(Fuster 1997) and a "supervisory attentional system" (Shallice 1988), both closely connected to internally driven exploring activity. We have no need for sensorimotor contingency for active exploring. O&N suggest that to possess visual awareness is to make use of sensorimotor contingency for the purposes of thought and planning; however, this should be read as follows: visual awareness is to make use of WM for the purpose of thought and planning (Osaka 2002).

Recent brain-imaging studies have attempted to identify functional brain anatomy underlying WM systems based on a WM model originally proposed by Baddeley (1986). An extended model by us assumes that two types of active WM are subserved by distinct cortical structures under the control of a central executive (CE). One is a vision-related WM consisting of dorsal (e.g., spatial WM) and ventral (e.g., face WM) streams. The other is verbal WM located close to the ventral (semantic) stream. The CE, located in the prefrontal cortex (Petrides et al. 1993), controls the processes that make a planned exploratory activity possible and coordinates the two types of WM. The allocation of WM resources is assumed to be coordinated by the CE. An example is the *n*-back dual task in visual WM in which the subject is asked to make an appropriate action when he or she detects the same visual pattern presented *n*-trials before the current trial. In this dual task, subjects have to store successively presented patterns, keeping them "alive" in short-term visual WM while updating information until the appropriate pattern can be monitored and detected (Smith & Jonides 1997). Recent fMRI studies clearly indicate that dorsolateral prefrontal cortex (DLPFC; Brodmann area 46/9), where the CE is assumed to function, is highly activated during *n*-back tasks (Owen et al. 1990) and object/face WM tasks (Courtney et al. 1998). CE appears to work also in the DLPFC in cooperation with the dorsal part of the anterior cingulated cortex, which is assumed to act as an attention-controlling system (Osaka et al. 2002; Petrides et al. 1993). Also, activation of the DLPFC has been observed when two kinds of exploratory activity are performed together (D'Esposito et al. 1995), and damage to the DLPFC is likely to decrease both the activity associated with exploring the environment and performance in spatial WM tasks (Owen et al. 1990). Therefore, we argue that the CE may work as a sensorimotor system based on attention-guidance. In this view, WM is the basis of visual awareness, and the seemingly outside world becomes the internal WM.

We agree with O&N that seeing is a way of acting and is a particular way of exploring the environment. However, one should not necessarily reject an internal representation theory based on brain activity. A theory of sensorimotor contingency might possibly be attributable, in some degree, to the brain's dynamic CE function. Visual experience is just a product of the relevant CE dynamics which guide and coordinate visual information to appropriate action in the environment.

Virtual action: O'Regan & Noë meet Bergson

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Abstract: Bergson, writing in 1896, anticipated "sensorimotor contingencies" under the concept that perception is "virtual action." But to explain the external image, he embedded this concept in a holographic framework where time-motion is an indivisible and the relation of subject/object is in terms of time. The target article's account of qualitative visual experience falls short for lack of this larger framework.

> *[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.*
> – Henri Bergson (1896/1912, pp. 6–7)

So Henri Bergson would initiate his thesis that perception is *virtual action.* It is a more succinct phrase for the important theme of O'Regan & Noë (O&N) (2001) wherein sensorimotor contingencies underlie vision, though the latter concept, as developed, lacks an appreciation of the power of Gibson's invariance laws in specifying events and as input to the action systems. But the primary point here is this: O&N lack the framework in which Bergson embedded this concept, and for this reason their attempt to use it to explain visual experience suffers.

What does the "world as external memory store" look like? If a fly is moving by in the external field, is it the buzzing being of our normal scale, is it flapping its wings heron-like, is it a whirling mass of electrons, a continuously transforming ensemble of quarks, a local pool of pulses in a vast universal sea? The external world as we know it is not simply there to be sampled. The brain imposes a scale of time. It is itself a dynamical system integrating multiple scales, from quark through electron through chemical flows through neuronal patterns. It can be asked, as did Hoaglund (1966), if, *in principle,* the process velocity underlying this global dynamics can be changed, if, for example, the "buzzing" fly of our normal scale could become a heron-like fly, barely flapping his wings – that is, a new specification of scale?

Scale implies *quality.* The "buzzing" fly is a certain quality, the heron-like fly another. Our normal "red" is one quality; the far more vibrant red of the heron-like scale, nearer the individual oscillations of the electromagnetic field, is another. That the underlying dynamics impose a scale, already takes us beyond the origin of quality as simply the interrelation of actions – beyond "sensorimotor contingencies at play" (sect. 6.3). Scale also implies *extent.* The buzzing fly defines a certain time-extent – a multiplicity of *past* events, such as wing oscillations, summed in a blurred visual display. The heron-like fly defines a much lesser extent, the quark-fly far less.

On the one side, we see the brain with its dynamics inherently incorporating the motor systems via their reentrant connections to visual areas, and thus supporting the sensorimotor contingencies. This dynamics, characterized perhaps by an attractor, looks nothing like the world of experience. On the other side, we have the world-out-there as experienced – these are two completely different terms; hence the gap. O&N would have us stop here. We need only the external memory store, waiting to be sampled, virtually acted upon. But action upon what? The external field looks nothing like the world as experienced. What is the four-dimensional extent of this field? At the null scale of time, it is, in the root sense, a non-imaginable field. Sensorimotor contingency, in and of itself, cannot explain the origin of our normal *image* of this field.

Bergson, 50 years before Gabor's discovery, 85 before Bohm (1980), saw this field as a holographic field. He visualized it as a vast field of *real* actions where every object is 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" (1896/1950, p. 28). Discarding the concept, as do O&N, that the brain develops a photograph or representation of the external world, Bergson 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. . . . 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. (1896/1912, p. 31)

Individual perception, Bergson 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. (1896/1912, pp. 31–32)

Put in holographic terms, the brain is now seen as a modulated reconstructive wave "passing through" a holographic field. The reentrant architecture, the resonant feedback loops, the "scales" of neural dynamics all ultimately support this modulated wave. As a wave traveling through a hologram specifies a virtual image, this brain-supported wave specifies a time-scaled, virtual subset of the field related to the body's action.

There is no homunculus here viewing a reprojected wave front (image). First, due to the holographic nature of the field, wherein each point carries the information for the whole, there is an elementary or "pure perception" in Bergson's terms defined across the field at the null scale. This is reinforced by the time-motion of the field, a motion that must be treated not as a series of discrete states or "instants" but as indivisible. As does Nottale (1996) now, Bergson rejected the differentiability of the space-time continuum. It is this indivisible motion that fundamentally supports the qualitative aspect of the world with its time-extents – "buzzing" flies or heron-like flies, or "mellow" violins (Robbins, in press). Secondly, the modulated wave supported by the body/brain is not spatially distinct from the field. The crucial principle of Bergson is this: "*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, emphasis in original). The buzzing fly and the transforming brain are phases of the same dynamically transforming field. At the null scale of time there is no spatial differentiation. But gradually raise the ratio of events in the matter-field to events at the highest scale or level (neural) of the brain and, from a vaguely outlined ensemble of whirling "particles," the form of the fly begins to coalesce, then barely move its wings, then becomes the heron-fly, then becomes the buzzing being of our normal scale. The dynamical state of the brain specifies a four-dimensional extent, a time-scaled subset of the *past* or the past motion of the matter-field; that is, *it is specific to a time-scaled subset of the elementary perception defined over the field.* Symmetrically, it is specific to the possibility of *future* action.

This is Bergson's framework for the relation of sensorimotor contingencies to external field, and therefore the origin of the "external" image; it is how we take "the perceived detail to be out there in the world" (sect. 6.7) The non-differentiable time-motion of this field underlying (scaled) four-dimensional extents is the true support for quality. Within this framework, and implicit in sensorimotor contingencies, is another implication (Robbins 2000; 2001; 2002). If perception is the display of virtual action, it is the display of capability of action (e.g., for the buzzing fly, his wing-beats a-blur, of the modulation of the hand-arm necessary to grasp the fly). But if the dynamics underlying this can be changed – that is, if the chemical velocities underlying this global dynamics are increased – then perception must change. The fly perhaps becomes the heron-like fly precisely because it is a new specification of the possibility of action, perhaps now showing the possibility of removing the fly from the air by his wing tip. This must be so if perception is to be ecologically valid. Albeit unclear practically how today, this is a testable consequence.

An epistemological account of visual consciousness

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Abstract: O'Regan & Noë's (O&N's) explanation of our stream of experience as activities depends on their denial of that palpable, most real aspect of experience: what they call "qualitative experience." Given the ontological primacy of the qualitative givenness of our experience and the complete absence of actions as experiences in our stream of consciousness, though, all such reductionistic attempts must fail.

According to O'Regan & Noë (O&N) (2001), visual awareness (or experience) is due to two processes: first, the brain abstracts laws of sensorimotor contingencies from sensory changes that co-occur with movements, and codes them. One must also exercise mastery of this information or expertly "know all about" (sect. 2.4 of the target article) these contingencies. Second, this knowledge is used for thought or planning, and with this, one becomes aware, or "you see it" (e.g., a color; sect. 2.6). It is important to note that the authors reject the phenomenal or qualitative aspect of experience, arguing that "[visual] qualia are an illusion" (sect. 6.3), and that qualitative experiences are simply "ways of acting. . . . They are things we do" (sect. 6.3). In essence "there is no simple, unanalyzable core of the experience. There are just the different things we do when we [experience]" (sect. 6.4.1). We have three critiques of their proposal.

First, at critical points they are either unclear or inconsistent in describing what experience consists of. For instance, they claim experience consists of many different activities, such as "eye movements, shifts of attention," and "the application of understanding" (sect. 6.4.1), but only one activity, the use of knowledge about sensorimotor contingencies, appears critical (sect. 2.6). In other sections, they equate experience with knowledge ("to experience a red object . . . is to know such things as" sensorimotor contingencies [sects. 6.6 and 6.8]), or knowledge with an activity, ("[seeing red] consists in the (implicit) knowledge associated with seeing redness" [i.e., the laws of sensorimotor contingencies; sect. 6.4.1]). Which of these "things we do" is critical for one to experience? Is experience just activity or is knowledge critical? If knowledge is a critical component of experience, then it is incorrect to state that there are just things we do when we experience unless knowledge is an activity. Since these authors argue against the intuitive understanding of the nature of experience as qualitative, it is critical that they should be clear in their description of their alternative reduction.

Second, and most fundamental, O&N have not provided a compelling argument to reject the existence of phenomenological or qualitative experience. In describing experience in terms of activities, they could argue one of two positions; qualitative experience exists but it is the same thing as activities (the identity argument), or phenomenological experience does not exist and the totality of experience is only activities (the eliminative argument). They argue for the elimination of the reds and qualia of experience, but their argument fails in this rejection of the qualia or red. Consizder their general argument for rejection: (1) vision consists of two processes; (2) if qualitative visual experience is a subset of vision, then experience consists of these processes; and (3) since processes are not qualitative sensory-like states, phenomenological experience must be rejected. Their argument depends on the first premise, that visual experience consists of only these processes. However, they argue only that these processes are involved. The possible existence of these processes, though, does not at all preclude the added existence of a phenomenological or qualitative aspect of experience.

This same basic problem occurs when O&N try to support their argument by demonstrating how experience can be described