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Essay

Scientific Observation Is Socio-Materially Augmented Perception: Toward a Participatory Realism

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Abstract: There is an overlooked similarity between three classic accounts of the conditions of object experience from three distinct disciplines. (1) Sociology: the "inversion" that accompanies discovery in the natural sciences, as local causes of effects are reattributed to an observed object. (2) Psychology: the "externalization" that accompanies mastery of a visual–tactile sensory substitution interface, as tactile sensations of the proximal interface are transformed into vision-like experience of a distal object. (3) Biology: the "projection" that brings forth an animal's *Umwelt*, as impressions on its body's sensory surfaces are reconfigured into perception of an external object. This similarity between the effects of scientific practice and interface-use on the one hand, and of sensorimotor interaction on the other, becomes intelligible once we accept that skillful engagement with instruments and interfaces constitutes a socio-material augmentation of our basic perceptual capacity. This enactive interpretation stands in contrast to anti-realism about science associated with constructivist interpretations of these three phenomena, which are motivated by viewing them as the internal mental construction of the experienced object. Instead, it favors a participatory realism: the sensorimotor basis of perceptual experience loops not only through our body, but also through the external world. This allows us to conceive of object experience in relational terms, i.e., as one or more subjects directly engaging with the world. Consequently, we can appreciate scientific observation in its full complexity: it is a socio-materially augmented process of becoming acquainted with the observed object that—like tool-use and perceiving more generally—is irreducibly self, other-, and world-involving.

Keywords: mind–body problem; sensory substitution; direct perception; enactive cognition; tool-use; fact–value gap; philosophy of mind; cognitive science; philosophy of science; consciousness

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> *I would just like to leave you with this reminder: when we adopt a paradigm in cognitive science, we enact a shared world—and enact ourselves into the bargain.*
>
> John Stewart (1942–2021)

1. Introduction

In this essay, I pay homage to John Stewart's contributions to the philosophy of science, by tracing the subject–object relationship through his interdisciplinary reflections. Stewart was fond of provocatively claiming that a value-neutral science would be without value (for a recent statement, see [1]). Even the production of mere instrumental value, such as technological gimmicks, would not be enough. Science should aspire to be an intellectual authority that provides guidance as to the layout of reality and affords inspiration for the future of humanity. Striving for these deeper values means that, ultimately, we cannot ignore the most foundational problem of all: how do we, ourselves, as we subjectively live our own existence, fit into this scientific worldview [2]?

In modern science there is little, if any, room for subjectivity in the material universe. In particular, advances in biology and neuroscience are highlighting tensions with our lived experience, including undermining our otherwise recognized status of being persons who act for reasons [3]. However, if a scientific worldview were to eliminate our subjectivity from reality, like a naïve realism that only assigns reality to objects fully describable by

physics, it would have the self-defeating consequence that there can be nothing rational about that scientific enterprise! This is because, like the human lifeworld more generally, science depends essentially on our capacity for consciousness—to perceive the world and to collectively reason to decisions accordingly. However, in much of science, there is little recognition of the importance of this foundational problem, i.e., that we still do not understand how subjects and objects can meaningfully coexist, such that our lived mental life *as such* can make a difference in the objective world, and vice versa. Without substantial progress on this core problem, we are faced by a failure of science to understand the conditions of its own possibility. In other words, the stakes are high, both scientifically and existentially.

In response to this situation, this essay aims to motivate an alternative position to naïve realism in the philosophy of science, namely, by assigning a constitutive role to the observing subject, but without thereby falling into the opposite extreme of an agnostic or even anti-realist stance. It aims to overcome the traditional dispute between this kind of anti-realism and realism by developing a middle ground—a kind of participatory realism, which is a realism that is both subject- and world-involving.

2. A Stalemate in the Philosophy of Science

Two major approaches in the philosophy of science, which we will refer to as objectivism and constructivism following Stewart's analysis [4], have been in a long-standing stalemate regarding how to best conceive the subject–object relationship. Worse, when their assumptions are unpacked and pushed to their logical extremes, each approach turns out to have drawbacks that make them less than ideal for scientific worldviews.

Objectivism aims to explain our experience of reality in completely observer-independent terms. However, if the subjectivity of the observer continues to be left out of the natural order—e.g., by being identified with just another objective mechanism, or even eliminated completely—we give up the essentially subjective quality of our own existence too soon. There should also be room in the natural world for human subjects who can make a difference to unfolding events based on their normative evaluations, and who can hence be held accountable for their actions and decisions. This is especially evident if we do not want science to be in tension with practices of responsible decision making, be they in politics, daily life, or even in science itself [1]. Granted, we may never completely understand the basis of our own agency, or fully solve the mind–body problem, but it is also important to note that an acceptance of the possible limits of our scientific understanding is not the source of this tension with lived experience. What we need to avoid is objectivism's overly narrow conception of reality, i.e., a naturalism that excludes subjectivity by definition, and which thereby already rules out in principle the mere possibility of a subject being able to make a difference in their own right [5,6].

Constructivism aims to explain our experience of reality in completely observer-dependent terms [7]. However, if a place for subjectivity in naturalism is bought at the expense of the notion of objectivity, such that it can no longer transcend the domain of our experience, we go too far to the other extreme and undermine science in a different way. It becomes hard to explain why science advances the way it does, why there is a difference between facts and opinions, why there can be broad consensus about scientific knowledge among people with diverse personal and cultural backgrounds, and why scientific knowledge translates into technology that works [8]. Constructivism, especially in its "radical" constructivist formulations, does grant that not everything goes, and that there are observer-independent constraints, yet it remains agnostic about these constraints, nor does it allow that our lived experience can be directly constituted or shaped by the world or by other people [9]. However, if we do not make conceptual space for non-subjective reality to be part of the basis of our experience even in principle, we give up on the hard problem of consciousness prematurely [10]. More disturbingly, we would place an insurmountable gap between the reality our own stream of consciousness—ourselves—and the reality of others and of the world. Again, granted, we may never completely understand the nature and

boundaries of consciousness, but this relative ignorance should not impel us to accept an overly narrow conception of subjectivity that ignores the possibility of a world-involving basis of subjective experience; this would be in direct tension with our everyday experience that we can engage with objects (and, more importantly, other people!) that exist beyond our personal experience of them.

In sum, despite the starkly opposing orientations of these two approaches regarding the relationship between subject and world, they share some deeper undesirable premises and implications. Each in their own way fails to do justice to the full complexities of our lived experience of reality—namely, of being conscious subjects embodied in an objective world. In essence, while objectivism rejects the possibility that subjectivity plays a role in the observer-independent world, radical constructivism leaves out the possibility that the observer-independent world plays a role in subjectivity. These approaches thereby promote two distinct one-sided pictures of reality, each with its own theoretical blind spots. Ultimately, their schism prevents them from better grappling with the complex entanglements of natural and human factors that are inherent in reality, and hence makes them unsuitable perspectives for making substantial progress in science.

It is helpful to think of these impoverished visions of reality as two sides of the same old Cartesian dualist coin; they are symptoms arising from the same scientifically unresolved mind–matter problem [11]. *Objectivism* tries to overcome that substance dualism by reducing everything to observer-independent matter, while *constructivism* tries to overcome that substance dualism by reducing everything to the observer-dependent mind; and yet, each side cannot fully reduce the other into itself: objectivism must always access the world from an observer-dependent perspective, while constructivism must always appeal to observer-independent constraints.

Given this shared diagnosis of philosophical ashes of a failed dualism, I propose that we need to step outside of the original dualist binary trap altogether. We need to search for an alternative starting point from which to develop a scientific account that respects the existence of *both* human subjectivity *and* worldly objectivity, whereby they are irreducibly and meaningfully related to one another, jointly participating in shaping reality. In the following I will offer some steps in this direction.

I propose that a fruitful path toward this alternative starting point is to address the unresolved mind–matter dualism indirectly—namely, by way of overcoming its contemporary, metaphysically sanitized heir: cognitivist internalism. Descartes famously thought the linkage between the conscious mind and physical matter was to be found inside the brain, and this localization is still the default assumption for the majority of cognitive scientists today. Both objectivism and constructivism—each in its own way—also assume that the basis of experience is restricted to the inside of the brain/subject. It is this premise of internalism regarding the basis of our experience that motivates objectivism's ideal to recover an external universe that is in itself observer-independent, just as it motivates constructivism's insistence that this is an impossible ideal, given that we could never step outside of the internal to confirm whether it matches the external; but what if the core of the mind–body problem, dating back to the origins of modern science, is the expulsion of the mind from the "external" world into a hidden "internal" realm? What if the basis of mind, and of perceptual experience more specifically, is actually relational and world-involving?

The rest of cognitive science has been developing more inclusive alternatives, commonly known as radical embodied or enactive cognition (e.g., [12–16]). From the perspective of these theoretical advances, the subject's living body is necessary—but not sufficient—for experience, and the environment plays a necessary role as well. This leads to a rejection of brain-centrism in cognitive science, and to the adoption of a more encompassing framework, which treats an agent's behavior as a relational property of the agent's brain–body–environment system as a whole [17]. The rejection of internalism also breaks down the oversimplified separation between observer-dependence and observer-independence, as the mind is instead treated as a regulated form of organism–environment

interaction, such that the world itself can make a difference to our experience [18], and our experience can make a difference to the world [5].

3. Three Case Studies of Object Experience

The beginnings of a philosophy of science that seeks to go beyond these classic oppositions can be found in Stewart's contributions to enactive cognitive science (e.g., [6,19]), which centers on the idea that the mind is realized by embodied interaction in the world. Varela had started to develop this new approach, following on from his more constructivist work with Maturana, with a radical guiding vision: "to the extent that we move from an abstract to a fully embodied view of knowledge, facts and values become *inseparable*" ([20], p. 260). In other words, the stated ambition of the enactive approach is to overcome the fact–value gap—which has haunted modernist intellectual life at least since the work of David Hume [21]—while similarly avoiding the collapse of the fact–value distinction altogether, as has occasionally happened in constructivist or postmodern discourse.

However, we can also see in Varela a lingering bias for the internal over the external, as he continues: "To know *is* to evaluate through our living, in a creative circularity" ([20], p. 260). Much will hang on precisely where the boundaries of "our living" are conceived, especially since Maturana and Varela had traditionally identified the boundary of an autopoietic system with its material surface [22]. If so, then brain-centrism would be extended into an organism-centrism, but nonetheless it would stop short of extending into the world and, hence, would remain a form of internalism. Indeed, there has been sufficient ambiguity on this point that some critics have attributed an internalist/subjectivist stance to this line of work [23–25]. More recently, proponents of the enactive approach have started to spell out in what sense this is better understood as a world-involving account, e.g., [3,26–28], and this conceptual clarification has gone hand in hand with a fruitful encounter with the concept of direct realism, as developed by some branches of analytic philosophy and by ecological psychology, e.g., [29,30].

Stewart's philosophy of science defends a stance that "is neither 'internalist,' nor 'externalist,' but rather seeks to go beyond the opposition between them" ([19], p. 18). Indeed, this ambition to go beyond the internalism/externalism dichotomy is one of the key motivations for why the enactive approach adopted phenomenological philosophy as an alternative to radical constructivist philosophy [31,32], and without this dichotomy, nothing stands in the way of the natural world itself participating in the process by which an object shows up in our perceptual experience and, by extension, in scientific observation. In this way, clarifying that perception is world-involving is of broader relevance, as it pertains to how we should understand the scientific process, including our interactions with other people. Indeed, Varela had long emphasized that it is more accurate to explicitly refer to an observer community rather than an observer [33], and as Stewart liked to highlight, cognitive science is inherently reflexive, as we are scientific observers investigating the basis of observation; therefore, a change in paradigm in this field has implications for science as a whole, e.g., [4]. In order to make these reflections more concrete, in the following I will develop this notion of world-involvement as it pertains to our experience of objects in terms of three of Stewart's favorite conceptual "hobby-horses" [34].

3.1. Latour's Concept of Inversion

Latour and Woolgar's [35] classic sociological and ethnographic study of modern laboratory life found that the problem faced by scientists is that "at the frontier of science, statements are constantly manifesting a double potential: they are either accounted for in terms of local causes (subjectivity or artefact) or are referred to as a thing 'out there' (objectivity and fact)" (p. 180). Accordingly, they investigated the process of scientific discovery, during which the double potential of a statement becomes stabilized into a fact:

> "Once the statement begins to stabilise, however, an important change takes place. *The statement becomes a split entity*. On the one hand, it is a set of words which represents a statement about an object. On the other hand, it corresponds to an

> object in itself which takes on a life of its own. [. . .] Consequently, an inversion takes place: the object becomes the reason why the statement was formulated in the first place. [. . .] Once splitting and inversion have occurred, even the most cynical observers and committed relativists will have difficulty in resisting that the "real" [object] has been found [. . .]."
>
> ([35], pp. 176–177)

However, Latour and Woolgar's aim is precisely to provide a constructivist position that resists such appeals to reality. A key contribution of their research is to highlight the role of socio-material practices in the scientific creation of facts. They make it evident that facts are the product of a complex process in the lab. However, they emphasize this role of the socio-material practices to the extent that they end up provocatively concluding that factual *statements* match external *objects* because "they are the same thing". Latour and Woolgar realize that this threatens to collapse the objective into the subjective, and they hasten to clarify that they reject a simple relativist position, and do not wish to say "that facts do not exist nor that there is no such thing as reality" (ibid., p. 180). Their main point is, rather, that a scientific object's appearance of "'out-there-ness' is the *consequence* of scientific work rather than its *cause*" (ibid., p. 182). As such, their primary aim is to account for an experiential change during the process of scientific discovery.

It is an important insight that scientific work can change our perception of the world, and that this process is itself amenable to scientific investigation. However, we do not need to fully subscribe to their interpretation. A more reasonable interpretation of the socio-material conditions necessary for the appearance of "out-there-ness", in combination with their concession that facts and reality may exist after all, is that scientific access to objects does not come for free; when science makes contact with aspects of reality outside of our everyday spatiotemporal scales, this is a complex achievement that requires both mastery and the use of the appropriate concepts and equipment. Both the subjective and objective aspects of scientific activity have to come together in just the right ways such that a statement about the world can become recognized as a fact by the observer community.

However, Latour and Woolgar insist on a more extreme interpretation, as they advise that "it is important to eschew arguments about the external reality and outside efficacy of scientific products to account for the stabilization of facts" (p. 183). This kind of bracketing may be a useful ethnographic technique if one's aim is to reveal the socio-material conditions of scientific discovery, but Latour and Woolgar take it too far, and thereby end up with a one-sided account. This prevents them from recognizing that rightfully granting a more prominent role to the "local causes" they identified does not require excluding the world itself from contributing to the establishment of a sense of reality "out there".

In addition, they appeal to the fragility of facts to defend their rejection of such a world-involving account of scientific discovery, but it does not follow from the possibility that statements can be mistaken that facts cannot be world-involving. On the contrary, the fallibility of statements is an essential part of science's capacity for self-correction, which arguably improves its grip on the world and, hence, increases its world-involvement.

Interestingly, Latour and Woolgar's skeptical argument from the fragility of scientific facts has the same form as the classic "argument from illusion" against direct realism in the philosophy of perception. In response to the latter, we can similarly reject its unjustified attempt at a generalization of fallibility: that we sometimes do misperceive does not entail that perception is never world-involving [28]. Conversely, the similarity of these arguments suggests a comparable similarity between observation and perception; scientific observation could then be fruitfully conceived as a socio-material augmentation of the basic perceptual process, rather than only as a socio-material construct.

The development of this conceptual connection could have already occurred in the context of Stewart's work, but unfortunately it remained a latent potential and, hence, is important future work for the enactive approach. Stewart's [36] brief reply to Beaton's [30] world-involving account of the sensorimotor basis of perceptual experience only rehashes

Latour and Woolgar's classic constructivist account of the scientific processes. He thereby misses the opportunity to confront the internalist assumptions of that constructivist account with Beaton's world-involving proposal, which is actually quite similar in spirit to Stewart's [19] own call to go beyond the opposition between internalism and externalism. Stewart and Beaton both reject the postulation of internal constructs as the sole basis of perceived reality, in favor of basing perception directly in distributed organism–environment interaction. Accordingly, we still need to better articulate the consequences of this enactive, world-involving account of perception for our understanding of the scientific process. A step in the right direction is to reconsider the role of technology in perception in a world-involving way.

3.2. Bach-y-Rita's Concept of Externalization

It will be useful to further bring out this latent connection between scientific observation and perceptual experience by considering an intermediate case, namely, the way in which tool-use generally tends to shape the user's perceptual experience, as particularly exemplified by sensory substitution devices. Importantly for our comparison with scientific observation, the Compiegne group, of which Stewart was a part, has long argued that such interfaces perform the role of "perceptual supplementation" rather than "sensory substitution" [37], and that this makes them illustrative of a broader class of "mind-enhancing" tools [38], including pen and paper, sketchpads, or calculators [39]. Thus, we have not moved far from the kind of scientific activity analyzed by Latour.

Sensory substitution devices were first studied by Bach-y-Rita et al. [40] using the Tactile Vision Substitution System, which translated an array of black/white pixels obtained from a camera into an array of on/off vibratory actuators placed on their back. They found that a user's mastery of this device gives rise to perceptual experience, whereby the local causes of sensory stimuli are externalized to distal objects:

> "Our subjects spontaneously report the external localization of stimuli, in that sensory information seems to come from in front of the camera, rather than from the vibrotactors on their back. Thus, after sufficient experience, the use of the vision substitution system seems to become an extension of the sensory apparatus."
>
> ([40], p. 964)

This account of the externalization of local stimuli is strikingly similar to Latour and Woolgar's account of scientific observation as involving splitting and inversion. It is suggestive of the possibility that scientific instrumentation may similarly become an extension of our perceptual processes. Indeed, for Stewart [10], the value of sensory substitution devices is precisely that they can be used as a scientific instrument—one that enables us to examine the embodied sensorimotor dynamics involved in perceiving, and to do so under minimalist conditions (see, e.g., Figure 1), thereby allowing us to make an informative comparison with the sensorimotor activity of simpler creatures, such as the tick (more on this below).

For the moment, let us consider in more detail Bach-y-Rita's pioneering research with the Tactile Vision Substitution System, which for the Compiegne group provided two fundamental results that inspired their own research program:

> "(i) If the camera is immobile, placed on a table, the discriminatory capacities of the subjects remain very limited; and the stimuli are perceived on the surface of the skin.
>
> (ii) If the camera is actively manipulated by the subject, the subjects exhibit spectacular capacities to recognize shapes; and the objects are perceived in a distal space, "out there" in front of the subject."
>
> ([31], p. 941)

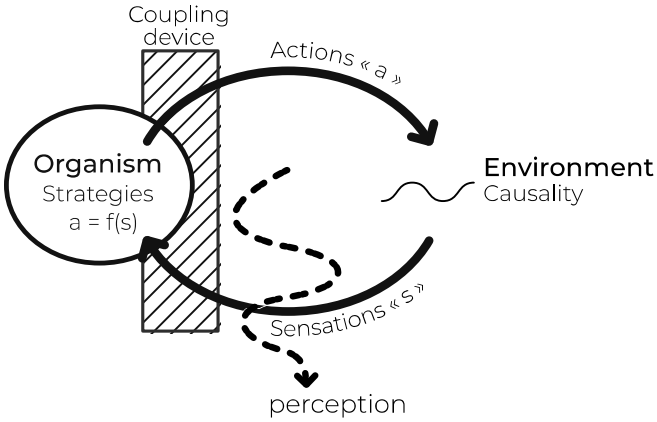

Figure 1. The augmented sensorimotor relation of perception spans the organism, coupling devices, and the environment. The coupling device could be any kind of tool, but the extension of perceptual experience becomes more marked with the skilled use of mind-enhancing tools, including sensory substitution devices and the advanced instrumentation used in scientific observation. Figure redrawn from Lenay and Steiner [31].

This phenomenon of externalization or distal attribution to something "out there" has been systematically studied, and can occur even when observers do not have any prior knowledge of the link between their actions with the device and the resulting variations of stimulations [41]. Accordingly, like Latour and Woolgar's analysis of the discovery of a previously unknown scientific object, we find that in the case of using a sensory substitution interface there are local/subjective aspects that, under suitable conditions, give rise to the experience of an outer/objective entity. Crucially, this distal attribution does not come for free; for a distal object to be perceived as such requires the subject's acquisition and active deployment of user expertise:

> "During the initial phase when the device is first employed, the attention of the user is drawn to the tactile stimuli on the skin. In fact, as long as the stimuli are controlled by the experimenter, the user remains unable to detach his attention from the stimuli. However, if the user himself is able to move the camera, then progressively, after 10–15 h of practice, he comes to perceive objects situated at a distance in front of him. At this point, there is a clear distinction for the subject between the tactile stimuli (which are sometimes a source of irritation) on one hand, and on the other the perception of an object out there in front of him."
>
> ([31], p. 941)

A comparison with Latour's own status as a novice in the lab, and as someone who insisted on remaining a detached observer, is instructive. Latour "was thus in the classic position of the ethnographer sent to a completely foreign environment" ([35], p. 273). As Lynch ([42], p. 503) has argued, Latour's approach will "sever the transivity of technical practices to their real-world objects of study"; hence, we can understand why for Latour it seemed that "a scientist's activity is directed, not toward 'reality,' but toward these operations on statements." ([35], p. 273). In fact, the expert scientists also had this response to his apprenticeship. With respect to his difficulty with understanding reports, "they argued that the observer was baffled because of his obsessive interest in literature had blinded him to the real importance of the papers: only by abandoning his interest in the papers themselves could the observer grasp the 'true meaning' of the 'facts' which the paper contained." (ibid., p. 75). The same consideration of the need for transparency regarding the basis of experience applies to the use of lab equipment: "The material setting both makes possible the phenomenon and is required to be easily forgotten" (ibid., p. 69).

In analogy with the sensory substitution case, if the user is intent on focusing on the local stimulations produced by the interface in a detached manner, and/or puts the control of the interface into the hands of the experimenter, then from the perspective of that naïve

user the proximal device will not become transparent, and the distal object will fail to become present in experience. In general, what is required for object perception to occur is that the subject is skillfully engaged in a world-directed interaction. This perceptual process can be supported in various ways, and sensory substitution devices serve as an illustrative example of the role that tools—and our socio-material practices in general—can play in shaping how subject and object relate to one another. Lenay et al. also point to the importance of a user community in constituting a meaningful perceptual experience when using such devices [43], similar to the role of an observer community in science. In this way, we again start to see that the discovery process identified by Latour and Woolgar may be a variation of the externalization process identified by Bach-y-Rita et al. Ultimately, both are forms of socio-materially augmented perception.

3.3. Von Uexküll's Concept of Projection

If the preceding analysis is on the right track, then we are close to securing the foundations of an account of science that does justice to both subject and object. Scientific observation is a socio-materially augmented form of object perception, yet for this to be a solid account, more conceptual work still must be done to fully stabilize the foundations, meaning to clarify the world-involving basis of perception.

As we have already discussed, despite the fact that the enactive approach has always emphasized the importance of organism–environment interaction, when it comes to a detailed explanation of the perceptual process, emphasis has typically been placed on the side of the organism [44]. To be fair, the basis of perception is no longer said to be within the brain, but it is often not quite clear how far the basis extends instead. Often it seems as if the basis has only extended to the outer boundary of the body, such that what matters to perception is the internal constitution of the organism—and especially the input–output pattern that plays across its sensorimotor surface. We can see this ambiguity in Stewart's work when he claims that "what the world 'is' *for* the organism amounts to neither more nor less than the consequences of its actions for its sensory inputs; this, in turn, clearly depends on the repertoire of possible actions." ([45], p. 3). The basis of perception certainly includes changes in sensory organs, but if it only includes those changes then it cannot be world-involving in any meaningful sense. It is possible that Stewart inherited this ambiguity regarding the status of the lived world from von Uexküll's [46] classic analysis of the sensorimotor basis of the *Umwelt*. One of his favorite examples was the tick:

> "Here is the story. The female tick climbs to the end of a branch, and . . . waits. If she gets a whiff of butyric acid, she lets herself fall; if she does not fall onto a hairy surface, she climbs up again onto a branch and starts over. If she does fall onto a hairy surface, she crawls until she finds a smooth surface. When she does find a smooth surface, she sticks her proboscis into the surface. If she finds underneath a liquid at roughly 37 °C, she sucks up the liquid to satiety."
>
> ([47], p. 57)

Interestingly, for von Uexküll each of these different functional circles involves a process of externalization (in German: *Hinausverlegung*, occasionally also translated as transposition, reassignment, or projection). Here is an example:

> "The skin glands of the mammal are the bearers of perceptual meaning in the first cycle, since the stimulus of butyric acid releases specific receptor signs in the tick's receptor organ, and these receptor signs are projected outside as an olfactory cue."
>
> ([48], p. 324)

Exactly how von Uexküll conceived of this process of projection is ambiguous, and the status of his concept of the *Umwelt* therefore remains an active area of debate [49]. Certainly, interpretations of the *Umwelt* that are compatible with the participatory realism promoted by the enactive approach and ecological psychology are possible [29]. On the other hand, it could also be interpreted in purely internalist, subjectivist terms. As Fultot

and Turvey [50] argue, it is likely that von Uexküll considered externalization to consist of a two-step process, whereby local activation of a receptor sign leads to the internal creation of a perceptual cue, which is then attributed to the environment in such a way that the organism can use it as standing for that external stimulus.

The form of this two-step process is similar to Bach-y-Rita et al.'s account of the change in experience associated with mastering a sensory substitution device, and it matches even more closely Latour and Woolgar's account of the change in status of a statement into a fact during the process of scientific discovery, which also involves a two-step process of the "doubling" of a scientific statement into a scientific object, followed by an "inversion" of the causal order such that the object "out there" ends up being given precedence over the local causes. Thus, we arrive again at the conclusion that these accounts derive their argumentative force from their logical consistency with an internalist starting point, rather than from doing justice to the empirical phenomena that they aim to describe.

However, once we reject internalism, an alternative account suggests itself: during these successful perceptual processes, the quality of the agent–environment interaction is transformed; the agent's grip on a specific aspect of the world is improved, and this allows that aspect to be grasped as a distal object. From this point of view, the local activity is still a necessary part of the process, but its role is fundamentally different: it no longer serves as the input for the internal construction of a putative object, but rather becomes part of the coupling through which the object is disclosed to experience. Of course, precisely how the object will make its appearance in experience will depend on how it is approached; experience is always perspectival, and this much of constructivism is retained. However, as Stewart also recognizes, this is not the only relevant dependence: "A point worth making here is that an *Umwelt* is not created by the organism alone, nor by the environment, but through the characteristic *relation* between the organism and its environment." ([47], p. 58). It is this insistence on an organism–environment *relation*, without an internal doubling or other intermediaries, that enables us to conceive of an enactive, world-involving, and world-directed account of perception without double-talk [51].

Noë [18] has long been developing such an enactive account; he argues that a perceptual relation must satisfy the conditions of both movement-dependence and object-dependence—that is, "we are perceptually in touch with an object when our relation to the object is highly sensitive to how things are with the object and to the way what we do changes our relation to the object" (pp. 22–23). In this way, the subjective and objective aspects of perception can be integrated into a unified account of how we find ourselves in the world: perceptual experience not only discloses how things are (objectivity), but also reflects how the perceiver relates to how things are (subjectivity): "When we encounter the world, we do so by encountering how it perceptually appears *from here*. We experience how things are, and we experience how they merely seem to be." (p. 68). For example, we perceive a whole coffee cup even if we always only ever immediately see one of its profiles from our perspective. It is our skillful engagement with the world that enables this contribution of subject- and world-involvement to become integrated into object perception, and it is our awareness of others' possible complementary perspectives that plays a constitutive role in our perception of the object being "out there" in the world [52].

4. From Perception to Scientific Practice

This enactive theory of perception is a productive middle ground for the philosophy of science—a sensorimotor basis of perception that loops through the body and the world makes it reasonable to accept the constructivist insight that object perception is always perspectival, while also accommodating the objectivist's appeal to the world's reality such that the object transcends this perspective. In addition, the basic perceptual relation through which we get a grip on the world can be transformed and empowered in different ways, which is a consideration especially relevant for a theory of scientific practice. It is beyond the scope of this essay to systematically develop this consideration in detail, but there is room for a few pointers for future work.

For the case of human perception, technics plays a particularly important constitutive role, but one that is already prefigured in other forms of life in the inventive creativity at play in organismic adaptation [53]. For our purposes, we are specifically interested in how the scope of the perceptual relation can be augmented with the skilled use of certain kinds of coupling devices, as illustrated in Figure 1.

Despite their many differences, sensory substitution devices and scientific instruments belong to the same broad category of coupling devices that augment our perception of the world. They do so by enabling skilled users to become sensitive to changes in their relation to the world that would otherwise remain inaccessible to them, and when these changes are responded to appropriately, they permit the user to get a grip on a previously inaccessible aspect of the world. This contact is experienced qualitatively as more perceptual when the contact is more direct, but even highly spatiotemporally, socially, and technologically mediated forms of sensorimotor interaction are never completely severed from the world. On the contrary, the kind of detached object perception that is most relevant for scientific observation is arguably a social achievement, which essentially depends on participatory sense-making [54]. In addition, it seems advisable to consider the scientific instruments supporting observation as participating in the coupled agent–environment system, and to treat the resulting observation as a relational property of that system [55]. The mediation afforded by scientific tools has long been a topic of post-phenomenology [56], but it remains to be seen how the enactive approach can address these specific forms of mediation on its own terms. More generally, it is crucial to explicitly include this irreducibly relational perspective in the interpretation of observations; the enactive approach to the philosophy of science is a situated approach [57].

Another important outstanding topic is how to include linguistic thought processes into such a world-involving account of the scientific process. One attractive possibility is to scale up basic perception–action loops by appealing to the right kind of socio-material affordances, such that they become linguistically enabled [58]. Noë similarly argues that some forms of thinking, at their core, retain a perceptual relation to the world: "Thought can be extended perception when one deploys sensorimotor skills (presumably in conjunction with other sorts of skills and knowledge) to achieve access to something or someone very remote." (2012, p. 27). An intriguing implication of conceptualizing thought in this manner is that, for Noë, such world-involvement places strict constraints on the form that the thought process can take. For example, he observes that "in the way I am now thinking of [something absent], it would not be possible to think of something nonactual." (p. 27). If so, then we could expect that scientists are forced to change their way of thinking once a statement changes its status from positing a possibly nonactual object to connecting with an actual object, and this is indeed what Latour and Woolgar observed to occur on such occasions, when "even the most cynical observers and committed relativists will have difficulty in resisting that the 'real' [object] has been found" (p. 177). This possibility of world-involving thought as another form of augmented perception is an exciting topic for future research.

5. Conclusions and Outlook

In the end, human experience of the world is a subject-, other-, and world-involving achievement, and this co-dependent basis of experience means that its limits are not within our brain–body and its supposed internal constructs—we genuinely relate to the worldly objects of our perception. We are at home in the world, and science is a sophisticated socio-material elaboration of this more basic situatedness.

Accordingly, no one-dimensional account of scientific facts will do; the scientific process cannot be reduced to the subjective perspectives and social conditions that enable it, nor can we take ourselves completely out of this process in the hope of elevating the targets of scientific investigation to observer-independent objects, as if they were uncovered by a "view from nowhere". This enactive approach to the philosophy of science is more humane because it does not undermine the lifeworld that makes science possible in the

first place, and it does not stop there, given the reflexivity of the sciences of the mind. If this world-involving theory of observation is on the right track, then it also promises to lead to better science in practice. We need to explicitly incorporate the fact that our experience of the world—including during scientific observation—is always perspectival:

> "When we try to understand reality by focusing only on physical things outside of us, we lose sight of the experiences they point back to. The deepest puzzles can't be solved in purely physical terms, because they all involve the unavoidable presence of experience in the equation." [59]

Importantly, an anti-realist interpretation of this irreducible presence of experience is blocked by the complementary insight that experience is also world-involving. The next step is to put this enactive approach to observation to the test and to turn it into a workable research program, including stepping outside of the traditional disciplines of cognitive science altogether—it is time for an enactive approach to physics.

For example, following phenomenological philosophy, Noë highlights that a defining characteristic of the reality of the world is that it is inexhaustible in principle from any and all perspectives, no matter the scale: "In the large, in the small, no experienced quality is so simple that it can be taken in all at once. The world is structured and complex and it always outstrips what can be taken in a glance" ([18], p. 95). The fact that the objects of experience transcend our perspective in this way is most parsimoniously explained by appealing to their dual status as being a part of the world while participating in the basis of experience. This transcendence of the real is characteristic of our everyday perceptual experience, but it similarly applies to scientific observation.

Consequently, it becomes intelligible why physics runs up against irreducible unobservables and indeterminacy when it socio-materially augments our perceptual relation with the world to its smallest and largest scales. At these scales, the limitations on experience imposed by the transcendence of the real can no longer be ignored, such as at the scale of cosmology when we try to grasp the entire universe as a whole [60], or at the quantum scale when we try to grasp the properties of an elementary particle all at once [61]. The discovery that the world in principle escapes our grasp in these extreme situations of scientific observation ceases to be mysterious. Instead, such observational limitations are an expected consequence of the world-involving basis of perception; hence, they come to be seen as reassuring evidence in support of a participatory realism [62]: we are real, so is the world, and so is our interaction.

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