BERGSON'S VIRTUAL ACTION

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Bergson (1896) left us a conception of virtuality much different than what is understood today. Perception, he stated, is virtual action. This concept was embedded within a holographic framework and within a model that established the relationship between subject and object in terms of time. The invariance structures of Gibson provide the information for driving the action systems and partitioning the environmental field into a virtual subset as Bergson required. When applied to the problem of the brain's imposition of a scale of time upon the universal field, where the brain is viewed as a dynamical system, this model reveals relativistic implications demanding a far different conception of perception and action.

Introduction

Perhaps we should like to think that virtuality is a child of this very modern age. It is not—like most other things under the sun. Henri Bergson (1896), over 100 years ago, left us a conception of virtuality more profound than the standard notions we have today. Our modern notions have been deeply inspired by the technology of the computing device. Paradoxically, to understand what Bergson saw, we need in fact to strip away the very layer of concepts that gave rise to the computer model. It is worth the effort. Integrally supporting Bergson however is the "direct perception" theory of J. J. Gibson (1950, 1966, 1979), and to set the stage for those unfamiliar, I begin with a brief summary of Gibson.

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Gibson, Invariance and Resonance

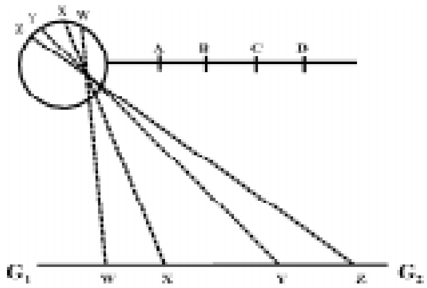

Figure 1: The "Ground".

Gibson's (1950) fundamental insight came in recasting the problem of depth perception. When considered from the viewpoint of Newtonian space, as stated by the bishop/philosopher 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 1, 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". 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 1). 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.

Gibson (1950) would introduce the notion of texture density gradients. A typical example of such a gradient can be a tiled floor, a rug, a beach, or a surface strewn with rocks (see Figure 3ok?). The rocks or 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 $S \propto 1/D^2$. This gradient of increasing density of texture units on the retina should produce a perception of continuous distance in all directions across the surface. Were the mouse of Figure 3 moving across this gradient towards the cat, the size constancy of the mouse as it moves is being specified, over time, by the invariant proportion, $S \propto 1/N$, where *S* is the (increasing) vertical size of the mouse on the retina, *N* the (decreasing) number of texture units it occludes ($SN = k$). When itself put in motion, as in driving down a road, the gradient becomes an optical flow field—a gradient of velocity vectors where there is an increasing point velocity as the distance from the eye decreases, $v = k/d^2$, all radiating from a single point, the point of optical expansion (Figure 2). All these mathematical relations we would routinely use to generate virtual scenes today. But for Gibson, the world is "directly specified" by this information, there is no code for a homunculus to unfold, no theatre of consciousness; the brain merely "resonates" to this information.

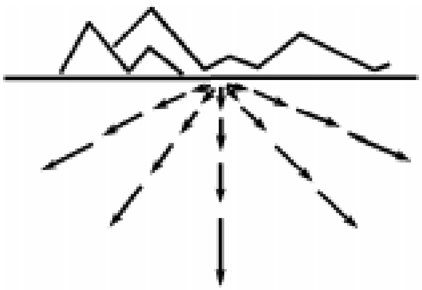

Figure 2: Optical flow field—a gradient of velocity vectors is created as the observer moves towards the mountains.

"Resonance" emerged as time became of the essence. Gibson (1966, 1979) realized that invariants such as the size constancy of the mouse or point of optical expansion of a flow field only exist over time, they cannot be transmitted over the nerves as bits of information; they cannot be found at some instant of time at some spatial position of the nerve. He began to speak of the brain as a circular process. The visual system was conceived as "tuning" itself, as one would dial a radio, by its continuous fixing and converging on details, continuous sharpening by lens focusing, involving tuning, adjustment from feedback in the system, etc. This adjustment to the highest fidelity "reception" Gibson began to term resonance. The notion would receive criticism from neural theorists (e.g., Ramachandran 1990) for being vague, but it was literally forced from a matrix of constraints relative to his understanding of the dynamic information defining events. Yet, not long after Ramachandran's critique, the awareness of the brain's re-entrant architecture and its "resonant" implications would become widespread (Edelman 1989; Freeman 2000). Zeki (1993) would describe in detail the re-entrant connections among the structures, V1 thru V5, of the visual system, while not long after that, Gibson and his resonance would be seen as a special case of the attractors of a dynamic system (Port & Van Gelder 1995; Clark 1997).

With this foundation, let us approach a fundamental problem noted by Bergson (1896, pp. 266–277), the importance of which is essentially ignored—the origin of the scale of time imposed by this dynamical brain.

On Scales of Time

Consider a wire cube in a darkened room, rotating slowly around a rod placed through the center of two opposing faces, and strobed periodically in phase with or at an integral multiple of its symmetry period. As Gibson had come to argue re the perception of form itself, the information specifying the shape of the cube is carried over time. In this case, it is this symmetry period, and as the cube maps onto itself every 90^{o}, a period of four. If this information is destroyed, e.g., if the cube is strobed arhythmically, it becomes a distorted, wobbly figure (Turvey 1977b). This is clearly an invariance (symmetry) specified over time. Supporting this perception, we can posit an attractor supported over the transforming neural patterns of the brain. The attractor must be "specific", to use Gibson's term, to the form of the cube as it transforms. There is not an instantaneous cross-section of time (or point in the phase space) that captures the invariance specific to the cube. The invariance exists only over time. The information specified over time can be destroyed in the case of the arhythmically strobed cube. Now if we consider a normal cube as it rotates, and gradually increase the velocity of rotation, we see that the cube transitions through a series of figures with increasing numbers of serrated edges—8, 12, 16…, each an integral multiple ($4n$) of its symmetry period. Finally, at a high enough rate, it becomes a cylinder surrounded by a fuzzy haze, i.e., a figure of infinite symmetry. Supporting these transitions yet must be our attractor.

Dynamical systems, such as we are positing here, are systems that naturally integrate scales. The combined action of a myriad of smaller scale elements forms a large scale pattern. As we apply heat to the bottom of a coffee cup or more precisely, the fluid in Libchaber's specialized container (Gleick 1987), the number of cylindrical rolls of fluid (bifurcations) continuously increase. Thus actions of a myriad of fluid molecules are coordinated to form large scale "rolls". Similarly, in the body/brain, there is a nested hierarchy of scales (cf. Keizjer 1998). The actions of myriads of atomic elements form large scale molecular movements. The actions of myriads of neurons form large scale neural patterns. It is this hierarchical dynamics, we must assume, that determines the time-scale of the perceived world.

We perceive at a certain scale of time. The cube, rotating at a certain velocity and perceived as a figure with 16 serrated edges, is a perception relative to a certain scale of time. The fly buzzing by, his wings a-blur, is an index of our scale of time. If we consider the brain, seen for a moment as simply a piece of the universal field, we see at the depths of this hierarchy, as physics tells us, "particles" with life spans on the order 10^{-9} nanoseconds and even vastly less. This is an incredibly rapid scale. From this we build to the slightly less rapid scale of quarks, then to the electrons, then to the molecular, then the neural. If the total dynamics defined over these scalar levels determines our normal perceived scale, yet at least in principle it has been argued (Fischer 1966), this dynamics can be changed. The basis of this is seen in biological clocks. The circadian oscillation for example must derive from some kind of continuous interplay among membrane potentials, ion fluxes across membranes, or concentrations of enzymes and their substrates (Winfree 1987). In oscillating systems, that interplay forces these quantities to bobble up and down around their average levels, and can be graphed as a trajectory which ultimately establishes a limit cycle. But the fundamental point is that even these forms of clocks are dependent on a chemical rate of flow. Hoaglund (1966) argued that this rate is subject to change, for example we can introduce a catalyst at the chemical level that modulates the orienting of appropriate bonds such that the velocity of chemical processes is increased. But if we introduce change at a given level, the system will be affected as a whole—there are no preferred levels in a coherent system. There will be an effect on the global dynamics. And there must be a perceptual consequence. The time-scale of the perceived world must change. Given a certain strength of catalyst, the fly, we can posit, may now be moving slowly by, his wings flapping like a heron's. The 16-edged, spinning cylinder-cube is now perceived as a 4-sided cubical figure slowly rotating.

To take a cue from physics, we have changed the "space–time partition". And as in the physical theory, it is only invariance laws (e.g., $d = vt$, or $d' = vt'$) that hold across these partitions (cf. Robbins 2000). The rotating cube remains a figure of $4n$-fold symmetry across partitions. The fly is specified by the same laws whether barely moving, or buzzing by. The aging of the facial profile, defined by a strain transformation applied to a cardioid figure fitted over the skull (Pittenger & Shaw 1975), is specified by the same law across partitions, whether it becomes a fast event or an even slower event.

Scale implies firstly, quality. The hundreds of wing oscillations per second of the buzzing fly, perceived at our normal scale with his wing-beats a-blur, is a certain quality. At the heron-like scale, there is a qualitative change. The color red, a proportion over trillions of oscillations of a field for but a second, is a certain quality. At a higher degree of the velocity of processes, where perception is closer to each developing oscillation, we have another, perhaps more vibrant quality of red. But equally, scale implies extent. The dynamical state of the brain is specific (or proportional) to a given 4-D extent of time, i.e., to a set of past states of the universal field in which it (the brain) is embedded. The buzzing fly, as opposed to the heron-fly, represents a far higher ratio of events at the highest scale of the brain to events in the environmental field—a proportion relative to a far greater history of events in the environment. As we raise the velocity of processes, the ratio of events at the highest scale of the brain relative to events in the external field lowers. The extent of the past specified in the heron-like case is far less than in the buzzing fly.

The External Image as Virtual Action

Let us consider the implications of what we have seen so far. On the one side, we have the transforming image of the cube. It is an image defining a scale on the universal field. On the other side, we have the dynamically transforming neural patterns of the brain, supporting, as we posited, an attractor. It is a dynamics we know must determine the time scale of the image, it is structurally related, it is even proportionally related. Gibson would have termed all this "resonance". But we come then to the critical problem. We see nothing in the brain that can possibly explain the experienced image of the cube. We see only attractors, neural patterns transforming. We stand before the famous gap.

Bergson explored a theory of mind beyond the gap. The dynamically changing field which carries the cube transforming, the fly buzzing, the neural patterns dynamically changing, Bergson, as Bohm (1980), saw as in essence a holographic field. In this field, “brain” and “body” and surrounding “objects” have no more independent or mutually external reality than the “particles” of physics. They are abstractions, born of the fundamental partition into “objects” and “motions” perception makes in this field. It is a partition valid only at a scale of time useful for the body’s action. But the time-motion of this field is critical. Bergson (1896) saw that it must be conceived, not as set of discrete instants or states, but as the motion of a melody, where each “state” (or “note”) interpenetrates the next, forming a dynamic, organic continuity. Treating the motion of time as a divisible line with “parts”—“instants”, “past”, or “present”—has no meaning in this conception. Time-motion is an indivisible. The 4-D “extents” of our scales are indivisibles. They do not consist of sets of past “parts” that cease to exist.

As did Mach, Bergson saw this field as an immense field of motion or real actions. Any given “object” acts upon all other objects in the field, and is in turn acted upon. It is in fact obliged:

“…to transmit the whole of what it receives, to oppose every action with an equal and contrary reaction, to be, in short, merely the road by which pass, in every direction the modifications, or what can be termed real actions propagated throughout the immensity of the entire universe. “ (1896, p. 28)

Defined over this field is an elemental form of awareness/memory. This is due, (1) to its holographic property wherein there is a reciprocal response of each field “element” to every other field element, and (2) to the fundamental time motion of this field wherein each ”state” is the reflection all previous states. When considered then at the null scale—the most minute possible scale of time—there is already an elementary form of perception defined across the field, in Bergson’s terms, an instantaneous or “pure perception” with (virtually) no admixture of memory. As such, the question is not how perception arises, but how it is limited. We have tended to take a photographic view of things, Bergson argued (and Gibson would echo), asking as it were how the brain develops a picture of the external world, or in current terms, how a representation is developed and interpreted as the external world. But he argued, in holographic terms:

“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 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". (1896, p. 31)

Individual perception, he argued, is virtual action. An organism is a system of field elements organized for action. Embedded in the vast (holographic) field of real actions, those influences to which its action systems can respond are reflected as it were as virtual action, the rest simply pass through.

"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, pp. 31–32)

Put in holographic terms, the brain is now seen as a modulated reconstructive wave in a holographic field. The re-entrant architecture, the resonant feedback loops, the "scales" of neural dynamics all ultimately create this modulated wave. As a wave travelling through a hologram is specific to a virtual image, this wave is specific to a virtual subset of the field related to the body's possible action. The modulated wave pattern is constrained by the information in the field to which the action systems can respond. This information, as we have already glimpsed, is the invariance described by Gibson. The wave is specific to a precise, action-related, time-scaled subset of this field—the "rotating" cube, the "buzzing" fly—but this subset is the past. Symmetrically, because it is a specification of action, the virtual image is simultaneously the display of how the organism can act at this scale.

Yasue, Jibu & Pribram (1991) have already described the brain an evolving wave. Globus (1995), discussing their work, describes the evolving brain states "as best thought of as complex valued wave flows. Constraints on the brain's (state) evolution are elegantly represented by Fourier coefficients of the wave spectrum of this formulation" (p. 145). In Pribram's original conjecture (1971) on perception, the external image of the "world–out–there" is somehow "projected" outwards from recorded wave patterns in the brain, while the 1991 work is couched in terms of "projecting invariants" through corticofugal paths. Missing in either case is the reconstructive light wave that transduces the recorded (neural) interference patterns into an optical image. Also unexplained is the homuncular eye which now views the projected image. More succinctly, Pribram yet sees the subject/object relation in terms of space, but this relation is critical.

Note that this dynamical "wave" is not separate, spatially, from the field. It defines a spatial perspective, but fundamentally it defines a scale of time. Subject is differentiated from object only in terms of time. As Bergson would state: "Questions relating to subject and object, to their distinction and their union, must be put in terms of time rather than of space" (1896, p. 77). The buzzing fly or rotating cube and the transforming brain are not separate; they are phases of the same field. At the null scale there is no differentiation. But gradually change the ratio of field events to events at the highest level of the brain: from a vaguely outlined ensemble of whirling "particles", the form of the fly begins to coalesce, then barely move its wings, then becomes the buzzing being of our normal scale. There is no homunculus in this. The dynamical state of the brain is specific to a time-scaled subset of the past states of the field, i.e., it is specific to a time-scaled subset or form of the elementary perception defined over the entire field.

The Relativity of Virtual Action

This subset of the past, we saw Bergson state, is virtual action. The function of the brain is not representation, he held, but the preparation of an array of motor acts. Highly related to Gibson's (1979) notion of the perception of "affordances", the perceived world thus becomes the reflection of an array of action possibilities.

"[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, pp. 6–7)

The order being carved out of the ambient energy flux is a particular order defined relative to the action capabilities of the organism. A large number of findings have in fact pointed to the general concept that the objects and events of the perceived world are in a real sense mirrors of the biologic action capabilities of the body (Viviani & Stucchi 1992; Viviani & Mounoud 1990; Glenberg 1997). Churchland et al. (1994) noted the importance to visual computation of re-entrant connections from motor areas to visual areas, while Weiskrantz (1997) has noted re the findings of Nakamura and Mishkin (1980, 1982) that blindness can result simply from severing visual area connections to the motor areas. Now 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 virtual action. Let us complete the implications, for there are objective consequences, testable in theory, to this principle.

Consider a cat viewing a mouse traveling across the cat's visual field (Figure 3). Recall firstly the complex projective invariance created by the texture density gradient, the size constancy of the mouse over time via an invariant ratio were it moving towards or away form the cat, etc. This entire structure (and much more than described) is supported by the "resonant" or dynamical pattern of the brain. The tuning parameters for the action systems (cf. Turvey 1977a) are an integral part of this dynamical pattern. In Turvey's "mass-spring" model of the action systems, these parameters are "stiffness" and "damping", which specify (as in releasing an oscillatory spring with a weight at one end) the end-point and velocity of an action. 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. Thus the needed muscle-spring parameters must be realized directly in the cat's 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.

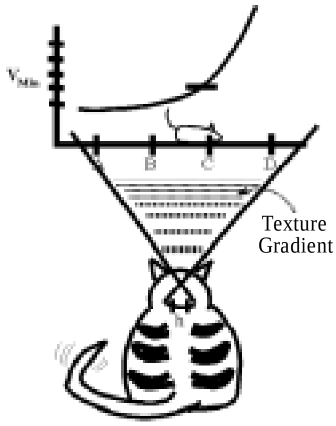

Figure 3: Hypothetical function describing the minimum velocity required for the cat to intercept the mouse at *D*.

The action can be simultaneously conceived to unfold via the coordinated control of various "schemas" as envisioned by Arbib et al. (1998). Could the cat grasp the mouse as a man, we would find pre-shaping schemas of the "virtual fingers" involved in gripping the mouse between them and coordination of the opposition spaces involved, transport or move-arm schemas, wrist rotation schemas, enclose schemas, etc. As Arbib et al. suggest, the trade-off between speed and accuracy implied in Fitts' Law may itself become implicit through experience, also modulating the velocity of the action to a value adjusted or appropriate to the rate of the delayed feedback/error signals received during the course of the action. These schemas themselves, Arbib et al. note, "are mediated by the explicit representation of the duration of each movement" (p. 67), for example, the time needed for transport is compared against the sum of times needed for preshape and enclose, the greater specifying the full time required. But whence the value of time? The mission of the cat is to time his leap to intercept the moving mouse at *D*. At our normal scale of time, we can envision a function relating the minimum velocity of leap (V_{min}) required for the cat to 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 standard to measure velocity. Perhaps he uses one rotation of a nearby rotating disk to define a "second". But if someone were 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/sec. to 1 ft/sec. But the body must use an internal reference system—a system equally subject to such changes. This system must be the internal chemical velocity of the body, a velocity we saw that can be changed by introducing a catalyst—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. 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. If the fly is now flapping its wings slowly, the perception is a specification of the action now available, e.g., in reaching and grasping the fly perhaps by the wing-tip.

This dynamic system, composed of environment and organism, is truly a tightly coupled, reciprocally causal system. As Shaw and McIntyre (1974) had pointed out, it is a symmetric system, and as in any symmetric system, referencing Mach (1902), a change in one part of the system demands a corresponding change in the other to maintain the system's equilibrium. In this case, as they noted, it is a cognitive symmetry, maintaining the equilibrium between the organism's psychological states and the information states of the environment (1974, p. 343). The relativistic principles we have just reviewed merely generalize this symmetry.

Some Implications

An immediate result of the foregoing must be to forestall a desire to construct or generate the perceptual world via the methods of virtual reality—a species of idealism. Clearly to do so would lead to a regress no less grievous than Pribram's re-projected image. We would need to explain the "space" or "screen" in/on which this generated image of reality occurs, "who" sees it, the origin of the scale of time it represents, and if the virtual action principle is correct, how this image is an integral reflection of the possibility of action. The framework presented above allows virtuality to resolve the two poles, realism and idealism. A brain state, isolated (only in our theories) from the physicist's and the realist's surrounding field with its vast and reciprocal interrelations, does not bear the burden of generating the "image" or consciousness. Brain and surrounding field, subject and object, form a single "block" in space, over time. In the terms of the symbol grounding problem (Harnad 1990), we are not yet wondering how internal symbols gain meaning, as we would still be with a constructed virtual reality. The "symbols" in this case are the objects/events of perception, located externally, in depth, in volume, and inherently meaningful as the reflections of the possibility of action.

Implicit in this framework is a different model of memory. If perception is not occurring solely within the brain, then experience is not being exclusively stored there. The brain as a reconstructive wave in a holographic field yet serves for remembering. The invariance structures defining events yet create the constraints defining the modulation pattern of this wave. I see a certain pattern of movement in the grass, and immediately the experience of seeing a snake long ago is reconstructed or "redintegrated". The invariance structure of the current event, *E*′, has driven the modulation of a wave reconstructing a past event, *E*.

This is a "broadly computational" architecture in a sense left fully open by Turing (cf. Copeland 2000). Within it, thought itself rests upon complex modulatory patterns defining waves which manipulate virtual objects/events in time. Even a simple thought, e.g., "The man is stirring coffee with a spoon", rests upon a dynamic invariance structure defined across experience and specifying the event—the radial flow field, the haptic inertial tensor (Turvey & Carello 1995) defining wielding of the spoon, the acoustical quality, etc. The higher the degree of abstraction, e.g., "The human moved the coffee surface with the utensil", or yes, the "computation" 2 + 2 = 4, the higher the order of invariance.

Bergson's virtual action then, taken in conjunction with the mathematical approach to events inherent in Gibson, provides a framework for using virtuality to resolve a long standing problem of perception, and carries, I believe, a potential we have barely begun to explore.

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