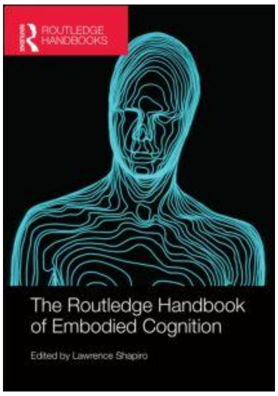

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ENACTIVE VISION

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Enactivism and the sensorimotor account

Enactivism, ever since its first formulation by Varela, Thompson, and Rosch, has always laid great emphasis on organism/environment interactions as the proper framework for studying cognition. Minds have to be understood as "enacted" by situationally embedded living organisms.

By proposing this approach to minds, enactivists have explicitly opposed themselves to cognitivists, who take representation as their central posit (Varela, Thompson, and Rosch, 1991). Thus, it is claimed that cognition is, rather than representation of the world, "the enactment of a world and a mind on the basis of a history of the variety of actions that a being in the world performs" (Varela, Thompson, and Rosch, 1991, p. 9; see also Thompson, 2007). True to the enactivist motto that "a path is laid down in walking"; the role of internally stored rules and representations in accounting for cognition is thus replaced by an embodied history of interactions.

By taking up this position, enactivism reveals itself as committed to a strong notion of embodiment. Such a concept has to be distinguished from other senses of embodiment. One way to use "embodiment" is to emphasize the role of the particular properties of the body in shaping our cognitive capacities. Thus, to give a rather trite example, it could be argued that having ten fingers lies at the basis of the decimal system, so that even mathematics has a basis in the body. Such a use of the notion of embodiment is in no way incompatible with a traditional cognitive science approach, in which computations and internal representations are assigned a key role for explaining our cognitive capacities. In particular, one could conceive of the specifics of the body as constraining the form or content of our representations or computations.

In the sense of "embodied" at stake here, "embodied" is used in contrast with "representational," such that saying that some capacity is embodied is to deny that it involves internal representations. One could argue, for example, that people embody the rules of their native language, in the sense that the rules are manifest, and only manifest in their utterances, or other practical dealings with language. The structure of language then is implicit in the practices; it is spread out in time, not represented anywhere. Of course, one could not embody rules without having a body engaged in the relevant, rule-manifesting, activities, but the emphasis here lies not on the specifics of that body, but on what could be called the primacy of embodiment over representation. We will take enactivism as stating that cognition is embodied in this strong, or "radical" sense (Chemero, 2009; Hutto and Myin, 2013).

In the domain of perception, enactivism has become associated with the so-called sensorimotor contingency approach presented in O'Regan and Noë (2001). Vision, according to the sensorimotor approach "is something we do, rather than something that happens in us" (O'Regan and Noë, 2001). The approach rejects the view of vision as aimed at producing a "faithful metric-preserving replica of the outside world inside the head" (O'Regan, 1992). Instead, seeing is conceived of as an "exploratory activity," "attuned to" sensorimotor contingencies, or ways in which sensory stimulation changes with movement—such as when a retinal image changes when one walks around an object. Seeing a scene or an object is, in the sensorimotor approach, comparable to feeling a surface or object, where the experience is of the whole surface or object, despite the fact that momentary tactile stimulation is limited to the fingertips making contact only at particular places.

Sensorimotor theorists have argued that the idea that vision should be understood as temporally extended interaction is supported by the insights it provides into the nature and character of perceptual experiences. According to the sensorimotor approach, perceptual experiences owe their identity to the patterns of sensorimotor contingencies typical of the kinds of organism/environment interactions those experiences normally arise in. For example, tactile feelings of hardness or softness are determined by particular patterns of experiences one has when engaging in such activities as squishing a sponge or pushing a brick wall. Similarly, that experiences of seeing differ as a class from experiences of hearing is due, according to the sensorimotor theory, to patterns of sensorimotor contingencies specific to vision and audition, such as that in seeing, but not in hearing, stimulation from a particular source stops when one turns one's head sideways, or closes one's eyes.

The crucial role played by patterns of sensorimotor contingency in shaping perceptual experience has been seen as supported by findings on adaptation to distorting or inverting glasses, as well as findings of experiments with sensory substitution devices (Hurley and Noë, 2003; Noë, 2004; O'Regan, 2011). For it seems that experiential change here follows on the heels of adaptation to patterns of sensorimotor contingencies.

The sensorimotor approach has been met with strong opposition and criticism, often formulated as criticism of enactivist approaches to perception generally (e.g. Block, 2005; Prinz, 2006, 2009). Critics of the sensorimotor approach have been puzzled, both by general claims about the role of sensorimotor contingencies in shaping experience and by the appeal to phenomena such as sensory substitution and distorted vision. Some critics have reached the verdict that these phenomena support the sensorimotor approach in no way whatsoever. They have further held that the sensorimotor claims regarding the determination of experiential quality fly in the face of the simplest observations about experience in imagery, dreaming or paralysis, in which experience seems radically disconnected from any presently obtaining patterns of sensorimotor interaction.

We will discuss the sensorimotor approach in the light of the broader enactivism as sketched above. We shall argue that spelling out the sensorimotor theory along enactivist lines, replacing representation by attunement due to a history of interactions, allows for a truly distinctive sensorimotor approach. This enactive sensorimotor approach is in perfect harmony with evidence about core phenomena such as vision with inverting glasses and sensory substitution. Moreover, an enactive sensorimotor approach allows for the accommodation of experiences such as in dreaming and perceptual imagery.

Enactive sensorimotor vision

Let us first return to the sensorimotor contingency account, as presented in O'Regan and Noë (2001). "Vision," it was said there, is "a mode of exploration of the world, mediated by knowledge of … sensorimotor contingencies" (p. 940), the latter being characterized as "the *structure of the rules* governing the sensory changes produced by various motor actions" (p. 941). It was emphasized that the knowledge involved is "implicit," leading to a view of perception as a "skillful activity." The sensorimotor approach was presented as being opposed to approaches based on the assumption "that vision consists in the creation of an internal representation of the outside world whose activation somehow generates visual experience" (p. 940).

In order to get a firmer grip on the sensorimotor approach, it is helpful to look in some more detail at how the sensorimotor approach has been applied to a number of perceptual phenomena, in O'Regan and Noë (2001), and on later occasions (e.g. O'Regan, 2011).

As a first one of such, consider *expanded vision*. By "expanded vision" is meant the kind of visual experience as when standing in front of a scene and overseeing it, looking at a large screen, or holding a book opened in one's hand and having the experience of seeing both pages. Expanded vision is characterized by the experienced spatial and temporal continuity of what is seen. Essentially, seeing a scene is having the feeling of being in roughly simultaneous visual contact with a certain extent of the world.

Though expanded vision comes very naturally to us, certain by now well-known facts seem to stand in the way of a straightforward explanation of it. One relevant fact is that subjects are not continuously accessing the whole scene in the same high-quality way, due to such factors as differences in the spatial distribution of receptors in the retina, and the presence of the blind spot (O'Regan, 1992, 2011). The absence of homogeneous simultaneous access is further highlighted by results from studies on change blindness and inattentional blindness, for they show that large changes in a scene can go unnoticed, for example when other changes are particularly conspicuous.

One way to explain expanded vision in the face of these facts it to relegate the homogeneity to something like the "internal representation of the outside world" (reiterating O'Regan and Noë, 2001). An inhomogeneous and gappy retinal image would be "filled in" to produce a homogeneous complete representation, to which or through which simultaneous access would still be possible.

The sensorimotor approach denies the need for such an inner simulacrum of temporal or spatial continuity. Instead it accounts for continuity in terms of sensorimotor regularities. One should not be misled by the fact of instantaneous access: perceivers have high-quality momentary access to only limited parts of the scene, while momentary access to other parts of the scene is of low quality. What is crucial, according to the sensorimotor approach, is that perceivers are set up to react to sudden changes in visual characteristics, so that, normally, any such significant change will not go unnoticed, but will lead the perceiver to focus on it. The trick to a successful change-blindness experiment is to tamper with this "grabbiness" or "alerting capacity" (O'Regan, Myin, and Noë, 2005) of environmental changes, by introducing an even larger visual alteration such as a blank screen between two pictures of a scene before and after changes. Seeing the scene in an expanded way, then, is not the consequence of an expanded representation, but of one's capacity to interact with the scene.

Next, consider seeing an object. Sensorimotor theorists, following Donald MacKay, have compared the visual experience in object vision to the tactile experience of holding a bottle. The actual tactile contact with the bottle is only limited to where the fingers touch the bottle. Nevertheless, the experience is of a bottle, and not of disconnected bits of hard material. Again, one could invoke a homogeneous representation to account for the experience of the whole object. Again the sensorimotor approach prefers an account in terms of being "attuned" to a sensorimotor pattern (O'Regan and Noë, 2001). The experience of feeling the whole bottle is then explained by the fact that one is attuned to the changes in stimulation that will occur when one makes certain movements. No representation needs to mediate, underlie or be causally involved in such a state of attunement. The same is claimed for seeing an object. To perceive a 3D object currently seen only from one side *as* a 3D object, one then does not need a representation: it suffices that one is attuned to the kinds of changes in stimulation that will result when either the object moves or when one moves with respect to it.

Thirdly, take seeing a color. It is a well-known fact, named "approximate color constancy," that we more or less see the colors surfaces actually have, even if the stimulus that reaches the eye is a product of both the surface's color and the contingent current illumination. Color experience is not a response to the local light as it currently reaches you; it is sensitive to a permanent surface property. A fundamental challenge for color science is to explain how this can happen. An enactive sensorimotor approach to color experience, in line with the accounts of expanded vision and object vision above, hooks on to the temporal extendedness of color perception (Broackes, 1992; Noë, 2004; O'Regan, 2011). The permanent property of color is identified with a *reflectance profile:* the way the surface reflects light under different lighting conditions. One can find out about the reflectance profile property by moving the colored object around or by observing surfaces under changing lighting conditions. Over time, one becomes sensitive to the underlying reflectance profile of a surface on the basis of minimal cues. Just as one can recognize a familiar person from a glimpse, one can recognize a reflectance profile on the basis of the behavior of the surface in a minimal set of lighting conditions. Such a minimal set, moreover, is almost always available, as it exists when different nearby objects reflect differently on a surface (Ruppertsberg and Bloj, 2007). In short, being capable of seeing colors then consists of being attuned to reflectance profiles, or to the changes in stimulation one would receive under various circumstances (see Philipona and O'Regan, 2006).

This way of looking at color illustrates the overall sensorimotor take on the qualitative character of perceptual experience. The sensorimotor approach claims that both the character of sensory qualities within a modality, such as the difference between softness and hardness, as well as differences between the character of modalities as a whole, are determined by differences in classes of sensorimotor contingencies typical of perceptual interactions. The experiential quality of softness differs from the quality of hardness, because of the different effects of pressing or squeezing. Similarly, touch differs from vision, among other things because tactile, but not visual, experience of an object comes to an end when immediate bodily contact is lost.

In the different cases of application of the sensorimotor approach surveyed in the above, the notion of "being attuned to sensorimotor contingencies" has played a prominent role. This raises questions about its precise meaning. What does it mean that a person is attuned to the sensorimotor contingencies of "red" or "softness"? A way of answering that question offered in O'Regan and Noë (2001) appeals to the exercise of the "mastery" or "knowledge" of sensorimotor contingencies, building on the already mentioned characterization of "vision as exploratory activity mediated by knowledge of sensorimotor contingencies."

A problem with an appeal to knowledge is that it allows a representational interpretation, while the representationalist framework was resisted in the context of inner simulacra accounting for expanded vision. On such an interpretation, having knowledge about sensorimotor contingencies involves representing those sensorimotor contingencies. Perhaps the specification, in O'Regan and Noë (2001) and elsewhere, that the knowledge is meant to be "implicit," is aimed at excluding such an interpretation in favor of an approach based on practical know-how, or skills. However, as pointed out by Daniel Hutto, insisting that knowledge is meant to be "implicit" is not compatible with supposing that the knowledge plays a "mediating" role (Hutto, 2005). An appeal to mediating knowledge would imply commitment to an intermediating representational stage. Consistency with the initial non-representationalism of the sensorimotor approach can be regained by conceiving of "attunement to sensorimotor contingencies" as embodied in the strong sense mentioned at the beginning of this entry. Attunement to sensorimotor contingencies then means that an organism has acquired, on the basis of a history of interactions, a sensitivity in its perception and action for the ways stimuli change with movement.

In line with the strong notion of embodiment, the development of perceptual attunement is not conceived of in representationalist terms: the past is not playing its role in the present as represented past—as mediated by representations of the past. Enactivists relying on the strong notion of embodiment will insist that what a history of attunement has yielded is just that: attunement. Of course, attunement is attunement *to* certain external conditions. Call this the external aspect of attunement. Moreover, attunement is impossible without changed conditions in the organism. Call this the internal aspect of attunement. The mere existence of external and internal aspects of attunement do not necessitate representational descriptions, however. It is not because an organism has become attuned to certain circumstances that it *represents* those circumstances by some internal means. This is obvious in non-cognitive evolutionary adaptations: a bird's wings partially constitute the bird's internal conditions for moving appropriately in an aerial environment, but this does not imply that the bird or its wings represent these external conditions. Analogously, in the cognitive case, there is no logical need to describe the internal conditions that mediate cognitive attunements as representing the external circumstances of attunement.

The upshot is that, once the strong notion of embodiment is adhered to, a historical or developmental aspect comes to the fore, in a non-representationalist shape. Representationalists cannot deny a role for an organism's history, but they may insist that an occurrent representation of the past needs to stand in for the real past, if the past is to yield an influence now. An enactive sensorimotor approach—that is, one defining attunement in the strong sense of embodiment—denies that the changes laid down in an organism's history need to be representational. Without being representational, these changes can still retain their causal powers and allow for a bridge between the past and the present.

The enactive sensorimotor approach thus has the advantage of offering a reading of "attunement to sensorimotor contingencies" which is consistent with the anti-representationalism present in the sensorimotor analysis of expanded vision, object vision and the experience of properties such as softness or color.

Attunement in action

How does the enactive sensorimotor position relate to evidence to which sensorimotor theorists have appealed, in particular findings about adaptation to distorting glasses or about sensory substitution? Critics of the sensorimotor approach to perception and perceptual awareness have challenged it on this front, claiming that neither findings about distorting glasses nor those about sensory substitution confirm the sensorimotor approach (Block, 2005; Prinz, 2006; Klein, 2007).

By means of lenses or prisms, the light entering the eyes can be inverted in a left-right and/or an above-below dimension. This introduces systematic changes in the perceiver's visual sensorimotor interaction with the environment. It has been reported that after extensive wearing of inverting glasses (within 6–10 days), visual abilities can be reacquired and one may once again learn to see where things are (e.g. Stratton 1896, 1897; Taylor, 1962; Kohler, 1964; Dolezal, 1982; but see for example Linden, Kallenbach, Heinecke, Singer, and Goebel, 1999, for negative findings).

A phenomenon consistently reported throughout the literature is that, on first wearing inverting glasses, the stability of visual experience breaks down with head movements, as if the scene moves in front of one's eyes. This confirms that visual experience depends on sensorimotor contingencies, or on the relation between sensory stimulation and bodily movement (Taylor, 1962), and not on sensory stimulation alone. For since sensory stimulation is only spatially inverted, dependence on sensory stimulation only predicts inverted, but not unstable experience. Over the days, free-moving subjects adapt to the new situation and movement of the head no longer disrupts visual stability. The subject has become attuned to the novel sensorimotor contingencies, so that environmental movements lead to a distinctively visual experience of movement of the scene, while movement of the perceiver's own point or direction of view does not.

The crucial role of sensorimotor contingencies is further evidenced by the finding that, when studies use a chin rest to avoid head movement, adaptation is very restricted. Indeed, it seems that only adaptation of proprioceptive experiences—and no adaptation of visual experience—takes place in studies in which subjects perform actions when head movements are thus avoided (for some examples see Harris, 1965). We can make sense of this by distinguishing kinds of sensorimotor contingency, such as those related to *exploratory* activities such as looking from *performatory* activities such as grasping (Gibson, 1964): genuinely visual adaptation to wearing inverting glasses depends strongly on active visual exploration.

It is also clear that the distortion brought about by glasses affects different kinds of sensorimotor contingencies differently. Since the early reports of Stratton (1896, 1897), the focus of analysis in inversion studies has often been on the altered relation between vision on the one hand, and touch or bodily experiences on the other. However, inverting glasses introduce a conflict within spatial vision itself (Degenaar, in press). Head movements and eye movements involve different patterns of sensorimotor contingencies, some of which are changed and some of which remain unaffected under the distortion. A subject wearing the glasses has to adapt to the altered patterns, while leaving the existing attunement to the unaltered patterns intact.

Instead of leading to a prediction of a complete "inversion of experience" (Klein, 2007), a sensorimotor position thus leads to the expectation that experience, while certainly changing in systematic ways, will also retain continuities with experience before the goggles were put on. Sensorimotor theorists have emphasized that the sensorimotor view of vision as a set of sensorimotor capacities naturally allows for partial adaptation, and have pointed to such observations as that wearers of distorting goggles might have learned to see the positions of moving cars correctly, while still seeing the license plates as in a mirror (O'Regan and Noë, 2001; O'Regan, 2011).

Partial adaptation challenges the idea that vision is based on a unitary image or representation in the brain. It is thinking of vision in this distinctively non-sensorimotor way which leads to an expectation of "re-inversion" of experience. The contrast between this way of thinking and a sensorimotor approach becomes even stronger when the latter is of the enactivist variety, for an enactivist sensorimotor approach is more fully, or at least more explicitly, non-representational.

Sensory substitution devices enable a new mode of interaction with the environment, for example by transforming an image recorded by a camera into a pattern of tactile stimulation on the subject's skin (e.g. Bach-y-Rita, 1984) or into a pattern of auditory stimulation (e.g. Auvray, Hanneton, Lenay, and O'Regan, 2005; Auvray, Hanneton, and O'Regan, 2007). It has been found that after practice with such tactile-to-visual or tactile-to-auditory substitution devices, in some cases blind or blindfolded subjects report the experience of objects in distal space, and describe vision-like experiences such as that objects increase in apparent size on approach. Following a training period, persons using a sensory substitution device have been found to acquire such capacities as involved in locomotor guidance, object localization, and object categorization (see Auvray and Myin, 2009, for further information and pointers to the literature).

As in the adaptation to inverting glasses, active exploration is required here: subjects must be able to control the camera in order to develop this kind of spatial experience (Bach-y-Rita, 1984; Auvray *et al.*, 2005). Sensorimotor theorists have referred to this adaptation as evidence for the approach, because it shows the pivotal role of sensorimotor contingencies in visual behavior and attunement. If a set of sensorimotor contingencies—such as those concerning change in size upon approach or retreat—are transferred from vision to touch then they seem to enable vision-like behavior and experience once the subject is attuned to the contingencies.

It is this positive point which is key: that, despite the novel modality these contingencies become embedded in, strikingly, they are able to entrain behavioral and experiential change. Critics of the sensorimotor approach have always been keen to point out that many, or at least some, aspects of experience remain linked to the modality the sensorimotor patterns are transferred to (e.g. Block, 2005; Prinz, 2006, 2009). Such an objection to the sensorimotor approach disregards the fact that the approach, just as was the case for inverting glasses, predicts a mixture of continuity and change in experience after one's having learned to perceive with a sensory substitution device. Sensory substitution devices add to the sensorimotor repertoire of the stimulated sense, without destroying the repertoire already present. Existing functionality—existing attunement to sensorimotor contingencies—remains in place. To the extent that aspects of the experiential character remain those of the "old" modality, this can be explained by the persistent attunement to the "old" sensorimotor contingencies. In other words, the sensory modality onto which the device is grafted, can show a level of "tenacity" (Myin, Cooke, and Zahidi, in press), or a lack of deference to the new sensorimotor context (Hurley and Noë, 2003).

Derivative experience

This nuanced sensorimotor perspective on inverting glasses and sensory substitution exemplifies how experience, at any moment, is a product of both the current stimulation and currently obtaining sensorimotor contingencies, *and* attunement due to a history of interactions. This basic tenet of the sensorimotor position allows it to meet an often formulated complaint that the sensorimotor approach cannot account for perceptual or perceptual-like experience under circumstances in which occurrent sensorimotor interactions differ from those characteristic of the experience. The range of cases invoked by critics includes dreaming, visual imagery and the perceptual experiences of paralyzed people.

Invoking these as counter-examples to the sensorimotor approach neglects the explanatory role played by the history of interactions. An appeal to this history of interactions, and the process of attunement it entrains, is essential in the sensorimotor account of all forms of perception. The fact that one feels the whole bottle on the basis of minimal sensory contact transcends one's currently occurring sensory stimulation precisely because of one's previous exposure to the sensorimotor contingencies of touching and exploring bottles. Because of this history, one is familiar with, or attuned to, a general pattern of sensorimotor contingencies typical of bottles, characterized by such regularities as that one will encounter more hard stuff when one slides one's fingers to either side. Dreaming, visual imagery and experience in paralysis, then, are cases in which the explanatory balance tips more fully in the direction of past sensorimotor contingencies. What one experiences under such circumstances is dictated almost exclusively by one's attunement to previous interactive regularities, rather than by one's current stimulation. In the sense in which the character of experience in such circumstances is due to past, rather than to current, interactions, such experience is derivative. The derivative status of experiences in dreaming, imagery or paralysis, far from revealing them as being distant from sensorimotor interactions, in fact shows them to be deeply entrenched in them.

Conclusion

An enactive sensorimotor account can answer common criticisms, and it has been shown, for example by the investigations of Philipona and O'Regan (2006) on color, that the approach offers rich prospects for empirical expansion. Of course, there is need for further clarification and elaboration of the theoretical basis of the approach. Relevant steps are taken for example in the work of Buhrmann, Di Paolo, and Barandiaran (2013) on the key concept of sensorimotor contingencies. The above makes clear that the sensorimotor approach, spelled out fully along enactivist lines, offers a strong, substantive and fruitful perspective on perception, for vision as well as for other modalities.

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Further reading

The sensorimotor approach to perception has been developed in somewhat different directions by Kevin O'Regan and Alva Noë—for example in the recent books, *Why red doesn't sound like a bell: Understanding the feel of consciousness* (New York: Oxford University Press, 2011), by Kevin O'Regan, and *Out of our heads: Why you are not your brain, and other lessons from the biology of consciousness* (New York: Hill & Wang, 2009), by Alva Noë. Among other divergences, O'Regan's book offers more links to empirical research, while Noë's book tries to advance a case for the idea that consciousness is not confined to the brain. Evan Thompson's *Mind in life: Biology, phenomenology, and the sciences of mind* (Cambridge, MA: Harvard University Press, 2007), has a chapter in which Thompson, one of the founders of enactivism, offers a sympathetic, but critical assessment of sensorimotor enactivism. Finally, Daniel Hutto and Erik Myin's *Radicalizing enactivism: Basic minds without content* (Cambridge, MA: MIT Press, 2013), presents arguments for construing enactivism and the sensorimotor approach in a radical, representation- or content-eschewing, way.