1. Introduction: the basic argument

Much work on the brain basis of vision and visual consciousness rests on the idea that for every conscious state of seeing (for every visual experience) there is a neural substrate whose activation is sufficient to produce it. It is widely supposed, in addition, that the function of this neural substrate is to produce sensory experience by generating a “representation” of what is experienced (Chalmers 2000). On this way of thinking, then, vision is the process in the brain whereby such a representation is produced.

In this paper we propose a very different conception of what vision is and of the role of the brain in vision. This paper is based on our previous work on what we call a “sensorimotor” approach to vision (O’Regan & Noë in press [a], in press [b]; Noë & O’Regan 2000; Noë in press [a], in press [b]).

According to this view, vision is not a process in the brain. Though the brain is necessary for vision, neural processes are not, in themselves, sufficient to produce seeing. Instead, we claim that seeing is an exploratory activity mediated by the animal’s mastery of sensorimotor contingencies. That is, seeing is a skill-based activity of environmental exploration. Visual experience is not something that happens in us. It is something we do.

Seeing, on this view, is comparable to dancing with a partner. Just as dancing consists in a delicate interaction between two partners, so seeing, we argue, depends on patterns of interaction between the perceiver and the environment. There is no doubt that neural activity is necessary to enable one’s skillful participation in a dance, but it is unlikely this neural activity is sufficient to give rise to the dancing. After all, the dance, with its weight changes, moments of disequilibria and rebounds, depends on the actions and reactions of the partner (not to mention the nonbrain body). For exactly similar reasons, we argue,
neural activity is not sufficient to produce visual experience. Seeing does not consist in the activation of neural structures (even though it causally depends upon such activation).

A further consequence of this approach to seeing and visual experience — seeing is something we do, not something that takes place inside us — is that it allows us to develop a new framework for thinking about the qualitative character of experience. One of the chief advantages of this new framework, we argue, is that it enables us to overcome the famous problem of the explanatory gap (Levine 1983).

In the first part of paper (§§2-4), we lay out the basic approach. In the remainder (§§ 5-6), we explore the implications of this approach for problems in visual neuroscience.

2. The nature of vision and visual consciousness

2.1 Vision and the laws of sensorimotor contingency

Consider a simple phototactic device such as one of Braitenberg's vehicles (Braitenberg 1984). The imagined vehicle is equipped with two light sensors positioned next to each other on the front of the wheeled vehicle. The left sensor is linked to the right rear wheel driving mechanism and the right sensor is linked to the left rear wheel driving mechanism. As a result of this wiring, the vehicle will orient itself toward light sources and move towards them. Such a simple mechanism can track and hunt light sources.

Suppose there is a light source on the left. This will cause the vehicle to turn in the direction of the light source. Once the vehicle has so turned, the light source is no longer on the left. It will now cause both the left and right wheel drive to activate at the same level, moving the vehicle toward the light source. In this way, what stimulation the system receives is dependent on what actions it performs, and what the system does is affected by what stimulation it receives. This vehicle is built in such a way as to embody, as it were, a set of rules of sensorimotor contingency (a set of rules of interdependence between stimulation and movement).

Now consider a more complicated device such as a missile guidance system. It pursues an airplane by making use, let us imagine, of visual information about the plane. The system is designed, let's say, to speed up in response to the diminishing of the image of the airplane in its camera and to maintain speed if the size of the image is growing. Similarly, it is capable of modifying its behavior depending on whether the image of the plane shifts to the left or right, up or down. For example, the system might be designed to shift to the left when the image of the airplane shifts to the left in its viewfinder, thus bringing the image of the plane back into the center. The missile guidance system, we may say, masters the sensorimotor contingencies of airplane tracking; it is built in such a way as to exploit, in its tracking activities, the interdependence between the availability of sensory information and its motor behavior. The system is, in this sense, attuned to the structure of sensorimotor contingencies. It is perceptually coupled with its environment.

We propose that perceptual systems in animals be thought of along the lines of the sort of simple systems described here. A visual perceiver is familiar with (masters) the ways in
which visual information changes as a function of movement of the perceiver with respect to the environment. Movement towards an object causes an expansion of the retinal projection. A flick of the eyes to the left causes a displacement of projected items to the right. Because of the curvature of the retina, the retinal projection of a straight line is deformed in a predictable manner as one directs one’s eyes upward. In addition, perceivers are familiar with the ways in which changes in the position of the object relative to its environment give rise to new patterns of stimulation. There are a vast array of sensorimotor contingencies; to be a perceiver is, at least, to be the master of these regularities. (See O’Regan & Noë in press [a], for more detailed exposition.)

Perceptual sensitivity, on the view advocated here, consists in the ability to explore the environment in ways mediated by implicit knowledge of the patterns of sensorimotor contingency that govern perceptual modes of exploration.

2.2 Beyond visual sensitivity: visual awareness

The simple systems we have described exhibit some measure of perceptual sensitivity. It would, however, be unreasonable to say that such a system is aware of that to which it is perceptually sensitive. Such a system does not see. However, we have described what we can think of as the ground of a system’s more full-blooded perceptual awareness, namely, the perceptual coupling of animal and environment that consists in the animal's access to environmental detail thanks to its mastery of the relevant sensorimotor contingencies. For an animal to be, in addition, perceptually aware of that to which it is perceptually sensitive is for it not merely to be appropriately coupled perceptually, but for it to integrate its coupling behavior with its broader capacities for thought and rationally guided action. The driver, for example, who fails to pay attention to what he or she is doing or to that to which he or she is responding is still able to exercise mastery of the sensorimotor contingencies needed to drive the car. Such a driver is, as it were, on “automatic pilot”. When in addition the driver is able to make use of information not only about that to which he or she is perceptually sensitive, but also about the character of his or her perceptual tracking of the environment, we say the driver is aware of what he or she perceives.

So, for example, perceptual sensitivity gets us to detect the changing of the traffic light as we drive. We only see the light (that is, become perceptually aware of it, in our sense), when we exert control over our coupling with the light and when we use the information about the light this coupling affords. (We will notice later, in §3, that this way explaining matters fits very nicely with the findings of recent psychological studies.)

We contrast, then, two distinct levels of perceptual capacities. First, there is perceptually guided activity or perceptual coupling. This is basic perceptual sensitivity. Second, there is access to and control over information about that to which we are perceptually coupled. This is perceptual awareness.

2.3 Visual consciousness

We have offered accounts of two levels of perceptual capacity: perceptual sensitivity and perceptual awareness. What, on our view, is visual consciousness? Visual consciousness,
we argue, is simply what we have been calling visual awareness. Importantly, there is no need to think of visual consciousness as constituting a further third level of perceptual capacity.

To explain, let us distinguish two kinds of visual consciousness: (1) *transitive visual consciousness* or consciousness of, and (2) visual consciousness in general.

(1) To be *transitively conscious* is to be conscious of a feature of a scene. Consciousness, in this sense, is what we have called visual awareness. Thus, to say that you are transitively conscious of (say) the shape of a parked car in front of you is to say that you are, first, currently exercising mastery of the laws of sensorimotor contingency that pertain to information about the shape of the car; and second, that you are attending to this exercise, in the sense that you are integrating it into your current planning, reasoning and speech behavior.

Notice that when you are transitively conscious of the shape of the car, you may fail to attend to its color, or to the fact that the object in front of you is a car. As you shift your attention from aspect to aspect of the car, features of the car enter consciousness. What happens when you thus shift your attention is that you draw into play different bits of implicit knowledge of the relevant sensorimotor contingencies.

(2) *Visual consciousness in general*, on the other hand, is a higher-order capacity. To be visually conscious in general is to be able to become aware of a present feature (that is, to become transitively conscious of it). In this sense of visual consciousness, we can contrast being visually conscious with being asleep or with being blind. Consciousness in this most general sense consists in one’s possession of the ability to become conscious of aspects of a scene (that is, in one’s ability to see, to explore aspects of the environment in a fashion mediated by the relevant sensorimotor contingencies).

2.4 *What is visual experience? A temporally extended pattern of skillful activity*

Implicit in this account is a somewhat unorthodox analysis of the nature of visual experience. We propose that visual experience is the activity of exploring the environment as mediated by mastery of appropriate patterns of sensorimotor contingency in ways that draw on broader capacities for action, thought, and (in humans) language use. Importantly, visual experience or conscious seeing, as opposed to the mere processing of visual information, is not something that occurs inside us. It is something we do.

To understand the force of this claim, consider the experience of driving a particular kind of car, say a Porsche. What does this experience consist in? Notice that, in one sense, there is no feeling of driving a Porsche. That is, the character of Porsche-driving does not consist in the occurrence of a special sort of momentary flutter or bodily sensation. What defines the character of driving a Porsche, rather, is *what you do when you drive a porsche*. There are characteristic ways in which the vehicle accelerates in response to pressure on the gas pedal. There are definite features of the way the car handles in turns, how smoothly one can change gears, and so on. What it is like to drive a Porsche is
constituted by all these sensorimotor contingencies and by one’s skillful mastery of them, one’s confident knowledge of how the car will respond to manipulations of its instruments.

In one sense, then, there is no single experience of driving a Porsche. What it is like to drive a Porsche depends on these various activities. In another sense, however, one can speak of the experience of driving a Porsche, but this must be understood not in terms of the occurrence of defining sensations, but rather, in terms of one’s comfortable exercise of one’s knowledge of the sensorimotor contingencies governing the behavior of the car.

Seeing (having visual experiences), we argue, is like Porsche driving. It is not something that happens in us, but something we do. And the character of seeing, like that of driving, is constituted by the character of the various things we do when we see (or when we drive). Suppose you stand before a red wall. It fills up your field of view. What is it like for you to see this red wall? Try to describe the experience. How do you fulfill this instruction? One thing you might do is direct your attention to one aspect or another of the wall’s redness. For example, you might focus on its hue, or its brightness. In this way you become transitively conscious of (that is to say, aware of) this or that aspect of the wall’s color. How do you accomplish this? In what does your focusing on the red hue of the wall consist? It consists in the (implicit) knowledge associated with seeing redness: the knowledge that if you were to move your eyes, there would be changes in the incoming information that are typical of sampling with the eye; typical of the nonhomogeneous way the retina samples color; knowledge that if you were to move your head around, there might be changes in the incoming information typical of what happens when illumination is uneven, etc. Importantly, there is not one thing in which the focussing of your attention on the hue (say) consists. Eye movements, shifts of attention, the application of understanding — seeing the red hue of the wall consists in all of this. There is no simple, unanalyzable core of the experience. There is just the different things we do when we interact with the redness of the wall.

Of course this is not to deny that vision may, under certain circumstances, involve feelings or sensations of a non-visual nature. So, for example, if you are trying to track the movement of an object without moving your head, you may feel a certain distinctive eye strain. If you witness an explosion, you may feel dazzled in a way which causes definite sensations in the eyes. If vision is, as we have argued, a mode of activity, then there may be all sorts of features of that in which the activity consists that in this way contribute to its “felt character.” And so, likewise, there may be sensations that occur when driving, e.g. the press of the steering wheel on one’s hands. But crucially these are not intrinsic or defining properties of the experiencing. They are rather more or less accidental accompaniments of the activity of seeing on a particular occasion.

2.5 The ineffability of the qualitative character of experience
We have proposed that experience is a temporally extended activity of exploration as mediated by the perceiver’s knowledge of sensorimotor contingencies. The differences in the qualitative character of perceptual experiences correspond to differences in the character of the relevant sensorimotor contingencies. Just as the difference between
driving a Porsche and driving a tank consists in the different things you do in driving it — or in the different skill-based understanding of how to drive the vehicle — so the difference between seeing a red flower and smelling a red flower consists in the different patterns of sensorimotor contingency governing one’s perceptual encounter with each. To experience a red object, or the feel of driving a Porsche, is to know such things as that if you change the illumination in such and such ways (or press down on the accelerator in such and such ways), it will produce such and such changes in the stimulation.

It follows, on this view, that to reflect on the character of one’s experience is to reflect on the character of one’s law-governed exploration of the environment, on what one does in seeing. Some of the sensorimotor contingencies governing vision are easily accessible to awareness. If you reflect on the character of your visual experience of a colorful flower, for example, it is easy to comprehend the manner in which the appearance of the flower is a function of viewing angle and illumination. If you look at a plate and turn it, you can become aware of the way its profile becomes elliptical. If you put on inverting lenses, it is immediately apparent that eye and head movements produce surprising patterns, thus enabling us to direct our attention to the disruption of familiar patterns of sensorimotor contingency. But though we have access to these aspects of the sensorimotor contingencies, there are other components of the sensorimotor contingencies which do not lend themselves easily to propositional description, and which are not so easily brought into consciousness: the exact laws that the flower’s color obeys when you change the illumination, the exact rule determining the modification of the plate's profile, the precise disruption caused by distorting lenses. Other examples which are even less accessible to consciousness are the particular way the macular pigment and the non-homogeneity of retinal sampling affect sensory input when the eye moves; the optic flow that occurs when the head rotates, etc.

We believe that these considerations enable us to get clear about a feature of experience that has often provoked puzzlement on the part of scientists and philosophers, namely, its apparent ineffability. It is very difficult to describe everything we do when we see, just as it is difficult to describe everything we do when we are engaged in other skillful activities such as athletic endeavors, playing an instrument, or speaking a language. A major portion of our mastery of sensorimotor contingencies takes the form of practical know-how. When we attempt to inquire into the more subtle features of what goes on when we perceive, we immediately come up against the fact that it is very difficult to describe any but the most high-level, gross sensorimotor contingencies.

There is nothing mysterious about this inability. In general, the ability to know how to do something does not carry with it the ability to reflect on what it is one does when exercising the ability in question. The difficulty of describing the character of experience is not evidence of the special character of experience in the world order. But it does bring forcibly to mind the fact that experiences are exercisings of complicated capacities, not ongoing occurrences in the mind or brain.
2.6 What are sensory modalities?

The approach to vision and visual experience developed here, according to which vision is a mode of exploration of the world that is mediated by knowledge of sensorimotor contingencies, offers a standpoint from which we can reconsider the question of the nature of sensory modalities. Not very much scientific investigation has addressed this kind of question. Most scientists seem satisfied with some variant of Müller’s [1838] classic concept of “specific nerve energy”. Müller’s idea, in its modern form amounts to the claim that what determines the particularly visual aspect of visual sensations is the fact that visual sensations are transmitted by particular nerve pathways (namely those originating in the retina and not in the cochlea) that project to particular cerebral regions (essentially cortical area V1). It is certainly true that retinal influx comes together in relatively circumscribed areas of the brain, and that this may provide an architectural advantage in the neural implementation of the calculations necessary to generate visual-type sensations. But what is it about these pathways that generates the different sensations? Surely the choice of a particular subset of neurons or particular cortical regions cannot, in itself, explain why we attribute visual rather than auditory qualities to this influx.

On our view, the differences between the sensory modalities are to be understood in terms of the different patterns of sensorimotor contingency governing perceptual exploration in the different modalities. To see a bottle, for example, is to explore visual-motor contingencies, e.g. transformations in the appearance of the bottle as one moves in relation to it. To touch it, on the other hand, is to explore the structure of tactile-motor contingencies. The bottle impedes, guides and informs tactile exploration of the bottle. The difference between seeing a bottle, and touching it, consists in just these sorts of fact about the active engagement the perceiver undertakes with the environment (see Noë in press [a], in press [b]).

3 Is the visual world a grand illusion?

3.1 An important empirical upshot: change blindness

An important consequence of this account of visual consciousness is that we are not, in general, aware of all the details present before us in the environment. We do not, that is, experience everything in the visual field all at once. We only see that to which we are currently attending. This idea was the impetus for a number of surprising experiments performed by O’Regan, Rensink and others (Rensink, O’Regan & Clark 1997; O’Regan, Deubel, Clark & Rensink 2000; O’Regan, Rensink & Clark 1999). In these experiments, observers are shown displays of natural scenes, and asked to detect cyclically repeated changes, such as a large object shifting, changing color, or appearing and disappearing. Under normal circumstances a change of this type would create a transient signal in the visual system that would be detected by low-level visual mechanisms. This transient would exogenously attract attention to the location of the change, and the change would therefore be immediately seen.

In these experiments, however, conditions were arranged such that the transient that would normally occur was prevented from playing its attention-grabbing role. This could
be done in several ways. One method consisted in superimposing a very brief global flicker over the whole visual field at the moment of the change. This global flicker served to swamp the local transient caused by the change, preventing attention from being attracted to it. A similar purpose could be achieved by making the change coincide with an eye saccade, an eye blink, or a film cut in a film sequence (for a review, see Simons & Levin 1997; Simons 2000). In all these cases a brief global disturbance swamped the local transient and prevented it attracting attention to the location of the change. Another method used to prevent the local transient from operating in the normal fashion was to create a small number of additional, extraneous transients distributed over the picture, somewhat like mudsplashes on a car windscreen (cf. O'Regan et al 1999). These local transients acted as decoys and made it likely that attention would be attracted to an incorrect location instead of going to the true change location.

The results of the experiments showed that in many cases observers have great difficulty seeing changes, even though the changes are very large, and occur in full view -- they are perfectly visible to someone who knows what they are. In other experiments, O'Regan et al. found that, in many cases, observers could be looking directly at the change at the moment the change occurred, and still not see it.

These results are surprising if one supposes that we do in fact experience all the detail present in the environment, or if one subscribes to the view that the visual system builds up a detailed internal representation of the three-dimensional environment on the basis of successive snap-shot like fixations of the scene. But under the view that what one sees is the aspect of the scene to which one is attending — with which one is currently interacting — then it is not at all surprising that large changes might go completely unnoticed if they happen to correspond to parts of the scene which have not been attended to.

Other results showing that people can be looking directly at something and not see it had previously been obtained. Neiser and Becklen used a situation which was a visual analogue of the "cocktail party" situation, where party-goers are able to attend to one of many superimposed voices. Neisser & Becklen visually superimposed two independent film sequences, and demonstrated that observers were able to single out and follow one of the sequences, while being oblivious of the other. Simons and Chabris (1999) have recently replicated and extended these effects.

Finally Mack and Rock (1998) have done a number of experiments using their paradigm of "inattentional blindness". In this, subjects will be engaged in an attention-intensive task such as determining which arm of a cross is longer. After a number of trials, an unexpected, perfectly visible, additional stimulus will appear near the cross. The authors observe that on many occasions this extraneous stimulus is simply not noticed.\(^1\)

\(^1\) In Noë & O'Regan (2000) we explore the philosophical significance of work on inattentional blindness.
3.2 The grand illusion hypothesis

How can we reconcile these striking results with our impression that, when we see, we are aware, as if all at once, of all the present environmental detail? Do phenomena such as change blindness and inattentional blindness demonstrate that visual consciousness is a grand illusion, as several authors have suggested (e.g. Blackmore, et al. 1995; Dennett, 1991, 1992, 1998; O'Regan 1992; Rensink et al 1997).

As pointed out by Noë, Pessoa and Thompson (2000) and Noë (in press [a]), this “grand illusion hypothesis” rests on a mistaken account of the everyday phenomenology of perceptual experience. It is true that most perceivers will assent to the claim that, when they see, they see the whole scene, with all the detail. That is, it is true that that normal perceivers take themselves to be aware of a detailed environment. They take themselves to learn that the environment is detailed thanks to their experience, and they are able, on the basis of their experience, to encounter each bit of (visible) detail. But importantly, there is no illusion in any of this. Perceivers are right to take themselves to have access to environmental detail, and to learn that the environment is detailed. Moreover, the change blindness results are entirely compatible with this account of the character of our visual experience.

What is called into question by the change blindness results (and by the inattentional blindness results) is the idea that when we see environmental detail, we have all of it in consciousness at once. What is challenged is the idea that all the detail is present in the head now. If all the detail were present in the head now, then surely we would not fall victim to change blindness.

But is there any reason to believe that normal perceivers are committed to this “details in the head” conception of visual consciousness? When normal perceivers assert that they take themselves to see the detailed environment, do they mean to say that they take themselves to have all the detail present to consciousness all at the same time? On our view there is absolutely no reason to think that normal perceivers believe this.

Consider, for a moment, what your perceptual experience is actually like. You open your eyes and you take in all this detail. Does it really seem to you now as if all that detail is in your consciousness now, all at once? Does it seem to you as if you simultaneously attend to all the detail? No. It seems to you as if the detail is there, in front of you, in the world, and as if you have access to that detail by means of eye, head and body movements. Perceivers all know, whether they reflect on this or not, that visual exploration of the environment requires continuous adjustments. We squint, lean forward, reach for our glasses, tilt our reading material to the light, and casually walk to the window to get glimpses. We act as though we believe that the detail is there, in front of us, and that to acquire detail, to bring it into consciousness, we need to act.

It is of course true that people find the change blindness experiments very surprising. In addition, students are apt to find surprising familiar psychology demonstrations of their inability to tell the color of an object held in peripheral vision. It is sometimes suggested that this astonishment is evidence that we do tend to think of our experience along the
lines of the “details in the head” conception. But there are other ways of explaining the astonishment. On our view, vision is a complicated skill-based activity. We tend to be unaware, when we are engaged in our perceptual lives, of the complicated things we do when we see. Just as dancers, musicians, or athletes are inattentive to the subtle modulations they undertake in the conduct of their activity, so perceivers fail for the most part to attend to the ways in which seeing depends on eye movements (as well as on head and body movements). The surprise we feel in demonstrations such as these is comparable to the surprise we feel when we discover how difficult it is to perform a manual task such as typing or driving with a cast on one’s little finger. We are insensitive to the complexity of the things we do when we do things.

3.3 The world as an outside memory

The account of vision developed here enables us to understand how it is possible to enjoy a sense of perceptual awareness of the whole scene, even though we only see that to which we direct our attention. Our sense of the perceptual presence of the whole scene stems from the fact that we have continuous access to the scene.

To explain this, consider that the environmental detail is present, lodged, as it is, right there before us and that we therefore have access to that detail by the mere movement of our eyes or bodies. According to the sensorimotor contingency view, perceivers are masters of the sensorimotor contingencies in virtue of which they can acquire perceptual information. This mastery consists not only in the possession of sensorimotor skills, but also -- and this is hugely important -- in the ability on the part of perceivers, effortlessly to draw on those skills as need arises. One way to capture the point we are trying to make is to note that we are seldom surprised by sensorimotor contingencies (as we would be, say, were we to put on inverting lenses). With the possession of skillful mastery of sensorimotor contingencies, then, there comes a readiness in the face of new experience. One might say, of this readiness, that it consists in the knowledge that the mere flick of an eye or turn of the head will make available currently unavailable information, but this would be somewhat misleading in so far as the sort of knowledge at play here is practical and nontheoretical.

On this analysis, there is no need for the brain to construct a detailed internal representation or model of the environment, since the environment is there to serve, in Brooks’ (1991) phrase, as its own best model. As O’Regan (1992) has proposed, the environment serves as a kind of external memory store. Information is available in the environment to be sampled as needed, by the flick of the eye or the turn of the head.

This analysis of our sense of contact with detail in terms of our confident skill-based access to detail is relevant to our understanding of the visual phenomenon of "amodal completion".

Take, as an example, the perceptual experience of partially occluded objects. When you see a cat through a picket fence, you take yourself to perceive a cat, even though, if we imagine that the cat stands still, you only really see strips of the cat’s surface through the slats of the fence. Crucially, there is a genuine sense in which you experience or perceive
and do not merely surmise the strictly unseen portions of the cat. One’s experienced relation to the unperceived portion of the cat is not at all like one’s relation to the hallway outside one’s door. The hallway is also felt to be present. But this feeling of presence is nonperceptual. The sensorimotor contingency theory offers an explanation of the difference between what is directly seen, what is amodally perceived, and what is merely ‘thought as present’ but not perceived. First, the perceiver of the cat “knows,” in a practical sense, that a step to the right will produce new cat-surface. It is the knowledge that movement or alteration of the sensory organ gives rise, in systematic and predictable ways, to new sensory data, which provides the sensory character of our contact with the cat. Second, it is precisely the absence of this sort of sensorimotor contingency in the case of the hallway outside one’s door, or the room behind one’s head, that makes these latter examples a ‘thought presence’ but not an ‘experienced presence.’ Consider, for example, that if you blink, this has no affect on your feeling of the presence of the room behind the head. This goes a long way to showing that the felt presence of the room behind the head is not a perceptual presence.

4. Visual consciousness reconsidered

4.1 The problem of qualia
It may be argued that there is still something missing in the present account of vision, namely, an explanation of the qualitative character of visual experience. Can the sensorimotor contingency theory in addition provide an explanation of what philosophers have called “the raw feel” or “qualia” of seeing?

On our view the qualia debate rests on what Ryle (1949) called a category mistake. Qualia are meant to be properties of experiential states or events. But experiences, we have argued, are not states. They are ways of acting. They are things we do. There is no introspectibly available property determining the character of one’s experiential states, for there are no such states. Hence, there are, in this sense at least, no (visual) qualia. Qualia are an illusion, and the famous explanatory gap (cf. Levine 1983) is no real gap at all.

It is important to stress that in saying this we are not denying that experience has qualitative character. We have already said a good deal about the qualitative character of experience and how it is constituted by the character of the sensorimotor contingencies at play when we perceive. Our claim, rather, is that it is confused to think of the qualitative character of experience in terms of the occurrence of something (whether in the mind or brain). Experience is something we do and its qualitative features are aspects of this activity.

4.2 What gives rise to the illusion of qualia?
Many philosophers, vision scientists, and lay people will say that seeing always involves the occurrence of raw feels or qualia. If this view is mistaken, as we believe, then how can we explain its apparent plausibility to so many? In order to make our case convincing, we must address this question.
To appreciate one main source of the illusion of qualia, consider once again the phenomenon of change blindness. Many people say that they have the impression that when they see, the entire visual field is present to consciousness in all its nearly infinite detail. The change blindness results suggest that we do not have such detailed, picture-like awareness. What explains the conviction that we do? As we have discussed above, and as argued by O’Regan (1992; O'Regan et al. 1999), the explanation is that we have access to all the detail by means of the mere flick of an eye or turn of the head, and so it is as if we had everything in view all the time. The feeling of presence of the detail stems from our implicit knowledge of the ways in which movements of the eye and head gives rise to new detail and new information. Importantly, one can explain this feeling without supposing that all the detail is represented in consciousness.

In exactly this way when we see something red, we feel that the redness has a certain definite, sensation-like presence and immediacy. The explanation for this is that we have access to the redness by the most minute of eye movements or attentional shifts. The redness is there, in the environment. The slightest eye, head or attention movement reveals further information about its character. Because we have continuous access to the redness in the environment, it may seem as if we are mentally in contact with it continuously. This leads us to say, mistakenly, that there is a feeling of redness (say) in our heads all along.

We have already considered an important second source of the illusion of qualia. We tend to overlook the complexity and heterogeneity of experience and this makes it seem as if in experience there are unified sensation-like occurrences. Just as there is no single, unitary quality of driving a Porsche, so there are not single unitary visual sensations.

4.3 Is the illusion of qualia really so widespread?

Is the illusion of qualia really as widespread as it would seem? Perhaps not. If you ask what a person sees, he or she will not bring up visual experiences and their intrinsic features. In everyday life, discussions of what we see are for the most part confined to discussions of things themselves (of the things we see). Even when we are viewing a piece of art, when we may deliberately try to reflect on the way the work affects us visually, nonphilosophers will rarely confuse the question what it is like to look at the piece (what it reminds one of, how it makes one feel, whether one finds it pleasant, or not) with that favorite question of philosophers’, namely, what is it like to have an experience as of seeing a painting (that is, what are the intrinsic, qualitative features of the visual experience)?

Another way to put this point is say that qualia-based accounts of the phenomenology of experience actually misdescribe the phenomenological character of experience (what experience is like). Qualia talk, one might say, is theory driven and the illusion of qualia is a theoretical illusion. Crucially, normal perceivers do not, in virtue of being normal perceivers, buy into the relevant theory.
4.4 Overcoming the explanatory gap (or Why there is no gap)
The problem of the explanatory gap is that of explaining qualia in physical or biological terms. We believe that our view bridges this gap. More accurately, it demonstrates that the gap itself is an artifact of a certain—we believe mistaken—conception of experience. There is not really any gap at all.

Our claim, simply put, is this: there is no explanatory gap because there is nothing answering to the theorist’s notion of qualia. That is, we reject the conception of experience that is presupposed by the problem of the explanatory gap. (Note that we can make this claim even though we do not, as we have been at pains to explain above, deny that there are experiences and that experience has qualitative character.)

To appreciate the structure of our claim, consider once again, very briefly, the Porsche-driving example. We have argued that the feeling of driving a Porsche is constituted by the different things we do when we drive a Porsche, and from our confident mastery of the relevant sensorimotor contingencies. We can now appreciate that there is no need to explain the physical or causal basis of the occurrence of the unitary Porsche-driving quality, for there is no such quality. And so, likewise, there is no need to seek a neural basis for the occurrence of visual qualia such as that of red, for, in the relevant sense, there are no such qualia.

To this it will be objected that it is no more easy to see how possession and mastery of sensorimotor skills is to bridge the explanatory gap than it is to see how different patterns of neural activity can accomplish the same feat. But this very question betrays a failure to understand our proposal. For our claim is not that knowledge and exercise of sensorimotor contingencies can solve the same feat. Our claim is that there is no feat to be accomplished and therefore no possible way in which neural activity can accomplish it. Let’s return again to simple examples. You hold a bottle in your hand. You feel the whole bottle. But the different parts of your hands make contact only with isolated parts of its surface. Nevertheless, don’t you feel the whole bottle as present? That is, phenomenologically speaking, the feeling of presence of the bottle is not a conjecture or an inference. The feeling you have is the knowledge that movements of the hand open up and reveal new aspects of bottle surface. It feels to you as if there’s stuff there to be touched by movement of the hands. That’s what the feeling of the presence of the bottle consists in. But the basis of the feeling, then, is not something occurring now. The basis rather is one’s knowledge now as to what one can do.

5. Vision and brain

5.1 Neural Correlates of visual consciousness?
A considerable amount of recent work in visual science and consciousness studies has been devoted to the quest for what has been called “neural correlates of consciousness” (Crick & Koch 1995, 1990, 1998) —for an illuminating review see Chalmers (2000). As an illustration of such work, we can use the impressive studies of Logothetis and colleagues (Logothetis, Leopold & Sheinberg 1996; Logothetis 1998; Leopold and Logothetis 1999) analyzing neural substrates of binocular rivalry in
laboratory monkeys. In binocular rivalry each eye is presented with a different stimulus (e.g. a horizontal bar, a face). Under these conditions the observer experiences not both stimuli, or some amalgam of the two, but rather a sequence of alternating percepts corresponding to one or other of the two stimuli. When one stimulus is dominant, the other is not perceived. The perceptual reversals occur irregularly and at intervals of a few seconds. Logothetis and collaborators show that in tested visual areas (e.g. V1/V2, V4, MT, IT, STS), some neurons are unaffected by perceptual reversals. The activity of these neurons is driven by the stimulus patterns entering the eyes, which remain unchanged. The activity of other neurons, however, depends directly on the internally generated shifts in the percept. The percentage of such percept-driven cells is substantially higher in IT and STS, where 90% of tested neurons correlate to percepts, than in other visual areas. (In V1/V2, for example, a much smaller percentage of neurons were percept-driven.) These data suggest (it is claimed) that neural activity in IT and STS forms the neural correlate of the experience.

Other kinds of neural representations or neural correlates of conscious perceptual experience arise in the context of perceptual completion phenomena. A classical example is the work of von der Heydt and his colleagues, who found neurons in V2 that fire for illusory contours in a very similar way that they fire for real contours (von der Heydt, Peterhans & Baumgartner 1984; von der Heydt, & Peterhans1989; Peterhans & van der Heydt 1989). A number of other examples involving perceptual completion have been reviewed by Pessoa, Thompson & Noë (1998). (See also Thompson, Noë and Pessoa 1999.)

Work like that described above has been received with enthusiasm: researchers believe that the discovery of neural representations that correlate with perceptual experience brings us closer to understanding what gives rise to the perceptual experience. The underlying assumption is that if a set of neurons is found in the brain which correlates strongly with aware perceptual states, then, because these neurons are probably linked to the mechanisms that are generating awareness, we are likely to be able to explain perceptual awareness by appeal to this neural activity.

But this reasoning is unsound. Indeed, consider what would happen if we were actually to find a set of neurons that correlated perfectly with visual awareness. For the sake of illustration, suppose we were to discover that in the pineal gland of macaque monkeys there were a tiny projection room in which what is seen by the monkey was projected on an internal screen whose activity correlated perfectly with the monkey’s visual awareness. On reflection it is clear that such a discovery (this would surely be the Holy Grail of a neural correlate of consciousness seeker!) would not bring us any closer to understanding how monkeys see. For we would still lack an explanation of how the image in the pineal gland generates seeing, that is, how it enables or controls or modulates the forms of activity in which seeing consists. We would certainly be entitled, on the basis of the strong correlation between features of what is seen and features of what is projected onto the pineal projection screen, to assume that this neural activity played some role in vision. But nothing more could be said about such a discovery.
Why do some researchers believe that to understand the nature of consciousness or vision it is necessary to track down the neural representations that correlate with conscious experience? One possible explanation is that these researchers are (perhaps unwittingly) committed to the idea that the discovery of perfect correlation would give us reason to believe that we had discovered the neural activity sufficient to produce the experience (as suggested by Chalmers (2000). Teller and Pugh (1983) call such a neural substrate of experience the bridge locus. In addition, thinkers may unwittingly subscribe to what Pessoa, Thompson and Noë (1998) and Thompson, Noë and Pessoa (1999) have called analytic isomorphism. This is the view that for every experience there will be a neural substrate whose activity is sufficient to produce that experience (a bridge locus) and that there will be an isomorphism (though not necessarily spatial or topographic) between features of the experience and features of the bridge locus. It is the existence of such an isomorphism that works to justify the claim that the discovery of such a neural substrate would explain the occurrence of the percept.

We believe that one must reject the metaphysical dogma of analytic isomorphism. As argued by Pessoa, Thompson and Noë, no neural state will be sufficient to produce experience. Just as mechanical activity in the engine of a car is not sufficient to guarantee driving activity (suppose the car is in a swamp, or suspended by a magnet), so neural activity alone is not sufficient to produce vision.

Note also that if this view is correct, then it is a mistake to expect to find neurons which are perfectly correlated with visual consciousness. Ultimately visual consciousness is not a single thing, but rather a collection of task and environment-contingent capacities each of which can be appropriately deployed when necessary. Furthermore, we expect that if neurophysiologists do find neurons that correlate strongly with awareness, then most likely this will only be for one or other set of conditions or tasks.

5.2 There is no need for "binding"

Neuroanatomists believe that the visual system is composed of numerous, more or less independent subsystems (or modules), which extract a variety of different attributes such as color, contrast, depth, orientation and texture from the visual stimulus (e.g. De Yoe & van Essen 1988; Livingstone & Hubel 1988; Zeki 1993). The fact that these modules operate independently and are often localized in different cerebral regions raises the question of how the separate streams of information ultimately come together to give us a unified experience. One suggestion for solving this so-called "binding problem" was the idea of the "grandmother cell" in which single cells or at least highly localized cerebral regions, combine information pertaining to specific percepts: e.g. face-sensitive cells (Rolls 1992); place sensitive cells (O'Keefe et al. 1998); view sensitive cells (Rolls & O'Mara 1995). A more recent idea which does not require bringing signals into a single brain location has also received support from neurophysiological evidence (c.f. Brecht, Singer & Engel 1998; Castelo-Branco, Neuenschwander, & Singer 1998; Abeles & Prut 1996; Llinas & ribary 1993; Gray & Singer 1989). Under this view, separate cortical areas which are concurrently analyzing the different aspects of a stimulus might oscillate in synchrony, and it might be this synchrony which provides the unity of perceptual experience (as well as the perceptual experience of unity).
There are two motivations in the reasoning which underlies these types of investigations: one concerns temporal unity, and the other concerns 'conceptual' unity. Certainly it is true that we have the impression that, when we recognize an object, all its attributes are seen simultaneously at one “perceptual moment”. This leads scientists to think that the objects' attributes must be bound together synchronously in the internal representation in order to provide the singleness of the perceptual moment. But this is a fallacy. Thinking that physical synchrony is necessary for having a synchronous experience is the same kind of fallacy as thinking that because we experience the world spatially, there must be topologically equivalent maps in the brain. Underlying this fallacy is the implicit assumption that the synchrony or coherence of perception requires presenting information in a synchronous or coherent way to an internal homunculus. In fact, just as the perception of the three-dimensional world does not require three-dimensional maps in the brain, subjective simultaneity does not require simultaneity of brain events. This point has been made by Dennett & Kinsbourne (1992); see also O’Regan (1992) and Pessoa, Thompson and Noë (1998). What explains the temporal unity of experience is the fact that experience is a thing we are doing, and we are doing it now.

Coming now to the issue of 'conceptual' coherence, a similar argument can be made: the fact that object attributes seem perceptually to be part of a single object does not require them to be "represented" in any unified kind of way, for example at a single location in the brain, or by a single process. They may be so represented, but there is no logical necessity for this. Furthermore, if they are represented in a spatially or temporally localized way, the fact that they are so represented cannot in itself be what explains the spatial, temporal or 'conceptual' phenomenology of perceptual coherence. What explains the conceptual unity of experience is the fact that experience is a thing we are doing, and we are doing it with respect to a conceptually unified external object.

Above we noted that were we to discover pictures in the brain that correlated with the experience of seeing, we would still have moved very little closer towards an explanation of seeing. But once we recognize this, then we further realize that there is no reason to suppose that to explain seeing we should seek for detailed internal pictures. There is no longer any rationale for supposing that there is a place in the brain where different streams of information are brought together and “unified” (whether conceptually or temporally). With the appreciation of this point we can dismiss the problem of binding as, in essence, a pseudo-problem.

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2 See Dennett (1991) and Dennett and Kinsbourne (1992) for a similar point.
3 A similar point can be made in connection with the supposed phenomenon of neural “filling in”. We don’t experience a gap in the visual field corresponding to the blind spot. From this it cannot be deduced, as noticed by Dennett (1991, 1992), that there is a neural representation of the filled in blind spot. After all, the brain may simply ignore the absence of information corresponding to the blind spot. If it does, then there’s no need for any neural process of filling in. But from this it follows, further, that if it were the case that the neural structures corresponding to our visual experience were spatially continuous and isomorphic to the content of our experience (as if “filling in” had occurred), this could not, in itself, explain our failure to notice the blind spot! These points are explored in Pessoa, Thompson and Noë (1998) and also in Thompson, Noë and Pessoa (1999).
6. Toward a sensorimotor approach to visual neuroscience

6.1 Experience does not derive from brain activity alone

We have already taken steps toward a positive characterization of the role of the brain in vision in claiming as we have that studies of the neural bases of vision must be framed by a consideration of the whole animal’s broader behavioral and cognitive capacities. In the following sections we try to extend these remarks.

Consider the missile guidance system we discussed earlier. Suppose that at the present moment the target airplane happens to have gone out of the field of view of the missile. No information, let us suppose, is coming into the missile's sights right now. Nevertheless the missile guidance system has a certain potential: it "knows" that by making the appropriate change in its trajectory, it should be able to bring the missile back into view. Thus, even though at this particular moment the airplane is not visible and no visual information is coming in, it is still correct to say that the missile is currently tracking its target.

Exactly the same point, we argue, can be made about seeing and the sensorimotor contingencies governing seeing. When you make an eye saccade, the sensory stimulation provided by an object will change drastically due to very strong retinal smearing. At that very moment you do not receive sensory input from the object. But there is no more reason to think that this interruption in stimulation leads to an interruption in seeing, than there is to think that the missile is no longer tracking the plane when the plane happens to go out of the missile’s sights. The missile continues to track the plane, and the perceiver continues to see, because each is master of the relevant sensorimotor contingencies and each is exercising those capacities in an appropriate manner. Seeing an object consists precisely in the knowledge of the relevant sensorimotor contingencies—in being able to exercise one’s mastery of the fact that if, among other things, you make an eye movement, the stimulus will change in the particular way typical of what happens when you move your eyes. If the stimulation due to the object did not change in that way, then you would not be seeing the object—you might, for example, be hallucinating it.

These considerations call attention to the fact that interruptions and discontinuities in stimulation (owing to saccades, blinks, eye movements, chromatic aberrations, and other supposed defects of the visual apparatus) are in fact part of what seeing is. It is one’s exercise of the mastery of just such regularities in sensorimotor contingencies in which seeing consists. What is striking for present purposes is that just as moments of stillness and inactivity may be essential to the performance of a dance, so moments of neural inactivity may be precisely what characterizes the exercise of sight. This is a fact that can only come into focus on a conception of vision as a mode of activity such as that developed by the sensorimotor contingency theory.

Considerations such as these show further that although neural activity is necessary for vision, there need be no one-to-one mapping between seeing and occurrent neural states and processes. Vision requires all manner of neural events, but crucially, on our view, the
experience of seeing itself cannot be equated with the simultaneous occurrence of any particular neural activity. This follows from the fact that, at any given moment, the brain may be inactive.

6.2 What is the function of the brain in vision?
What then is the function of the brain in vision? Very generally speaking, it is to enable the knowledge and exercise of sensorimotor contingencies. Seeing, we argue, is constituted by the brain’s present attunement to the changes that would occur as a consequence of an action on the part of the perceiver. Visual experience just is the exercise of the mastery of relevant sensorimotor contingencies. An example may help to make the point clearer. Your visual apprehension of the roundness of a plate consists in part in your knowledge that changes in your relation to the plate (movements relative to the plate) will induce changes in the plate’s profile. That it looks round to you now, despite its elliptical profile, is constituted by your application, now, of skillful mastery of the appropriate rule of sensorimotor contingency. Other rules of sensorimotor contingency may be, as it were, more low level. As you move your eye across a straight line, there is a characteristic pattern of transformation of the retinal stimulation. The brain is attuned to this pattern. One important function of the brain may thus consist in the testing of the appropriateness of the application of certain patterns of sensorimotor contingency.

An important advantage of this view is that it allows us to escape from the problem of having to explain how brain activity could give rise to experience. We escape from this problem because we propose that experience does not derive from brain activity. Experience just is the activity in which the exploring of the environment consists. The experience lies in the doing.

6.3. Strategies for future research
A good deal of recent neuroscientific research shows that to understand the role the brain plays in supporting perceptual and motor capacities, it is necessary to keep clearly in view the broader context of the animal’s skillful task-oriented activity. Specific neural states cannot be perfectly correlated with specific perceptual states. You cannot understand the contribution of neural activity if you restrict yourself to a brain’s-eye view. This fits with our model of vision and visual consciousness. Seeing is not a simple occurrence; it is a rich, exploratory activity within a certain environment and with certain sensory apparatus, drawing on a number of heterogeneous capacities. Neural activity does not in itself produce experience. Neural activity contributes to experience only as enabling mastery and exercise of laws of sensorimotor contingency.

An exhaustive survey of this neuroscientific research goes beyond the scope of the present discussion. Here we briefly indicate some examples.

1. Neural Plasticity and sensory substitution. A currently very active domain of investigation in neurophysiology concerns findings showing that cortical representations of visual or somatosensory information can change as a function of stimulation, use, or lesion. For example Pascual-Leone et al. (1993) show that the sensorimotor representation
of the reading finger in the cortex of proficient Braille readers becomes greatly developed at the expense of the representations of other fingers (c.f. Sterr et al 1998). Sadato et al. (1998) have suggested that in proficient Braille readers, tactile processing is "rerouted" to occipital visual cortex (c.f. Cohen et al. 1999). The cortical representation of owl monkeys' fingertips become enlarged when the monkeys engage in haptic exploration training (Jenkins et al. 1990). Iriki, Tanaka & Iwamura (1996) found that receptive fields of bimodal (somatosensory and visual) neurons in the caudal postcentral gyrus of macaque monkeys were altered during tool use “to include the entire length of the rake or to cover the expanded accessible space.” Other examples include reorganization of cortical representations as a result of intracortical microstimulation, cortical lesions, digit amputation or fusion (cf. Wall et al.1986; Merzenich et al. 1984; Merzenich et al 1987; Jenkins 1990 b), a well as the work of von Melchner, Pallas and Sur showing that auditory cortex of ferrets can be "rewired" to process visual information.

Perhaps the most exciting work in this area is that undertaken by Bach-y-Rita and his colleagues on tactile vision substitution systems (TVSS) (Bach-y-Rita 1972). In TVSS, optical images picked up by a camera (worn, say, on the head) are transduced in such a way as to activate an array of stimulators (vibrators or electrodes) in contact with the skin (on, e.g. the abdomen, back or thigh). Optical images in this way produce a localized pattern of tactile sensation. After an initial period of training, congenitally blind subjects cease to experience tactile sensations when they use the TVSS device, and come to report that they experience objects as arrayed out before them in three-dimensional space, just as captured by the camera. As Bach-y-Rita writes, “They learn to make perceptual judgments using visual means of analysis such as perspective, parallax, looming and zooming, and depth judgments” (unpublished English translation of Bach-y-Rita 1996).

Such tactile-perception enables subjects to make judgments of shape, size and number and also to perceive spatial relationships between things, of the sort normally made by vision. With sufficient practice, subjects are able to engage in tasks requiring skillful sensorimotor coordination, e.g. batting a ball or working on an assembly line. In addition, TVSS-aided perception is liable to familiar forms of visual distortion and illusion, e.g. distant objects look small, objects can occlude each other, etc. At the present time, tactile-vision is a very poor substitute for seeing (resolution is low, function diminishes in cluttered environments), but it is indeed a substitute.

2. Attention and action. Rizzolatti and his colleagues have developed a “premotor theory of spatial attention” according to which, first, “conscious space perception results from the activity of several cortical and subcortical areas, each with its own neural space representation” (Rizzolatti, Riggio, & Sheliga 1994), and second, these “neural maps” directly function in the guidance of movement and action. There are not two systems, one for spatial attention and one for action. “The system that controls action is the same that controls what we call spatial attention (p.256).” These claims dovetail with psychophysical, psychological and neuroscientific evidence demonstrating linkages between perception and motor action. For example, Kustov and Robinson (1996) “studied superior colliculus in monkeys as they shifted their attention during different tasks, and found that each attentional shift is associated with eye-movement preparation” (p.74). Another line of evidence linking spatial attention and motor activity comes from studies of neglect in animals and humans with damage to cortical motor areas.
(Kinsbourne 1987, 1995; Rizzolatti, Matelli, & Pavesi 1983). Neglect appears to be best understood as a difficulty in shifting attention to the affected part of the visual field. The fact that neglect should arise from damage to cortical areas serving motor activity further demonstrates the link between attention and motor activity.

3. Two visual systems: the what and the how. In the last few years a very influential view of the structure of the visual brain has surfaced, according to which there are two streams of visual processing, a dorsal stream and a ventral stream. Opinions differ on the exact functions of the two systems, but Ungeleider & Mishkin (1992) distinguished between a dorsal "where" system devoted to localizing objects, and a ventral "what" system devoted to identifying them. A somewhat different classification was proposed by Goodale and Milner (1992) (c.f. also Milner and Goodale 1995), who emphasize that the dorsal system is concerned with coordinating actions directed towards objects, whereas in the ventral system recognition and classification operations are performed which allow persons to memorize and reason about objects. Jeannerod (1997) refers to the dorsal stream as "pragmatic", in that it provides the ability to make the necessary transformations between visual input and motor output to locate an object with respect to the body, and to grasp and manipulate it, and calls the ventral stream the "semantic" system. Evidence for this latter interpretation of the two streams hypothesis comes from studies of the effects of lesions in humans (Milner and Goodale 1995). As they point out, damage to the dorsal stream is associated with impairments of visuo-motor control such as optic ataxia (Harvey 1995) in the absence of impairments of the subject’s ability to make verbal reports about the shape, features and location of what is seen. Conversely, damage to the ventral stream produces visual agnosias (Benson and Greenberg 1969; Milner et al. 1991) without impairing visuo-motor functioning.

From the standpoint of the sensorimotor contingency view we propose here, the possibility of this kind of double dissociation is not surprising. In our view, seeing is an activity depending on a broad range of capacities, e.g. capacities for bodily movement and guidance, on the one hand, and capacities for speech and rational thought on the other. To the extent that these capacities are independent, it is not surprising that they can come apart in the manner described. It is not surprising, therefore, that the dorsal system can operate in relative isolation from the ventral system.

Our approach lead us to doubt, on certain interpretations at least, Milner and Goodale’s claim that what the visual agnosia patient DF (who retains normal visuo-motor skill) lacks is visual awareness of what she sees. Milner and Goodale suggest that, like DF, normals carry out visually guided actions using information that is not present in awareness, and say that only information in the ventral stream enters awareness. According to the view developed here (the sensorimotor contingency view), people are aware of what they see to the extent that they have control over that information for the purposes of guiding action and thought. Awareness is always, we argue, a matter of degree. Even the distracted driver is somewhat aware of what he sees, to the extent that, if we were to ask him, he would tell us what he is looking at. The case of DF is thus a case of what would seem to be partial awareness. She is unable to describe what she sees, but she is otherwise able to use it for the purpose of guiding action.
This may seem like a purely verbal dispute, but there is an important point at stake here. What makes the information conscious or aware, on our view, cannot consist just in the activity or lack of activity in a certain brain region (e.g. the ventral stream). Consciousness or awareness is not a property that informational states of the brain can just come to have in that way. Rather, visual awareness is a fact at the level of the integrated behavior of the whole organism. The work of Milner and Goodale suggests that damage to the ventral stream disrupts non-visuo-motor aspects of seeing. This is an important finding. But it would be a mistake to infer from this that the ventral stream is therefore the place where visual awareness happens.

Apart from the above provisos, the “two visual systems” view fits well with the position we develop in this paper. First, as expected from the sensorimotor contingency based approach, at the neural level there is a tight connection between seeing and moving. Second, the two-systems approach provides evidence supporting a claim we have made at different stages in this paper, namely, that seeing does not depend on the existence of unified representations of what is seen. On the two-systems approach, for example, there is not one single representation of space in the brain.

4. Downward causation. There is considerable evidence that when neural correlates of consciousness have been found, these are sensitive to mood, attentional set, and task. Varela and Thompson (e.g. Thompson and Varela, forthcoming) have referred to the modulation of individual neurons by patterns of activity of populations of neurons and also by the attitude or set of the whole animal as “downward causation.” So, for example, as stressed by Varela (1984); Varela, Thompson and Rosch 1991; Thompson 1995; Pessoa, Thompson and Noë 1998; Thompson and Varela, forthcoming), responses in visual cells depend on behavioral factors, such as body tilt (Horn and Hill 1969), posture (Abeles and Prut 1996), and auditory stimulation (Morell 1972; Fishman and Michael 1973). Other studies show that attention and the relevance of a stimulus for the performance of a behavioral task can considerably modulate the responses of visual neurons (Moran and Desimone 1985; Haenny, Maunsell and Schiller 1988; Chelazze et al. 1983; Treue and Maunsell 1996). Leopold and Logothetis themselves write of binocular rivalry: “we propose that the perceptual changes are the accidental manifestation of a general mechanisms that mediates a number of apparently different behaviors, including exploratory eye movements and shifts of attention. We also propose that while the different perceptions of ambiguous stimuli ultimately depend on activity in the ‘sensory’ visual areas, this activity is continually steered and modified by central brain structures involved in planning and generating behavioral actions” (Leopold & Logothetis, 1999, p.254). Leopold and Logothetis suggest that to understand perceptual reversals of the kind encountered when we view an ambiguous figure, or when we undergo binocular rivalry, it is necessary to consider not only neural activity in visual cortex, but the animal’s capacities for thought and action.

Upshot. Work in these and other areas provides evidence in favor of ways of understanding the role of the brain in vision and consciousness that are different from the ideas in the neural correlate of consciousness and binding problem research programs.
Like work in the fields of dynamic systems theory (e.g. Kelso and Kay 1987) and embodied cognition both in robots and in animals or humans (Brooks 1991; Ballard, 1991; Clancey 1997; Aloimonos 1992; Cotterill 1995, 1997), this research suggest the importance of accounts of the brain as an element in a system and not, as it were, as the seat of vision and consciousness all by itself.

7. Conclusion

In this paper we have targeted for criticism a widespread conception of vision as a process in the brain. We have proposed a very different conception of vision and visual consciousness, according to which vision is an activity of exploration of the environment drawing on the perceiver’s understanding of the ways in which what we do (e.g. eye movements) affects the character of sensory input. According to this sensorimotor approach to vision, vision is a capacity not of the brain, but of the whole active, environmentally situated, perceiver.

Our approach has important implications for the understanding of the brain-basis of vision and visual experience. First, negatively, our view rejects the idea that neural activity could be sufficient, as a matter of law, to produce visual consciousness. For this reason, we think a good deal of research on the so-called neural correlates of visual consciousness is misdirected. Second, positively, our view leads to the conclusion that the role of the brain in producing vision is to enable active exploration based on implicit knowledge of sensorimotor contingencies. We have indicated, briefly, the ways our approach supports avenues of research into such phenomena as neural plasticity, sensory substitution, attention and action and downward causation. Crucially, on our view, studies of the neural basis of vision must be framed by consideration of the whole animal’s broader behavior and cognitive capacities. Finally, we believe that the approach taken here enables us to give an account of the qualitative character of perceptual experience that avoids the mysteries and pitfalls associated with other accounts.
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