Does what we dream feel present? Two varieties of presence and implications for measuring presence in VR

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Abstract

What's presented in our normal waking perceptual visual experiences feels present to us, while what we "see" in pictures and imagine does not. What about dreams? Does what we "see" in a dream feel present? Jennifer Windt has argued for an affirmative answer, for all dreams. But the dreams which flow from the brain's registration of myoclonic twitches (body-driven dreams) present a challenge to this answer. During these dreams (so I argue) motion-guiding vision is shut off, and, as Mohan Matthen has argued, motion-guiding vision seems to be a key mechanism underlying the feeling of presence. I propose that the feeling of presence in fact involves two components: the feeling of immersion, and the feeling of availability for action. I suggest that only the feeling of availability for action derives from motion-guiding vision, and, hence, hypothesize that body-driven dreams lack this component to the feeling of presence (while still having the feeling of immersion). Finally, the distinction between these two varieties of presence has implications for measures of presence in virtual environments, as these measures can diverge over which of the two varieties they track.

1 Introduction

As I look around the room, I find myself visually presented with objects arrayed in space and instancing properties (Dickie 2010; O'Callaghan 2016;

Matthen 2019). To my right appears the peach-yellow sheet rock panel of one wall, while straight in front of me appears a faux midcentury sofa wrapped in orange-tinted beige pleather. These items phenomenally seem to me to be out in the actual environment in which I'm situated. As Mohan Matthen puts it (2010, 108), what's presented in my visual experience is accompanied by a *feeling of presence*.[1]

Matthen (2005, 304–319) says that (i) experience of what we visually imagine, and (ii) experience of what's depicted in pictures, isn't accompanied by this feeling of presence. Similar claims are made by others as well (e.g. Dokic and Martin 2017, 299). For example, if I look to my right and imagine a second sofa, I may be able to conjure up a vivid visual experience of a sofa, but this imagined sofa will not phenomenally seem to me to actually be there. Similarly, if I look at a photo or realistic drawing of my sofa, I visually experience a depicted sofa, but I do not visually experience it as present in front of me.

Is what we visually experience in dreams accompanied by this feeling of presence? Some think so (e.g. Revonsuo 1995; Nanay 2016). Here I will focus on Jennifer Windt, who has argued (2010, 304) that dreaming characteristically involves a "sense of spatial and temporal presence" within the dream environment. Windt (2018, 2583) says that:

> This robust *here-and-now* experience marks a deep commonality between dreaming and the feeling of presence in ... standard wake states. It also sets dreams apart from waking imaginings and daydreams: even when we are lost in a vivid daydream and imagine experiencing events from an internal point of view ... ongoing perceptual and bodily experience prevent us from feeling fully present in these imaginary worlds. By contrast, even passive observer dreams are immersive: they involve a phenomenal *here* and are experienced from an internal first-person perspective in a more robust sense related to the phenomenology of presence.

Based on scientifically collected dream reports, Windt (2010) argues that this immersive character of dreaming is fundamental, or even definitional. Hence, *all* dreams should involve the feeling of presence.

The problem is that, according to Matthen (2005; 2010), the feeling of presence derives from motion-guiding vision, while Windt (2018) has a view

[1] As Dokic and Martin (2017) point out, this idea that perceptual experience involves a feeling of presence goes back to at least Edmund Husserl.

of sensorimotor processing during REM sleep which entails that motion-guiding vision is shut off during at least some dreams. These dreams result from cortical registration of muscle twitches caused by brainstem activity, and, hence, are (as I'll call it) *body-driven*. If the feeling of presence derives from motion-guiding vision, then objects "seen" in body-driven dreams (or the whole visual dream environment) should not feel present to us.[2] Thus, we have an apparent dilemma: either Matthen is wrong about the role of motion-guiding vision, or Windt is wrong that all dreams (including body-driven ones) involve a feeling of presence. It's worth emphasizing that this dilemma flows from the particular case of body-driven dreams. The category of dreaming is broad, including experiences had during sleep-wake transitions, NREM sleep, and REM sleep.[3] Body-driven dreams occur during REM sleep, although there's no reason to suppose that all dreams, even during REM sleep, are body-driven.

This paper starts by explaining Matthen's proposed connection between motion-guiding vision and the feeling of presence (section 2) and Windt's view of dreaming (section 3). Next, it shows how body-driven dreams lead to the above dilemma (section 4). After that, it gives a possible way to resolve the dilemma while saving the spirit of Windt's and Matthen's proposals (section 5). The key is to distinguish (a) the experience of being *immersed* within an environment one views from their spatial perspective, and (b) the experience of a presented object as being *available for bodily action*. These can come apart, as a subject can feel present within an environment filled with objects that don't phenomenally seem to be potential targets of actions like grasping. There's a difference between feeling yourself to be spatially related to the objects you seem to see, and feeling those objects to be available for action.[4] I'll call (a) 'the feeling of immersive presence', and (b) 'the feeling

[2]Here I put the word 'seen' in scare quotes to indicate that it's not successful visual perception. This use of scare quotes to talk about dreams is shorthand for more cumbersome locutions. For example, when I refer to "seeing" something in a dream, what I mean is that the phenomenal state of the dreamer is very similar to their phenomenal state when successfully using their eyes when awake. The dreamer phenomenally seems, from within their private stream of consciousness, to be seeing.

[3]Hypnagogic and hypnopompic imagery are strange cases. These are the static, picture-like imagery (or auditory sensibilia) which one sometimes seems to be "looking" at (or "hearing") during sleep onset or when waking up. Windt (2010, 304) excludes this imagery from dreaming proper because it's something one "looks" *at*, as opposed to seeming to be immersed *in*.

[4]I thank Mohan Matthen (personal communication) for suggesting this way of putting

of motor presence'.[5]

With this distinction in hand, it's a short move to point out that the dilemma is resolvable if body-driven dreams involve the feeling of immersive presence, but lack the feeling of motor presence. If so, then the apparent dilemma can be avoided by (i) taking only the feeling of *motor* presence to derive from motion-guiding vision, and (ii) limiting Windt's claim that all dreams involve a feeling of presence to the claim that all dreams involve a feeling of *immersive* presence. What Matthen misses is that the feelings of immersive and motor presence are dissociable components of the overall phenomenal character of typical waking perceptual experiences; he deploys a concept of presence which involves aspects of both immersive and motor presence. What Windt misses is that some dreams fail to reproduce the full feeling of presence found in typical waking experiences; body-driven dreams only reproduce the feeling of immersive presence.

My proposed solution to the dilemma rests on the speculative hypothesis that body-driven dreams lack the feeling of motor presence. After showing how this hypothesis resolves the dilemma (section 5), I discuss how this hypothesis might be tested (section 6). I conclude the paper with some discussion of how the distinction between the feelings of immersive and motor presence has important implications for how "presence" is measured in research on virtual reality (section 7).

This paper makes five contributions. First, it shows that Matthen's interesting and well-developed account of the feeling of presence entails that the visual scene in body-driven dreams does not feel present. Second, it distinguishes between two varieties of presence (the feelings of immersive and motor presence) and shows how this distinction allows us to save Windt's plausible claim that all dreams involve some feeling of presence. Third, it formulates the question of whether body-driven dreams lack the feeling of motor presence and discusses how it might be tested. Fourth, while the feeling of presence is often thought of as a unitary feeling or phenomenal property, this paper untangles the rich complexity of the dissociable aspects to the feeling (including the feelings of immersion, motor significance, accessibility, and reality). Fifth, this paper identifies further important implications for the measurement of the feeling of presence in virtual reality research.

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the idea, which I've here reproduced with only slight paraphrase.

[5] I will follow the standard philosophy convention of using single quotes when mentioning terms, and using double quotes for direct quotations and scare quotes.

2 The role of motion-guiding vision

Matthen starts his theory of the feeling of presence with the division of human visual processing into two distinct systems: one which categorizes distal retinal stimuli and represents them in allocentric coordinates, and another which encodes distal retinal stimuli in egocentric coordinates for the purpose of guiding bodily actions like reaching and gaze-shifting. While these two systems are often thought to be respectively localized in the ventral and dorsal visual streams (e.g. Milner and Goodale 2006), Matthen (2010, 119) sets their implementation aside to focus on them as functionally dissociable systems: 'descriptive vision' vs 'motion-guiding vision'. This functional dissociability is demonstrated by how a subject's ability to describe or recognize a visual stimulus can be impaired while their ability to grasp or shift their gaze to it is left intact, and vice versa.

Matthen suggests (2005, 304) that, in an idealized case of lacking motion-guiding vision, we wouldn't (for example) "see things as an arm's length away, [or as] hurtling towards ourselves". He says (ibid) that we would "see things as three feet away or as moving in a trajectory that will soon intersect with our own", but that this experience "would possess little ergonomic significance". This visual state would allow us to *think* about spatial relations, but not immediately or intrinsically help us physically *act* towards visual stimuli. What's missing in this case without motion-guiding vision (but isn't missing normally) is a connection, of bodily significance, to what's presented in our visual experiences. Our visual experiences wouldn't present seen distal stimuli *as present*, i.e. as in a space connected to our body.

The idea is that there are two spatial frames of reference within which we can represent stimuli: one built in a coordinate system in which our body has no special significance (e.g., a 3D Cartesian grid centered on an arbitrary point a few meters in front of us), and another in which locations are specified in terms of something like the body movements required to reach them. In the normal case, our visual experience is built on underlying representations placing retinal stimuli in both sorts of reference frames, with computations that automatically and seamlessly translate between them. But if we lacked motion-guiding vision, the computations underlying our visual experience would lack the movement-based spatial representations, thereby stripping the content of these visual experiences of any immediate bodily or motor significance. We could, of course, deduce (using post-perceptual reasoning) various implications of what's presented in visual experience (e.g., that we

needed to duck, or that we could reach a nearby object with such-and-such arm motions), but these would involve an effortful translation of one spatial reference frame into another. Visual experience itself would not encode any inherent connection or translation between the two spatial frames of reference, and because of that lack of inherent connection to motor-relevant representations, what's presented in the experience would not feel present to us.[6]

According to Matthen (2005, 305), the sense of presence (deriving from movement-based representations in motion-guiding vision) is its own phenomenological feel (i.e., is a component of the overall phenomenal character of our visual experience) and serves as an assertion operator over a visual state, signaling that what's represented by the state is the environment itself. That is, it signals that what's represented by the state is available for action. He suggests that motion-guiding vision is only active when using the eyes to look, or at least only active when our visual and motor systems take themselves to be coordinating for the purpose of using the eyes to gather information. He says (ibid, 306) that "Visual states produced by *looking* have an implied assertion operator—they convey to us an act of sensory classification performed by the visual system on an object that is present." The upshot is that the feeling of presence arises only when motion-guiding vision, activated by a subject's looking, represents (or purports to represent) a distal visual stimulus in a way that gives it immediate significance for action.

To support this account, Matthen appeals (2005, 306–19) to seeing what's depicted in pictures. He makes two claims: (1) that while pictures themselves engage motion-guiding vision, what's depicted in them does not; and (2) while pictures themselves feel present, what's depicted in them does not.[7] Importantly, what's depicted in a picture still engages descriptive vision.

[6]This is an explanation, not a conceptual or logical deduction. It, of course, does not necessarily follow from the mere lack of motor integration that visual representations would generate experiences without the feeling of presence. Perhaps there might have been other physical mechanisms or metaphysical bases for the feeling of presence. Matthen's proposal is that, in fact (in normal humans), this integration of motor-relevant representations is the actual mechanism or basis behind the feeling of presence. His argument, as I lay out below, is that (again, as a matter of empirical fact), when you disconnect visual experience from these motor-relevant representations, you lose the feeling of presence.

[7]I assume the distinction between a picture (e.g., a physical canvas with marks, or an illuminated screen with some pattern of pixels) and what it depicts (e.g., a house, person, rock, etc) is familiar to the reader. Matthen (2005, 306–7) cites Wollheim (1973) and Lopes (1996) as his sources for the distinction.

Matthen, thus, takes seeing-in-pictures as a case in which descriptive and motion-guiding vision are dissociated, and the result is a lack of the feeling of presence.

To support (1), Matthen (2005, 310) points to how visual illusions like the Titchener circles (the Ebbinghaus illusion) affect subjects' descriptions of stimuli without affecting their ability to make the proper grasping motions for those stimuli.[8] Hence motion-guiding vision only engages the actual marks on the paper or screen, not the illusory objects they cue. Matthen further points out (ibid, 315) that it's even difficult to pretend convincingly to handle what's depicted in a picture.

To support (2), Matthen (2005, 316–17) points out that the depicted space in a picture seems to lack a "here". Further, as you approach a picture, what's depicted in it doesn't appear to get any closer to you. Thus, depicted objects presented in visual experience, as well as the whole depicted scene, fail to be presented in a way which affords any translation of the depicted space into the egocentric space defined by our body movements. When viewing a picture, one has no idea how to get to the depicted space, or what movements are required to handle objects in the depicted space. At best one could engage in pretense, pantomiming the movements needed to engage what's depicted, or one could try to use cues in the picture to deduce (post-perceptually) the needed movements.

3 Embodied dreams

Windt (2018) starts with the observation, often neglected by philosophers, that dreams can incorporate sensory stimuli. Dreaming is often thought of as an "envatted" state in which brainstem blockades of sensory input and motor output cut the cortex and other higher brain areas off from the body and the outside world (e.g. Hobson 2009, 809). But everyday cases gainsay this simple picture: e.g., an alarm's sound not only can wake you, but can be

[8]The classic experimental result here is from Aglioti et al. (1995). There have been subsequent experiments which seem to show that grasping motions can be affected by the Ebbinghaus illusion, although current research suggests a complicated explanation that still is supportive of Matthen's overall point (e.g., see Katsumata 2019; Smeets et al. 2020). Since my purpose is not to defend Matthen's theory of the feeling of presence, but examine its compatibility with Windt's claim that dreams involve the feeling of presence, a rigorous examination of Matthen's argument is outside the scope of this paper.

incorporated into a dream in the moments before waking. Similarly, it's plausible that dreams of flying or falling can be explained by the incorporation of vestibular feedback.[9] Windt points out (2018, 2588) that psychologists have studied stimulus incorporation in dreams, showing that, in the lab, visual, auditory, and tactile stimuli can all be incorporated and are so at varying rates. For instance, a blood-pressure cuff on a leg is incorporated 40-80% of the time, resulting in (for example) "dreams of wearing strange shoes, having trouble walking, or even experiencing pain" (ibid).

These examples so far all involve the incorporation of exafferent (i.e., externally generated) feedback, but reafferent (i.e., internally generated) proprioceptive feedback can be incorporated as well. For example, the feeling of being stuck or unable to move during a dream might be explained by sleep paralysis, i.e. the muscle atonia induced by the brainstem's motor blockade. During REM sleep, typical adult (and infant) humans (as well as other mammals) generate what are known as myoclonic twitches: quick, sharp leg kicks or arm jerks generated by firing in the brainstem.[10] These twitches prompt proprioceptive feedback registering the movement, and that actual movement seems to be sometimes incorporated into dreams as experience of associated dreamed body movements, like running or kicking. At the neural level, work in rats (Tiriac et al. 2014; Dooley and Blumberg 2018) shows that twitches prompt cortical activation (motor cortex), showing that their reafferents make it through the brainstem's sensory blockade, although the exact response patterns of motor cortex neurons to twitches changes over the course of infant development.

In addition to stimulus incorporation, dreamed actions can leak into the waking world, resulting in (for example) sleep walking and sleep talking (Windt 2018, 2589). Windt notes that stimulation incorporation and action

[9]Thanks to the Einsteinian equivalence of gravitational force with acceleration in a gravity-free frame of reference, vestibular feedback while sleeping supine is the same as the vestibular feedback you would receive, were you upright and accelerating forward (Windt 2018, 2610). So the vestibular feedback received while asleep is ambiguous between those two states, and dreams of flying, at least, might be explained by the brain misinterpreting these signals as indicating that your head is upright and moving forward. Coupled with the lack of proprioceptive feedback indicating walking, it's not hard to see how representations of flying could result. Windt suggests (ibid) that sleep-onset out-of-body experiences may likewise result from the combination of prior knowledge that one is lying in bed and misinterpreted vestibular feedback (see also Wong 2017, 322-23).

[10]If you haven't observed another person or infant sleeping lately, you may have at one point watched a dog or cat sleep and observed how their legs forcefully twitch or "kick".

leakage aren't always haphazard; sometimes "dream movement is modulated by and perhaps even responsive to incoming sensory signals" (ibid, 2595). This comes out in REM sleep behavior disorder (RBD), in which subjects sometimes seem to act out complicated motions from their dreams, often even handling actual objects as props of sorts. Even normal dreams can involve this sort of coupling, for example as when the drooping head of someone falling asleep seated causes the dreamed body to droop, and the dreamed body's head raise in turn causes the actual head to rise (ibid, 2612). Because of this coupling and the aforementioned incorporation of exafferent tactile and reafferent proprioceptive feedback, Wind suggests that much of our bodily experience in dreams is actual *perceptual* (albeit illusory) experience of the sleeping body.[11]

It's worth saying a bit more about RDB, as some of the issues it introduces will be important later. RBD is a complex sleep disorder, often (but not always) related to Parkinson's disease or other neurological motor degeneration. Its exact neural pathology isn't yet well understood, but its behavioral manifestations are clear enough. In RBD, most behaviors are simple, if exaggerated, myoclonic twitches. Around 13-31% are more complex movements, seeming to evince the execution of motor programs, and around 1.8% are interactive, potentially object-directed movements, which could be interpreted as acting out a dream (Blumberg and Plumeau 2016, 35). The common understanding of RBD holds that it's *primarily* an unmasking of the activity in the motor cortex generating dreamed body movement. But as Blumberg and Plumeau (2016) argue, there's good evidence that most

[11]Here I'm using the term 'perceptual' as philosophers often do (e.g. Chisholm 1957, 162), to indicate that the experience is not hallucinatory. On this usage, in a *perceptual* experience the object of the experience is some actual distal stimulus with which you are engaging through your sensory systems, while in *hallucinatory* experiences the object of the experience is merely intentional, i.e. it isn't anything presently out in the world with which you're interacting through your sensory systems. Illusory experiences, under this classification, are perceptual experiences that are in some way inaccurate, nonveridical, or distorted (see Macpherson 2013). While there are, of course, ways of defining hallucinations that exclude dreams (e.g., by defining them as clinical cases involving neurocognitive disfunction), the standard view of dreams takes all experience during dreams to be hallucinatory in the sense just outlined, including any dream experiences of a body. That is, the standard view has it that the body you experience while dreaming isn't your actual sleeping body (with which you're interacting through your proprioceptive and tactile systems), but instead is some merely intentional, hallucinated body. This is what Windt is denying when she claims that bodily experience in dreams is perceptual.

behavior in RBD is driven by activity in the brainstem, and that dreamed bodily movement (in RBD) results from cortical registration of proprioceptive reafference from these brainstem-generated movements.[12] But Blumberg and Plumeau admit that, even if this view of RBD holds in general, the most sophisticated and interactive movements seen in RBD are likely generated by motor cortex activity "leaking" through the brainstem's blockade.

Connecting back to the feeling of presence, Windt suggests (2018, 2596) that "some degree of functional embodiment might facilitate or even enhance the sense of presence [in dreams] ... autosensory imagery may be closely associated with the immersive structure of dreaming". The idea is that the visual scene in a dream *feels present* because it seems to go along with actual (illusory) experience of the subject's body—at least, it goes along with bodily experiences that are coupled to actual feedback from the sleeping body. Specifically, Windt suggests (ibid, 2615) that "vestibular orienting is a driving factor underlying dream imagery generation", and (ibid, 2614) rapid eye movements during sleep play some role in generating dream visual imagery.[13] If vestibular feedback leads to dream experience of turning my body, or eye movements lead to dream experience of gaze shifts, and this bodily feedback likewise leads to the appropriate change of the visual dream scene, then it makes sense that I would have the experience of being present within the scene. Supposing that the visual dream scene is reactive to bodily feedback in the right ways, we would plausibly expect that objects visually presented in that scene would feel present to us. Windt argues (2010) that this is just what we find in scientifically collected dream reports, which indicate that despite wide variation along a number of dimensions, subjects consistently report their dreams as being immersive.

[12]The contrast here is between dreams generating or causing RBD behavior ("acting out dreams"), vs RBD behavior causing the dreams ("dreaming our actions") (Blumberg and Plumeau 2016, 35).

[13]Windt's idea that the feeling of presence depends on correspondence between exteroceptive sensory experience and proprioceptive experience is also found in, and supported by, the literature on inducing the feeling of presence in virtual reality environments (see Sanchez-Vives and Slater 2005; Slater 2009). Windt's specific suggestion that vestibular orienting plays a role in the sense of presence is echoed by Hong Yu Wong. Wong (2017, 320–26) argues that the vestibular system plays a key role in establishing self-location and a sense of being embedded in the world. Specifically, his point (ibid, 320) that vestibular reference frames anchor the reference frames of other sensory systems to fix a referent of "here" is at least within the spirit of Windt's claim that correlation with vestibular feedback is what makes the scene represented by vision feel present.

It's worth contrasting Windt's explanation for the feeling of presence with Matthen's explanation. According to Windt, what you "see" in dreams feels present because it accompanies proprioception: you are aware of your own movement, and how things visually appear to you covaries with that movement in expected ways. For example, it feels as if I'm actually in the visual dream scene because, when I shift my gaze, the corresponding part of the scene comes into "view". In contrast to this body-centered approach, Matthen takes an object-centered approach. He would say that it feels as if I'm actually in the visual dream scene because the objects in that scene are presented in a way that feels relevant for action. For example, it feels as if a dreamed object is present because that object looks as if I could grasp it by reaching out with the right arm and hand trajectory.[14]

Because dreams are often dominated by visual imagery, and because bodily experience in dreams is rarely discussed in the philosophical literature, it's worth saying a bit more. While there is much intrapersonal and interpersonal variation in dream content and phenomenology, dreams do sometimes involve the experience of a body, or even of being embodied. Common folk examples, as mentioned, include dreaming of flying or feeling as if one is stuck or can't move in their dream. Dreams of finding oneself naked (another common folk trope) also seem to involve some sort of awareness of one's body. This could include visual experience of a dreamed body, tactile experience of physical contact, proprioceptive experiences of limb position and movement, or whole-body sensations related to exertion or atonia (muscle paralysis). Windt (2018) suggests that, generally, these bodily experiences during dreams are limited, gappy or fragmentary, indeterminate, and distorted. They do not replicate the full, rich suite of bodily experience enjoyed normally during typical moments of waking life. So, Windt's claim is that it's these limited bodily experiences during dreams which are (at least sometimes) genuine perceptual (but illusory) experiences of the actual sleeping body. (Given the limited bodily feedback processed during dreams, and its unusual processing (more on this below), it's not surprising that the experience of one's body enjoyed during a dream is limited, gappy or fragmentary, indeterminate, and distorted.) It's the coupling to these limited bodily experiences which makes the visual dream scene feel present.

[14]Thanks to Mohan Matthen for helping me to sharpen the contrast between Windt's and his proposals, including suggesting some of the wording used here.

4 The problem: body-driven dreams

While Windt says the visual dream scene feels present because it depends on actual interoceptive feedback from the sleeping body, Matthen instead claims that visually experienced objects feel present in normal wakeful perception because of how motion-guiding vision tracks those objects for guiding gaze-shifts, grasping, and other bodily actions.[15] That these are different accounts should be clear, but it's not immediately obvious that they could not be synthesized, nor is any acute problem manifest. The problem arises when we consider Windt's overall view of the *function* of sensorimotor processing during REM sleep and how she views that processing as leading to a certain kind of dream. Windt summarizes the function of sensorimotor processing during REM sleep, by contrasting it with sensorimotor processing when awake, as follows (italics added):

> Wakefulness, ... *is dedicated to orienting and localizing the (bodily) self in the world*, and what we experience as our body is modulated to a considerable degree by externally generated sensory and especially visual input. By contrast, dreams involve the generation of spatiotemporal and often visual imagery in response to internally generated vestibular sensations and altered own-body perception. ... *while wakefulness is about locating oneself in the world and interacting with persons and objects in it, dreaming is about creating a world centered on the bodily self.* (Windt 2018, 2616)

The above description mixes dreaming with sensorimotor processing, but it still captures the essential idea. It will take some work to unpack this idea, but the key upshot will be that it suggests that motion-guiding vision isn't operating during REM sleep. Hence, if Matthen is correct, the dreams that flow from this sensorimotor processing (body-driven dreams) should lack the feeling of presence.

[15] Windt's and Matthen's explanation for why visual imagination lacks the feeling of presence differ as well. Matthen would attribute this to the disengagement of motion-guiding vision from the imagined scene. Windt (2018, 2583) says that "ongoing perceptual and bodily experience prevent us from feeling fully present in these imaginary worlds", although clearly it's also open for her to say that imagined scenes fail to feel present because they don't depend on interoceptive feedback from the body (e.g., from the eyes). This latter explanation still would not match Matthen's.

To start, Windt (2018, 2602–4) grounds the claim of differing functions in research, from Mark Blumberg and his collaborators, suggesting that efferent (i.e., motor) activity and its proprioceptive reafferent uptake are not aberrations during REM sleep, but functional (Blumberg 2010, 2015; Blumberg et al. 2013; Tiriac et al. 2014; Blumberg and Plumeau 2016; Dooley and Blumberg 2018).[16] Blumberg and his collaborators focus on myoclonic twitches. Given how proprioceptive reafferent feedback from these twitches causes cortical responses, and given how that response profile develops over the first two weeks of life in neonatal rats (Tiriac et al. 2014; Dooley and Blumberg 2018), Blumberg and his collaborators hypothesize that these twitches play a role in the development, maintenance, and updating of the brain's many motor and somatosensory maps (see Blumberg 2015; Blumberg and Plumeau 2016). The brain needs to find out (during development) and check and update (during adulthood and growth, or post injury) the effects of each population of motoneurons. During REM sleep, overall muscle atonia provides the brain the needed opportunity, allowing it to fire these populations, yielding twitches which result in isolated high-fidelity proprioceptive feedback. This feedback thus allows the brain to "observe" the effects of each motoneuron population, without the noise of reafferent signals from other populations or exafferent input from external stimuli. As Blumberg summaries, "twitches can be considered a form of motor exploration by which animals probe the structural features of their limbs and build motor synergies, thereby laying a foundation for goal-directed wake movements" (2015, 34).

Windt calls this motor exploration *bodily self-sampling*. She construes this self-sampling within a predictive-processing framework (see Windt 2018, 2597).[17] The suggestion is that the brain predicts body movement based on the twitch-generating efferent motor commands and updates its somatosensory and motor maps based on any mismatch between actual and predicted

[16]The standard theory of this efferent activity (resulting in twitches) is that it results from the nonfunctional "leakage" of cortical motor commands through the brainstem's motor blockade (Blumberg 2015, 32–33).

[17]Windt is not the first to attempt to explain dreaming with a predictive-processing framework (e.g., see Clark 2012; Hobson et al. 2014; Hobson and Friston 2014). But other attempts (e.g. Clark 2012) explain dreaming as the result of the brain's prediction mechanisms running offline, without the constraints of sensory input. Windt explains dreaming as resulting from those mechanisms attempting to predict the consequences of bodily self-sampling.

proprioceptive feedback. According to this speculative proposal, the brain's attempt to predict body movement results in bodily experiences while asleep: dreamed body movement is simply the represented predicted movement (see also Blumberg and Plumeau 2016, 40). In these cases, *visual* dream experience of an external scene is driven by attempts to simulate what the environment would be like, were the body moving as predicted. For instance, if the brain predicts that a kick will result from a given efferent signal, visual imagery of one's leg kicking a ball might be generated. Thus, one would have a dream in which they "saw" themselves kick a ball.

What I've referred to above as 'body-driven dreams' are these dreams which result from the brain's attempt to predict twitching movements and the brain's further simulation of an external environment in which to situate those movements. Body-driven dreams are a proper subset of the broader phenomena of embodied dreams. For example, dreams at sleep onset can be embodied (i.e. can incorporate exafferent feedback like tactile pressure or an external sound and reafferent feedback like the proprioceptive signal of a head droop), but since the unique sensorimotor processing of twitching is absent, they are not body-driven. So, Windt's claim is not that all dreams are body-driven (or even embodied); it's just that at least some dreams are. It's plausible that dreams can be messy, mixing various degrees of embodiment, or full-blown body-driven nature, with purely "envatted" or internally driven experience, but I'll set this complication aside.

Both Windt and Blumberg emphasize circuit-level differences in motor processing between REM sleep and normal wakefulness. While awake, voluntary action is initiated by cortical circuits originating in the primary motor cortex (Scott 2003; Kleim 2009; Feher 2012). Both because the brain needs a way to keep track of self-generated and external motion, and because proprioceptive feedback is too slow to facilitate online motor correction, copies of motor commands (efference copies) are used by the brain to construct forward models (Miall and Wolpert 1996; Tuthill and Azim 2018). These are models representing the state of the body the brain predicts will result from those motor commands, or models representing the reafferent feedback the brain predicts will result. It's thought that the neural implementation of these models serves to cancel out reafferent feedback, i.e. the feedback caused by self-motion, allowing the brain to isolate sensory signals due to external stimuli. During REM sleep this processing, Windt and Blumberg suggest, is fundamentally altered: motor commands originate in the brainstem (Blumberg and Plumeau 2016, 36), and without efference copies to

inhibit reafferent feedback, the resulting proprioceptive feedback is allowed to propagate through the cerebral cortex and cerebellum (Tiriac et al. 2014; Sokoloff et al. 2015; Tiriac and Blumberg 2016).[18] As Windt (2018, 2603–4) describes and interprets it, "in REM sleep, twitching is processed not as self-generated movement, but activates the sensory cortex as if it were unexpected and had been other-produced" (see also Blumberg 2015, 35; Blumberg and Plumeau 2016, 38).

The developmental role of twitching and these circuit-level differences lead to Windt's proposal (2018, 2616), quoted above, about body-driven dreams: "while wakefulness is about locating oneself in the world and interacting with persons and objects in it, dreaming is about creating a world centered on the bodily self." Instead of suppressing reafferent (self-generated) input and tracking body position (via efference copies and exafferent visual input) in order to facilitate engagement with the external environment, during REM sleep the brain tracks body position, by listening for reafferent input, in order to learn the effects of its motoneuron populations.[19]

[18]The actual processing is more complicated than this brief summary suggests. Efference copies are not entirely absent from twitches. Evidence for them being sent to the cerebellum has been found (Mukherjee et al. 2018), suggesting that post-twitch cerebellar activity (e.g. Sokoloff et al. 2015) may actually be instantiating a forward model of twitching. This dampens talk of fundamental wake-sleep motor-processing differences, although, at least in neonatal rats, wake vs sleep reafference leads to drastically different responses in primary motor cortex (Tiriac et al. 2014). The presence of efference copies for twitches and possible twitch-related forward models in the cerebellum is helpful for Windt's predictive-processing interpretation of this work, which requires these copies and models.

[19]Much of this picture and its supporting evidence is highly speculative. For example, the work Blumberg (Blumberg 2015; Blumberg and Plumeau 2016) and Windt (2018) cite in support of the claim that reafferent proprioceptive input is processed differently during REM sleep than it is while awake is work done in rats that are 8–11 days old (see Tiriac et al. 2014; Sokoloff et al. 2015), and the differences largely disappear by day 12 (see Dooley and Blumberg 2018). Evidence that twitching originates in the brainstem largely comes from work in cats. The only evidence for processing differences in adult humans is indirect: in Parkinson's patients who suffer from RBD, the tremors of waking movements are absent during RBD movements, suggesting motor processing differences (Blumberg 2015, 33). Referring specifically to the REM sleep of adult humans, Blumberg himself (2015, 35) says, "None of these ideas has been tested; indeed, it is not yet known whether twitches trigger brain activity in adults as they do in infants." My aim here is not to critique the Windt-Blumberg proposal, but to discuss whether it's consistent to accept that proposal, while also accepting Windt's claim that the visual dream scene feels present and accepting Matthen's account of the feeling of presence.

This brings us to the problem. Given the functional difference just articulated, there's no reason to suppose that motion-guiding vision, as a distinct sensorimotor processing system, is up and running during REM sleep. Presumably, motion-guiding vision is engaged during normal wakefulness precisely because sensorimotor processing is functioning to facilitate engagement with the external environment. This engagement requires representing external objects in a coordinate system suitable for motor control, which is what motion-guiding vision provides. If, while asleep, sensorimotor processing is functioning to refine motor maps, then there's no reason to think that the visual system is tracking objects, or running as if it's tracking objects, for the sake of facilitating movements (like gaze-shifts or grasping) towards those objects. Instead, according to Windt's proposal, visual representations are built on the basis of body representations, as a way of filling out an environment around the body. This seems to place visual functioning, during body-driven dreams, more along the lines of *visual imagination*. Visual cortical machinery is not functionally geared towards processing retinal exafferent input, but instead is put to use imagining an environment. Since this kind of visual imagination doesn't engage motion-guiding vision while awake, that's further reason to suppose it doesn't engage motion-guiding vision during body-driven dreams.

There are two potential objections to this argument. First, it might be objected that the *function* of sensorimotor processing during body-driven dreams is a red herring; what the neural machinery of sensorimotor processing is "supposed" to be doing tells us nothing about what motion-guiding vision is actually doing. Second, it might be objected that Windt is just wrong when she proposes that vision shifts to an imagination-like processing role during REM sleep; despite the shift in *motor* functioning, perhaps the visual system continues to hum along just as it did while awake, effectively *mis*functioning. For example, motion-guiding vision can presumably run mistakenly while hallucinating, affording motion-guidance with respect to hallucinated objects, so why can't it likewise mistakenly run when dreaming?[20]

[20]Given the character of some real-life clinical hallucination cases, such as in Charles Bonnet syndrome (ffytche 2013), it seems unlikely that motion-guiding vision is still running in these cases. Still, if we consider more radical hallucination cases, such as in traditional philosophical thought experiments in which sensory stimuli are removed while proximal receptor stimulation is maintained, it seems that motion-guiding vision will continue to run as normal.

The first objection misunderstands Matthen's theory. For the purpose of explaining the feeling of presence, Matthen conceives of motion-guiding vision in functional terms. He's clear that the actual physical implementation of this system (e.g., whether it runs through the dorsal stream) does not matter (see Matthen 2010, 119). So, what sensorimotor processing is doing, in terms of functional goal, really does matter (for the purpose of explaining the feeling of presence). Perhaps the neural machinery implementing motion-guiding vision when awake still runs during body-driven dreams. This is not enough, on Matthen's account, to allow for the feeling of presence in body-driven dreams, since his claim is that the feeling of presence arises from what this machinery functions to do while awake: track distal objects for the sake of guiding body movements. It's not enough for the neural machinery of motion-guiding vision to still run during body-driven dreams, but for a different purpose (e.g., for assisting in the imagining of a dream environment). After all, this machinery can presumably function during, and contribute to, normal wakeful visual imagination.[21] For example, when I visualize an object, I do (or can do) so from my spatial perspective, thereby using rich egocentric representations. While motion-guiding vision (or, rather, the dorsal-stream activity implementing it) is not the *only* source of egocentric visual representations (more on this below), there is good reason to think that it contributes to central aspects of egocentric spatial experience (see Wu 2014). Hence, the neural machinery of motion-guiding vision plausibly plays some role in normal wakeful visual imagination, but visually imagined objects do not feel present (and, thus, function really does matter).

So, only the second objection gets off the ground. There isn't definitive evidence one way or the other about whether motion-guiding vision remains functioning during body-driven dreams, "tracking" objects in the visual dream scene for the purpose of guiding movement. Still, it's difficult to see how it would work, given the overall sensorimotor functioning proposed by Windt and Blumberg. The whole point is that, during body-driven dreams, *movement isn't guided by the dreamed environment*. The goal while dreaming isn't for the visual system to guide (say) hand or eye movement with respect to whatever "seen" objects are represented by the system. Bodily movement in the dream is its own end. It's bodily self-sampling done for

[21] It's a widespread view in cognitive science and neuroscience that imagination and other offline forms of representation (e.g., episodic memory) are facilitated by the reactivation of representations in the neural circuits responsible for online sensory perception (Hesslow 2012; Horikawa and Kamitani 2017; Bone et al. 2020).

the sake of learning the effects of motoneuron populations.

Perhaps more revealing are the circuit-level differences. If motion-guiding vision was indeed online and functioning to guide bodily movements, then we would expect to find visual input affecting motor control circuits and playing some role in efferent output. But this is not what's observed; instead, motor output during REM sleep is a kind of "motor babbling" (Windt 2018, 2603) initiated by the brainstem. Again, what the neural machinery behind motion-guiding vision is functioning to do in any particular case cannot be discerned from the inherent operation of that machinery. It's not enough that this neural machinery "supplies" potentially motion-guiding representations of the visual scene; if the end user of these representations (the motor system) isn't "listening", then that visual neural machinery isn't functioning to guide movement (Millikan 2004).[22]

Because it plays a central role in Matthen's explanation, it's worth discussing the specific action of *looking*. It's true that one can, while dreaming, "scan" the visual scene, and that this dream action is (perhaps) coupled to actual (rapid) eye movements (Windt 2018, 2614). We can assume this is specifically possible during body-driven dreams. It might be suggested that this is evidence that motion-guiding vision operates, during body-driven dreams, in the way Matthen says underlies the feeling of presence.

As an initial point, Matthen's proposal is only that looking is a *necessary* condition on the feeling of presence. He claims that the feeling of presence arises only when the action of looking feeds information into motion-guiding vision; the claim is not that the action of looking itself explains, or suffices for, the feeling of presence (that would fall more along the lines of Windt's explanation for the feeling of presence).

The appeal to dream "scanning" might be bolstered by pointing out that looking itself is an action which requires motion-guiding vision. For example, in order for the motor system to activate the right gaze shifts for scanning the visual scene, it needs egocentric visual representations from motion-guiding visual processing. So, an ability to "scan" the visual scene would be evidence that motion-guiding vision operates while dreaming. The idea here is that REMs are a physical manifestation of the dreamed action of scanning, or looking. In the dream one looks, or scans the visual scene, and this look-

[22]Compare this case with a hypothetical case of wakeful hallucination. If I hallucinate an object and motion-guiding vision is still engaged, presumably my motor system is still taking those visual representations as input. For example, a hallucinated spider still primes me to recoil away, evincing that visual output still had an affect on motor processing.

ing or scanning manifests in actual eye movements (REMs). Blumberg and Plumeau (2016, 37) call this idea the 'scanning hypothesis'. If the scanning hypothesis is correct, it would seem that visual representations (those underlying the visual dream scene) guide a certain class of movements: those REMs manifesting the dreamed actions of looking or scanning.

The problem with this approach is that there's evidence against the scanning hypothesis. As Blumberg and Plumeau (2016, 37) note, "congenitally blind humans have REMs without visual dream imagery" and "cats with lesions of the visual cortex continue to exhibit REMs". Blumberg and Plumeau instead suggest that REMs are just another form of myoclonic twitches generated in the brainstem. They cite two other pieces of evidence for this claim. First they note that:

> To explore this issue, recordings were made directly from the extraocular muscles of infant rats (Seelke et al. 2005). At postnatal day (P) 3, because the eye cannot yet move independently within its socket, eye movements were not detected. Nonetheless, spikes were clearly evident in the extraocular electromyogram (EMG) that were indistinguishable from twitch-related spikes recorded from the nuchal muscle. By P15, the age of eye opening, identical EMG spikes occurred, but they were now followed by clear REMs. Thus, extraocular muscle twitches precede REMs in development, and REMs—when they emerge—are homologous with other limb twitches. (Blumberg and Plumeau 2016, 37)

Second, they note (ibid, 38) that work in adult humans shows that "wake-related saccades were immediately preceded by a so-called readiness potential", but "In contrast, no such potential was observed immediately preceding REMs, suggesting that REMs are not generated in response to activity in visual cortex." In addition, wakeful saccades and REMs elicit responses in *different* locations of parieto-occipital cortex (ibid).

So, it does not seem that REMs are evidence of vision-guided motor commands. Instead, REMs are a form of "motor babbling". Even if REMs are somehow coupled to visual imagery in body-driven dreams, the connection isn't the right sort to suggest the engagement of motion-guiding vision. Plausibly, in a body-driven dream you don't shift your gaze to get a better look at a visually presented item. Instead, you get a better "look" because your gaze happened to shift. Gaze shifts, during body-driven dreams, are not guided

by visual input and are not done for the purpose of situating the body within an external environment.

Finally, notice also that gaze shifts alone aren't enough to indicate that motion-guiding vision is involved in a way that supports a sense of presence. After all, picture-viewing involves gaze shifts to bring different parts of the depicted scene into view (especially when the picture extends into peripheral vision), but without any sense of presence. Similarly, as I imagine a sofa against my empty wall I can literally shift my gaze around the space it would occupy, bringing into "view" different parts of the imagined sofa, without the sofa feeling present.

I conclude that if Windt and Blumberg are right, then body-driven dreams flow from a type of sensorimotor processing (bodily self-sampling, as Windt calls it) which precludes the operation of motion-guiding vision. Since Matthen proposes that visually presented objects feel present because they are tracked by motion-guiding vision, his account implies that the visual scene in body-driven dreams does not feel present, pace Windt's claim that all dreams involve the feeling of presence.

It's important to note that the above discussion does *not* show that Matthen's proposal implies body-driven dreams (should) lack a perspective. Recall picture viewing and visual imagination. Both involve (or can involve) visual experience of an object *from some perspective*, even though motion-guiding vision is disengaged. Matthen does not claim that motion-guiding vision is necessary for, or fully explains, the perspectival character of our visual experience. So, the absence of motion-guiding visual processing during body-driven dreams does not entail (on Matthen's proposal) that dreamed objects are not "seen" from a perspective. Given that there is also egocentric representation in (what Matthen calls) descriptive visual processing, his proposal also doesn't entail that visual dream experience is purely allocentric. For example, ventral-stream, or descriptive, visual processing presumably involves, at some point, something like Marr's (1980) 2½-D sketch, which carries with it an encoding of the distance and angle of stimuli from the body. Thus, this representation is egocentric (not allocentric), but the spatial coordinates employed are not the movement-based ones computed by motion-guiding vision. Motion-guiding vision would encode a stimulus as (for example) a shoulder rotation of n° up, m° forward and arm extension of l° away, while the 2½-D sketch encodes the same stimulus as (say) a meters

out, $b°$ right, and $c°$ up from the body.[23] There's no reason to deny that the perspectival, and even egocentric, representations of *descriptive* vision are activated during body-driven dreams, and, thus, no reason (on Matthen's view) to deny that the visual experience during these dreams is perspectival, or even egocentric. This point hints at a way of resolving the tension between Matthen and Windt, which I will now explore in the next section.

5 Two varieties of presence

The previous section ends on a true dilemma because all three components are plausible: (i) the feeling of presence depends on motion-guiding vision, (ii) in body-driven dreams motion-guiding vision is offline, but (iii) these dreams nonetheless still involve the feeling of presence. A tempting resolution is to posit that different varieties of presence are involved. Motion-guiding vision affords one variety of presence, while dreams characteristically involve another variety. In this section I suggest we can resolve the dilemma by distinguishing between two varieties of presence: *immersive* presence and *motor* presence.

Windt (2010) argues, on the basis of dream reports, that all dreams involve the feeling of presence. Although dream reports can vary in many ways (e.g., describing experience in any combination of sensory modalities, or being bizarre or mundane), they all seem to involve "a hallucinatory scene that is organized around an internal, spatiotemporal first-person perspective ... as well as a sense of spatiotemporal self-location, i.e., the sense of occupying a space (...), plus an experienced 'now' and the experience of duration" (2010, 304). This first-person perspective is a "purely geometrical feature of an egocentric model of reality" (ibid, fn 12). She further explains that "the phenomenology is that of being *in* the dream, rather than of looking *at* a visual pattern" (ibid, 304). Dreams involve "the sense of immersion or of (unstable) location in a spatiotemporal frame of reference" (ibid, 306–7). Thus, Windt describes one particular kind of presence: *presence within a space*. This felt sense of presence within a space is what I'm calling 'the feeling of immersive presence'.[24]

[23] Actually, all sensory processing is presumably unit-free, or at least not in our units of degrees and meters.

[24] Windt's claim that *all* dreams involve (what I would call) the feeling of immersive presence is influenced by Antti Revonsuo's (1995) work on consciousness. Revonsuo high-

Matthen's own discussion of the feeling of presence provides a helpful case in which the feeling of immersive presence is absent: viewing the visual scene depicted in a picture. As Matthen (2005, 315) points out, when you look at a picture, the *depicted* space feels disconnected from your own space. There is no felt sense to *where* that space is. It's certainly not where the picture itself is, and it doesn't seem to be anywhere with respect to you. There is a strong case to be made for Windt's claim that dreams are unlike this: the dreamed space is felt to be your space (see also Revonsuo 1995, 45). You phenomenally seem to be (as she says) *immersed* in it. Unlike depicted space, dreamed space is connected to you. You not only experience the dream visual scene from a certain spatial perspective, but that perspective phenomenally seems to be your spatial perspective, and seems to be a perspective on something in your space.

It might be helpful to contrast *immersive* experience (involving the feeling of immersive presence) with merely *perspectival* and *egocentric* experience. Objects in pictures are depicted from some perspective, and hence your visual experience of them presents them (in part) from that perspective. That perspective is not tied to your own body position—in fact, your body has no position relative to the depicted object—and hence the experience is not egocentric. If, in contrast, you imagined (say) a cat nearby, visualizing that cat as it would appear to you if it really were there, then your experience of the imagined cat is not only perspectival, but egocentric—from *your* perspective. Now, this imaginative cat experience isn't *immersive* because it doesn't involve an entire scene (or space) in which you might be placed, but even just considering a single imagined object, we can distinguish egocentric experience from immersive experience. Consider what happens to the imagined cat as you (say) walk towards it. Does its appearance change in ways an actual seen cat's appearance would change, e.g. by increasing in apparent size as you moved forward? Presumably you could put the effort into imagining the cat so that the experience exhibited this sort of sensorimotor dependency. But if not, the imagined cat would not feel to be *in* your space, even if you put in enough effort to imagine the cat as it would appear from your (egocentric) perspective. So, the full feeling of immersion (of immersive presence), of being *in* a space, involves more than merely egocentric

lights the immersive character of dreaming, which he takes to reveal something about the fundamental structure of consciousness. Specifically, he says it shows that, whether asleep or awake, consciousness is a kind of virtual world construction akin to what happens as we use virtual reality systems.

perspectival experience.

Although Matthen describes the feeling of presence as involving the feeling of immersive presence, he also refers to another feeling of presence. Recall from section 2 that Matthen describes the feeling of presence as being wrapped up with *bodily significance*, or *significance for action*. For example, an object seen approaching you, if felt as present, is visually experienced *as hurtling towards* you, or as *able to be caught* with the right arm and hand movement (Matthen 2005, 304). Matthen's discussion intertwines this second variety of presence with immersive presence, suggesting some connection between them. But it's possible to feel immersively present within an experienced visual scene, or to feel as if a visually experienced object is in your space, without there being any bodily significance to the experienced scene or object.

To show this dissociation, consider the cat case just mentioned. Say you did put in the effort required to visually imagine how the cat's appearance would change as you approached it, and hence that the experience was "immersive" insofar as the cat was felt to be in your space. Still, it would not phenomenally seem to you as if you could reach out and pick up up the cat. Alternatively, consider the case of hyper vivid, immersive (wakeful) imaginative experiences. If I had an especially powerful and vivid imagination, I could imagine not only a sofa against my empty wall, or a nearby cat, but a whole visual scene around me. If I imagined a whole visual scene around me while standing in a perfectly darkened room, there's no reason to think I couldn't imagine the scene so that I'm situated within it. If my imagination was powerful enough, I could not only imagine myself in the scene, but I could build out the entire space around me with my visual imagination—and I could further continually update that imagined space so that its visual appearance reflected my movements. Such a visually imagined scene would have the feeling of immersive presence: I would not only experience the scene from some (or my) spatial perspective, but I would phenomenally seem to be *in* the space. At the same time, the immersive imagined scene would lack the second variety of presence; it wouldn't have any felt phenomenal significance for action. For example, it would not phenomenally seem to me that I could sit on the imagined sofa, even if that sofa was part of an entire immersive imagined scene.

We can call this second variety of presence 'the feeling of motor presence'. Visually experienced objects that feel motor present feel present in a way that has bodily significance. Now, as a matter of fact, motor presence is not

dissociable from immersive presence. If a space is your space (is immersively present), it's also motor present, i.e. it has significance for action. It's the space in which your body is in, after all. But although these two varieties of presence go together in terms of basic physical facts, their registration at the phenomenal level seems to be based on dissociable psychofunctional or neural systems. (Hence, this means that any cases of dissociation involve illusory experience: an experienced space cannot actually be immersively present without being motor present.[25]) This phenomenal dissociation is what's shown by the cat case above, or by the case of hyper vivid immersive imaginative scenes. The experience of such imagined objects or scenes involves a feeling of immersive presence without a feeling of motor presence.

Whether these two feelings of presence are dissociable in the other direction (motor presence without immersive presence) is unclear (Wong 2017, 321, suggests not), but the first direction is enough for dissolving the dilemma. Given that motion-guiding vision functions to represent retinal stimuli in a way that's suitable for action, it's plausible that it underlies the feeling of motor presence.[26] Assuming that motion-guiding vision is offline during body-driven dreams, and that body-driven dreams involve the feeling of immersive presence, the upshot is that motion-guiding vision does not underlie the feeling of immersive presence. A plausible story is that the feeling of immersive presence is supported by the egocentric representations in descriptive (i.e. ventral) vision, plus (as Windt suggests) the dependency of those representations on motor and proprioceptive activity (see also Sanchez-Vives and Slater 2005; Slater 2009).

So, Matthen oversteps in proposing that depicted space does not feel connected to our space because motion-guiding vision is not activated by

[25]Depending on precisely how we want to define 'motor presence', it might be possible to have immersive presence without motor presence. Consider the situation of standing in the middle of a room, enclosed in a small glass box. The room is immersively present, but, because of the glass enclosure, is not actually available for action. If the glass is not seen (or is seen but doesn't affect the neural processing underlying the feeling of motor presence), this might be a case in which you inaccurately experience objects as motor present.

[26]My discussion here is limited to the feeling of motor presence (or any variety of presence) in visual experiences, or experiences with visual components (since there are few *pure* visual experiences that don't involve aspects of other sensory modalities, O'Callaghan 2019). I don't mean to make any claims about the role of motion-guiding vision in the feeling of presence in nonvisual modalities.

depicted scenes.[27] Still, he's correct that motion-guiding vision facilitates *a* feeling of presence, namely, the feeling of motor presence. Likewise, Windt is right that all dreams involve the feeling of presence, but this claim needs to be limited to the feeling of immersive presence.[28] Both Matthen and Windt miss something. Matthen misses that one kind of phenomenal presence (the feeling of immersive presence) can be had in the absence of the other (the feeling of motor presence). Windt misses that dreams, having only the feeling of immersive presence, fail to reproduce the full feeling of presence from normal wakeful perception.

6 Is there the feeling of motor presence in body-driven dreams?

The above resolution rests on the proposal that the visual scene in body-driven dreams does not feel motor present. Whether the proposal is true is an empirical question. It might be tested by waking subjects after myoclonic twitches are observed and asking them for a dream report, or asking if what they "saw" felt motor present.

Before discussing this potential testing in more detail, it's worth first addressing some anecdotal dream reports which may provoke skepticism about my proposal. Some people report that, when dreaming, the things they "see" feel as if they are there to be engaged with. They report that, when dreaming, they feel as if they can reach out and touch what they "see". Sometimes they do reach out, in the dream, and touch what they "see", and what's "seen" reacts to the touch (e.g., an item crumbles when touched).[29]

[27] Matthen would presumably agree with this point, as he agrees (personal communication) that egocentric spatial connection is not enough for the sense of presence.

[28] Windt is likely amenable to this proposal, given that she notes that some dream reports indicate a lack of "self", as in, the dream scene was experienced passively, instead of the dreamer feeling like an active participant (Windt 2010, 300). Although "phenomenal selfhood" (feeling like an active agent) is not the same thing as the feeling of motor presence, one would expect dreams lacking phenomenal selfhood to lack the feeling of motor presence.

[29] Specifically, Valerie Bernard (personal communication) reports to me that this is what her dreams are like. She reports items sometimes crumbling when touched. I assume that many other people (although perhaps still a minority) would second this report. My own dreams are seldom, if ever, like this, although I have not attempted to keep a systematic log.

I will assume that anecdotal dream reports like these are accurate (see Windt 2013). Whether they motivate skepticism towards my proposal depends on two things: (1) whether these are reports of body-driven dreams, and (2) whether these reports actually describe, or evince, the feeling of motor presence.

If these *are* reports of the feeling of motor presence, they only falsify my proposal if they are reports of body-driven dreams. It could just be that reported dreams in which one feels they can grasp what's "seen" aren't body-driven dreams. The Windt-Blumberg proposal on sensorimotor processing during REM sleep does not preclude motion-guiding vision from operating during some dreams. Hence, nothing stops dreams which aren't body-driven from involving the feeling of motor presence. Extreme cases of RBD behavior in which the motor cortex seems to take over from the brainstem might evince a dream state in which motion-guiding vision can run. Similar to extreme cases of RBD, sleep walking can involve dreams that are integrated with the actual movements of the sleeper (Oudiette et al. 2009); the complex, coordinated movements of the sleeper would seem to require the functioning of motion-guiding vision. Likewise, lucid dreams, in which a subject exerts intentional control of their actions and looking, might also involve the activation of motion-guiding vision. Plausibly, body-driven dreams occupy a middle space between fleeting hypnagogic/hypnopompic imagery and rich lucid, RBD, and sleep-walking dreams. Perhaps some people, through practice or cultivation of their dreams, regularly enjoy more sophisticated, semi-lucid dreams. These semi-lucid dreams may fall somewhere between rudimentary body-driven dreams and full lucid dreams, and involve the engagement of motion-guiding vision.[30] Perhaps those who report the feeling of motor presence in dreams are simply reporting on these semi-lucid dreams, or on other dreams that aren't body driven. Hence, it is important to test my proposal under controlled conditions (e.g. when twitching is observed) so as to avoid

[30]If motion-guiding vision does run (albeit in a misfunctioning way) during some dreams and these dreams do involve the feeling of motor presence, that would speak against those dreams being a form of imagination, or, at least, be a major way in which these dreams are unlike typical waking imaginative states. Thus, these cases would provide a challenge to anyone who wanted to argue that *all* dreams are imaginative states (e.g. Ichikawa 2009, 2016). (Of course, if we can and do perceptually experience our sleeping bodies while dreaming, then that itself is a major challenge to an imagination view of dreams; but here I'm specifically thinking of the *visual* experiences within dreams and attempts to explain those, specifically, as imaginative states.)

this confound.

But it's also not clear that the reports, noted above, actually do indicate the feeling of motor presence. For example, if, in your dream, a "seen" object appears supersaturated or has some other unusual or striking appearance, then you might have the *desire* to reach out and touch it. You may even reach out, in the dream, and touch it; it may respond to your touch (e.g. by crumbling). Still, that's compatible with the absence of the feeling of motor presence. A subject might confuse their curiosity or desire to reach out and touch some dreamed object with the feeling that that object is accessible via the right arm and hand movements. The fact that, in the dream, they subsequently "reached" out and "touched" the object does not show that it ever felt motor present, since the dreamed reaching and touching may simply have been driven by the brain's registration of arm and hand twitches. The dreamed environment need not have guided their hand movement; instead, the visual dream scene may have simply been reimagined to conform to random brainstem-driven twitches.

This last point raises another issue with interpreting dream reports. Care is needed to distinguish the imaginative, visual component of a dream from the perceptual, twitch-driven component. For example, a report of kicking a ball is not necessarily evidence that the visual experience of the dreamed ball involved the feeling of motor presence. Instead, the dreamed kick could have resulted from actual perception of a leg twitch, with visual imagery of the dreamer kicking the ball merely overlaid without any feeling of motor presence. For example, if, while awake, a doctor taps your knee so as to cause a reflexive kick, and you simultaneously imagine a ball in the path of your foot being kicked, the imagined ball would not feel motor present, even though you could report having imagined kicking a ball. The point is that dream reports describing interactions with objects (e.g., walking up to them, kicking them, squeezing them, etc), when collected after twitching, are not evidence that the dreamed object felt motor present to the subject.[31]

A final worry is that even if reports of dreamed objects feeling graspable evince a *kind* of feeling of motor presence, this feeling might be different

[31] An anonymous referee has pressed me on cases in which a subject dreams they are rock climbing or skiing—activities that normally require a high-degree of motion-guiding vision. Assuming reports of such dreams were taken after twitching, they will face this same issue. Just because someone reports they dreamed they were climbing or skiing does not mean that the visual scene around them felt motor present, as opposed to merely being an imagined scene overlaying a twitch-driven bodily experience.

from the one accompanying normal waking vision. Perhaps what it's like for a visually experienced object to feel motor present is different when dreaming compared to when awake. Motion-guiding vision underlies the wakeful feeling of motor presence, while some other mechanism explains the dream feeling of motor presence. This suggestion gains some plausibility when we consider an important aspect of the feeling of motor presence highlighted by Alva Noë (2004; 2006). When awake and looking at objects, these objects not only feel available for action, but their visual appearances feel as if they depend on our action. For example, I implicitly understand how the 2D projections of the facing surfaces of an object will change as that object, or I, move. This understanding leads to certain expectations which contribute to the overall phenomenal character of my experience. Noë goes so far as to suggest that these sensorimotor expectations *constitute* my experience of the object itself. As he says, we experience things' presence in their absence. I experience a visual scene of full, 3D objects arrayed in space—while only ever, in a moment, having the appearance of 2D projections in my stream of phenomenal consciousness—because I understand how to bring unseen parts of those objects into view. The objects feel *accessible* or *explorable* to me via the right bodily motion. This feeling of accessibility, or explorability, is an important component of the feeling of motor presence during normal wakeful perception. Part of what it is to feel as if a seen object is available for (say) grasping is to feel as if more of the object could be uncovered through the right eye, head, or body movements.

Now, my suggestion is that even if some dreams involve the feeling that "seen" objects can be grasped, this feeling of dream motor presence lacks the wakeful feeling of accessibility or explorability. My own dreams, at least, always involve a visual scene that is exhausted by what I take into my stream of phenomenal consciousness at any given movement. That is, what I "see" in my dreams is exhausted by what I take in at a glance. I don't feel as if there's more to be accessed through the right exploratory movements. Of course, as I dream I do "see more"; the dream scene unfolds over time, and I often am an active participant in the dream. Still, newly revealed parts of objects don't feel as if they were there all along. Note also that this lack of the feeling of accessibility holds even when my dreams are richly detailed, stable, or vivid (see Rosen 2018). Just as a picture can be richly detailed or vivid without experiences of that picture feeling as if there is more to be uncovered through body movements, dreams can go the same way. A similar dynamic plays out in imagination: although I can imagine a rich complete scene around me and

"scan" that scene, shifting my gaze between imagined objects, no matter how vivid my imagination, the imagined objects don't feel as if they have parts that are out of view but accessible. Perhaps the operation of motion-guiding vision is required for the *full*, wakeful version of the feeling of motor presence, including the feeling of accessibility or explorability.[32]

Thus, all considered, anecdotal reports of dreamed objects feeling graspable do not pose a challenge to my proposal that body-driven dreams lack the feeling of motor presence. As noted, what's needed are reports collected, or queries posed, after waking subjects observed twitching. Further, these queries, or the analysis of these reports, need to be sensitive to the issues raised in the above discussion.

Specifically, the above discussion shows that the following sorts of reports do *not* demonstrate the feeling of motor presence:

1. Reports of *wanting*, or *desiring*, to reach out and grasp or touch dreamed objects.

2. Reports of *interacting* with dreamed objects, e.g. reports of kicking balls or rock climbing.

3. Reports combining the above two elements, e.g. reports of reaching for, and touching, some object that grabbed your curiosity.

The problem, as noted, is that the feelings of desire or curiosity need not reflect the feeling of motor presence, and dreamed interactions may merely be visual imagination overlaying twitch-driven bodily experience.

What sort of reports would demonstrate the feeling of motor presence? Reports describing actions more tightly associated with the feeling of motor presence would provide some evidence. For example, if a subject reports that, in the dream, they had to duck in response to a "seen" object coming at them, that would be some evidence for the feeling of motor presence. Care is still necessary, since such a dream might merely involve an imaginative visual component (of an object flying towards the subject) overlaying twitch-driven bodily experience. What might usefully distinguish the two cases is some report of accompanying emotional affect. For example, if the dreamed object was reported as inducing fear, or reported as feeling dangerous, then

[32]That, anyway, would be the thing for Matthen to propose. Noë, as is well known, has suggested that the feeling of accessibility or explorability actually arises out of our extended, world-involving interactions with sensory stimuli (Noë 2004, 2007).

that may support interpreting the report as showing the feeling of motor presence. Further, vivid ergonomic terminology in reports (e.g. 'hurtling', 'graspable'), or ergonomic descriptions (e.g. 'it looked too far away to reach'), may also be good indicators of the feeling of motor presence.

Certain sorts of reports would tell against the feeling of motor presence in a dream. Assuming, as I've proposed, that the feeling of accessibility or explorability is a key component of the feeling of motor presence, reports which signal the lack of this feeling could be taken as signaling the lack of the feeling of motor presence. These would mostly be reports describing a dream in overly imagistic terms: e.g. reports of "seeing" static or moving images. Given that prime examples of picture viewing and (waking) imagination lack the feeling of accessibility, strong comparisons of a dream to these cases would indicate a lack of the feeling of accessibility.

Finally, researchers might try explaining the feeling of motor presence to naïve subjects, then querying them about whether their dream had that feeling. Here Matthen's contrasting examples are perhaps useful. It could be pointed out to subjects that (for example) an actual apple looks as if you could reach out and grab it, while there is no analogous look with a picture of an apple. Another useful contrast would be the difference between watching an actual ball hurtling towards you, vs watching a video of a ball hurtling towards a camera. Subjects should grasp that in the former, but not latter, case you feel the urge to duck. If subjects evinced understanding of the idea, they could perhaps be directly asked, upon waking, whether what they "saw" felt present.

7 Measuring presence in VR research

The feeling of presence is often discussed in virtual reality (VR) research and applications. VR researchers aim to create virtual environments (VEs) via sensory input devices like headsets. For many applications (e.g., training surgeons, therapeutic treatments of phobias or social anxiety, gaming) it is important, if not essential, that the subject feel present within the VE (Sanchez-Vives and Slater 2005). So, VR researchers pay attention to the factors affecting the feeling of presence within a VE, and cultivating that feeling is often the primary design goal (Grassini and Laumann 2020). This requires measuring the extent to which a subject feels present in a virtual environment, and, so, VR researchers have developed various ways to measure

the feeling of presence. These measures include a myriad of questionnaires, physiological correlates (e.g., heart rate), and behavioral correlates (e.g., hesitating near a virtual cliff).

Unlike the work here, which starts from phenomenological observations about normal waking perceptual experience, "presence" research in VR and related fields starts from questions about when and how artificial media induce the feeling of presence. So, from this research perspective, "presence" is sometimes taken, conceptually, as applying only to VEs (e.g. Lee 2004). I assume it's clear that, despite these parochial differences, both traditions are talking about (roughly) the same thing. Just as you might or might not feel present in a VE, you might or might not feel present within (a) the physical environment you naturally experience through your senses, (b) a dream scene, or (c) a depicted or imagined scene. Of course, it's normal to feel present in your everyday perceptual scene, and normal to not feel present within a depicted or imagined scene.

There are other terminological differences. VR researchers often use 'immersive' as a term describing the extent to which a given VR setup physically immerses a subject in artificial sensory stimuli, reserving the term 'presence' for the subjective (phenomenological) feeling of being in a VE simulated by an immersive setup (e.g. Slater 2003; Sanchez-Vives and Slater 2005; Grassini and Laumann 2020). In contrast, I've used the term 'presence' for the objective, physical immersion of a subject in an environment, and 'feeling of presence' for the subjective experience of that presence. I assume these terminological differences are trivial and easy enough to translate between.

A vexed point in work on VEs is that different terminology and concepts of presence (or, rather, the feeling of presence) are used by different researchers (see Slater 2003; Lee 2004; Grassini and Laumann 2020). Still, common themes arise. The core concept of presence in play in this research seems to be what I've here called 'the feeling of immersive presence'. For example, Sanchez-Vives and Slater (2005, 333) say that "[t]he common view is that presence is the sense of being in a VE rather than the place in which the participant's body is actually located", while Grassini and Laumann (2020, 14), citing (Nash et al. 2000), say "[p]resence is the sensation of being in the place presented in a VE" (see also Slater 2009, 3551 on the "place illusion"). Two other aspects of the feeling of presence are emphasized in this research. The first is (the feeling of) *involvement*, i.e. the engrossment of a subject in some virtual task within a VE. The second is (the feeling of) *reality*, i.e. the feeling that the VE or virtual objects in it are real. Mel Slater (2009, 3553)

has called this the "plausibility illusion". Sometimes the feeling of reality is further divided into feelings of reality about presented physical objects, social actors, and the self or its avatar (Lee 2004). The feeling of reality is, presumably, related to what philosophers often describe as a phenomenology of mind-independence (e.g. Siegel 2006; Dokic and Martin 2017; Matthen 2019). Here the point is that while normal sensory stimuli phenomenally seem to us to be objective, or out in the world independent of our mind, some things presented in experience (e.g. phosphenes) lack this appearance.

Despite cutting these various distinctions, VR researchers have not distinguished between the feelings of immersive and motor presence.[33] Alternatively put, they have not identified the feeling of motor presence as a dissociable component of (what they call) presence. This is important because it has implications for the measurement of presence. Specifically, many measures used in VE research actually seem to be measures of the feeling of motor presence. For example, a physiological correlate like a heart rate spike, or a behavioral correlate like ducking, are plausibly associated with the feeling of motor presence, and not necessarily the feeling of immersive presence. As I've stressed in this paper, it is possible to feel immersed in a space, as if it is *your* space, the space connected to you body, without feeling as if the objects in that space have ergonomic significance. So, for instance, while failing to find common physiological or behavioral correlates is often taken to indicate a lack of the feeling of presence (Sanchez-Vives and Slater 2005; Grassini and Laumann 2020), this absence probably only indicates the lack of the feeling of *motor* presence. It's possible that someone who, say, doesn't hesitate at the edge of a virtual cliff, or doesn't reflexively duck under an incoming virtual ball, still nonetheless is having an experience of the VE that includes the feeling of *immersive* presence. That is, it's possible they still feel as if their body is embedded in the VE. This dissociation between the feelings of immersive and motor presence, and the confound it makes for common measures of presence, may even contribute to recent difficulties replicating results or difficulties validating common measures (see Grassini

[33] At first glance, you might wonder if the feeling of motor presence isn't just what VR researchers have identified as the feeling of reality, or the "plausibility illusion". To see that the two are different, consider how the feeling of reality/plausibility illusion can attach to what you see on a TV screen, e.g. as it does when you watch live video of an event of some significance. Although, in this case, you feel as if what you see is real, it lacks the feeling of motor presence. You do not, for example, feel as if you could reach into the screen and grab what you see.

and Laumann 2020). To take a simple example, physiological or behavioral measures may not consistently correlate with self-reports because the self-reports may track the feeling of immersive presence, while the physiological and behavioral measures track the feeling of motor presence.

The above discussion is also relevant for the search for neural correlates of presence. If the above discussion is correct, it turns that out the feelings of immersive and motor presence have different neurocognitive explanations. The feeling of motor presence (at least in visual experience) derives from the operation of motion-guiding vision, likely located in the dorsal stream, while the feeling of immersive presence likely has something to do with egocentric ventral visual representations and their dependency on proprioceptive feedback. These different neural mechanisms, underlying different, dissociable feelings of presence, are likely to introduce a serious confound into attempts to isolate (via electroencephalography or functional magnetic resonance imaging) neural correlates of the feeling of presence (see Grassini and Laumann 2020).

Of course, researchers working on VEs are already well aware of many confounds for their measures (e.g., heart rate is affected by affective content in a VE), and the various distinctions they have already cut (e.g., between presence and involvement) are important. My aim is not to supplant this existing framework, but to add to it by pointing out an important, so far missed, distinction.

8 Conclusion

In this paper, I've argued that motion-guiding vision is offline during body-driven dreams. Since Matthen proposes that motion-guiding vision underlies the feeling of presence, his view entails that objects "seen" in body-driven dreams should fail to feel present. This poses a dilemma, since while Matthen's explanation is well supported, evidence from dream reports suggests that body-driven dreams do involve the feeling of presence. I've proposed that we can resolve this dilemma by distinguishing between the feelings of immersive and motor presence: all dreams, including body-driven ones, involve the feeling of immersive presence, while motion-guiding vision underlies only the feeling of motor presence.

This resolution depends on the hypothesis that body-driven dreams lack the feeling of motor presence. This is an empirical question to be answered by

further study, and I've made suggestions for how tests might be done. Still, the hypothesis is prima facie plausible, and reflection on this initial plausibility of the hypothesis brings out the rich phenomenal landscape of presence. Not only are there the feelings of immersive vs motor presence, but also distinguishable aspects to the feeling of motor presence itself. Specifically, the feeling of motor presence when awake involves the feeling of accessibility (presence-in-absence, as Noë calls it). These aspects of the feeling of presence are independent of other commonly discussed aspects, including the feeling of reality (or mind-independence) and the feeling of involvement.

Finally, I've suggested that the distinction between the feelings of immersive and motor presence has important methodological implications for research in VR and VE. Specifically, common physiological and behavioral measures of presence in these fields look more like measures of the feeling of motor presence, while self-report measures look more like measures of the feeling of immersive presence.

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