Across the threshold: a somaesthetic approach to the design of extended realities

Tom McGuirk and Alan Summers

... my body is geared onto the world when my perception presents me
with a spectacle as varied and as clearly articulated as possible,
and when my motor intentions, as they unfold, receive the responses
they expect from the world. This maximum sharpness of perception and action
points clearly to a perceptual ground, a basis of my life,
a general setting in which my body can co-exist with the world.
Maurice Merleau-Ponty[1]

1. Introduction

The prospect that extended realities (XR) will become a seamless part of our everyday environment comes ever closer with the development of mixed reality headsets. These devices allow a blending of digital objects with the user's actual spatial environment. The user interacts with the virtual objects and these objects can, in turn, interact with the 'real-world' environment. We argue that the design and interpretation of these extended realities requires design thinking that questions the dominant standard model of cognition, which is indebted to Cartesian perspectivism. We suggest that situated and enactive models of cognition furnish a better understanding of how the body, mind and environment are essentially integrated, enabling us to apply such understanding advantageously to the design of these devices and environments.

XR technologies which incorporate augmented (AR), virtual (VR) and mixed realities (MR), have the potential to transform our engagement with our environment in profound ways that increasingly have implications for how we dwell in it. These phenomena present both design challenges and opportunities, and they invite a somaesthetic approach to the conceptualisation of the user experience. An appropriate understanding of the significance of the body in the design of these 'realities' is therefore of crucial importance.

[1] Maurice Merleau-Ponty, *Phenomenology of Perception*, (London: Routledge, 2002), 292.

Nomenclature is in this regard, in itself, significant. We speak of; augmented *reality*, virtual *reality* and so forth, thereby advancing a claim to represent the 'real'. But where does the body stand in relation to such realities? This question is important because, we will argue, the philosophical bases, cognitive models and technological foundations on which these 'realities' are constructed are neither neutral nor are they particularly sympathetic to the active and situated entity that is the human body. These 'realities' are, after all, constructed artificial environments, sometimes overlaid onto the user's physical environment and, more significantly, onto their psychophysiological space.

The way in which the relationship of the user to this space is understood is crucial to the design of these environments. In that regard, we examine alternatives to the standard model of cognition – often automatically and uncritically deferred to in their design – and we posit that situated and enactive models offer a more appropriate understanding of how the body can be conceptualised as integrated with the environment. As Bredo explains with regard to situated cognition theory:

> A common theme uniting many situated approaches to cognition is a shift in the way the person/environment relationship is conceived. Rather than a person being "in" an environment ... the activities of person and environment are viewed as parts of a mutually-constructed whole. ... This shift in view is made more plausible by viewing person and environment in terms of their contributions to an activity rather than as separately described *things*. Viewed actively, the adaptation of person and environment involves dynamic mutual modification ...[2]

We shall return to this point later. For now, let us remark that situated and enactive models, which conceptualise cognition in terms of a "dynamic coupling across brain–body–environment",[3] by placing emphasis on action and bodily engagement, provide an apt and fertile grounding for the design of virtual spaces. They afford, moreover, a sounder footing than the standard model of cognition, indebted to Cartesian perspectivism, in which subject/object, mind/body and body/environment dualisms inhere.

---

[2] Eric Bredo, "Cognitivism, situated cognition and Deweyian pragmatism." 1994.
[3] Shaun Gallagher, "Educating the right stuff: Lessons in Enactivist learning." *Educational Theory*, 2018, 68(6): 626.

2. Alberti's Window

Leon Battista Alberti (1404 – 1472) in describing his perspectival method, referred to looking through a window.[4] Alberti's window and the perspectival system he pioneered has proven remarkably successful. Jay identifies it as, "the dominant scopic regime of the modern era."[5] We have elsewhere characterised Albertian/Cartesian perspective as a cultural juggernaut.[6] In questioning the absolutist truth claims of perspective, Panofsky recognises, however, that it presents a somewhat arbitrary and, moreover, culturally specific worldview.[7] A number of studies testify to this cultural specificity by examining responses to perspectival displays when comparison is made between Western and East Asian subjects.[8]

Panofsky appraised Albertian perspective as being but one "symbolic form" amongst others; no more than, as Hung phrases it, "a symbolic system that organizes an aspect of reality and gives meaning to it ... rather than reality itself."[9] Panofsky accepted Cassirer's understanding that the "homogenous space" of Albertian perspective is not a "given space" but rather a "space produced by construction."[10] Significantly both Cassirer and Panofsky recognise the inadequacy of perspective's claim to a monopoly with regard to the presentation of the real. And just as these scholars questioned the dominance of such perspectival systems, so the comparable truth claim of extended reality systems is similarly open to question. This is especially the case since, in both technological and design terms, but also theoretically and philosophically, these technologies build upon Albertian/Cartesian perspectivism.

Davies outlines some of the implications of this indebtedness:

---

[4] Leon Battista Alberti, *On Painting*, (Cambridge: Cambridge University Press, 2013), 39.
[5] Martin Jay, *Downcast eyes: The denigration of vision in twentieth century French thought*, (Berkley: University of California Press, 1994) 69-70.
[6] Tom McGuirk and Alan Summers, "Albertian Perspective and Augmented Reality: Lessons from Panofsky." In *Proceedings Of The 7th International Conference: Internet Technologies and Applications* (ITA), 2017.
[7] Erwin Panofsky, *Perspective as Symbolic Form*, (New York: Zone Books, 1991)
[8] Takashiko Masuda et al., "Culture and Aesthetic Preference: Comparing the Attention to Context of East Asians and Americans." *Personality and Social Psychology Bulletin*, 2008, vol. 34: 1260 –1275; Hannah Faye Chua, "From The Cover: Cultural variation in eye movements during scene perception". *Proceedings of the National Academy of Sciences*, 2005, vol. 102: 12629–12633.
[9] Wai-Shun Hung, "'No Recipe for the Visible': The Theory of Linear Perspective in Merleau-Ponty's 'Eye and Mind'". *Philosophy Today*, 2013, 57(3): 295.
[10] Panfosky, *Perspective as Symbolic Form*, 30.

> The origins of 3D digital technology lie deep within the Cartesian philosophic tradition, a tradition whose dualistic privileging of mind over body, male over female, and human over "nature", has arguably contributed to an historic devaluation and objectification of the body, women, and animals, and to the ongoing plunder of the natural environment as a resource for profit and human consumption.[11]

The worldview that Davies outlines is not one that embraces the soma, its meaning nor the way the body engages with space. Neither, as we shall see, is a worldview based on this tradition equipped to properly assess the role of the body in cognition. It therefore provides little assistance in understanding the body's place in the landscapes that these technologies usher in.

Justin Hendrix, executive director at NYC Media, refers to the goal of "the ultimate display" (that holy grail of AR) as "total immersion - a *photorealistic reality* in full spherical view" (our emphasis).[12] This would appear a laudable goal, yet the reference to "photorealistic reality" is noteworthy, referencing as it does the ostensible veracity of photography; its presumed status as the benchmark of the real with regard to these technologies. As we have already seen, Panofsky dismisses a similar reification of Albertian perspective. In this regard, Merleau-Ponty's succinct analysis is perhaps useful in the context of our broader discussion; perspective, he insists, is merely "one of the ways man has invented for projecting before himself the perceived world, and is not a copy of this world."[13]

One aspect of this inflation of the truth claims of perspective, which Panofsky instances, is that in accepting perspectival images, we ignore numerous disparities, including the fact that the spheroidal retina means that in such displays the visual image is distorted at its margins by comparison with our normal vision, yet these disparities generally go unrecognised. This, Berchenko suggests, is because we "have learned to see perspectivally, rather than learning to represent the way that we see."[14] In this regard,

---

[11] Char Davies, "Rethinking VR: Key Concepts and Concerns." *VSMM*. 9th International Conference on Virtual Systems and Multimedia, Montreal, 2003.
[12] Justin Hendrix, "Building the ultimate display Stanford's Bernd Girod lays out a research agenda for immersive video." *Haptic.al*, Feb 27, 2017.
[13] Merleau-Ponty as cited in Hung, "'No Recipe for the Visible'", 295.
[14] Daniel Berchenko and Melanie Gilligan, *Dan Berchenko*, (Glasgow: Transmission Gallery, 2008), 8.

Panofsky implicates photography, suggesting that, the acceptance of such distortion, is "due to our habituation" to perspectival systems and this is "further reinforced by looking at photographs."[15]

The fact that photography stubbornly maintains its status as a yardstick in this matter testifies to its enduring pre-eminence as a symbolic form, whereby, "spiritual meaning is attached to a concrete, material sign and intrinsically given to this sign."[16] Photography, like its progenitor Albertian perspective, is thereby endowed with such meaning, embodying a notion of verisimilitude so profoundly embedded in the collective psyche as to become unquestionable. This, despite Panofsky's demonstration that such a status is neither inevitable nor unassailable. Moreover, just as a backdrop hides the backstage workings, the phenomenal success of both perspective and photography as symbolic forms masks artifice; their facture becomes transparent and we accept without demur their presentations of space, as Berchenko observes: "Alberti's window posit[s] its own presuppositions and produce[s] the view that is projected onto it. ... Our images produce the space of relations that they represent. And the retroactive positing of this space is itself never visible."[17]

If we consider it, the space that perspective presents is scarcely one that is accessible or amenable to the human body. Commentators as diverse as Bourdieu and Heidegger regard the Albertian/Cartesian perspectival model as representing a worldview characterized by attitudes of detachment, surveillance and control. Bourdieu identifies this with the "scholastic disposition" and the supposed objectivity of Western science, from which he suggests the body is purposefully excluded. He recognises, moreover, in the development of pictorial perspective, the *camera obscura* and "scientific" cartography, the emergence of a "distant lofty gaze", the dominance of this worldview he characterises as, "that point of view on which no point of view can be taken". It represents for him a "blind spot" only countered by Panofsky's tactic of putting "perspective into historical perspective." [18]

3. Other Windows

[15] Panofsky, *Perspective as Symbolic Form*, 34.
[16] Cassirer as cited in Panofsky, *ibid.*, 14.
[17] Berchenko, *Dan Berchenko,* 11.
[18] Pierre Bourdieu, *Pascalian Meditation*, (Stanford: Stanford University Press, 2000)

XR technologies typically employ a screen interface between the human being and virtual space. This screen has its geneses in Alberti's window. Brooks knowingly references this in paraphrasing the words of the pioneer of VR and CAD design, Ivan Sutherland in Sutherland's seminal paper *The Ultimate Display*:[19]

> Don't think of that thing in front of you as a screen; think of it as a window. Through that window one looks into a virtual world. The screen is a window through which one sees a virtual world. The challenge is to make that world look real, act real, sound real, feel real.[20]

Sutherland had, by 1968, invented the first VR headset. In doing so he had made a door of this window, carrying us across the threshold into virtual space. It is to the space beyond this door, presented by VR, that we now turn, and as we shall argue, crossing that threshold might be better done if we also cross from one model of cognition, Cartesian perspectivism to an entirely different one; situated and enactive cognition.

4. Vision and Movement

Its foundations in Albertian/Cartesian perspective mean that XR as a field of design, confronts a number of preconceptions and deep-seated biases regarding how we engage with space itself. Sutherland likened these developments to "a looking glass into a mathematical wonderland."[21]

Panofsky also recognises that perspective "mathematizes …visual space" and represents a highly artificial "ordering of the visual phenomenon."[22] A range of commentators has reflected on the implications of this, which are psychological (Panofsky), epistemological (Bourdieu) and ontological (Schrödinger).[23] Moreover, as

---

[19] Ivan E. Sutherland, "The Ultimate Display", in Wayne A. Kalenich (ed.), *Information Processing 1965: Proceedings of IFIP Congress*, Vol. 1, (London: Macmillan, 1965), 506-508.
[20] Frederick P. Brooks, "What's real about virtual reality?" *IEEE Computer graphics and applications 19*, no. 6 (1999): 16-27.
[21] Sutherland, "The Ultimate Display," 506.
[22] Panofsky, *Perspective as Symbolic Form*, 71
[23] Erwin Schrödinger, *What is Life?* (Cambridge: Cambridge University Press, 1992), 118-119.

we have already mentioned, its cultural specificity, as a decidedly Western worldview has also been acknowledged.[24]

Of most relevance to our current discussion is the fact that Albertian/Cartesian perspectival vision, purposely excludes two essential characteristics of the body, stereoscopic vision and that arguably more fundamental and existential bodily characteristic; movement. From a somaesthetic standpoint, technologies indebted to a worldview founded in Albertian/Cartesian perspectivism, and which take as their benchmark of verisimilitude, photographic realism, are unlikely to engage adequately with the body, nor more specifically with the individual's psychophysiological engagement with the environment.

Significantly, Panofsky critiqued two implausible assumptions of Albertian perspective the "first, that we see with a single and immobile eye, and secondly, that the planar cross section of the visual pyramid can pass for an adequate reproduction of our optical image."[25] As he points out, neither assumption can be objectively upheld, yet both are inherent in the digital tools and screen displays used in VR design, which are to a considerable degree based on monocular photography. In his analysis, Panofsky points out that these assumptions are no small concessions, but are "rather bold abstractions from reality."[26] More significantly, from the point of view of our present discussion, he cautions that the consequent, "purely mathematical space - is quite unlike the structure of psychophysiological space."[27] Separated by the very window through which she accesses the environment, the Albertian subject, with her "single and immobile eye" is by definition passive, a mere onlooker; an ossified cyclops.

Any discussion of the design of VR environments from a somaesthetic stance, must concern itself with the participant's psychophysiological responses. In this regard, the psychophysiological experience of movement is of crucial significance.

Alberti, somewhat frustratedly, references the painter's technical challenge in imitating "what does not, without interruption, maintain the same aspect."[28] His perspectival system specifically and tellingly addressed the *problem*, as he saw it, of movement, of change. As Gal and Chen-Morris explain, "Alberti's hope [was] that linear

---

[24] Allister Neher, "How perspective could be a symbolic form." *The Journal of aesthetics and art criticism*, 2005, 63(4), 359-373; Chua, "From The Cover"; Masuda et al., "Culture and Aesthetic Preference".
[25] Panofsky, *Perspective as Symbolic Form*, 29.
[26] *Ibid*.
[27] *Ibid*., 29-30.
[28] Alberti, *On Painting*, 51.

perspective [would] guide the eye beyond Nature's change and motion and into the secrets of beautiful order."[29] The Albertian viewpoint emphasises, Jay suggests, a predisposition towards stasis and passivity, it "justifies a spectatorial rather than incarnate eye, the unblinking eye of the fixed gaze rather than the fleeting glance."[30] Jay's characterisation exposes the inherent antipathy of Alberti's vision to the lived psychophysiological experience of vision in the active, moving human body.[31] As he explains:

> The viewpoint was that of a monocular unblinking, fixed eye (or more precisely, abstract point), rather than the two active, stereoscopic eyes of embodied actual vision, which give us the experience of depth perception. This assumption led to a visual practice in which the living bodies of both the painter and the viewer were bracketed, at least tendentially, in favor of an eternalized eye above temporal duration.[32]

Harries reflects,[33] just as Bourdieu does, on the relationship between the development of perspective and the emergence of objectivist scientific method. She emphasises the alteration this development produced with regard to the conception of, and engagement with, space and the environment:

> Historically ... the phenomenon of perspective, as it expresses itself for instance in the development of renaissance and baroque art, goes ... hand in hand with the emergence of the objective conception of space which is presupposed by the new science.[34]

This worldview, with its implications for our conception of the body and for our embodied psychophysiological experience of space, persists as a basis for the standard

---

[29] Ofer Gal and Raz Chen-Morris, "Nature's drawing: problems and resolutions in the mathematization of motion." *Synthese*, 2012, 185: 433.
[30] Jay, *Downcast eyes*, 81.
[31] Bourdieu recognises an embedded and automatic distain for the action and any association with practical life in what he characterises as the "scholastic disposition" he analyses as indebted to Albertian/Cartesian perspectivism. (Bourdieu, *Pascalian Meditations*)
[32] Jay, *Downcast eyes*, 54-55.
[33] Karsten Harries, "Descartes, perspective, and the angelic eye." *Yale French Studies*, 1973, (49): 28-42.
[34] Harries, "Descartes, perspective, and the angelic eye," 30.

model of cognition, a "key attribute" of which is a "disembodied and rational unitary subject."[35] Premised as it is on subject/object dualism, in this model, the passive, indeed static, subject is separated by a metaphorical screen not only from the object of their attention, but also from almost the entirety of their spatial and indeed social environment. The a-temporal "ideal observer" is characterised by Harries as the angelic eye/I, [36] adopting what Thomas Nagel's famously termed "the view from nowhere."[37]

5. Detachment

This progress towards disembodiment is taken still further; not merely is the earthly body replaced by an ideal disembodied subject but the inherent subjectivity of the individual viewpoint is also negated. As Jay puts it: the "specificity of the subject could be bracketed out in any cognitive endeavor" in a world where "all beholders would see the same grid of orthogonal lines."[38] Harries explains that the embodied individual disappears and is replaced by a mere cypher: "our truths have their measure in what … an ideal observer would find true, where it is important to note that the ideal observer need not exist to provide this measure."[39]

Harries also recognises in this gambit a manoeuvre towards abstraction where the exclusion of the body and its isolation from the environment is pivotal. In its "search for a secure foundation" Albertian/Cartesian perspectivism involves "an attempt to lift the self out of this world, to leave behind the prison of the body and to become the pure 'I'. But far from leading to reality this ascent to angelic heights leaves only the emptiness of abstraction."[40]

Let us remember that Descartes, in elucidating the *cogito* argument, states that while he could not doubt that he was a thinking thing, he could more easily "pretend

---

[35] Kristie S. Fleckenstein, "A Matter of Perspective: Cartesian Perspectivalism and the Testing of English Studies". *JAC*, 2008, 28: 92.
[36] For further discussion of the "angelic eye (I)" and why "Descartes's dualism leads logically ... to an epistemology of the spectacular ..." see Erica Harth, *Cartesian women: Versions and subversions of rational discourse in the old regime*, (New York: Cornell University Press, 1992), 75.
[37] Thomas Nagel, *The view from nowhere*, (Oxford: Oxford University Press, 1989).
[38] Jay, *Downcast eyes*, 189.
[39] Harries, "Descartes, perspective, and the angelic eye," 41.
[40] *Ibid.*, 40.

that I had no body" and significantly, "that there was no world nor any place where I was."[41]

Such mind/body and body/environment dualism is, however, countered extensively in the phenomenological and American pragmatist philosophical traditions and within related theories of situated and enactive cognition, indebted to those traditions, which present the antithesis of this view, to which we now turn.

6. A Different Cognitive Model

Robbins and Aydede provide a useful description of the three principal component theses of 'situated cognition', namely, the embodiment thesis, the embedding thesis and the extension thesis:

> First, cognition depends not just on the brain but also on the body (the embodiment thesis). Second, cognitive activity routinely exploits structure in the natural and social environment (the embedding thesis). Third, the boundaries of cognition extend beyond the boundaries of individual organisms (the extension thesis).[42]

This reflects what Shusterman terms the "pragmatist picture of cognition", which presents it as embodied, embedded and extended (3Es model), to which he initially, and with regard to our argument, usefully, suggests the addition of a fourth "E"; enactive cognition, comprising what he terms a "4E" pragmatist understanding of cognition, (as we refer to later, he further proposes a 6E model to include, emotive and "esthetic" dimensions).[43] Situated cognition theory, with, as we have seen, roots in American pragmatism, presents cognition as inextricably embedded within an environment, moreover; this embeddedness directs both perception and cognition. This brings us a long way from that ossified cypher – the disembodied subject of the Albertian/Cartesian indebted standard model. Dewey, Gallagher points out, realised that thinking is not

---

[41] René Descartes, *Discourse on method*, (Indianapolis: Hackett Publishing, 2001), 28.
[42] Philip Robbins and Murat Aydede (Eds.), *The Cambridge Handbook of Situated Cognition*, (Cambridge: Cambridge University Press, 2008), 3.
[43] Richard Shusterman, "Affective cognition: from pragmatism to somaesthetics." *Intellectica* 60, no. 2 (2013): 49.

confined to an isolated entity called the 'mind' but is an embodied "activity or event *in* the world" (our emphasis).[44] Cognition, on this view, is *decided* by the sensory-motor responses we have to the physical world of affordances into which we are, in a Heideggerian sense, *thrown.* In this context, Johnson points to "Dewey's continuity principle", which viewed the operations of mind in evolutionary terms; as having evolved through the development of increasingly complex sensorimotor activity through processes of engagement with the environment.[45] Whereas, as we have seen, models of cognition grounded in Albertian/Cartesian perspectivism disregard in particular the active, moving, engaged body and, indeed, its very relationship to space, by contrast, situated and enactive models view the body as inexorably situated within the environment and as being intrinsic to all perception and cognition, as well as all meaning and thought.

According to Gallagher, Heidegger understood that Cartesian cognitive models "overlook [the] basic ontological situatedness of the cognitive agent."[46] As Steiner explains (echoing Harries comments above), for Heidegger this represents an attempt,

> to [in Heidegger's words] "leap through or across the world" ... in order to arrive at the noncontingent purity of eternal ideas or of mathematical functions and certitudes. But this attempted leap from and to abstraction is radically false to the facticity of the world as we encounter it, as we live it.[47]

7. Embodiment Vision and Action

Situated and enactive models of cognition reject the dismissal of the role of the body in cognition. With regard to the issue of perception, for example, the enactive model presented by Noë,[48] asserts that vision, which the standard model presents as a passive receptive process, is in fact an active, assertive and explorative interaction with the environment, more analogous to the way a blind person might use her stick than to

---

[44] Shaun Gallagher, "Philosophical antecedents to situated cognition." In P. Robbins and M. Aydede (eds.) *Cambridge Handbook of Situated Cognition*, (Cambridge: Cambridge University Press, 2009), 38-39.
[45] Mark Johnson, *The Meaning of the Body*, (Chicago: Chicago University Press, 2007). 228.
[46] Gallagher, "Philosophical antecedents to situated cognition," 8.
[47] George Steiner, *Martin Heidegger*, (Chicago: University of Chicago Press, 1987), 88.
[48] Alva Noë, *Action in Perception*, (Cambridge, MA: The MIT Press, 2004).

conventional understandings that appeal to 'internal representation' – the passive 'pictures in the mind' paradigm. As Noë explains:

> According to this approach to perceptual experience, the content of an experience is not given all at once, as is the content of a picture .... Rather, the content is given only thanks to the perceiver's exercise of knowledge, of sensorimotor contingencies. The content of experience isn't really given at all - it is enacted. Perceptual experience ... is itself a temporally extended activity, an activity of skill based exploration of the environment.[49]

This understanding takes us a long way from the stasis of the standard cognitive model. By contrast, according to the enactive model, embodiment, action and movement are paramount, thereby presenting an understanding of perception as not merely dependent on, but indeed "constituted by" the possession of "sensorimotor knowledge."[50]

8. Embeddedness

Situated and enactive models of cognition also reject the detachment from the environment which, as we have seen, is associated with the standard model, as Robbins and Aydede, explain:

> The Cartesian tradition is mistaken in supposing that the mind is an inner entity of any kind, whether mind-stuff, brain states, or whatever. Ontologically, mind is much more a matter of what we do within environmental and social possibilities and bounds. Twentieth-century anti-Cartesianism thus draws much of mind out, and in particular outside the skull.[51]

---

[49] Alva Noë, "Art as enaction." 2002, in the proceedings of *The Art and Cognition* (virtual conference November 2002 – February 2003), Euro-edu Association, http://cognitionandculture.net/wp-content/uploads/archive_1.pdf Accessed 22 November 2020.
[50] Noë, *Action in Perception*, 2.
[51] Robbins and Aydede, *The Cambridge Handbook of Situated Cognition*, 8.

On this view, just as there is no radical mind/body separation, subject/object dualism is also rejected. As Bredo explains: "put simply the inside/outside relationship between person and environment is replaced by a part/whole relationship."[52] Johnson also posits an enactive and situated approach partly founded in pragmatist philosophical theory whereby, as he explains, "subjects and objects are really just abstractions from the interactive of organism-environment-transactions."[53]

9. Extension

A yet more radical understanding of situated and extended cognition; "active externalism" is presented by Clark and Chalmers in their seminal text, *The Extended Mind*.[54] As described by Noë, this theory is premised on the notion that "the environment can drive and partially constitute cognitive processes."[55] This is a radical take on the "extension thesis" encountered earlier. As Clark and Chalmers argue:

> If, as we confront some task, a part of the world functions as a process which, were it done in the head, we would have no hesitation in recognizing as part of the cognitive process, then that part of the world is "part of the cognitive process." In these cases, the human organism is linked with an external entity in a two-way interaction, creating a coupled system that can be seen as a cognitive system in its own right.[56]

Noë characterises this process as one where: "the mind reaches ... beyond the limits of the body out into the world."[57]

Notwithstanding this, it is surprising how persistent, ingrained and indeed quotidian, the standard model of cognition remains. Hurley references what she describes as the "classical" view that privileges the cerebral mind as "cardinal."[58] On this view, the roles of perception and action in cognition are considered separate,

---

[52] Bredo, "Cognitivism, situated cognition and Deweyian pragmatism."
[53] Johnson, *The Meaning of the Body*, 67.
[54] Andy Clark and David Chalmers, "The extended mind". *Analysis*, 1998, 58: 10-23.
[55] Alva Noë, "Experience without the head" in Gendler and Hawthorne (eds.), *Perceptual Experience*, (Oxford: Oxford University Press, 2006), 411.
[56] Clark and Chalmers, "The extended mind," 11.
[57] Noë , "Experience without the head", 411.
[58] Susan Hurley. "Perception and action: alternative views." *Synthese*, 2001, 129(1): 3-40.

subordinate, peripheral and discrete.[59] By contrast, according to Gallagher's enactivist "conception of cognition":

> the unit of explanation is not just the brain, not just the body, and not just the environment, but the body–brain–environment understood as a dynamically coupled structure or gestalt. On this view, ... the brain is not in the center of a circle issuing radial commands to elements on the circumference; rather, it is one element on that circumference, along with body and environment.[60]

The enactive and situated cognitive model outlined by Gallagher, Hurley, Noë and others, presents us with what we suggest is a convincing and appropriate theoretical framework to guide analysis and design thinking. In this regard, it provides us with a comprehensive account of the role of the body in cognition, specifically in relation to the design of immersive interaction and enactive engagement with extended reality environments.[61]

10. Design at the threshold

XR is an umbrella term encompassing current and future scenarios whereby real and digital environments are combined. The digital content of any XR system may comprise text, image, moving-image and 'three-dimensional' objects, up to and including complete digital environments. It is important that the design of these digital objects ensures that they appear part of the user's psychophysiological space, situating them within the user's extended reality, such design, we argue, profits from an analysis that utilises situated and enactive models of cognition.

However, at some point in the design and development process the designer of an XR experience will be confronted with a perspectival representation of an empty space containing three axes and a camera icon. This view of the Cartesian space is itself rendered on a two-dimensional screen where the designer is herself enframed, in

---

[59] *Ibid.*, 3.
[60] Gallagher, "Educating the right stuff: Lessons in Enactivist learning," 625.
[61] Shusterman, in reflecting on the "4E" pragmatist approach to understanding cognition, outlined earlier, usefully suggests the inclusion of "the affective and aesthetic dimensions of cognition" thereby presenting what he terms a "6E approach" comprising embodied, embedded, extended, enactive, emotive and esthetic dimensions. (Shusterman, "Affective cognition", 50.)

Albertian/Cartesian terms, as a monoscopic entity; a single eye observing another single eye (camera viewpoint). It would be hard to think of a viewpoint more alienated from the embodied experience (Fig. 1.).

Determining how, during the design process, the situation represented by this disembodied camera view might be reimagined in embodied terms, specifically with regard to an understanding of the user's body as situated within the space and actively participating in an enactive sense, requires a somaesthetic approach. One pathway into the design of these extended realities is through a consideration of reach.

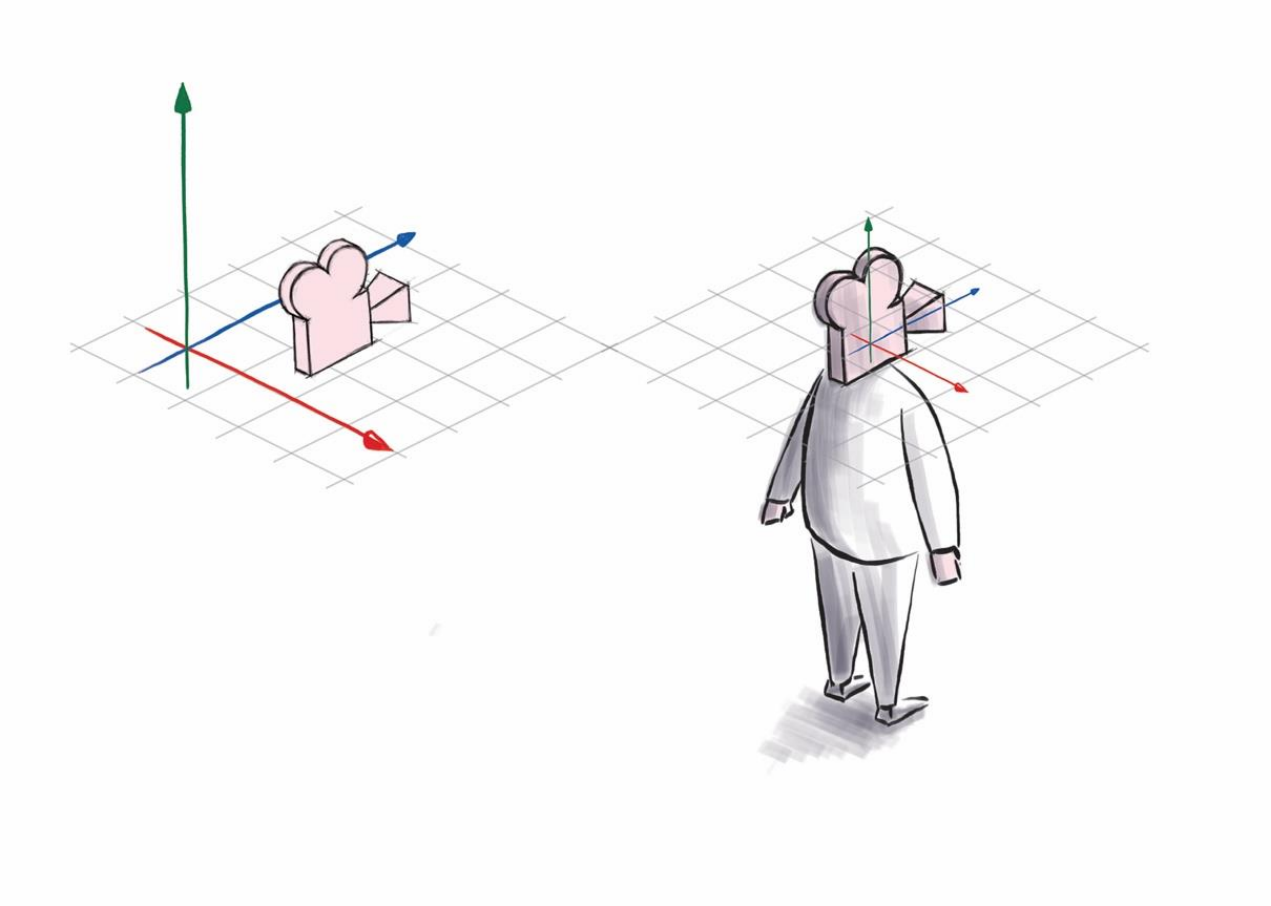

Figure 1: Cartesian Man: The disembodied camera or an embodied user? Copyright © A. Summers 2020

Reach as an embodied action epitomises the user's enactive engagement with the environment. Reach is both a physical and a mental act. We have already reached out to the object even before any sensorimotor actions take place. Asking ourselves can we reach somewhere, we have to some extent, in terms of intentionality, (and in terms of

what we now understand regarding mirror-neurons in the brain) already virtually reached that location.[62] Reach is an important experience from a somaesthetic stance, by considering reach the designer can think with their own body and consider the possibilities for the user's unique and individual soma in their design process. In XR environments, where both the digital and physical coexist, considering reach creates a design discussion regarding what might constitute appropriate design considerations if we employ the "brain–body–environment" enactive model. Consider how reach situates the user in mixed reality environments; it is reach, as we shall see, that can countermand the expectations of Cartesian logic.

11. Virtual Reality

VR is a completely immersive digital environment, where the user wears a headset and headphones to surround themselves with an alternative visual and aural landscape; a virtual space. Within this space, hand movement is most often recognised through the tracking of hand-held control devices that allow and control functionality within the virtual world, but gestural interaction through hand tracking is becoming increasingly accessible at a consumer level.

To reach out to an object in VR is to intend to reach something in the digital space, all the while knowing implicitly that it cannot be physically touched. In VR it is vision that is the trigger for the sensorimotor action of reaching out and it is usually the primary indicator that the body has reached the object, as there will be no actual physical contact with a digital object. In reaching, as an embodied action, participants rely on knowledge of the location of the object, informing them how far to reach, whilst the intrinsic shape of the object informs them how to position the body to interact with it. However, if the embodied action does not correspond with the visual interaction that creates dissonance, a disconnect, whereby an expected concrete movement becomes

[62] As Shusterman points out: " ... we should not [make] too sharp an opposition between thought and action; for one of the key insights of classical pragmatism is that genuine thinking also involves action, as does all perception, because cognitive life is fundamentally active. This essentially active nature, moreover, is not simply reactive as the traditional stimulus-response model suggests. Rather, as Dewey powerfully argued long before enactive theories became popular, our very perception or awareness of the stimulus always already involves actions of attention (that always involve somatic movements or adjustments, even if only very subtle ones) and also actions (such as locomotion or reaching) that bring us to encounter that stimulus and even shape that stimulus as a stimulus." (Shusterman, "Affective cognition", 61.)

abstract, pulling into focus, while simultaneously disrupting, the participant's enactive engagement within the virtual space.

Therefore, visual information and the visual array is generally regarded as the primary consideration in achieving immersion with regard to the design of VR environments, with aural input considered an essential enhancement. The user's bodily movements will be dependent on design functionality such as the narrative requirements of a game environment or the learning element in training environments. The visual aspects of the designed environment tend to dominate in this regard. The artist Char Davies sees this scopic bias as problematic: "In fact, our experience shows that rather than enhancing the immersive effect, high-resolution in the graphics actually decreases the subjective experience of immersence by overriding the body's other non-visual modes of experiencing spatiality."[63]

Game designers have explored movements involving reach that do not rely on vision. An example of this involves the player reaching over their shoulder for a digital object attached to their back; an arrow from a quiver in *The Lab*[64] or a backpack containing supplies.[65] In these scenarios the participant does not engage with these affordances primarily through vision but instead they become connected to the soma as part of the body schema. This appropriates non-conscious knowledge that, as Svanæs puts it, "includes 'tacit' knowledge of the structure and specifics of our body, such as the length of the arm."[66] It is the body schema that enables us to move through the world without constantly colliding with objects and it expands to include the tools employed by our body.[67] The player accepts the tools on their back as incorporated into their body schema and the embodied action of reaching reinforces this, further situating the player within the virtual world.

To reach distant locations within the virtual space a point and 'teleport' system is often employed, without any requirement for the physical act of walking, as ambulatory movement is normally curtailed by, for example, obstacles in the real-world environment. This system of pointing to a location effects a more calculated Cartesian

---

[63] Davies, "Rethinking VR: Key Concepts and Concerns."
[64] Valve, *The Lab*, (Valve, 2016).
[65] Joel Green, "Finding the magic in VR-centric design: Backpack Inventory." *Gamasutra*. 2018, June 14.
[66] Dag Svanæs, "Interaction design for and with the lived body: Some implications of Merleau-Ponty's phenomenology." *ACM Transactions on Computer-Human Interaction*, 2013, 20(1): 8:1–8:30.
[67] David Kirsh, "Embodied cognition and the magical future of interaction design." *ACM Transactions on Computer-Human Interaction*, 2013, 20(1): 3:1–3:30.

understanding of distance through vision, one that eschews the embodied physicality of movement.

By contrast, Davies in her artwork *Osmose,* gives precedence to bodily interaction, where movement in the immersive virtual space, is based on the user's breathing and balance, thereby intentionally creating a more embodied experience that negates the conventional, fixed location of the user's body.[68] With the user floating in the immersive virtual space their gaze can reach out to a location, then by means of focusing on breathing to move vertically, and through adjusting balance to move laterally, the user floats towards that location. Thus, an amplified sense of embodiment is achieved through the engagement of alternative sensorimotor systems that are harnessed to control movement within the environment. This design approach prompts a dialogue regarding alternative ways of reaching a location within VR environments, providing, as it does, an example of alternative techniques and tools, used to explore alternative enactive landscapes. Davies is critical of the way that VR design more generally, usually presents a reinforcement of the Cartesian worldview:

> it is only when virtual environments are constructed in ways that circumvent or subvert the technology's conventions (i.e., its bias towards mimetic representation, disembodiment, and will to dominate and control) that the medium of immersive virtual space can be used to convey alternative sensibilities and world-views.[69]

Her comments regarding this bias towards "mimetic representation, disembodiment, and will to dominate and control" are particularly salient with regard to our discussion, reflecting as they do the characteristics of Albertian/Cartesian perspectivism as recognised by numerous commentators.[70] By contrast, Gallagher's presentation of enactive cognition as a non-hierarchical model that emphasises an enactive, embodied and situated (including socially situated) engagement with the environment could not be further removed from such a worldview, as evidenced in his outline of the "principles of enactivism" which include the assertions:

---

[68] Char Davies, *Osmose* [Digital]. 1995.
[69] Davies, "Rethinking VR: Key Concepts and Concerns."
[70] Bourdieu, *Pascalian Meditation*; Harries, "Descartes, perspective, and the angelic eye"; Jay, *Downcast eyes*; Martin Heidegger, *Being and Time*, (Oxford: Blackwell, 1962).

> [That] cognition is not simply a brain event. It emerges from processes distributed across brain–body–environment. [That] the world (meaning, intentionality) is not pre-given but is enacted by cognition, action, and social interaction. [That] enactivist approaches ... emphasize the relevance of dynamical coupling and coordination across brain–body–environment. [And that], cognitive systems are extended, intersubjective, and socially situated.[71]

He suggests, moreover, that according to the enactivist view, "we engage with the world and with others in an affordance-based fashion."[72] In other words, tools, equipment and technology, as parts of our environment, are integrated within our cognitive brain–body–environment processes, and indeed the way we respond to affordances is dependent also on the kind of bodies we, as humans, have, and importantly our predisposition to social engagement.

Davies suggests that within VR there is often a distortion in terms of a dominance of the scopic, which overrides other forms of somatic engagement with VR affordances. A focus on the concept of reach as a design principle could help readdress this.

12. Augmented Reality

Augmented reality (AR) does not obscure the user's vision of the real world as VR does, but overlays digital objects and information onto that vision using smart phones, tablet devices or smart glasses. On a phone or tablet screen, digital objects – augmentations, overlie the camera's video feed, whilst on smart glasses they are projected onto the lenses. In both cases, this situates them as apparent objects in the real world, where they remain in place as the user moves 'around' them. Kirsh points out that designers create enactive landscapes by designing tools, crucially these smart devices can be considered such.[73]

The increasing accessibility of AR development software for designers means the smart phone's impact on every part of our environment is increasing exponentially.

---

[71] Gallagher, "Educating the right stuff: Lessons in Enactivist learning.", 626.
[72] *Ibid.*, 805.
[73] Kirsh, "Embodied cognition and the magical future of interaction design."

Content providers are bringing AR functionality to phone-based search engines, map-based navigation services, photo and social media applications. This development of AR as a pervasive element within our built environment proceeds at a dizzying pace. Due to the ubiquity of smart phones, users are increasingly accustomed to these tools, which simply require subject matter to be framed on screen.

The development of smart glasses brings a different aspect to AR into focus, here the augmentation is directly superimposed over the user's field of vision, mapping it to the environment from the camera, set within the frame of the glasses. Control mechanisms for interaction are often in the form of a handheld tracker-pad facilitating movement of a cursor around the augmented graphical user interface. Whether or not AR eyewear will become as ubiquitous as AR capable phones currently are remains to be seen, but as costs decrease consumer applications are likely to be developed, making AR eyewear more accessible, attractive and affordable to consumers.

Phones with only one screen and camera mean the 'phone view' constitutes a monoscopic Albertian perspective that cannot align perfectly with the optical image. The eyes see more than the screen; they also see the real-world objects beyond it in their peripheral vision, however the central gaze is dominant, reaching through the screen, which acts as a window through which is viewed the augmentation's apparent real-world location. If we analyse this experience from a situated and enactive cognition standpoint the viewer can, nevertheless be said to be thinking with and through their body and, by extension, with the device while, in an enactive way, positioning themselves relative to the augmentation. Clarke and Chalmers' "active externalism" conception becomes significant here because in psychophysiological terms the digitally generated elements constitute part of the user's environment;[74] constituted in Gallagher's words, through, "dynamical coupling and coordination across brain–body–environment"[75] and thereby part of their cognitive system. And the socially situated aspect of all of this is also significant; the digital objects also represent affordances presented to the viewer in a social context, assisting them whether in accessing information, communicating, sightseeing, shopping or merely navigating their environment.

[74] Clark and Chalmers, "The extended mind."
[75] Gallagher, "Educating the right stuff: Lessons in Enactivist learning," 627.

13. In Darwin's Garden

Figure 2: Render of In Darwin's Garden showing full augmentation to scale. Copyright © A. Summers 2020

The large-scale augmented reality artwork, *In Darwin's Garden* (2014), by Chris Meigh-Andrews in collaboration with Alan Summers,[76] (Fig. 2), explored the use of phones, tablets and glasses during its development. The artwork consisted of a large cloud of digital images, presented within a physical framework, that users could move through and around.

When the work was displayed in an indoor gallery setting, for practical reasons, the gallery audience were provided with iPad's set within specially designed plywood frames, the design of these was such that it necessitated that the viewer held the device using both hands when pointing it towards the sculptural structure (see Fig. 3).

[76] Chris Meigh-Andrews and Alan Summers, *In Darwin's Garden,* [Mixed Media], 2014.

Figure 3: CAD render of the In Darwin's Garden framework. Copyright © A. Summers 2020

It was observed that due to this alteration the audience members engaged with the sculpture and space in a markedly different way to previous participants who had used AR spectacles. It was noticeable that now their engagement was, by contrast, far more physical, taking the devices in both hands they moved around and reached up and through the sculpture, apparently pushing aside the digital foliage in a more embodied interaction within the sculpture's enactive landscape, which this tool facilitated (Fig. 4).

Figure 4: Using the viewing device with In Darwin's Garden. Copyright © Wrexham Glyndwr University 2020, with permissions

One possible explanation for this difference is that when audiences engaged with the mixed reality space using glasses they used these devices in a far more passive way.[77] We would argue that this may be due to the way glasses passively sit on the face, whereas the plywood devices, resembling a steering wheel, needed to be physically pointed and directed, necessitating a more active engagement. We would also suggest that in the case of the use of smart glasses – which employ a monoscopic camera – that the augmentation appearing directly in the field of view, meant that the intrinsic logic of the camera, with origins in Albertian/Cartesian perspectivism, affected a more passive engagement with the space. Providing the viewer with a different tool, one demanding a more embodied engagement with the environment, resulted in the production of an altered, indeed enhanced, enactive experience, altering in turn perceptions and revealing affordances hitherto unnoticed or unappreciated. The user's familiarity with the embodied action of framing camera images on their phone is arguably amplified and brought into stronger focus by holding this tablet device with both hands and reaching

[77] Alan Summers, "In Darwin's Garden: An evolutionary exploration of augmented reality in practice." In R. Earnshaw, S. Liggett, P. Excell, & D. Thalmann (Eds.), *Technology, Design and the Arts - Opportunities and Challenges*, (Springer International Publishing, 2020), 335–352.

out to frame the augmentation. This reflects Kirsh's analysis of the way tool design affects the creation of enactive landscapes and points to the consideration designers might give to the act of reaching in that context.

14. Enactive Landscapes

Kirsh suggests that through the design of tools designers construct and constitute an altered epistemic environment. His approach is in agreement with the "embedding thesis" we examined earlier. The assertion is that one of the most significant ways in which cognition "exploits structure in the natural and social environment", is through our use of tools.[78] Similar observations have been made by Heidegger.[79] Kirsh outlines his understanding of what he terms "enactive landscapes" thus:

> … an enactive landscape [is] ... the structure that an agent co-creates with the world when he or she acts in a goal-oriented manner. An enactive landscape is meant to capture the goal- or activity-dependent nature of the perceptual world. ... The idea of an enactive landscape is a useful concept for designers to bear in mind when inventing new tools or systems because when a person has a tool in [their] hands [their] enactive landscape is reshaped: people perceive more things and properties when working with a tool than they would when working unaided. In a sense, designers create new enactive landscapes by designing tools.[80]

Kirsh's observations are relevant to our discussion because they illustrate that the adoption of an enactive cognition standpoint helps us to understand the epistemic significance of tools including how they ultimately partly constitute our environment through our engagement in the use of equipment. This relates to Heidegger's concept of *Zuhandensein* or *"*'readiness-to-hand',[81] the idea, as Gallagher explains, that "things are not only available for our manipulation – we find ourselves already immersed in such

---

[78] Robbins and Aydede, *The Cambridge Handbook of Situated Cognition*.
[79] Heidegger, *Being and Time.*
[80] Kirsh, "Embodied cognition and the magical future of interaction design," 3:10-3:11.
[81] Heidegger, *Being and Time*, 95-102.

manipulations or dealings, and the possibilities of such dealings shape our perceptions and actions."[82] Kirsh too acknowledges that this has implications for the design of our new digital environments where we employ digital tools, whether in a digital or mixed environment with equal epistemological effect. As he explains:

> To an agent, the world is a constellation of intersecting, overlapping enactive landscapes, engendered by the tools in hand and the resources nearby. When a tool is picked up or let go there is a change in capability that leads to a change in the enactive landscapes that are active. ... With further development this idea may have useful application in understanding how digital interactivity will reshape our sense of what we can do.[83]

Here, Kirsh both describes a model for understanding AR engagement and identifies the challenges for the designer. Virtual tools and the body itself, when integrated within the virtual and mixed digital space, alter our psychophysiological responses and our engagement with that space, moreover in a real sense they also constitute cognition, in line with Gallagher's "body–brain–environment" cognitive model.

As we presently reach a turning point, where the technology is becoming standardised, designers now have a particularly important part to play in the future of augmented realities, in, for example, designing smartphone operating systems and in relation to the debate around standardisation for pervasive augmentation.[84] As these technologies move inexorably closer to ubiquity, timely consideration of the tools and embodied actions that shape the user's enactive landscape will support the design and development of augmented communication experiences that seamlessly integrate into the psychophysiological space of the user.

15. Mixed Reality

[82] Gallagher, "Philosophical antecedents to situated cognition," 39.
[83] Kirsh, "Embodied cognition and the magical future of interaction design," 3:27.
[84] Jens Grubert et al., "Towards Pervasive Augmented Reality: Context-Awareness in Augmented Reality." *IEEE Transactions on Visualization and Computer Graphics*, 2017, 23(6): 1706–1724.

MR, as defined on Milgram's Reality-Virtuality Continuum,[85] includes AR and a range of other varieties of mixed realities. However, for the purposes of this discussion we will consider MR in the context of the development of headsets that are marketed as 'mixed reality'. The headset's transparent visor acts as a screen displaying digital objects mapped directly onto the environment, apparently overlaid upon the visual field, while also sometimes apparently moving behind actual physical objects. These systems detect hand movements, allowing the user to reach out and interact with the digital objects; apparently throwing them about the real world, where they may appear to bounce off walls and even roll behind real-world objects.

So that in MR the digital space is visually and spatially mapped onto the user's real-world space such that user interaction also affects that blending, situating the user in both spaces simultaneously while they perceive a single, apparently unified, space. The digital space with its Cartesian logic is thereby effectively embedded within the user's psychophysiological space.

Mixed Reality produces a blended environment composed of both physical and digital affordances, which together form an altered enactive landscape where interactions with digital objects appear in the context of a blended environment. However, the affordances within the digital realm are not subject to some of the constraints (gravity for example) which naturally govern the physical-space affordances. The designer of this digital realm embedded within the real space, can choose for example to reinforce Cartesian logic or disregard it. This is a freedom that is not always embraced, and many designers hold fast to illusionistic perspectivist 'tropes'. Panofsky's lesson is pertinent here; all constructed visual presentations, digital or otherwise, fall into the category of symbolic forms and as such are subject to contestation, having no absolute claim to a categorical verisimilitude.

In an MR environment where a user is required to pick up a digital object that is apparently out of reach vis-à-vis the real environment, logic would dictate that the user walks over to the object to interact with it, or else a digital tool could be used to select the object and bring it closer to them. But if we chose to reach past the logic of Cartesian perspective, the mind and the body could direct the user to hold out their forefinger and thumb in line of sight of the object, close them to pinch the digital object, picking it up in

[85] Paul Milgram et al., "Augmented reality: A class of displays on the reality-virtuality continuum." *Telemanipulator and Telepresence Technologies*, 1995, 2351.

the process. Precisely where this object sits in Cartesian space becomes irrelevant, and the accompanying logic is replaced by another, one that sets the virtual object within the context of an altered body schema. All digital objects thereby come within reach, even if they may appear out of physical reach. In mixed reality, the designer has the opportunity to alter the expectations of the user within the altered enactive landscape which they effectively co-create, allowing the viewer to counter much of the logic that otherwise permeates their engagement with the world.

16. Conclusion

In 1965, at the outset of VR design, Sutherland made a prescient observation that anticipates an extreme somatic engagement with extended realities:

> The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining ... With appropriate programming such a display could literally be the Wonderland into which Alice walked.[86]

While we may not have reached this Wonderland quite yet, we are now stepping through the looking glass. Advances in extended realities mean a designer can consider whether this room might be a virtual room containing real world-like affordances or a real room with the addition of mixed reality affordances. Whichever they choose, there is one element that is true for both scenarios; the room will present an enactive landscape that requires the user to be its co-creator. This, of necessity, requires soma-centred design thinking that engages with embodied experience, because in this design relationship there can be no distant gaze, the designer's body will give way to the user's body, for only such design thinking and practices will help us understand how to develop these environments.

In our epigraph Merleau-Ponty remarks, "... my body is geared onto the world when my perception presents me with a spectacle as varied and as clearly articulated as possible, and when my motor intentions, as they unfold, receive the responses they

[86] Sutherland, "The Ultimate Display," 507.

expect from the world." In this, he acknowledges the need for the body to feel at home in the spaces it occupies, to have, as he terms it, a solid "perceptual *ground*, ... a general setting in which my body can co-exist with the world."[87] This requirement for a solid "perceptual *ground*" is as relevant to our dwelling within the VR environment as it is to that in the real world. Across Sutherland's threshold that requirement to feel bodily at ease will still be crucial. In the design of VR environments this can best be achieved when the designer gives due consideration to the lived body and its coexistence with these augmented environments. In that regard enactive and situated cognitive models are particularly disposed to promote the embeddedness to which Merleau-Ponty alludes. They provide a solid ground for design thinking focused on the body's relation to space. Feeling at home in these environments requires that our body schema is synchronised with that world. Moya describes this synchronisation as:

> … an engagement of body and world, in which a relation is created that serves as the basis or ground for the rest of the actions of the subject, and which permits him or her to be especially "at home," comfortable, able to move in an oriented way in a given space.[88]

As we have seen, the tools we design augment our body schema, which as Kirsh has demonstrated opens in turn new vistas in terms of enactive landscapes.[89] The emergence of these enactive landscapes has the potential to counter the dominance of vision in the design of XR environments; that legacy of the historic pre-eminence of Cartesian perspectivism. We must therefore, above all, not neglect those non-visual elements of perception. Extended realities are capable of not only enhancing reality through embodied engagement, but also of extending it through the design of different tools that create new enactive landscapes, thereby challenging cognitive models grounded in Cartesian perspectivism and dualism, and in doing so, exploring alternative ways to augment and engage with psychophysiological space.

A simple instance of this is seen in the case of the design of the apparatus that allowed the gallery audience to reach out to, and engage with, the augmentation within

---

[87] Merleau-Ponty, *Phenomenology of Perception*, 292.
[88] Patricia Moya, "Habit and embodiment in Merleau-Ponty." *Frontiers in human neuroscience*, 2014, 8: 542.
[89] Kirsh, "Embodied cognition and the magical future of interaction design."

the *In Darwin's Garden* sculpture. Here, the design of effectively a new tool amplified an already familiar embodied action, encouraging the viewer to engage with and co-curate a different experience of the environment and to thereby experience an altered enactive landscape. By this ostensibly banal step the viewer's attitude was altered from a relatively passive stance to one encompassing greater enactive engagement.

We suggest that in this simple shift of attitude we see in microcosm an alteration, a transformation even, from the detachment and stasis that we have ascribed to the Albertian/Cartesian subject, to an entirely different active stance reflecting Gallagher's dynamic enactivist; "body–brain–environment" cognitive model. With one gesture we move from contemplation to action through the simple act of picking up, reaching out, and with a new tool engaging with a space altered in turn by our action.

References

Alberti, Leon Battista. *Leon Battista Alberti: On Painting: A New Translation and Critical Edition*. Cambridge, UK: Cambridge University Press, 2013.

Berchenko, Daniel and Gilligan, Melanie. *Dan Berchenko*. Glasgow, UK: Transmission Gallery, 2008. As accessed 15th July 2020. https://www.transmissiongallery.org/docs/publications/Gillian_and_Berchenko_2008.pdf

Bourdieu, Pierre. *Pascalian Meditation.* Stanford: Stanford University Press, 2000.

Bredo, Eric. "Cognitivism, situated cognition and Deweyian pragmatism." 1994. As accessed 7th August 2020. http://methodenpool.uni-koeln.de/apprenticeship/Bredo%20-%20COGNITIVISM,%20SITUATED%20COGNITION,%20AND%20DEWEYIAN%20PRAGMATISM.htm

Brooks, Frederick P. "What's real about virtual reality?" *IEEE Computer graphics and applications* 19, no. 6 (1999): 16-27.

Chua, Hannah Faye. “From The Cover: Cultural variation in eye movements during scene perception”. *Proceedings of the National Academy of Sciences*, 2005, vol. 102: 12629–12633.

Clark, Andy and Chalmers, David. “The extended mind”. *Analysis*, 1998, 58: 10-23.

Davies, Char. *Osmose* [Digital]. 1995. See also http://www.immersence.com/osmose/ As accessed 7th August 2020.

Davies, Char. "Rethinking VR: Key Concepts and Concerns." *VSMM*. 9th International Conference on Virtual Systems and Multimedia, Montreal, 2003.

Descartes, René. *Discourse on method, optics, geometry, and meteorology*. Translated by P. J. Olscamp. Indianapolis IN: Hackett Publishing, 2001.

Fleckenstein, Kristie S. "A Matter of Perspective: Cartesian Perspectivalism and the Testing of English Studies". *JAC*, 2008, 28: 85-121.

Gal, Ofer and Chen-Morris, Raz. "Nature’s drawing: problems and resolutions in the mathematization of motion." *Synthese*, 2012, 185: 429–466. https://doi.org/10.1007/s11229-011-9978-5

Gallagher, Shaun. "Philosophical antecedents to situated cognition." In P. Robbins and M. Aydede (eds.) *Cambridge Handbook of Situated Cognition*. 35-52. Cambridge, UK: Cambridge University Press, 2009.

Gallagher, Shaun. "Educating the right stuff: Lessons in Enactivist learning." *Educational Theory*, 2018, 68(6): 625-641.

Green, Joel. "Finding the magic in VR-centric design: Backpack Inventory." *Gamasutra*. 2018, June 14. As accessed 7th August 2020. https://www.gamasutra.com/blogs/JoelGreen/20180614/319908/Finding_the_magic_in_VRcentric_design_Backpack_Inventory.php

Grubert, Jens; Langlotz, Tobias; Zollmann, Stefanie and Regenbrecht, Holger. "Towards Pervasive Augmented Reality: Context-Awareness in Augmented Reality." *IEEE Transactions on Visualization and Computer Graphics*, 2017, 23(6): 1706–1724. As accessed 7th August 2020. https://doi.org/10.1109/TVCG.2016.2543720

Harth, Erica. *Cartesian women: Versions and subversions of rational discourse in the old regime*. New York: Cornell University Press, 1992.

Harries, Karsten. "Descartes, perspective, and the angelic eye." *Yale French Studies*, 1973, (49): 28-42.

Heidegger, Martin. *Being and Time*. Oxford, UK: Blackwell, 1962.

Hendrix, Justin. "Building the ultimate display Stanford's Bernd Girod lays out a research agenda for immersive video." *Haptic.al*, Feb 27, 2017. As accessed 7th August 2020 https://haptic.al/building-the-ultimate-display-65ac5c35e983

Hung, Wai-Shun. "'No Recipe for the Visible': The Theory of Linear Perspective In Merleau-Ponty's 'Eye And Mind'". *Philosophy Today*, 2013, 57(3): 295-302.

Hurley, Susan. "Perception and action: alternative views." *Synthese*, 2001, 129(1): 3-40.

Jay, Martin. *Downcast eyes: The denigration of vision in twentieth century French thought. Berkley*. CA: University of California Press, 1994.

Johnson, Mark. *The Meaning of the Body*. Chicago IL & London UK: Chicago University Press, 2007.

Kirsh, David. "Embodied cognition and the magical future of interaction design." *ACM Transactions on Computer-Human Interaction*, 2013, 20(1): 3:1–3:30.

Masuda, Takashiko; Gonzalez, Richard; Kwan, Letty and Nisbett, Richard. E. "Culture and Aesthetic Preference: Comparing the Attention to Context of East Asians and Americans." *Personality and Social Psychology Bulletin*, 2008, vol. 34: 1260 –1275.

Merleau-Ponty, Maurice. *Phenomenology of Perception*. London: Routledge, 2002.

McGuirk, Tom and Summers, Alan. "Albertian Perspective and Augmented Reality: Lessons from Panofsky." In *Proceedings Of The 7th International Conference: Internet Technologies and Applications* (ITA), 2017.

Meigh-Andrews, Chris and Summers, Alan. *In Darwin's Garden*. [Mixed Media]. 2014.

Milgram, Paul; Takemura, Haruo; Utsumi, Akira and Kishino, Fumio. "Augmented reality: A class of displays on the reality-virtuality continuum." *Telemanipulator and Telepresence Technologies*, 1995, 2351. https://doi.org/10.1117/12.197321

Moya Patricia. "Habit and embodiment in Merleau-Ponty." *Frontiers in human neuroscience*, 2014, 8: 542. https://doi.org/10.3389/fnhum.2014.00542

Nagel, Thomas. *The view from nowhere*. Oxford, UK: Oxford University Press, 1989.

Neher, Allister. "How perspective could be a symbolic form." *The Journal of aesthetics and art criticism*, 2005, 63(4), 359-373.

Noë, Alva. Art as enaction. *2002, In the proceedings of The Art and Cognition* (virtual conference November 2002 – February 2003)*,* Euro-edu Association, http://cognitionandculture.net/wp-content/uploads/archive_1.pdf As accessed 22 November 2020.

Noë, Alva. *Action in Perception*. Cambridge, MA and London: The MIT Press, 2004.

Noë, Alva. "Experience without the head" in Tamar Gendler and John Hawthorne, eds. *Perceptual experience*. 411-433. Oxford: Oxford University Press, 2006.

Panofsky, Erwin. *Perspective as Symbolic Form*. New York, NY: Zone Books, 1991.

Robbins, Philip and Aydede, Murat. (Eds.). T*he Cambridge Handbook of Situated Cognition*. Cambridge UK; Cambridge University Press, 2008.

Schrödinger, Erwin. *What is Life?: With Mind and Matter and Autobiographical Sketches*. Cambridge UK: Cambridge University Press, 1992.

Shusterman, Richard. "Affective cognition: from pragmatism to somaesthetics." *Intellectica* 60, no. 2 (2013): 49-68.

Steiner, George. *Martin Heidegger*. Chicago IL: University of Chicago Press, 1987.

Summers, Alan. "In Darwin's Garden: An evolutionary exploration of augmented reality in practice." In R. Earnshaw, S. Liggett, P. Excell, & D. Thalmann (Eds.), *Technology, Design and the Arts - Opportunities and Challenges*. 335–352. Springer International Publishing, 2020. https://doi.org/10.1007/978-3-030-42097-0

Sutherland, Ivan. E. "The Ultimate Display." In Wayne A. Kalenich (ed.), *Information Processing 1965: Proceedings of IFIP Congress*, Vol. 1, 506-508. London: Macmillan, 1965.

Svanæs, Dag. "Interaction design for and with the lived body: Some implications of Merleau-Ponty's phenomenology." *ACM Transactions on Computer-Human Interaction*, 2013, 20(1): 8:1–8:30. https://doi.org/10.1145/2442106.2442114

Valve. *The Lab*. Valve, 2016.