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Enactivism and the Unity of Perception and Action

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Abstract This paper contrasts two enactive theories of visual experience: the sensorimotor theory (O'Regan and Noë, Behav Brain Sci 24(5):939–1031, 2001; Noë and O'Regan, Vision and mind, 2002; Noë, Action in perception, 2004) and Susan Hurley's (Consciousness in action, 1998, Synthese 129:3–40, 2001) theory of active perception. We criticise the sensorimotor theory for its commitment to a distinction between mere sensorimotor behaviour and cognition. This is a distinction that is firmly rejected by Hurley. Hurley argues that personal level cognitive abilities emerge out of a complex dynamic feedback system at the subpersonal level. Moreover reflection on the role of eye movements in visual perception establishes a further sense in which a distinction between sensorimotor behaviour and cognition cannot be sustained. The sensorimotor theory has recently come under critical fire (see e.g. Block, J Philos CII(5):259–272, 2005; Prinz, Psyche, 12(1):1–19, 2006; Aizawa, J Philos CIV(1), 2007) for mistaking a merely causal contribution of action to perception for a constitutive contribution. We further argue that the sensorimotor theory is particularly vulnerable to this objection in a way that Hurley's active perception theory is not. This presents an additional reason for preferring Hurley's theory as providing a conceptual framework for the enactive programme.

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1 Introduction

The enactive theories of visual experience[1] defend the idea of the perceiver as an agent. A primary motivation for the development of the enactive theories is the failure of the classical computational theories of vision to recognise the contribution of agency to vision. Moreover, the classical theories leave opaque just how the computational processes they describe could generate conscious experiences even after decades of research conducted within the paradigm.

Enactive theories of perception, by contrast, stress the importance of understanding experience as it unfolds in an embodied subject situated in an environment. The visual system is not a passive recipient of sensory input from the world. Vision is an activity in which the perceiver is constantly moving his eyes, head and body picking up task-relevant information from the world as when it is needed (Findlay and Gilchrist 2003). The enactive theories present an evolving paradigm and as such do not as yet have rigidly defined concepts. In this paper we focus on two influential and apparently similar theories within the enactive programme, namely, the sensorimotor theory and Hurley's theory of active perception. We will begin by explaining how both of these enactive theories depart from the classical computational theories in arguing for an interdependence of perception and action. Both theories take perceptual

[1] Whenever we use the terms "perception" or "experience" in this paper we mean visual perception. We leave it as an open empirical question whether the claims we make in this paper can also be extended to other sense-modalities, and if so how.

experience to be inseparable from a perceiver's agency. Thus both theories share some important common assumptions.[2] However there are also substantial and hitherto unnoticed disagreements between these theories concerning the relation between sensorimotor behaviour and cognition. Noë and O'Regan both endorse a distinction between mere sensorimotor behaviour and cognition. We believe this is a distinction that cannot be sustained based on arguments Hurley (1998) has made in attacking what she dubbed the "sandwich" conception of cognition. Moreover this distinction is also challenged by empirical work on active vision, some of which we will describe in the final section of our paper. Hurley's theory of active perception rejects any distinction between sensorimotor behaviour and cognition. For this reason it provides the basis for a more robust defence of the enactive programme than the sensorimotor theory of O'Regan and Noë.

2 A Potted History of the Enactive Approach

Varela et al. (1991) use the term "enactive" to designate a conception of the agent and a worldview built on the notion of autopoiesis and a school of Buddhist metaphysics (see the essays by Di Paolo and Thompson & Stapleton in this volume). We will not follow this meaning of enaction in what follows. Instead the term "enactive" will be used for a cluster of theories that take action and perception to be interdependent. Some of the theories of vision that count as "enactive" in our sense reject the role of mediating cognitive processes in perception (e.g. Gibson 1979). Others deny that the notion of representation has any role to play in accounting for perceptual experience (e.g. Hutto 2005). However the enactive programme also includes theories that while not opposed to the use of traditional explanatory tools, offer a reconceptualisation of these tools by considering them in the context of a perceiver in interaction with its environment (Hurley 1998; O'Regan and Noë 2001). It is the latter theories that will occupy much of the discussion to follow, though we will have something to say about Gibson's anti-cognitivism.

Disagreements about how much enactivists need to borrow from classical theories of vision notwithstanding, all enactive theories share a commitment to the following two claims:

(1) Perception and action are interdependent processes.
(2) The vehicles of perception are distributed across brain, body and world.

Classical computational theories of vision by contrast rely heavily on the idea that the visual system functions like a camera delivering snapshots of the world to the perceiver in the form of detailed internal representations. They represent the perceiver as a passive recipient of sensory stimuli, which get rapidly processed through successive layers of visual cortex eventually culminating in visual experience. These theories omit to mention the natural agency of the perceiver. This failure to recognise the agency of the perceiver can be traced to an assumption on the part of classical theories that an explanation of visual experience will be found at the computational level of description. The computational level of description, as classically conceived, abstracts away from the constraints imposed by the actual implementation of the computational processes. Marr's (1982) theory of vision is an extremely influential example of such an approach. According to Marr's theory the visual system processes sensory information in three stages: (1) the primal sketch; (2) the 2½-D sketch; and (3) the 3-D model. The final step consists in "… transforming the viewer-centred surface description into a representation of the three-dimensional shape and spatial arrangement of an object that does not depend upon the direction from which it is viewed" (Marr 1982, p. 37). Marr's theory makes no reference to either the agency or the embodiment of the perceiver to account for how things are perceived.

Interestingly Marr's theory was a reaction to the ecological theory of Gibson (1966, 1979). Marr was describing what kinds of computational processes have to operate in order for the perceiver to extract information about the spatial layout of his environment from retinal information. Gibson, however, is widely agreed to be a forerunner of the contemporary enactive theories of perception. Thus we can read enactive theories as a return to Gibson in the light of Marr's critique. The difference between Gibson's approach and the classical computational theories begins with the idea of information itself. Instead of adopting the idea that visual representations result from the hierarchical processing of impoverished sensory stimuli, Gibson argued that information reaching the senses is already structured in ways that *specify* the layout of the environment to an animal. The perceiving animal picks up on this structure by movements of its sense organs. Moreover, not only can an animal directly perceive how things are laid out before it in space, but it can also see the possibilities for interaction that things afford. Perception, for Gibson, was always perception of a world rich in meaning.

Gibsonian theories provide descriptions of the interdependence of perception and action at both personal and sub-personal levels of description.[3] The Gibsonian concept

[2] It should be noted that the sensorimotor theory as developed by Noë in his recent single-authored work has undergone some significant changes from its original formulation in Noë's co-authored work with O'Regan. We will discuss some of these changes below (in §5).

[3] There is no consensus on exactly how to draw the personal/subpersonal distinction. In the context of our discussion, personal

of affordances establishes an interdependence of perception and action at the personal level. Affordances are the possibilities for action that a perceiver can directly perceive. A perceiving organism can see that a piece of fruit affords eating, or that a tree affords climbing, or that a cave affords shelter. For followers of Gibson, the detection of affordances is quite literally the detection of meaning. Objects of perception are meaningful just to the extent that perceiver has a grasp of the possibilities for action the object affords.

Gibsonian theories claim that an interdependence of perception and action also holds at the sub-personal level of description. The perceiver discovers the layout of surfaces in the environment by actively exploring the structure in the ambient optic array—the light that fills space and interacts with the objects that occupy the space around the perceiving animal. Normal vision is not static but is ambulatory: as the perceiving animal moves, so it can extract invariants from the flowing array of ambient light produced by its movement. Perceiver and environment are tightly coupled: they are constantly involved in a high-bandwidth interaction (Haugeland 1998, ch. 9). The interactions between perceiver and environment are not simple and well-defined so that we could treat the eyes and other sense-organs as interfaces connecting perceiver and environment. Rather perceiving, according to the Gibsonian, is the outcome of the ongoing interaction between a perceiving animal and its environment. First-order and higher-order invariants in the ambient optic array can be extracted by the perceiver on the basis of this interaction.

The Gibsonian understanding of perception as an exploratory and purposeful activity forms the basis for many of the ideas to be found in contemporary enactive theories of perception. However we will see in the next section that while enactive theories are deeply influenced by Gibson they also describe a deeper interdependence of perception and action than is to be found in the work of Gibson.

3 The Interdependence of Perception and Action

Gibson is well known for his thoroughgoing repudiation of cognitivist, information-processing explanations of perception. He rejected outright theories that appeal to internal cognitive processes such as inference and memory to explain how sensory signals get transformed into perceptual experiences. According to Gibson, the perceiver directly picks-up or registers invariant structures in the ambient array rendering any appeal to inferential mechanisms in the explanation of perception unnecessary. Not all enactive theories follow Gibson on this point. Hurley (2001, p. 19) for instance claims that Gibson's wholesale rejection of the role of internal cognitive processes in perception was probably an "overreaction" to the classical theories of perception. She writes:

> Perhaps the received tradition has focussed too much on the internal aspects of perception and ignored the external aspects. But we can correct this bias and take on board the role of movement in making information available, without going to the opposite extreme of denying that the brain processes information at all …. The right response to Gibson is ecumenical: both movement through real environments by whole organisms and brain activity play essential roles in extracting information from the environment and enabling a creature to have a perceptual perspective (Hurley 2001, p. 20).

Hurley agrees with Gibson that motor movement can enable the perceiver to discover constancies and invariants in perceptual input. She also accepts Gibson's claim that the flow of sensory input can provide the perceiver with information about its own movements. However she criticises Gibson for his failure to recognise the different contributions that active and passive movement can make to perception. For Gibson there is no real difference between feedback generated by externally generated movements of the body and feedback that is self-generated. Hurley argues that external feedback of the kind Gibson emphasises isn't the only kind of feedback from movement. In addition there is a kind of feedback she calls "internal feedback". Internal feedback is sometimes referred to as "efference copy" or "corollary discharge". Both internal and external feedback can make a record of movement available to other systems in the brain including perceptual systems.

According to Hurley, Gibson's theory implies at best what she calls an "instrumental dependence" of perception

Footnote 3 continued
level descriptions will be concerned with the contents of experience. Questions concerning the contents of experience are personal-level questions because contents of experience enter into normative, rational relations with an agent's intentions and beliefs and desires. The contents of experience can act as reasons for a person to form an intention to act. Sub-personal level descriptions by contrast are concerned with causally explanatory functional and neural mechanisms upon which perceptual experiences supervene. Sub-personal descriptions are descriptions of vehicles that are bearers of contents. While we think that the distinction between sub-personal and personal levels of description needs to be respected, we also think there is an interesting story to be told about the relation between the processes that determine content at the personal-level and the sub-personal processes that carry content. Indeed, we will argue that one of the advantages that Hurley's theory of active perception has over the sensorimotor theory is that the former but not the latter addresses this issue.

and action. Such an instrumental dependence of perception and action is uncontroversial: no one will deny that movement can be a means by which a change in perceptual content is brought about. It is true that Gibson described something more interesting than this mundane form of instrumental dependence. We have seen how he argued that perceptual content is determined by patterns or invariant structures in sensory input that are extracted through movement. Hurley's point is that this remains a kind of instrumental dependence, with movement serving at best the function of generating changes in the ambient array. Hurley argues for a stronger relation of dependence between perception and action. She argues that the contents of perception are a function of higher-order relations that hold between patterns of sensory input and motor output. On this view motor output isn't just the cause of different perceptual contents. Rather there are law-like relationships that hold between sensory input and motor output in a given environment. Perceptual content can depend on relationships of this kind between input and output as well as on relationships between sensory inputs of the kind Gibsonian theories describe.

While Gibson rejected the appeal to internal cognitive processes in explaining perception, Hurley rejects the separation of cognition from perception and action. The commitment to this separation is something that Gibson ironically shares in common with the classical theories he so vehemently attacked. Hurley's (2008) shared-circuits model describes in intricate detail the continuity of perception, action and cognition. Her shared-circuits model shows how so-called "higher" cognitive processes such as imitation, mindreading, counterfactual thinking and deliberation might have originated in sensorimotor control processes. Here, however, is not the place to retell this story. We wish instead to briefly mention a different argument she makes against classical theories in challenging their separation of perception from action. This will enable us to identify a key difference between her theory of perception and that of other enactivists such as Noë and O'Regan.

Hurley attacked classical computational theories for holding what she dubbed a "sandwich" conception of cognition. The classical theories locate cognitive processes at the centre of the mind and treat perception and action as peripheral process. The perceptual systems provide sensory inputs to cognitive systems while the motor system, based on action plans formed by cognitive systems, produces motor output. We have already seen how Hurley argued for an account of perception according to which perceptual content depends on complex dynamic relationships between sensory input and motor output. Thus there is no way of neatly mapping personal level perceptual content onto sensory inputs, on her account. Hurley also argued for an account of action according to which intentions to act can have a content that depends on relationships between motor output and sensory input. The latter account, like much of Hurley's work, is rather complex and we cannot enter into the details here. What is important for our purposes is that if her account is correct there is no way of mapping intentions to act onto motor output. The contents of intentions also supervene on complex dynamic relations between input and output.

In place of the sandwich conception of cognition, Hurley recommends instead what she called a "two-level interdependence" account of the relation between perception and action. The contents of both perception and intention are functions of relationships that hold between sensory input and motor output within a dynamic feedback system. There is an interdependence of sensory input and motor output at the sub-personal level because of dynamic feedback loops that link sensory input to motor output and vice versa.

There is also an interdependence of perception and action at the personal level. Perceivers are perspectivally self-conscious:

> The idea of having a perspective or a point of view is part of our concept of what it is to be conscious. Unity is a basic feature of the perspectival aspect of consciousness. But so is agency. At the personal level, having a perspective means that what you experience and perceive depends systematically on what you do, as well as vice versa. Moreover, it involves your keeping track, even if not in conceptual terms, of the interdependence between what is perceived and what is done, and hence awareness of your own agency (Hurley 1998, p. 86).

As I turn my head to the left for instance, the stationary object in front of me changes its location in my visual field and comes to occupy a position to my right. Moreover this change in perceptual content that is brought about my head movement is just what I expect to happen (Hurley 1998, p. 140). This ability to correctly anticipate how the contents of perception will change with movement is what Hurley means when she talks of an agent's "keeping track" of the systematic relations of dependence between perception and action. An agent that can track the sensory consequences of movement will also be able to distinguish its own self-generated movements from movements that are taking place in the world. The ability to distinguish self and world in this way is a core part of what Hurley is calling "perspectival self-consciousness".

Agents can also learn novel behaviours through imitation and this is something they can do, according to Hurley's (2008) shared circuits model, by exploiting action-effect associations. The perceiver observes the performance of an action that has certain effects and using her learned action-effect associations, she can work out which motor representation caused the observed novel behaviour. This motor representation can then provide her with the means for carrying out the very same novel behaviour herself.

The two-level interdependence Hurley describes is really a description of the same dynamic process as viewed from the sub-personal and personal levels. When viewed from the sub-personal level we find cycles of dynamic feedback in which motor output affects sensory input and sensory input affects motor output. At the personal level we find a perceiver that is able to keep track of dynamic perception-action-perception cycles. The subpersonal vehicles that carry personal level perceptual content are cycles of dynamic sensorimotor feedback that couple the perceiver with the environment.

In the next section we will see how Noë and O'Regan's sensorimotor theory of perception denies that sensorimotor coupling is sufficient for perceptual experience. We shall argue that in doing so they run the risk of reintroducing the sandwich conception of cognition which Hurley's arguments have shown cannot be sustained.

4 Noë and O'Regan's Sensorimotor Theory of Perception

We have seen how in Gibsonian theories perception is understood as the process of extracting first-order and higher-order invariants from the ambient optic array through movement. O'Regan and Noë's sensorimotor theory builds on this idea arguing that the perceiver has an implicit understanding of the lawful ways in which movements are correlated with changes in sensory input. Movement towards an object, for instance, brings about a looming effect, an expansion of retinal projection. Moving one's head to the left causes objects in centre of one's visual field to shift to the right. O'Regan and Noë call laws like these "sensorimotor contingencies". Perceiving is, they argue, a skilful exploratory activity in which the perceiver draws on her mastery of sensorimotor contingencies. We will henceforth refer to this kind of understanding of sensorimotor contingencies as "sensorimotor knowledge".

Noë and O'Regan (2002) deny that the exercise of this kind of sensorimotor knowledge suffices for visual consciousness. They insist on a distinction between mere *perceptual sensitivity* and *perceptual awareness*. A perceiver can exhibit sensitivity to its environment just by exercising sensorimotor knowledge. A missile guidance system exhibits perceptual sensitivity in this sense. Noë and O'Regan imagine a missile guidance system that is programmed to speed up if the image of the target in its camera gets smaller and maintain speed if the image is growing in size. The missile guidance system has mastery of sensorimotor contingencies as they arise in the context of aeroplane tracking. No one, however, would want to attribute even the glimmer of perceptual awareness to the missile guidance system. To exclude cases like this one from the domain of the conscious, Noë and O'Regan recommend that we distinguish the kind of perceptual sensitivity a sensory system can exhibit by coupling with the environment from visual awareness. Visual awareness, they say, requires the integration of perceptual sensitivity with "… broader capacities for thought and rationally guided action" (Noë and O'Regan 2002, p. 569).

We think that Noë and O'Regan's distinction between sensitivity and awareness lands them with an unsatisfactory separation of perception, action and cognition. Perceptual sensitivity is achieved through perceptual coupling with the environment, a process that on their view can happen separately from capacities for thought and rationally guided action. Perceptual coupling of this kind looks to us suspiciously like a process that unfolds at the periphery of the perceiver. Sensorimotor coupling is transformed into perceptual experience by being plugged into central cognition, or what Noë and O'Regan describe as an agent's capacities for thought and rationally guided action.

We have seen how Hurley rejected any separation of perception, action and cognition. Perceivers can keep track of how what they experience depends on what they do, an ability that involves perception, action and cognition. Crucially this ability is enabled by complex dynamic feedback systems at the subpersonal level. Noë and O'Regan, by contrast, describe sensorimotor knowledge in terms of a perceiver's ability to keep track of relations of dependence between the sensory stimulation the system receives and the movements it performs. It is access to and control over information gathered through perceptual coupling that yields awareness. This suggests to us that sensorimotor coupling can, on the Noë and O'Regan view of perception, come apart from cognition. We don't for the moment wish to deny that access and control are required for awareness. However we do deny that sensorimotor coupling can unfold independently of processes of access and control, more on which later in §6. We side with Hurley in arguing that subpersonal dynamic sensorimotor coupling *enables* personal-level cognitive abilities to track the effects of action on perception. We reject the separation of sensorimotor behaviour from perceptual awareness of the kind Noë and O'Regan seem to endorse.[4]

[4] We are rejecting the distinction between sensorimotor coupling and cognition that we take to be implied by Noë and O'Regan's account of the difference between sensitivity and awareness. We don't mean to deny that there is a difference between sensitivity and awareness. Such a distinction is clearly required if we are to avoid admitting the missile guidance system into the realm of the conscious. We dispute

Noë (2002, 2004, ch. 6) takes issue with Hurley's claim that perspectival self-consciousness is a non-conceptual mode of self-consciousness. He argues that the ability to keep track of the dependence of what we see on what we do (which Hurley calls "perspectival self-consciousness") is a conceptual ability. We will briefly rehearse his argument since it further underlines the difference between the sensorimotor theory (as defended by Noë) and Hurley's theory of active perception.

Noë describes seeing as an exploratory activity in the course of which the perceiver is led to ask all manner of questions about what she ought to believe or do in the light of her experience (2002, p. 190). In keeping track of the ways in which her perceptual experience depends on what she does, Noë says, she will also be keeping track of how things are in the world. We are keeping track of what our experience "tells us about the world" (*op cit*). This capacity to learn about the world from our experiences is something we can do only because experience is integrated with conceptual and inferential skills. Noë stresses that the conceptual and inferential skills he has in mind aren't cognitively demanding. They do not, for instance, require the perceiver to be able to deploy concepts in making explicit deliberative judgements. Nor does the perceiver need to know the criteria that govern the application of the concept in order to qualify as possessing the concepts in question. Noë is also keen to point out that perception also depends on the exercise of sensorimotor skills that are subpersonal and therefore non-conceptual. An example, he tells us, "is our mastery of the laws governing the particular way the macular pigment and the non-homogeneity of retinal sampling affect sensory input when the eye moves" (Noë 2002, p. 194). The sensorimotor skills that perspectival self-consciousness depends on are however personal level and conceptual.

While Noë insists on the conceptual character of perspectival self-consciousness, Hurley's position allows her to remain neutral on this issue. Hurley makes a distinction between what she describes as "intentional access" to contents and "cognitive access". If a perceiver has cognitive access to an experience she can form a belief that she is having this experience. It is admittedly an open question whether beliefs must have conceptual content, but on many views of belief a subject must possess the concepts required for specifying the proposition believed. Thus on these views, cognitive access will imply the possession of conceptual abilities. Intentional access to content, by contrast, occurs when a creature can form correct intentions to act based on its experience. "The information whose consciousness is in question … provides the reason for which the agent acts intentionally" (Hurley 1998, p. 149). Intentional access to contents doesn't require conceptual abilities. Consider how the tracking abilities Hurley appeals to in characterising perspectival self-consciousness relate to intentional access. The perceiver's ability to track the ways in which her possibilities for action depend on her experience just consists in her ability to correctly form intentions on the basis of her experience. Since the latter capacity doesn't require the possession of conceptual abilities, nor does perspectival self-consciousness.

What is at issue here is the conditions perceptual experience must meet if perception is to count as a personal-level or animal-level phenomena. Noë is insisting that it must be integrated with broader capacities for thought and inference. Hurley on the other hand argues that practical reason (or intentional access) can provide the normative context, which is required for content-bearing states to count as personal-level states. We will not attempt to resolve this dispute here. However notice that it is an upshot of Noë's position that sensorimotor behaviour that is not integrated with capacities for thought and inference unfolds independently of cognition. His position on the conceptual nature of perspectival self-consciousness implies a separation of mere sensorimotor behaviour from cognition. We believe that this separation is unacceptable. In the next section we will argue that Noë and Noë and O'Regan's sensorimotor theory run into problems that are avoided by Hurley's theory of active perception. Hurley's theory provides more solid foundations on which to construct an enactive approach to perception.

5 Problems for the Sensorimotor Theories

Noë's presentation of the sensorimotor theory in his (2004) book differs in many respects from his earlier collaborative work with O'Regan. Most notable is the different account of sensorimotor contingencies we find in this work. In Noë's work with O'Regan, sensorimotor contingencies are described as laws or rules relating patterns of sensory stimulation to movement. In his (2004) book however Noë makes a distinction between two levels of perceptual content, which we will call "factual" and "perspectival" content. Factual content relates to how things *are* while perspectival content is determined by how things *look*. Factual content is a function of a perceiver's implicit understanding of the lawful ways in which movements are correlated with changes in perspectival content. Sensorimotor knowledge in Noë (2004) is a perceiver's understanding of the lawful ways in which perspectival content changes with movement. Experiences acquire perceptual content through the exercise of sensorimotor

Footnote 4 continued
however that Noë and O'Regan have offered a satisfactory conceptualisation of this distinction.

knowledge of this kind. Sensorimotor knowledge is "exercised" in the course of a perceiver's probing and exploring her environment by moving her eyes, head and body.

Particularly interesting for our purposes are some comments Noë makes towards the end of his book that suggest he may have modified his (and O'Regan's) earlier view of the relations between sensorimotor behaviour and cognition. He writes for instance that a simple organism like a phototactic bacterium "embodies a kind of sensorimotor "knowledge"" (Noë 2004, p. 229). He goes on to add that the bacterium already possesses the "… ingredients needed for the enactment of experience" (*op cit*). What differentiates the phototactic bacterium from more complex lifeforms is the complexity of its repertoire of sensorimotor behaviour. He writes that as organisms acquire an increasingly complex range of sensorimotor behaviour so they also increase in their cognitive complexity. Sensorimotor complexity and cognitive complexity march in step.

Noë seems to be claiming here that there is no sharp division between sensorimotor behaviour and cognition. Such a claim certainly looks inconsistent with the separation of sensorimotor behaviour and cognition, which we have argued is entailed by Noë and O'Regan's distinction between perceptual sensitivity and awareness.

However earlier in his book (pp. 3–11) Noë's offers an interesting discussion of what he calls "experiential blindness" that strikes us as being not entirely consistent with the claim that sensorimotor behaviour and cognition are inseparable. We will argue that his account of experiential blindness reveals a lingering commitment to a distinction between mere sensorimotor behaviour and cognition.

Experiential blindness is a form of blindness that is not due to damage to a perceiver's sensory apparatus and a consequent lack of sensation. It is a form of blindness that occurs as a result of an "inability to integrate sensory stimulation with patterns of movement and thought" (Noë 2004, p. 4). Blindness of this kind occurs following the removal of cataracts in congenitally blind patients. Removal of the cataracts in these patients restores visual sensation but it does not fully restore sight. Patients that have undergone this operation report undergoing sensations that lack form. Sack's patient Virgil reports for instance movement and colour that is "all mixed up"; "meaningless"; and "a blur" (Sacks 1995, 114, quoted by Noë 2004, p. 5). Noë claims that sensorimotor knowledge continues to be disrupted in these patients. They lack any understanding of how the visual sensations they undergo are significant for thought and action.

Experientially blind subjects differ from the missile guidance system or the phototactic bacterium insofar as they lack sensorimotor knowledge. The bacterium and guidance system lack experience because while they have sensorimotor knowledge they lack broader capacities for thought and inference. Experientially blind subjects, by contrast, lack experience because while they have capacities for thought and inference they lack sensorimotor knowledge. This lack of sensorimotor knowledge means they are unable to integrate whatever sensory stimulation they undergo with their capacities for thought and action (Noë 2004, p. 4).

Experientially blind subjects must however manifest a basic level of sensorimotor coupling with their environment. They do after all undergo sensations that are *visual*: the patients are aware of being *visually presented* with something rather than being aware of something under an auditory mode of presentation. The experientially blind subjects must therefore engage in some form of sensorimotor coupling with the environment. However according to Noë this coupling occurs independently of their capacities for thought and action. So while there are important differences between experiential blind subjects and missile guidance systems both engage in sensorimotor coupling in the absence of cognition. Noë's description of experiential blindness therefore entails a continuing commitment to a distinction between mere sensorimotor behaviour and cognition. This is a distinction we believe must be dropped.

We will offer some further reasons for opposing this distinction in the next section of our paper. First we want to describe three problems that arise for Noë's account of experiential blindness that have recently been raised by Aizawa (2007).

Aizawa (2007) along with Block (2005) and Prinz (2006) accuses enactive theories of conflating the claims that sensorimotor skills can make a *causal contribution* to experience with the claim that experience is *constituted* by the exercise of sensorimotor skills. We started this section by rehearsing Noë's claim that experience is constituted through the exercise of sensorimotor knowledge. Noë conceives of experience as an activity of exploring or probing the environment for information, where this activity is mediated by sensorimotor knowledge. In experientially blind subjects we find this probing activity taking place in the absence of sensorimotor knowledge. For this reason they undergo sensations that fall short of experiences of their environment. Noë is thus clearly committed to the claim that the exercise of sensorimotor knowledge is constitutive of experience. Subjects that fail to exercise sensorimotor knowledge undergo sensations but not experience.

Aizawa offers three arguments against Noë's treatment of experiential blindness. The first is that he hasn't ruled out the possibility that the patient's sensory deficits are due to problems with the sensory processing of visual information. He cites some interesting studies that establish deficits in "grating acuity, spatial contrast sensitivity, temporal contrast sensitivity, peripheral vision, stereo acuity, perception of global form, and perception of global motion" (*op* *cit*, p. 13). Aizawa's first objection is that there may be a purely sensory explanation of the deficits of experientially blind subjects that doesn't require us to appeal to absence of sensorimotor knowledge. We would dispute that the explanations of the processing deficits described above will be in terms of purely sensory processing as contrasted with *sensorimotor* processing. To fully deal with his criticism however would require an extended discussion of the empirical literature, which space constraints preclude. We will therefore set this first objection to one side for now. We plan to address this criticism at length in future collaborative work.

The second objection Aizawa raises is, we think, a significant problem for Noë. Aizawa notes that blindness comes in many forms from achromotopsia (colour blindness) to akinetopsia (motion blindness) to various agnosias. Patients suffering from these forms of blindness do not entirely lack experience. The same would seem to be true of the patients Noë describes as experientially blind. Aizawa writes:

> As a conceptual possibility, it appears to be possible that some humans might perceive things, only without these perceptions being integrated into patterns of personal movement and thought. The only thing that might preclude this possibility is if Noë's concept of perceptual experience simply includes being constituted, in part, by sensorimotor skills.

Noë could grant this conceptual possibility while denying that this possibility holds in the actual world we inhabit. The question remains however what would entitle him to such a denial. Why say that the patients in question have no experiences whatsoever when we are reluctant to say the same of agnosics or of patients suffering from other forms of sensory deficit mentioned above? Noë can't simply stipulate that this claim is true by defining experience as an exploratory activity mediated by sensorimotor knowledge.

The final problem Aizawa raises for Noë's treatment of experiential blindness appeals to the causal/constitution conflation mentioned above. Noë claims that the cataract patients lack experience because they lack sensorimotor knowledge. It is their lack of sensorimotor knowledge that explains their failure to integrate the sensations they undergo with their sensorimotor skills. Aizawa argues that an alternative explanation of this failure would be that the patients "sensorimotor skills are not yet causally connected to their sensory apparatus in the proper way" (*op cit*, p. 16). Aizawa denies that the exercise of sensorimotor knowledge is constitutive of perceptual experience. Instead sensorimotor skills play a causal role in shaping perception. One way to understand the latter claim is to return to a distinction Hurley makes between *instrumental* and *non-instrumental* dependence of perception of action. Perception is instrumentally dependent on action if action is simply a means to bring about differences in the contents of perception. Aizawa can be read as making the point that Noë fails to establish a non-instrumental as opposed to a merely instrumental dependence of perception and action.

We think that the problems Aizawa raises are serious ones for enactive theories. However we also believe they are answerable. We will answer the second of Aizawa's objections in what remains of this section. In the final section of our paper we will address his third objection.

We agree with Noë's description of the cataract subjects as experientially blind however we dispute his diagnosis of their problems. We suggest that the cataract patient's experiential blindness has its origins in the nature of their sensorimotor coupling. That their sensorimotor coupling is impaired can be clearly seen if we focus on the eye movements of these patients. The eye movements of the cataract patients fail to follow the pattern of a normal perceiver's. This has the consequence that the sensory stimulation they undergo lacks form, and literally does not make sense to them. Consider the case of Virgil described by Sacks (1995, p. 114, cited by Noë 2004, p. 5). Sacks describes how when Virgil's bandages were removed he failed to move his eyes normally: "He seemed to be staring blankly, bewildered, without focusing, at the surgeon, who stood before him, still holding the bandages". Gregory and Wallace (1963) report something similar for patient S.B. (also discussed by Noë). They write that S.B. "had no nystagmus. Searching eye movements were minimal, and when they did move over a large amplitude, they did so in larger than normal saccadic jerks which were plainly visible" (1963, reproduced 2001, p. 17).

In our view it is not the failure to integrate sensory stimulation with capacities for thought and action that accounts for the cataract patient's experiential blindness. Rather the breakdown in experience occurs because the lawlike relationships between sensory input and motor output that determine perceptual content don't obtain in these patients. This is a deficit that obtains at the level of the patient's sensorimotor coupling with the environment.

We follow Hurley in claiming that the complex dynamic relationships that hold between sensory input and motor output enable personal-level cognitive abilities. These cognitive abilities include abilities to keep track of the ways in which what one experiences depends on what one does. When Noë talks of the exercise of sensorimotor knowledge, we take him to be referring to tracking abilities of this kind. However we deny that it is lack of sensorimotor knowledge that explains the cataract patient's deficits in experience. We claim instead that the patient's lack of sensorimotor knowledge is explained by breakdowns in the sensorimotor mechanisms that couple perceivers to their environments. These patients cannot correctly anticipate how their experience will change with movement. They lack this anticipatory capacity because of deficits relating to their sensorimotor coupling.

So far we have argued that the sensorimotor behaviour which couples a perceiver to her environment cannot be separated from the perceiver's cognitive abilities because subpersonal mechanisms of sensorimotor coupling enable personal-level cognitive abilities. We will see in the next section how the contribution eye movements make to ongoing perceptual experience is itself a cognitive contribution. This establishes a further reason why the distinction between sensorimotor coupling with the environment and cognition cannot be sustained. It will also provide us with an answer to the often-made objection that enactive theories are guilty of confusing the causal contribution of action to perception for a constitutive contribution.

6 The Inseparability of Sensorimotor Behaviour and Cognition

We might naturally suppose that the function of eye movements is little more than to receive new visual inputs. However the contribution of eye movements to vision is a good deal more interesting than this. Consider for instance the role of visual sampling. Findlay & Gilchrist maintain: "… the sampling procedure is the very place where cognitive contributions to perception occur. The eye samples what is interesting but what is interesting can change from moment to moment, guided by the observer's thought processes and action plans" (Findlay and Gilchrist 2003, p. 6). In a similar vein, Henderson et al. (2007) argue that a main motivation for studying gaze redirection in real-life situations stems from the task-relevant nature of human vision. We tend to move our eyes to parts of a scene that are relevant to the task we are engaged in. Vision unfolds as a temporally extended pattern of saccades and fixations in accordance with ongoing visual and cognitive computations. Our gaze is typically directed at the present target of analysis. Eye movements "… provide an unobtrusive, sensitive, real-time behavioral index of ongoing visual and cognitive processing" (Henderson et al. 2007).

Further empirical support for the goal-directed character of eye movements come from studies that establish it is the task the agent is performing that determines where the agent directs her gaze, not the properties of a scene (Henderson and Hollingworth 1998; Richardson and Spivey 2000; Land and Hayhoe 2001; Findlay and Gilchrist 2003; McCarley et al. 2003; Turano et al. 2003; Henderson and Ferreira 2004; Hayhoe and Ballard 2005; Henderson et al. 2007). Eye movement studies have also indicated the vital role of these movements in disambiguating sensory input. Hafed and Krauzlis (2006) have shown that motor commands contain additional spatial information that enabled perceivers to resolve the ambiguity of the retinal signal.

Eye movements are deployed in the course of a perceiver's sensorimotor coupling with her environment. They are one example of the kind of exploratory movements of the body enactive theories claim are central to explaining perceptual experience. As advertised at the end of the last section, they also establish a further way in which sensorimotor behaviour and cognition are inseparable. Findlay and Gilchrist (2003) write:

> … Saccades are an action system in that they are a visually controlled motor response. However they are not just this, since their operation controls the input visual sampling also. Their involvement with vision takes the form of a continuously cycling loop, so that vision and cognition can integrate in an intimate way (Findlay and Gilchrist 2003, p. 7).

Eyes movements couple a perceiver with her environment in ways that fit with her goals and the tasks she is engaged in. Eye movements ensure that visual awareness proceeds as a dynamic goal-directed engagement of a cognitive agent with her environment. We have argued, following Hurley, that a perceiver's dynamic sensorimotor coupling with her environment enables personal level cognitive abilities. What we learn from the study of eye movements is that the perceiver's dynamic sensorimotor coupling is itself already cognitive.

Let us consider in the light of this news, the frequently encountered objection that enactive theories commit a causal/constitution error, mistaking an uninteresting causal contribution of sensorimotor behaviour to experience for a decidedly more exciting constitutive contribution. If we just focus on eye movements for the moment, the two interpretations of the enactive theory are as follows:

> Causal Hypothesis (CAH): Perceptual content causally depends, in part, on eye movements. Eye movements generate new visual inputs.
> Constitutive Hypothesis (COH): Perceptual content is constituted, in part, by eye movements.

In our discussion of experiential blindness we have suggested that it might be the eye movements of the cataract patients that are not functioning properly. Perceptual content is determined by relationships between sensory input and motor output. The abnormal eye movements of the cataract patients mean that these normal relationships don't obtain. This has the consequence that the visual system of the cataract patients cannot form coherent percepts, and it is for this reason that they are experientially blind. Eye movements, on our account, aren't simply a means of generating new visual inputs. Rather perceptual content is itself a function of relations between sensory inputs and motor outputs, an important subset of which are eye movements. Disrupt the relationship between sensory input and motor output and this profoundly disturbs a perceiver's ability to experience the world.

We can add some further flesh to the bones of this hypothesis now we have seen how eye movements are goal-directed and task-relevant. We suggest that the cataract patient's eye movement lack this property: they are precisely not goal-directed and task relevant. Eye movements have this property in normal perceivers because of the relations that hold between eye movements and attention. The exact nature of the relationship between attentional mechanisms and eye movements is at present far from clear. However an increasing amount of research on eye movements is devoted to exactly this question. There is widespread agreement that there is an interesting relationship between covert attention (i.e. endogenously generated attention) and overt eye movements. For example, Findlay and Gilchrist (2003), claim that every overt shift of gaze is preceded by a covert shift in attention i.e. before the execution of the motor movement of gaze redirection there is necessarily the deployment of cognitive mechanisms in the form of attentional control. Chun and Wolfe (2000) outline two critical roles of attention in the context of vision as:

> First, attention can be used to select behaviourally relevant information and/or to ignore the irrelevant or interfering information. In other words, you are only aware of attended visual events. Second, attention can modulate or enhance this selected information according to the state and goals of the perceiver. With attention, the perceivers are more than passive receivers of information. They become active seekers and processors of information, able to interact intelligently with their environment (Chun and Wolfe 2000).

The relationship we have sketched between covert attention and overt eye movements highlights the cognitive nature of the perceiver's sensorimotor coupling with its environment. The degree of attentive engagement varies with the demands of the tasks, but it is never all or none. Studies of eye movements reveal that this activity is rarely absent, even during periods of fixation. Indeed the movements during fixation are in fact necessary for perception (Findlay and Gilchrist 2003; Martinez-Conde et al. 2004). According to our hypothesis the cataract patient's eye movements may have become decoupled from their attentional mechanisms in a way that profoundly impacts their experience. In normal subjects eye movements work in conjunction with covert attention. Sensorimotor coupling is always an attentive engagement with the environment. It is this attentive engagement with the environment that enables experiential content.

7 Conclusion

The sensorimotor theory of O'Regan and Noë (2001) and Noë (2004) is committed to an unacceptable separation of sensorimotor behaviour from cognition. We have endorsed Hurley's theory of active perception, which describes how a perceiver's sensorimotor coupling with the environment can enable both perceptual experience and perception based cognitive abilities. Perception, action and cognition, on this view, turn out to be inseparable processes. The role of eye-movements in vision presents a clear example of this inseparability. There can be no visual experience without eye movements. Eye movements however perform cognitive function directing our gaze to parts of a scene that are relevant to the tasks we are engaged in. Once we recognise the inseparability of perception, action and cognition a robust response opens up to the charge often made against enactive theories that they conflate the causal contribution of action to perception with the constitutive contribution of action to perception. We have seen how eye movements help establish normal relationships between sensory input and motor output that determine perceptual content. Action isn't making a merely causal contribution here generating new sensory input. Rather it is the relations between sensory input and motor output that determine perceptual content. If the capacity to perform eye movements is impaired this disrupts the lawlike relationships between input and output that determine perceptual content. This disruption occurs at the level of the perceiver's sensorimotor coupling with the environment. Its profound effect on perceptual content establishes that sensorimotor behaviour can make a truly constitutive contribution to the contents of experience.

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Reference

Aizawa K (2007) Understanding the embodiment of perception. J Philos CIV(1):5–25
Block N (2005) Review of action in perception. J Philos CII(5):259–272
Chun MM, Wolfe JM (2000) Visual attention. In: Goldstein GB (ed) Blackwell handbook of perception. Blackwell Publishers Ltd, Oxford, pp 272–310
Findlay JM, Gilchrist ID (2003) Active vision: the psychology of looking and seeing. Oxford University Press, Oxford
Gibson JJ (1966) The senses considered as perceptual systems. Houghton Mifflin, Boston

Gibson JJ (1979) The ecological approach to visual perception. Houghton Mifflin, Boston
Gregory RL, Wallace JG (1963) Recovery from early blindness: a case study. Experimental Psychology Society. Monograph no. 2
Hafed ZM, Krauzlis RJ (2006) Ongoing eye movements constrain visual perception. Nat Neurosci 9:1449–1457
Haugeland J (ed) (1998) Mind embodied and embedded. In: Having thought: essays in the metaphysics of mind. Harvard University Press, Cambridge
Hayhoe M, Ballard DH (2005) Eye movements in natural behavior. Trends Cogn Sci 9:188–194
Henderson JM, Ferreira F (2004) Scene perception for psycholinguists. In: Henderson JM, Ferreira F (eds) The interface of language, vision, and action: eye movements and the visual world. Psychology Press, New York, pp 1–58
Henderson JM, Hollingworth A (1998) Eye movements during scene viewing: an overview. In: Underwood G (ed) Eye guidance while reading and while watching dynamic scenes. Elsevier, Oxford, pp 269–298
Henderson JM, Brockmole JR, Castelhano MS, Mack M (2007) Visual saliency does not account for eye movements during visual search in real-world scenes. In: van Gompel R, Fischer M, Murray W, Hill R (eds) Eye movement research: insights into mind and brain. Elsevier, Oxford, pp 537–562
Hurley S (1998) Consciousness in action. Harvard University Press, Cambridge
Hurley S (2001) Perception and action: alternative views. Synthese 129:3–40
Hurley S (2008) The shared circuits model: how control, mirroring and simulation can enable imitation and mindreading. Behav Brain Sci 31:1–58
Hutto DD (2005) Knowing what? Radical versus conservative enactivism. Phenomenol Cogn Sci 4:389–405
Land MF, Hayhoe M (2001) In what ways do eye movements contribute to everyday activities? Vis Res 41:3559–3565
Marr D (1982) Vision: a computational investigation into the human representation and processing of visual information. W. H. Freeman, San Francisco
Martinez-Conde S, Macknik SL, Hubel DH (2004) The role of fixational eye movements in visual perception. Nat Rev Neurosci 5:229–239
McCarley JS, Wang RF, Kramer AF, Irwin DE, Peterson MS (2003) How much memory does oculomotor search have? Psychol Sci 14:422–426
Noë A (2002) Is perspectival self-consciousness non-conceptual? Philos Q 52(207):185–194
Noë A (2004) Action in perception. The MIT Press, Cambridge
Noë A, O'Regan JK (2002) On the brain-basis of visual consciousness: a sensorimotor account. In: Noë A, Thompson E (eds) Vision and mind. The MIT Press, Cambridge, pp 567–598
O'Regan JK, Noë A (2001) A sensorimotor account of vision and visual consciousness. Behav Brain Sci 24(5):939–1031
Prinz J (2006) Putting the brakes on enactive perception. Psyche 12(1):1–19
Richardson DC, Spivey MJ (2000) Representation, space and hollywood squares: looking at things that aren't there anymore. Cognition 76:269–295
Turano KA, Geruschat DR, Baker FH (2003) Oculomotor strategies for the direction of gaze tested with a real-world activity. Vis Res 43:333–346
Varela FJ, Thompson E, Rosch E (1991) The embodied mind. The MIT Press, Cambridge