–838.

Engelkamp, J. (1998). *Memory for actions*. East Sussex: Psychology Press.

Feynman, R. P., & Hibbs, A. R. (1965). *Quantum mechanics and path integrals*. New York: MacGraw-Hill.

Fodor, J., & Pylyshyn, Z. (1995). Connectionism and cognitive architecture. In C. MacDonald & G. MacDonald (Eds.), *Connectionism: Debates on psychological explanation*. Oxford: Basil Blackwell.

Gelernter, D. (1994). *The muse in the machine: Computerizing the poetry of human thought*. New York: Free Press.

Gibson, J. J. (1950). *The perception of the visual world*. Boston: Houghton-Mifflin.

Gibson, J. J. (1966). *The senses considered as visual systems*. Boston: Houghton-Mifflin.

Glassman, R. B. (1999). Hypothesized neural dynamics of working memory: Several chunks might be marked simultaneously by harmonic frequencies within an octave bank of brain waves. *Brain Research Bulletin, 30*(2), 77–93.

Gray, R., & Regan, D. (1999). Estimating time to collision with a rotating nonspherical object. In M. A. Grealy & J. A. Thomson (Eds.), *Studies in perception and action V*. New Jersey: Erlbaum.

Heidegger, M. (1927). *Being and time*. New York: Harper and Row.

Hoaglund, H. (1966). Some bio-chemical considerations of time. In J. T. Fraser (Ed.), *The voices of time*. New York: Braziller.

James, W. (1890). *Principles of psychology, vol. II*. New York: Holt and Co.

Kim, N., Turvey, M., & Carrelo, C. (1993). Optimal information about the severity of upcoming contacts. *Journal of Experimental Psychology: Human Perception and Performance, 19*(1), 179–193.

Klein, D. B. (1970). *A history of scientific psychology*. New York: Basic Books.

Kock, W. E. (1969). *Lasers and holography*. New York: Doubleday-Anchor. Q4

Kugler, P., & Turvey, M. (1987). *Information, natural law, and the self-assembly of rhythmic movement*. Hillsdale, NJ: Erlbaum.

Lombardo, T. J. (1987). *The reciprocity of perceiver and environment: The evolution of James J. Gibson's ecological psychology*. Hillsdale, NJ: Erlbaum.

Lynds, P. (2003). Time and classical and quantum mechanics: Indeterminacy versus discontinuity. *Foundations of Physics Letters, 16*(4), 343–355.

Mach, E. (1902). *Science of mechanics: A critical and historical account of its development*. Chicago: Open Court.

Molenaar, P., & Raijakers, M. (2000). A causal interpretation of Piaget's theory of cognitive development: Reflections on the relationship between epigenesis and non-linear dynamics. *New Ideas in Psychology, 18*, 41–55.

Mussati, C. L. (1924). Sui fenomeni stereocinetici. *Archivo Italiano di Psycologia, 3*, 105–120.
Nottale, L. (1996). Scale relativity and fractal space–time: Applications to quantum physics, cosmology and chaotic systems. *Chaos, Solitons and Fractals, 7*, 877–938.
Piaget, J. (1946). *The child's conception of movement and speed*. New York: Ballentine.
Pittenger, J. B., & Shaw, R. E. (1975). Aging faces as viscal elastic events: Implications for a theory of nonrigid shape perception. *Journal of Experimental Psychology: Human Perception and Performance, 1*, 374–382.
Pribram, K. (1971). *Languages of the brain*. New Jersey: Prentice-Hall.
Prinz, J., & Barsalou, L. (2000). Steering a course for embodied representation. In E. Dietrich & A. B. Markman (Eds.), *Cognitive dynamics: Conceptual and representational change in humans and machines*. New Jersey: Erlbaum.
Robbins, S. E. (1976). Time and memory: The basis for a semantic-directed processor and its meaning for education. Doctoral dissertation, University of Minnesota.
Robbins, S. E. (2000). Bergson, perception and Gibson. *Journal of Consciousness Studies, 7*(5), 23–45.
Robbins, S. E. (2001). Bergson's virtual action. In A. Riegler, M. Peschl, K. Edlinger & G. Fleck (Eds.), *Virtual reality: Philosophical issues, cognitive foundations, technological implications*. Frankfurt: Peter Lang Verlag.
Robbins, S. E. (2002). Semantics, experience and time. *Cognitive Systems Research, 3*, 301–335.
Robbins, S. E. (2004a). On time, memory and dynamic form. *Consciousness and Cognition, 13*, 762–788.
Robbins, S. E. (2004b). Virtual action: O'Regan and Noë meet Bergson. *Behavioral and Brain Sciences, 27*(6), 907–908.
Robbins, S. E. (2006). On the possibility of direct memory. In V. W. Fallio (Ed.), *New developments in consciousness research*. New York: Nova Science.
Savelsbergh, G. J. P., Whiting, H. T., & Bootsma, R. J. (1991). Grasping tau. *Journal of Experimental Psychology: Human Perception and Performance, 17*, 315–322.
Shaw, R. E., & McIntyre, M. (1974). The algoristic foundations of cognitive psychology. In D. Palermo & W. Weimer (Eds.), *Cognition and the symbolic processes*. New Jersey: Lawrence Erlbaum Associates.
Shaw, R. E., McIntyre, M., & Mace, W. (1974). The role of symmetry in event perception. In: R. B. MacLeod & H. L. Pick (Eds.). Perception: Essays in honor of James J. Gibson (pp. 276–310). Q4
Sherry, D., & Schacter, D. (1987). The evolution of multiple memory systems. *Pscyhological Review, 94* (4), 439–454.
Smythies, J. (2002). Comment on Crook's "Intertheoretic identification and mind-brain reductionism". *Journal of Mind and Behavior, 23*, 245–248.
Sperry, R. W. (1952). Neurology and the mind-brain problem. *American Scientist, 40*, 291–312.
Taylor, J. G. (2002). From matter to mind. *Journal of Consciousness Studies, 9*, 3–22.
Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of memory*. Academic.
Turvey, M. (1977a). Preliminaries to a theory of action with references to vision. In R. E. Shaw & J. Bransford (Eds.), *Perceiving, acting and knowing*. New Jersey: Erlbaum.
Turvey, M., & Carello, C. (1995). Dynamic touch. In W. Epstein & S. Rogers (Eds.), *Perception of space and motion*. San Diego: Academic.
Weiss, Y., & Adelson, E. (1998). Slow and smooth: A Bayesian theory for the combination of local motion signals in human vision. MIT A. I. Memo No. 1624.
Weiss, Y., Simoncelli, E., & Adelson, E. (2002). Motion illusions as optimal percepts. *Nature Neuroscience, 5*, 598–604.
Winograd, T., & Flores, F. (1987). *Understanding computers and cognition*. Norwood, NJ: Addison-Wesley.
Yarrow, K., Haggard, P., Heal, R., Brown, P., & Rothwell, J. C. (2001). Illusory perceptions of space and time preserve cross-saccadic perceptual continuity. *Nature, 414*, 302–304.
Yasue, K., Jibu, M., & Pribram, K. H. (1991). A theory of non-local cortical processing in the brain. In K. H. Pribram (Ed.), *Brain and perception*. New Jersey: Erlbaum. Q4

AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES.

Q1. Byrne and Hilbert (2003) was cited in text but was not found in the reference list. Please check.

Q2. Cassirer (1927/1929) was changed to Cassirer (1929/1957).

Q3. O' Regan (1992); O' Regan and Noe (2001); and Galton (1883) were cited in text but were not found in the reference list.

Q4. Bell (1987); Craig and Bootsma (2000); Kock (1969); and Shaw, et al. (1974) are uncited references. Please provide citations for these references list, whichever is the most appropriate.