

Drug-Induced Alterations of Bodily Awareness

Raphaël Millière
Columbia University
rm3799@columbia.edu

NOTE: This is a slightly longer version of a chapter to appear in the *Routledge Handbook of Bodily Awareness*, Adrian Alsmith & Matt Longo (Eds.).

1 Introduction

Philosophical and empirical research on bodily awareness has mostly focused so far on bodily disorders – such as anorexia nervosa (Cash & Brown, 1987), somatoparaphrenia (Vallar & Ronchi, 2009), or xenomelia (body integrity dysphoria) (McGeoch et al., 2011) – and bodily illusions induced in an experimental setting – such as the rubber hand illusion (Botvinick & Cohen, 1998), or the thermal grid illusion (Craig, Reiman, Evans, & Bushnell, 1996). Studying these conditions can be illuminating to investigate a broad range of issues about the nature, function, and etiology of bodily experience (Frédérique de Vignemont, 2019, 2020a). However, a number of psychoactive compounds can also induce a remarkably wide variety of bodily effects that have received little attention despite their relevance to these issues. Some of these effects are similar to those associated with bodily disorders or experimental bodily illusions, while others appear to be unique. The purpose of this chapter is to provide an overview of these lesser known bodily effects of psychoactive compounds, and outline some ways in which they can bear on recent debates regarding bodily awareness and bodily ownership.¹

There are a few reasons why we should pay more attention to drug-induced alterations of bodily awareness. Firstly, even within psychopharmacological research on the sensory effects of psychoactive molecules in human subjects, bodily phenomena are less studied than visual phenomena – perhaps a symptom of the more general bias towards visual processing in psychology and neuroscience (Hutmacher, 2019). Secondly, the sheer diversity of drug-induced bodily experiences warrants further investigation to broaden our repertoire of interesting bodily phenomena. Just as studying drug-induced visual hallucinations can be helpful to consider a wider range of edge cases in the philosophy of perception (González, 2010), the discussion of many philosophical issues regarding bodily experience can benefit from considering drug-induced bodily hallucinations and related phenomena (Blom & Sommer, 2012). Thirdly, gaining more insight into the wide-ranging bodily effects of psychoactive drugs may help us discriminate bodily-related dimensions of consciousness at a higher fineness of grain,

¹Note that some bodily experiences reported after drug consumption cannot be attributed to their effects on neuroreceptors or neurotransmitters in the brain, but are merely related to the route of administration. For example, consuming the seeds of *Argyrea nervosa* often causes intense stomach pain unrelated to their high concentration of the serotonergic psychedelic LSA. I will discard such effects to focus on those mediated by neuropharmacological pathways.

and inform our taxonomy of global states of consciousness (Bayne & Carter, 2018; Fortier-Davy & Millière, 2020). Fourthly, for some specific issues, drug-induced alterations of bodily awareness may offer a richer body of evidence than bodily disorders of neurological origin. Indeed, they can easily, and often safely, be studied in healthy subjects in the laboratory – being almost always fully reversible, and in some cases very short-lasting. Furthermore, retrospective reports about drug-induced experiences can be easier to interpret than available reports from isolated case studies of bodily pathologies: they are generally not associated with delusional beliefs, and are often much more detailed. Finally, gaining a better understanding of the bodily effects of various compounds, as well as the underlying mechanisms through which they reshape bodily representations, may lead to novel pharmacological therapies for bodily disorders such as anorexia nervosa (Foldi, Likhaitzky, Williams, & Oldfield, 2020; Ho, Preller, & Lenggenhager, 2020; Nichols, Johnson, & Nichols, 2017).

In what follows, I will group drug-induced bodily experiences within three categories: (a) non-illusory bodily experiences, (b) bodily illusions and hallucinations, and (c) bodily deficits. The first category is intended to include bodily experiences induced by psychoactive compounds that do not clearly involve misrepresenting properties of one’s body, or representing properties of non-existent objects. I include in this category what Armstrong (1962) calls “bodily sensation”, such as fatigue and stimulation; as well as sensations of physical euphoria, relaxation, and pain. The second category is intended to include anomalous bodily experiences that can be characterized as *illusory* – representing one’s body as having a property it does not in fact have – or *hallucinatory* – representing a non-existent object as being part of, or interacting with, one’s body. The distinction between illusions and hallucinations is difficult to draw in the case of anomalous bodily sensations. Those that fall under one label given a particular description often fall under the other given a slightly different description, which may be equally apt depending on further commitments regarding the metaphysics of bodily experience. For this reason, I will group anomalous bodily experiences that can be characterized as illusions or hallucinations together. The third category pertains to disruptions of bodily awareness that result in the *inhibition* or *loss* of certain features of ordinary experience, rather than the occurrence of additional anomalous sensations.

Whether this trichotomy carves (drug-induced) bodily experiences at their natural joints is an open and substantive question. On some representationalist accounts of pain, for example, one might describe painful experiences induced by drugs in the absence of bodily damage as illusory, and prefer to group them in the second category. Likewise, some instances of what I call bodily deficits might be described as involving an illusory component. My purpose here is not to justify the legitimacy of these categories, but to use them as convenient classes to chart the varieties of drug-induced bodily experiences. Within each category, bodily experiences can be further broken down according to the sensory modality and representational features involved. Again, there is room for disagreement about the individuation of bodily modalities, but I will not engage in this debate here. As we shall see, some drug-induced bodily experiences also appear to be multimodal. Psychoactive compounds themselves can be categorized within broad classes according to the main neuropharmacological mechanism(s) mediating their subjective effects (see table 1 for a non-exhaustive summary).

Table 1: Main classes of psychoactive compounds

Pharmacological class	Main mechanism	Compounds (examples)
Classic psychedelics	5-HT _{2A} receptor agonism	Psilocybin, LSD, DMT
Empathogens	5-HT/NE release/reuptake inhibition	MDMA, MDA, αMT
Stimulants	DA/NE release/reuptake inhibition	Amphetamine, Cocaine

Pharmacological class	Main mechanism	Compounds (examples)
Dissociative anesthetics	NMDA receptor antagonism	Ketamine, DXM, MXE
κ -opioid dissociatives	κ -opioid receptor agonism	Salvinorin A
Cannabinoids	CB receptors agonism	THC, JWH-018
Deliriant	mACh receptor antagonism	Scopolamine, DPH
Depressants	GABA _A receptor modulation/agonism	Ethanol, Aprazolam
Opioids	μ -opioid receptor agonism	Heroin, Tramadol

2 A note on methodology

Experimental research on the subjective effects of psychoactive compounds on human subjects is currently undergoing a renaissance, particularly with classic psychedelics such as psilocybin and LSD (Lawrence, Sharma, Griffiths, & Carhart-Harris, 2021). Nonetheless, there is still a limited number of studies investigating drug-induced bodily experiences in a controlled setting, and many compounds used recreationally have not yet been studied in the laboratory. To compensate for the relative scarcity of experimental studies, I conducted a novel exploratory analysis of a curated corpus of 22,154 reports of drug-induced experiences.² I identified reports describing salient bodily effects by semantic search of the corpus with a state-of-the-art natural language processing algorithm optimized for sentence similarity. Specifically, I used a modified RoBERTa language model (Liu et al., 2019), trained on the Stanford Natural Language Inference (SNLI) (Bowman, R., Angeli, Potts, & Manning, 2015) and the Multi-Genre Natural Language Inference (Multi-NLI) (Williams, Nangia, & Bowman, 2018) corpora, and fine-tuned on the Semantic Textual Similarity (STS) benchmark.³ The model was modified with a siamese network structure to derive semantically meaningful sentence embeddings that can be compared using cosine similarity (Reimers & Gurevych, 2019). I subsequently performed a qualitative analysis of the reports identified as describing salient bodily effects, to summarize frequently described effects in each category and select relevant quotes. For each report quoted below, I have included (a) the psychoactive compound taken, (b) the pharmacological class to which it belongs (as outlined in table 1), and (c) the unique identifier of the report, which can be used to retrieve it online.

3 Non-illusory bodily experiences

3.1 Fatigue and stimulation

Fatigue is a common effect of many psychoactive compounds, such as depressants, opioids and deliriant. Among depressants, alcohol is somewhat unique in that it can have both stimulant and sedative effects (Hendler, Ramchandani, Gilman, & Hommer, 2013). Other depressants such as benzodiazepines and barbiturates are used as anxiolytics because of their tranquilizing effects, reported as feelings of drowsiness and lethargy (Greenblatt, 1992), while opioids cause bodily numbness and sedation associated with their analgesic properties (Benyamin et al., 2008). Drowsiness is also a side effect of first-generations antihistamines, such as diphenhydramine, abused for their deliriant properties at high doses (Gengo, Gabos, & Miller, 1989).

²Retrieved from <https://erowid.org/experiences>, excluding drug combinations.

³<https://ixa2.si.ehu.es/stswiki/index.php/STSbenchmark>

By contrast, other classes of psychoactive compounds are associated with bodily stimulation, particularly stimulants, empathogens and classic psychedelics. Stimulants such as cocaine, amphetamine, and methamphetamine have energizing effects mainly mediated by dopaminergic activity (Panenka et al., 2013; Sofuoglu, DeVito, & Kosten, 2021; Vari, Pichini, Giorgetti, & Busardò, 2019). So-called empathogens like MDMA are closely related to classic stimulants (most of them being substituted amphetamines), and also have stimulant properties associated with feelings of elation (Baylen & Rosenberg, 2006; Iversen, White, & Treble, 2014). Likewise, many psychedelics induce stimulating bodily effects, colloquially described by recreational users as a “body buzz”, generally characterized as pleasurable:

My body was buzzing with incredible energy. [Psilocybin | psychedelic | #26644]

3.2 Bodily euphoria and pain

Many compounds can induce feelings of general bodily pleasure and euphoria, either associated with sedation (e.g., opioids) or with stimulation (e.g., stimulants, empathogens, and psychedelics). Thus, initial exposure to opioids for recreational rather than analgesic purposes is often described as profoundly relaxing and euphoric (Bieber et al., 2008; Comer & Zacny, 2005). Some stimulants, such as methamphetamine, can induce feelings of bodily pleasure associated with increased energy and motivation (Cruickshank & Dyer, 2009). Likewise, the euphoric effects of empathogens and psychedelics are generally related to stimulation:

I began to feel the body buzz and as a few minutes progressed, it became more and more strong. I felt very euphoric and excited. When we sat down, I noticed that sitting felt amazing. Every breath felt so good. [Psilocybin | psychedelic | #32521]

However, psychedelics can also induce painful bodily sensations:

My tactile sensations were overwhelmed and I felt every molecule of air touching my body and it was horrible [...]. I felt in so much pain I was sure if I let myself close my eyes I would die. I was in so much pain at one point I just wanted to give up. [5-MeO-DMT | psychedelic | #32032]

Interestingly, some experiences of bodily pain caused by psychedelics are described as lacking the negative valence of ordinary nociception:⁴

I [...] was walking through the rice terraces scraping against briars. I felt the pain, but it also was apparent what an illusion the pain was. I reached in front of me and squeezed a branch of the briar hard, just to prove to myself the pain was immaterial. the pain rippled through me in shards, but it felt silly and small and I forgot about it instantly. [LSD | psychedelic | #27413]

I fell on my back somehow and hit my head on the concrete. [...] I remember feeling something sharp in my head that was probably pain, but didn't feel like pain at all. [LSD | psychedelic | #88438]

These reports are strikingly similar to descriptions of pain asymbolia, a rare condition caused by brain lesions to the posterior insula, characterized by indifference towards painful sensations (Berthier, Starkstein, & Leiguarda, 1988). Grahek (2007) suggests that pain asymbolia is a counterexample to

⁴See also Keats & Beecher (1950) for somewhat similar experiences after morphine and pentobarbital administration, and Park (2019) for a critical discussion. Note that experiences of indifference to pain induced by psychedelics do not appear to be mediated by partial analgesia, like those induced by opioids and depressants.

motivationalism about pain, the view that motivational force is an intrinsic property of painful experience. In response, Klein (2015) argues that asymbolics are unresponsive to painful sensations not because those are not intrinsically unpleasant, but because asymbolics lack the capacity to care about their bodily integrity. However, it is not immediately obvious that this alternative interpretation would be equally plausible for cases of drug-induced indifference to pain like those reported above, which seem to emphasize a change in the sensory quality of the pain rather than the subject's attitude towards bodily integrity. A more systematic investigation of indifference to pain in drug-induced states might shed further light on the plausibility of motivationalist accounts.

4 Bodily illusions and hallucinations

We can distinguish at least five broad categories of bodily illusions and hallucinations, based on the sensory modality or representational features involved (Blom & Sommer, 2012): tactile experiences pertaining to cutaneous pressure, stretch and vibration; proprioceptive experiences pertaining to limb position and movement; body image disturbances pertaining to enduring bodily properties; vestibular experiences pertaining to balance and spatial orientation; and interoceptive experiences pertaining to internal bodily sensations and temperature. In what follows, I will loosely classify bodily illusions and hallucinations within these five categories. An interesting feature of drug-induced bodily illusions and hallucinations is that many of them are multimodal, and may involve not only several somatosensory modalities, but also exteroceptive modalities such as vision. For the sake of simplicity, I will fit multimodal illusions and hallucinations within the above categories, using the dominant bodily modality as a guide. I will refer to all experiences discussed in this section as “hallucinations”, although many might also be described as illusory, as mentioned in the introduction. As we shall see, some of the most remarkable drug-induced bodily hallucinations, including multimodal tactile, proprioceptive, body image, and vestibular disturbances with unique characteristics, are caused by the κ -opioid receptor agonist Salvinorin A, an atypical and short-lasting dissociative naturally occurring in *Salvia divinorum* (Addy, Garcia-Romeu, Metzger, & Wade, 2015; Butelman & Kreek, 2016; Maqueda, 2021; Maqueda et al., 2015).

4.1 Tactile hallucinations

Tactile hallucinations can occur in a number of pathological conditions, including schizophrenia (Pfeifer, 1970), Parkinson's disease (Kataoka & Ueno, 2017), Alzheimer's disease (Ali & Darbe, 2019), dementia with Lewy bodies (Ukai, 2019), and Ekblom's syndrome (Orsolini, Gentilotti, Giordani, & Volpe, 2020). The clinical literature also contains case reports of tactile hallucinations induced by psychoactive compounds. The most commonly reported kind of drug-induced tactile hallucination is formication, the hallucination of bugs crawling on one's skin (Medical Writers, 2017; Nakamura & Koo, 2016). It is mostly reported after the use of stimulants, antiparkinsonian agents, and antidepressants, and can trigger delusional parasitosis, the delusion of being infested by parasites. For example, formication has been associated with cocaine (Roncero et al., 2017) and methamphetamine (Fisher & Stanciu, 2017) use, and observed after clinical administration of methylphenidate (Rashid & Mitelman, 2007). Isolated cases of formication have also been reported after intoxication with drugs in other pharmacological classes, including heroin (Nair et al., 2016) and alcohol (Sarff & Gold, 2010). Beyond formication, tactile hallucinations have been described after intoxication with the novel dissociative 3-MeO-PCP (Stevenson & Tuddenham, 2014, “He said that he could feel people touching him,” p. 60), chronic ketamine use (Lim, 2003), and trihexyphenidyl administration (Funakawa & Jinnai, 2005).

While these clinical cases reports are interesting in their own right, they do not constitute a representative sample of the wide variety of tactile hallucinations described in anecdotal reports of drug-induced experiences. Some of these hallucinations are particularly elaborate, involving intricate themes, multiple limbs, and/or several sensory modalities. For example, formicative hallucinations induced by deliriants can be complex and multimodal:

I felt something prickly on my left hand. [...] I felt a sharp prick on my hand, between my thumb and index finger, much like a bite. [...] I saw a spider on my hand, but tried to ignore it, thinking the hallucination would go away. I then saw it bite me and disappear, but in its place I could see a bright red dot where apparently, it had bitten me. Then, to make things worse, I felt a numbing sensation spread across my arm, as if toxin was entering my blood stream. [...] The touch sensory hallucinations were easily the worst part, because I couldn't just ignore something that I see and feel as a hallucination, as far as I knew, it WAS a real spider. [Diphenhydramine | deliriant | #36520]

Aside from formication, common tactile hallucinations also include the feeling of being touched by other people or entities:

I could feel many fingers touching me, and poking me. They were all over my body, and I wondered if it was everyone touching me. [...] I touched myself, to see if there were people touching me but I didn't feel anything. [Ayahuasca | psychedelic | #109100]

I remember the weirdest hallucinations. Not just visual or auditory, but tactile [...]. I felt as though God himself grabbed from behind with his gigantic, mighty hand and slammed me against a planet [...]. [*Salvia divinorum* | κ -opioid dissociative | #47277]

Some experiences involve both tactile and nociceptive components. Consider for example the following hallucination of being nailed to a cross, caused by consumption of *Amanita muscaria*, an atypical hallucinogenic mushroom whose effects are mediated by muscimol (a potent GABA_A receptor agonist) and ibotenic acid (an NMDA receptor agonist):

With every swing of my arms and legs, the pain in my invisible wrists and feet became excruciatingly more intense. It felt like there were nails piercing my wrists and feet [...]. I couldn't see any nails or what they were attached to. [...] I estimate that it was only another 15 minutes of being nailed to the cross that I finally knocked the first nail out of my right wrist. I didn't see any nail fall out. [*Amanita muscaria* | atypical hallucinogen | #87567]

Similarly, the following experience with ayahuasca (a South American brew containing the serotonergic psychedelic DMT) appears to involve visual, tactile, and nociceptive components:

I see snakes in the darkness, penetrating my body, searching for something. It is very unpleasant. I feel sick. My whole body is in pain. I feel pain in each little part of my body. [Ayahuasca | psychedelic | #89360]

4.2 Proprioceptive hallucinations

Proprioceptive hallucinations involve experiences of limb position or movement that are inaccurate or even physiologically impossible. While such hallucinations are not widely documented in the clinical and scientific literature, they are not uncommon in reports of drug-induced experiences:

The strange thing is that I feel my own body bending in weird shapes. [Psilocybin | psychedelic | #29618]

Throughout the entire experience, my body was bending in impossible ways. My legs bent around as though there were many joints which made my leg bend any way I imagined. [5-HO-DMT | psychedelic | #50335]

Common proprioceptive disturbances also include anomalous kinesthetic experiences, involving either altered perception of self-motion, or wholly hallucinatory self-motion:

I then decided to go for a walk [...]. Movement was very strange. It felt like I was not really moving, but somehow continuously changing position with everything around me. [...] I felt like I was not walking at all – as if my movement was a constant part of my existence. [4-HO-DiPT | psychedelic | #31901]

Lying in bed [...] I became aware of a figure holding a painting in front of me. I noticed with annoyance that the picture was incomplete, so I reached over and picked up a pastel from my desk, then colored in the blank spot on the paper. A moment later the image vanished. It was at that point that I realized that I had never moved my arms from under the blanket. [Trihexyphenidyl | deliriant | #76758]

4.3 Body image disturbances

Two long-term, global body representations are commonly distinguished in the philosophical and empirical literature: the *body schema*, which represents enduring properties of the body for action, and the *body image*, which underpins the perception of enduring properties of the body (Frederique de Vignemont, 2010; Dijkerman & de Haan, 2007; Paillard, 1999). However, there is no consensus on the precise definition of these two kinds of representation, whether they interact, and how.

Disturbances of the body image have been described as experienced distortions of the size, mass, spatial configuration, and shape of the body or body parts (Lukianowicz, 1967). Pitron & de Vignemont (2017) suggest that studying the impact of such disturbances on motor control may shed light on the relationship between body image and body schema, but focus only on pathological cases. Broadening the focus of this research program to drug-induced body image disturbances can provide a wealth of additional evidence. Indeed, such disturbances are particularly common with dissociative anesthetics, psychedelics, and κ -opioid dissociatives. I will focus here on five kinds of body image disturbances: limb displacement or disconnection, changes in size and weight, splitting or stretching of the body image, and metamorphosis.

Illusory displacement of limbs has been reported in some patients with parietal lesions, who feel as if one of their limbs were detached from their body (Critchley, 1965). Similar experiences are commonly reported after intoxication with dissociative anesthetics (at sub-anesthetic doses) and psychedelics:

I FELT (and not imagined) my body REALLY dismembered (i.e. the head kilometers from the left arm, the legs other miles away, etc.) [...]. [Ketamine | dissociative | #3282]

Limbs feel unconnected to body. [...] As I walk, I realize that I don't feel connected to my legs, I'm just 'floating' along, above the ground. [Dextromethorphan | dissociative | #1887]

My body parts were all over the place and I didn't really know what part was what or that they were connected. [...] My body concept was like after coming out of a blender. [Psilocybin | psychedelic | #113995]

When I was laying in bed my legs seemed really far away and I felt disconnected from my body. [LSA | psychedelic | #14595]

Another relatively common drug-induced disturbance of the body image is the so-called Alice in Wonderland syndrome (AIWS), characterized by the experience of part or totality of the body as *larger* (macrosomatognosia) or *smaller* (microsomatognosia) than it is. In the clinical literature, AIWS has been mostly documented in patients suffering from migraine, infectious diseases, and brain lesions, although there is also a handful of isolated case reports concerning drug-induced occurrences (see [Blom, 2016](#) for a review). However, there is no shortage of anecdotal reports of drug-induced AIWS, particularly with psychedelics and dissociatives:

My body feels enormous. [The] body image feels bloated, enhanced, expanded. [Methox-propamine | dissociative | #113720]

My sensations of my body are becoming distorted, like I am some huge, fat person. [DPT | psychedelic | #9656]

I feel VERY large as I walk around my house. I feel like I do not fit. My hands also feel very far from my body. [5-MeO-DMT | psychedelic | #17740]

I am shrinking [...]. I would say I got about 10%-15% smaller. My hands, head, the inside of my mouth, everything is smaller. [2C-C | psychedelic | #31896]

Other reports about psychedelics and dissociatives describe the distinct experience of the body or body parts feeling *heavier* or *lighter* than they really are:

My legs seem heavy and the body appears heavier. [...] I feel like I have to make a huge effort to walk. [4-HO-MET | psychedelic | #92502]

I tried to lift my body onto [the chair] but I was incredibly heavy, it felt like I was grappling with unbearable weight. [Psilocybin | psychedelic | #110704]

All of a sudden my head felt like it weighed a ton and it fell back and slammed against the wall. [It was] like my body weighed more than it could really hold up. [Ketamine | dissociative | #32474]

My body felt amazingly light, and every movement I made felt effortless [...]. [LSD | psychedelic | #56890]

Salvia divinorum reliably induces unique disturbances of the body image ([Maqueda et al., 2015](#)). A very common one involves feeling one's body split in half, usually along the mid-line:

My body felt as if it was opening in two halves. [*Salvia divinorum* | κ -opioid dissociative | #80543]

It was as if I was split in two [...]. [*Salvia divinorum* | κ -opioid dissociative | #894]

Suddenly I felt half of my body split in half [...]. [*Salvia divinorum* | κ -opioid dissociative | #52763]

It also felt as if my head and body were being bisected, I was being split according to my bilateral symmetry. [*Salvia divinorum* | κ -opioid dissociative | #52763]

My body felt cut in two along a vertical axis [...]. It felt as if the rear half of my whole body had merged with the rest of the world and as I stumbled to my feet it felt as if I had to carry the weight of the world with me on my back. [*Salvia divinorum* | κ -opioid dissociative | #43116]

It was as if all of the universe had been split in two, with my body directly on the separation line. [*Salvia divinorum* | κ -opioid dissociative | #41292]

The corporeal sensation was of a force dividing my body in half [...]. (Maqueda et al., 2015, p. 12)

A very potent force split my body in two halves [...]. (Maqueda et al., 2015, p. 12)

Interestingly, similar hallucinations have been observed in rare cases of migraine aura (Lippman, 1952; Podoll & Robinson, 2002), schizophrenia and epilepsy (Lukianowicz, 1967), and parietal lesions (Critchley, 1965).

Salvia divinorum also induces very characteristic multimodal hallucinations described as the experience of one's body being stretched, compressed, or flattened by an invisible force, as if run over by a steamroller, from feet to head:

The only term I could use to describe the next sensation is that I was steamrolled. [...] It was like something way bigger than me and weighing hundreds of tons, started at my feet and rolled up over my entire body, transforming me as it went. [*Salvia divinorum* | κ -opioid dissociative | #38234]

A giant, heavy steamroller-like cylinder was now rolling over me in the direction of my toes to my head. [...] At one point it was such a powerful crushing force that my whole body felt like I had run into a brick wall at full speed, a sensation like I had been decked in the face, except all over my body. [*Salvia divinorum* | κ -opioid dissociative | #42111]

My entire body felt like pins and needles [...]. It felt like I was being put through some kind of machine [...]. My whole body [...] was being forced through a very small space. A steam roller of sorts. [*Salvia divinorum* | κ -opioid dissociative | #112812]

It felt like my body was run over by a steam roller, from the feet up. [*Salvia divinorum* | κ -opioid dissociative | #31688]

Finally, many *Salvia divinorum* reports describe experiences of body metamorphosis. Unlike rare cases of zoophilic metamorphosis described in schizophrenia (Lukianowicz, 1967), *Salvia*-induced metamorphosis generally involves the hallucination that one's body turns into, or merges with, an inanimate object from one's immediate environment (often after feeling physically drawn to it):

My hands blended into the bed as though being melted or fused into one thing. I became the bed, and the bed became me. [*Salvia divinorum* | κ -opioid dissociative | #45765]

I felt a very deep melting sensation. It was as if my legs had instantly become one with the bed, and as such, I was melded in place. I could not move. [*Salvia divinorum* | κ -opioid dissociative | #52823]

My face had merged with the walls in my room, I had become part of the room. [*Salvia divinorum* | κ -opioid dissociative | #40612]

After being pulled for a minute or so, I realized where I was going. Into the couch, of course. It didn't feel like I was glued down, or stuck, or unable to move. It just felt like I'd been pulled so far back into the couch that I was a part of it, we melted together and were seamless in that moment. [*Salvia divinorum* | κ -opioid dissociative | #47541]

It felt like something was pulling hard on my sleeve and left side. Pulling me down into the couch which was now flattening out. I was becoming the couch [...]. [*Salvia divinorum* | κ -opioid dissociative | #31398]

I found myself stumbling through the doorway, & attempting to walk down the stairs. As I left the room, I found that the room & all its contents had attached itself to my body. Each millimeter I would move would distort some other part of my surroundings, & I tried to fix the distortion by moving back, but this would only cause more problems. [...] With great physical effort I left the room, feeling as though I was dragging the entire room with me, attached to my body, stretching like bungy cords. I was the room. [*Salvia divinorum* | κ -opioid dissociative | #51367]

Building upon their analysis of AIWS, which appears to be associated with congruent distortions of the body schema only in some cases, Pitron & de Vignemont (2017) argue that body image and body schema are functionally distinct, yet can interact and reshape each other (see also Pitron, Alsmith, & de Vignemont, 2018). Taken together, drug-induced body image disturbances may provide additional support for that view. Indeed, while a number of subjects explicitly emphasize that the relevant disturbances did not impair their movements, others clearly describe congruent motor impairments. This is consistent with the claim that transient changes in body image may cause transient changes in body schema.

4.4 Vestibular hallucinations

The vestibular system is composed of semicircular canals and otolith organs; the former sense head rotation in three orthogonal planes, while the latter sense linear head acceleration (caused by gravity or self-motion) in three dimensions (Cullen, 2019). It is not only vital to stabilize gaze and posture, but also makes important contributions to the perception of self-motion and spatial orientation (Lenggenhager & Lopez, 2015). Whether there is a distinctive vestibular sense is debated, in part because vestibular signals are deeply integrated with proprioceptive and visual signals in everyday life (Garzorz & Deroy, 2020). Nonetheless, some experiences clearly involve vestibular components, such as sensations of acceleration and dizziness. Furthermore, vestibular disorders can cause a number of anomalous vestibular sensations (Lopez & Elzière, 2018). Some drugs, such as deliriants and depressants, are used to treat vestibular disorders (Soto & Vega, 2010); others, however, can induce vestibular hallucinations, particularly *Salvia divinorum*, dissociative anesthetics, and psychedelics. I will focus on two types of vestibular hallucinations: otolithic vertigo involving the experience of tilting or being pulled by a gravity-like force; and rotatory vertigo involving the experience of spinning.

The room tilt illusion is a transient disorder of the environmental visuospatial perception consisting of rotation of the visual scene by 90° or 180° along the coronal or sagittal plane (Sierra-Hidalgo et al., 2012). Related hallucinations are reported in drug-induced states, involving a 90° or 180° rotation of sensed direction of gravity rather than of the visual scene itself:

I slid off the bed onto my (real) floor and found out that gravity was a really confusing thing. The ceiling and the floor were now the walls in this room, the wall I was looking at was the floor and the other wall was exerting this weird force-field on me, some part of me actually knew it was called gravity but I didn't really care anymore. [LSA | psychedelic | #65209]

This phenomenon can be described as a form of otolithic vertigo, involving a static tilt of vertical point (Brandt, 2001). *Salvia divinorum* commonly induces another form of otolithic vertigo, involving a sensation of linear motion in a given direction, perceived as the pull of an irresistible force similar to

gravity. It can be associated with lateropulsion, or irresistible lateral falls, also observed in patients with acute caudal brainstem lesions, vestibular thalamic lesions, or vestibular cortex lesions (Brandt, 2003). In *Salvia*-induced experiences, these vestibular hallucinations may also involve a tactile component:

It was being pulled, or rather it felt as though there was something on the sides of my head, so I could only move it up and down or backwards and forwards but couldn't turn. [*Salvia divinorum* | κ -opioid dissociative | #10562]

It felt like the whole room was moving. And I was being pulled, not in any particular direction, just being pulled. I could look at the room, and see that nothing was moving, but I could feel it, kinda like riding in a car. [...] My balance was very off. [*Salvia divinorum* | κ -opioid dissociative | #11150]

I felt like a pulling... Like I was being pulled by certain parts of my body, I'd feel it on my legs mostly like a line was wrapped around and being tugged on. [*Salvia divinorum* | κ -opioid dissociative | #55769]

I immediately began to feel as if I was falling. I felt as if hands were on my shoulder pulling me back towards the ground. [*Salvia divinorum* | κ -opioid dissociative | #35395]

Every cell in my body starting with my hands and moving progressively towards my torso and then my hips and then my legs and then finally my head started pulling my down into the seat of the car. [*Salvia divinorum* | κ -opioid dissociative | #55603]

Some psychoactive compounds can also induce rotatory vertigo, characterized by the vestibular sensation of spinning around. Alcohol intoxication is known to cause rotatory vertigo (Fetter, Haslwanter, Bork, & Dichgans, 1999). *Salvia divinorum* does too, with the added complication that subjects often report having trouble disambiguating self-motion from world-motion:

I felt like the world was turning with me. I felt aware of this, as if the gravity of the earth was pushing my back into the ground and turning with me. My head felt as though it were spinning around. [*Salvia divinorum* | κ -opioid dissociative | #15423]

I soon noticed an interesting spinning effect. I was not spinning, but something was spinning through me and everything. [...] The spinning motion I sensed earlier was now all-encompassing. It was like there was a non-material sphere spinning violently. And everything was part of it. [*Salvia divinorum* | κ -opioid dissociative | #81112]

[I] began to feel like I, or everything else, was spinning. [This] feeling became so intense I stood up and started spinning down the hallway... [I] had to hold on to the frame of a door to stop. [*Salvia divinorum* | κ -opioid dissociative | #16539]

4.5 Interoceptive hallucinations

Interoception refers to the perception of the body "from within", including internal signals from the cardiovascular, gastrointestinal, and respiratory systems (Craig, 2002; Seth & Tsakiris, 2018). Interoceptive hallucinations of neurological origin are not very well documented, although they have been reported to occur in paroxysmal neurological disorders such as epilepsy or migraine (Blom & Sommer, 2012). By contrast, many anecdotal reports of drug-induced states describe interoceptive hallucinations:

I felt like my organs inside my body were being subtly pulled and stretched different ways, and it was quite uncomfortable. [*Salvia divinorum* | κ -opioid dissociative | #62637]

I can feel gears moving. My organs spinning around my body. I can feel my blood pumping through my veins. I can feel my heart slipping out from in between my lungs. [LSD | psychedelic | #6828]

I can remember [...] the feeling of a hole being opened up in my head. And a big drill coming down into my head, cleansing the innards of my skull with great force. It felt like a hole being opened up in my head, and somebody or something [...] starting to clean the very innards of my head. [Ayahuasca | psychedelic | #109514]

Thermal sensations are also commonly reported, and do not always match the external temperature or the actual body temperature:

I am shivering now. I feel cold. [...] Oral Temperature: 98.2 degrees F. The body's a weird thing. I feel freezing. [DPT | psychedelic | #9656]

Out in the street, I felt unusually warm and content despite the literally freezing temperatures at the time. [2C-T-7 | psychedelic | #5788]

5 Bodily deficits

Aside from distorting bodily experience and producing bodily hallucinations in the absence of sensory input, psychoactive compounds can also inhibit various aspects of ordinary bodily experience. In this section, I will review four types of bodily deficits: deficits related to touch, proprioception, or body image; deficits of motor control and agency; loss of the sense of bodily ownership; and complete loss of bodily awareness.

5.1 Tactile, proprioceptive, and body image deficits

Ordinary bodily sensations carry two kinds of spatial content, respectively conveying information about (a) the body part in which the sensation occurs, independently of posture; and (b) its posture-dependent location relative to the trunk (Bermúdez, 2005 calls the former A-location, and the latter B-location). In some drug-induced states, tactile sensations can lack either kind of spatial content, such that it becomes difficult to determine from touch alone in which body part, or at which posture-relative location, the sensation occurs:

I could feel pressure from parts of my body against the chair: heel, heel, knee, knee, elbow, elbow, but I could not discern which sensation was coming from which body part. I brought my hands together and interlocked my fingers. I could feel a sensation from each hand, but I couldn't tell which sensation was coming from which hand, and I couldn't tell they were touching each other. [α MT | empathogen | #67674]

I couldn't tell which hand I had things in unless I looked at my hands. [5-MeO- α MT | empathogen | #22996]

The feeling of "falling back to my body" was extremely strange. All my sensations had no location attached to them. [Psilocybin | psychedelic | #113995]

I would press my fingers into the desk, and I perceived the resistance between my fingers and the desk as something that wasn't happening in Euclidean space. It had no location.

It was just a feeling. There was no direction, no distance, nothing, just the sensation of pressure. [Psilocybin | psychedelic | #92246]

Some of these reports are reminiscent of autotopagnosia, a disorder characterized by the inability to localize body parts or identify one's posture (Schwoebel, Coslett, & Buxbaum, 2001). Similarly, *Salvia divinorum* frequently disrupts the perception of limb position, such that subjects can no longer determine their posture from proprioception:

I can't tell if I'm standing or sitting or laying down. [...] I know I have an arm, I just don't know if it's to my left, right, above, below, in front, or behind me. It's 'there' but I can't tell where it attaches to my body. [*Salvia divinorum* | κ -opioid dissociative | #31488]

When I got into a sitting position, I was unsure if I was in a sitting or laying down position, so uncertain was I that I repeatedly had to ask, "Am I sitting up yet or am I laying down?" I could not tell if I was sitting up or lying down [...]. [*Salvia divinorum* | κ -opioid dissociative | #51866]

Self-touch normally involves the so-called "*touchant-touché*" phenomenon, whereby the tactile sensation of the touching limb coincides with the tactile sensation of the touched limb (Merleau-Ponty, 1968; Schütz-Bosbach, Musil, & Haggard, 2009). Interestingly, some drugs can disrupt this phenomenon, inhibiting one or the other tactile sensation during self-touch:

Although I had the sense of touch, my sensation of being touched was not existent anymore! I was touching my arm and although I could feel how my arm feels, I could not feel the touch of my other hand! It was exactly like I was touching a third person! I started experimenting with my head, my lips, my cheeks, my legs and it was all the same! [MDMA | empathogen | #105895]

When I ran my fingers across my stomach, or knees, or face, what I felt was utter alienness, something entirely new. That feeling you get; that link between your nerves in your fingers and whatever part of you you're touching, was completely gone. When I touched my neck, shoulder, or side, I was completely unaware of its connection to the very hand I touched it with, for this I could no longer feel. [psilocybin | psychedelic | #12395]

Finally, dissociative anesthetics like ketamine can also produce body image deficits in which subjects are unable to perceive specific body parts, or lose their sense of bodily boundaries (Millière, 2017):

I felt like parts of my body were missing. My hands seemed to be disconnected from my arms, or I was no longer aware of anything between my hands and shoulders. [Ketamine | dissociative | #78894]

I had no feeling of the boundary of my body, I had no sense of where I was [...]. [Ketamine | dissociative | #77765]

When I had my eyes closed I was unable to determine where my body ended and where the outside universe began [...]. [Ketamine | dissociative | #19628]

5.2 Motor control deficits

Motor deficits are also common with a number of psychoactive compounds, including dissociative anesthetics and psychedelics. These deficits involve various forms of ataxia, or lack of voluntary coordination of muscle movements, including hypermetria (overshoot of the intended position of a limb,

Hore, Wild, & Diener, 1991), and can be associated with a loss of the sense of agency over one's bodily movements (Haggard, 2017):

My motor coordination was shot. It felt as if my mind had actually been removed from my body and put into a new one and I was slowly learning how to walk and control my body. [Dextromethorphan | dissociative | #37045]

I found it very difficult to walk, and my perceptions were getting altered, when I tried to move a limb it was extremely exaggerated. For example, I remember once I was holding a cigarette, and moved my arm to take a drag. I could not judge how much I was moving my arm and I swung the cig into the air and it fell on the ground next to me. When I reached down to pick it up, my hand slammed into the ground. [LSD | psychedelic | #42715]

It felt as though I wasn't really controlling my body movements. [...] Although I had control of my body it felt as though someone else did. [Methoxetamine | dissociative | #94887]

5.3 Loss of bodily ownership

It is widely believed that bodily awareness is intimately tied to a form of self-awareness: in having bodily sensations, we are normally aware of our body not just as any other object in the world, but *as our own* – what has come to be known as the sense of bodily ownership (Frédérique de Vignemont, 2007, forthcoming; Martin, 1995). There is an ongoing debate about whether there is a *distinctive phenomenology* of bodily ownership, whether the sense of ownership can be reduced to spatial, agentic, or affective qualities of bodily sensations, or whether it is simply a matter of doxastic attitudes (Alsmith, 2015; Bermúdez, 2015; Frédérique de Vignemont, 2013, 2018; Gallagher, 2017). Proponents of the existence of a phenomenology of bodily ownership rely on arguments from phenomenal contrast, comparing ordinary bodily experience to conditions in which the sense of ownership is allegedly missing (Frédérique de Vignemont, 2020b). However, such arguments mostly focus on pathological conditions, such as somatoparaphrenia and depersonalization. Once again, broadening the focus of this discussion to drug-induced states might prove illuminating.

Many reports concerning psychedelics, dissociative anesthetic, and *Salvia divinorum* describe the experience of feeling as if one's body or body parts were no longer one's own:

I look at my arm, and I feel it's not part of "myself." I attempt to pull my skin off, but not in a deliberately hard or violent way. [...] As I tugged on my skin, I did feel [a] sensation, yet I still felt that it wasn't "me." Me was lost. [LSD | psychedelic | #97287]

I run my hands over my body and both my hands and body parts feel weird, and disconnected – they do not feel like me. [Ketamine | dissociative | #14967]

I was aware of 'my' body, but in a different way [...]. It was something like my 'I' was floating in the body, seeing through the eyes in that unusual way... but there wasn't the normal sense of being the body. [*Salvia divinorum* | κ -opioid dissociative | #2160]

I looked down at my feet stretched out in front of me, and suddenly, I could not tell if my feet were indeed my feet or if they were my hands. I kept asking, "Are those my arms?" I was completely confused over what were my arms and what were my legs. [...] Then, I became confused over the legs sprawled out in front of me (my own legs), and kept asking things like "Whose legs are those?", "Are those my legs?" "Are those my legs or my

arms?” I then began slapping my foot and asking, “Whose foot is that? Why is that hand slapping that foot?” [*Salvia divinorum* | κ -opioid dissociative | #51866]

As with pathological conditions, there is room for disagreement on the interpretation of the experiences described in these and other similar reports. Instead of lacking the phenomenology of bodily ownership that allegedly pervades ordinary bodily experience, they might lack some other feature; or they might involve an *additional* anomalous sensation of alienation towards one’s body. In any case, reports of drug-induced bodily disownership deserve careful consideration in debates about the sense of bodily ownership.⁵

5.4 Loss of bodily awareness

The most extreme bodily deficit that can be induced by psychoactive compounds is none other than the complete cessation of bodily experience. This phenomenon has been reported after administration of various compounds (Millière, Carhart-Harris, Roseman, Trautwein, & Berkovich-Ohana, 2018), including 5-MeO-DMT (Millière, 2020), and DMT in a controlled setting (Timmermann et al., 2019). Anecdotal reports of cessation of bodily awareness abound:

I couldn’t feel my body but I could still technically ‘see’ and had a field of vision. I wasn’t exactly physically high since I had no physical body, my consciousness was condensed to my field of vision [...]. [DMT | psychedelic | #92052]

I completely forgot I had a body. [Later] I could suddenly feel sensation coming back into my arms. Around this time my brain goes “Holy shit! How could you forget you belong to a body?” My arms started grasping at my legs that I still couldn’t feel but I knew they were there because my arms could feel them. Over the next minute sensation came back to the rest of my body and I realized for the first time that my eyes were shut. Before now, it was like I had no eyes. [DMT | psychedelic | #112599]

I could not feel my body, and with my eyes closed I was no longer aware of my body or my room or the bed I was on [...]. Only when I opened my eyes could I see how contorted my body was, I was in a very uncomfortable position with my arms both behind my back and head, on my side, but I simply couldn’t feel any of that and barely had the ability to move myself. [4-AcO-DMT | psychedelic | #110557]

I had no sense of a physical presence at this point. I couldn’t see or even feel my body. I didn’t even know I had a body. [*Salvia divinorum* | κ -opioid dissociative | #57217]

I didn’t feel myself breathing. I couldn’t feel my body – I didn’t have a body. [Dextromorphan | dissociative | #109773]

Drug-induced cessation of bodily awareness is a counter-example to the claim that bodily awareness is a ubiquitous feature of conscious experience (Gurwitsch, 1953/2010, p. 515; James, 1890, p. 242). This claim is also undermined by the occurrence of dreams that completely lack bodily sensations or the representation of a dream body (Cicogna & Bosinelli, 2001; LaBerge & DeGracia, 2000; Occhionero & Cicogna, 2011); however, reports of drug-induced cases can be richer in detail and thus potentially more compelling.

⁵See Millière (forthcoming) for a more in-depth discussion of drug-induced bodily disownership.

6 Conclusion

Drug-induced alterations of bodily awareness are remarkably diverse across the pharmacological spectrum of psychoactive compounds. Some molecules, such as Salvinorin A, cause unique bodily effects that have not been well-documented thus far. A number of drug-induced bodily experiences, hallucinations, and deficits are particularly relevant to ongoing discussions in philosophy and cognitive science, including issues regarding the nature of pain, the relationship between body image and body schema, and the existence of a phenomenology of bodily ownership. Further investigation of the bodily effects and underlying mechanisms of various psychoactive molecules has the potential to improve our understanding of various features of bodily experience, as well as our cognitive ontology of bodily representations. Future research could test hypotheses prompted by quantitative and qualitative analysis of anecdotal reports in controlled laboratory studies.⁶

References

- Addy, P. H., Garcia-Romeu, A., Metzger, M., & Wade, J. (2015). The subjective experience of acute, experimentally-induced *Salvia divinorum* inebriation. *Journal of Psychopharmacology*, 29(4), 426–435. <https://doi.org/10.1177/0269881115570081>
- Ali, T., & Darbe, S. (2019). Tactile Hallucinations in a Patient with Alzheimer's Disease. *Psychiatric Annals*, 49(4), 182–184. <https://doi.org/10.3928/00485713-20190312-03>
- Alsmith, A. (2015). Mental Activity and the Sense of Ownership. *Review of Philosophy and Psychology*, 6(4), 881–896. <https://doi.org/10.1007/s13164-014-0208-1>
- Armstrong, D. M. (1962). *Bodily Sensations*. London and New York: Routledge.
- Baylen, C. A., & Rosenberg, H. (2006). A review of the acute subjective effects of MDMA/ecstasy. *Addiction (Abingdon, England)*, 101(7), 933–947. <https://doi.org/10.1111/j.1360-0443.2006.01423.x>
- Bayne, T., & Carter, O. (2018). Dimensions of consciousness and the psychedelic state. *Neuroscience of Consciousness*, 2018(1). <https://doi.org/10.1093/nc/niy008>
- Benyamin, R., Trescot, A. M., Datta, S., Buenaventura, R., Adlaka, R., Sehgal, N., ... Vallejo, R. (2008). **Opioid complications and side effects**. *Pain Physician*, 11(2 Suppl), S105–120.
- Bermúdez, J. L. (2005). The Phenomenology of Bodily Awareness. In D. W. Smith & A. L. Thomasson (Eds.), *Phenomenology and Philosophy of Mind*. Oxford: Clarendon Press.
- Bermúdez, J. L. (2015). Bodily ownership, bodily awareness and knowledge without observation. *Analysis*, 75(1), 37–45. <https://doi.org/10.1093/analys/anu119>
- Berthier, M., Starkstein, S., & Leiguarda, R. (1988). Asymbolia for pain: A sensory-limbic disconnection syndrome. *Annals of Neurology*, 24(1), 41–49. <https://doi.org/10.1002/ana.410240109>
- Bieber, C. M., Fernandez, K., Borsook, D., Brennan, M. J., Butler, S. F., Jamison, R., ... Katz, N. P. (2008). Retrospective accounts of initial subjective effects of opioids in patients treated for pain who do or do not develop opioid addiction: A pilot case-control study. *Experimental and Clinical Psychopharmacology*, 16(5), 429–434. <https://doi.org/10.1037/1064-1297.16.5.429>
- Blom, J. D. (2016). Alice in Wonderland syndrome: A systematic review. *Neurology: Clinical Practice*, 6(3), 259–270. <https://doi.org/10.1212/CPJ.0000000000000251>
- Blom, J. D., & Sommer, I. E. C. (2012). Hallucinations of Bodily Sensation. In J. D. Blom & I. E. C. Sommer (Eds.), *Hallucinations: Research and Practice* (pp. 157–169). New York, NY: Springer. https://doi.org/10.1007/978-1-4614-0959-5_13
- Botvinick, M., & Cohen, J. (1998). Rubber hands “feel” touch that eyes see. *Nature*, 391(6669), 756–756. <https://doi.org/10.1038/35784>

⁶I am grateful to Stephen Gadsby, Jasmine Ho, and two anonymous referees for their comments on this chapter.

- Bowman, R. S., Angeli, G., Potts, C., & Manning, C. D. (2015). A large annotated corpus for learning natural language inference. *Proceedings of the 2015 Conference on Empirical Methods in Natural Language Processing (EMNLP)*. Association for Computational Linguistics.
- Brandt, T. (2001). Otolithic vertigo. *Advances in Oto-Rhino-Laryngology*, 58, 34–47. <https://doi.org/10.1159/000059110>
- Brandt, T. (2003). *Vertigo: Its Multisensory Syndromes* (Second edition). New York: Springer-Verlag. <https://doi.org/10.1007/978-1-4757-3801-8>
- Butelman, E. R., & Kreek, M. J. (2016). The Widely Available Hallucinogenic Plant *Salvia divinorum* and Its Main Component, Salvinorin A: A Unique κ -Opioid Receptor (KOP-r) Agonist with Powerful Behavioral and Neurobiological Effects. In V. R. Preedy (Ed.), *Neuropathology of Drug Addictions and Substance Misuse* (pp. 739–746). San Diego: Academic Press. <https://doi.org/10.1016/B978-0-12-800212-4.00069-8>
- Cash, T. F., & Brown, T. A. (1987). Body Image in Anorexia Nervosa and Bulimia Nervosa: A Review of the Literature. *Behavior Modification*, 11(4), 487–521. <https://doi.org/10.1177/01454455870114005>
- Cicogna, P., & Bosinelli, M. (2001). Consciousness during Dreams. *Consciousness and Cognition*, 10(1), 26–41. <https://doi.org/10.1006/ccog.2000.0471>
- Comer, S. M., & Zacny, J. P. (2005). Subjective effects of opioids. In M. Earleywine (Ed.), *Mind-altering drugs: The science of subjective experience* (pp. 217–239). Oxford: Oxford University Press.
- Craig, A. D. (2002). How do you feel? Interoception: The sense of the physiological condition of the body. *Nature Reviews Neuroscience*, 3(8), 655–666. <https://doi.org/10.1038/nrn894>
- Craig, A. D., Reiman, E. M., Evans, A., & Bushnell, M. C. (1996). Functional imaging of an illusion of pain. *Nature*, 384(6606), 258–260. <https://doi.org/10.1038/384258a0>
- Critchley, M. (1965). Disorders of corporeal awareness in parietal disease. In S. Wapner & H. Werner (Eds.), *The Body Percept* (pp. 68–81). New York: Random House.
- Cruikshank, C. C., & Dyer, K. R. (2009). A review of the clinical pharmacology of methamphetamine. *Addiction*, 104(7), 1085–1099. <https://doi.org/10.1111/j.1360-0443.2009.02564.x>
- Cullen, K. E. (2019). Vestibular processing during natural self-motion: Implications for perception and action. *Nature Reviews Neuroscience*, 20(6), 346–363. <https://doi.org/10.1038/s41583-019-0153-1>
- de Vignemont, Frédérique. (2007). Habeas Corpus: The Sense of Ownership of One's Own Body. *Mind & Language*, 22(4), 427–449. <https://doi.org/10.1111/j.1468-0017.2007.00315.x>
- de Vignemont, Frederique. (2010). Body schema and body image—Pros and cons. *Neuropsychologia*, 48(3), 669–680. <https://doi.org/10.1016/j.neuropsychologia.2009.09.022>
- de Vignemont, Frédérique. (2013). The mark of bodily ownership. *Analysis*, 73(4), 643–651. <https://doi.org/10.1093/analys/ant080>
- de Vignemont, Frédérique. (2018). *Mind the Body: An Exploration of Bodily Self-Awareness*. Oxford: Oxford University Press.
- de Vignemont, Frédérique. (2019). Mind the body (4) What kind of first-personal content? In *The Brains Blog*. Retrieved from <http://philosophyofbrains.com/2019/02/28/mind-the-body-4-what-kind-of-first-personal-content.aspx>
- de Vignemont, Frédérique. (2020a). Bodily awareness. In E. N. Zalta (Ed.), *The Stanford encyclopedia of philosophy* (Fall 2020). Metaphysics Research Lab, Stanford University.
- de Vignemont, Frédérique. (2020b). What Phenomenal Contrast for Bodily Ownership? *Journal of the American Philosophical Association*, 6(1), 117–137. <https://doi.org/10.1017/apa.2019.34>
- de Vignemont, Frédérique. (forthcoming). The phenomenology of bodily ownership. In M. Garcia-Carpintero & M. Guillot (Eds.), *The sense of mineness*. Oxford: Oxford University Press.
- Dijkerman, H. C., & de Haan, E. H. F. (2007). Somatosensory processes subserving perception and

- action. *The Behavioral and Brain Sciences*, 30(2), 189-201; discussion 201-239. <https://doi.org/10.1017/S0140525X07001392>
- Fetter, M., Haslwanter, T., Bork, M., & Dichgans, J. (1999). New insights into positional alcohol nystagmus using three-dimensional eye-movement analysis. *Annals of Neurology*, 45(2), 216–223. [https://doi.org/10.1002/1531-8249\(199902\)45:2%3C216::AID-ANA12%3E3.0.CO;2-F](https://doi.org/10.1002/1531-8249(199902)45:2%3C216::AID-ANA12%3E3.0.CO;2-F)
- Fisher, A. H., & Stanciu, C. N. (2017). Amphetamine-Induced Delusional Infestation. *American Journal of Psychiatry Residents' Journal*, 12(12), 12–13. <https://doi.org/10.1176/appi.ajp-rj.2017.121204>
- Foldi, C. J., Likhaitzky, P., Williams, M., & Oldfield, B. J. (2020). Rethinking Therapeutic Strategies for Anorexia Nervosa: Insights From Psychedelic Medicine and Animal Models. *Frontiers in Neuroscience*, 14. <https://doi.org/10.3389/fnins.2020.00043>
- Fortier-Davy, M., & Millière, R. (2020). The multi-dimensional approach to drug-induced states: A commentary on Bayne and Carter's "dimensions of consciousness and the psychedelic state." *Neuroscience of Consciousness*, 2020(1). <https://doi.org/10.1093/nc/niaa004>
- Funakawa, I., & Jinnai, K. (2005). Tactile hallucinations induced by trihexyphenidyl in a patient with Parkinson's disease. *Rinsho Shinkeigaku = Clinical Neurology*, 45(2), 125–127.
- Gallagher, S. (2017). Self-defense: Deflecting Deflationary and Eliminativist Critiques of the Sense of Ownership. *Frontiers in Psychology*, 8. <https://doi.org/10.3389/fpsyg.2017.01612>
- Garzorz, I., & Deroy, O. (2020). Why There Is a Vestibular Sense, or How Metacognition Individuates the Senses. *Multisensory Research*, -1(aop), 1–20. <https://doi.org/10.1163/22134808-bja10026>
- Gengo, F., Gabos, C., & Miller, J. K. (1989). The pharmacodynamics of diphenhydramine-induced drowsiness and changes in mental performance. *Clinical Pharmacology & Therapeutics*, 45(1), 15–21. <https://doi.org/10.1038/clpt.1989.3>
- González, J. C. (2010). On pink elephants, floating daggers, and other philosophical myths. *Phenomenology and the Cognitive Sciences*, 9(2), 193–211. <https://doi.org/10.1007/s11097-010-9164-0>
- Grahek, N. (2007). *Feeling pain and being in pain* (Second edition). Cambridge, MA: MIT Press.
- Greenblatt, D. J. (1992). Pharmacology of benzodiazepine hypnotics. *The Journal of Clinical Psychiatry*, 53 Suppl, 7–13.
- Gurwitsch, A. (2010). *The field of consciousness: Phenomenology of theme, thematic field, and marginal consciousness* (R. M. Zaner & L. E. Embree, Eds.). Dordrecht ; New York: Springer. (Original work published 1953)
- Haggard, P. (2017). Sense of agency in the human brain. *Nature Reviews Neuroscience*, 18(4), 196. <https://doi.org/10.1038/nrn.2017.14>
- Hendler, R. A., Ramchandani, V. A., Gilman, J., & Hommer, D. W. (2013). Stimulant and sedative effects of alcohol. *Current Topics in Behavioral Neurosciences*, 13, 489–509. https://doi.org/10.1007/7854_2011_135
- Ho, J. T., Preller, K. H., & Lenggenger, B. (2020). Neuropharmacological modulation of the aberrant bodily self through psychedelics. *Neuroscience & Biobehavioral Reviews*, 108, 526–541. <https://doi.org/10.1016/j.neubiorev.2019.12.006>
- Hore, J., Wild, B., & Diener, H. C. (1991). Cerebellar dysmetria at the elbow, wrist, and fingers. *Journal of Neurophysiology*, 65(3), 563–571. <https://doi.org/10.1152/jn.1991.65.3.563>
- Hutmacher, F. (2019). Why Is There So Much More Research on Vision Than on Any Other Sensory Modality? *Frontiers in Psychology*, 10. <https://doi.org/10.3389/fpsyg.2019.02246>
- Iversen, L., White, M., & Treble, R. (2014). Designer psychostimulants: Pharmacology and differences. *Neuropharmacology*, 87, 59–65. <https://doi.org/10.1016/j.neuropharm.2014.01.015>
- James, W. (1890). *The principles of psychology*. New York: Henry Holt and Company.
- Kataoka, H., & Ueno, S. (2017). A review of tactile hallucinations in Parkinsons disease. *Neuropsychy-*

- chiatry, 7(3), 224–227. <https://doi.org/10.4172/Neuropsychiatry.1000202>
- Keats, A. S., & Beecher, H. K. (1950). Pain Relief with Hypnotic Doses of Barbiturates and a Hypothesis. *Journal of Pharmacology and Experimental Therapeutics*, 100(1), 1–13.
- Klein, C. (2015). What Pain Asymbolia Really Shows. *Mind*, 124(494), 493–516. <https://doi.org/10.1093/mind/fzu185>
- LaBerge, S., & DeGracia, D. J. (2000). Varieties of lucid dreaming experience. In *Advances in Consciousness Research. Individual differences in conscious experience* (pp. 269–307). Amsterdam, Netherlands: John Benjamins Publishing Company. <https://doi.org/10.1075/aicr.20.14lab>
- Lawrence, D. W., Sharma, B., Griffiths, R. R., & Carhart-Harris, R. (2021). Trends in the Top-Cited Articles on Classic Psychedelics. *Journal of Psychoactive Drugs*, 0(0), 1–16. <https://doi.org/10.1080/02791072.2021.1874573>
- Lenggenhager, B., & Lopez, C. (2015). Vestibular Contributions to the Sense of Body, Self, and Others. In T. K. Metzinger & J. M. Windt (Eds.), *Open MIND*. Frankfurt am Main: MIND Group. <https://doi.org/10.15502/9783958570023>
- Lim, D. K. (2003). Ketamine associated psychedelic effects and dependence. *Singapore Medical Journal*, 44(1), 31–34.
- Lippman, C. W. (1952). Certain hallucinations peculiar to migraine. *The Journal of Nervous and Mental Disease*, 116(4), 346–351.
- Liu, Y., Ott, M., Goyal, N., Du, J., Joshi, M., Chen, D., ... Stoyanov, V. (2019). RoBERTa: A Robustly Optimized BERT Pretraining Approach. *arXiv:1907.11692 [Cs]*. Retrieved from <https://arxiv.org/abs/1907.11692>
- Lopez, C., & Elzière, M. (2018). Out-of-body experience in vestibular disorders – A prospective study of 210 patients with dizziness. *Cortex*, 104, 193–206. <https://doi.org/10.1016/j.cortex.2017.05.026>
- Lukianowicz, N. (1967). “Body Image” Disturbances in Psychiatric Disorders. *The British Journal of Psychiatry*, 113(494), 31–47. <https://doi.org/10.1192/bjp.113.494.31>
- Maqueda, A. E. (2021). Salvia divinorum. In C. S. Grob & J. Grigsby (Eds.), *Handbook of Medical Hallucinogens* (pp. 313–326). New York, NY: The Guilford Press.
- Maqueda, A. E., Valle, M., Addy, P. H., Antonijoan, R. M., Puntos, M., Coimbra, J., ... Riba, J. (2015). Salvinorin-A Induces Intense Dissociative Effects, Blocking External Sensory Perception and Modulating Interoception and Sense of Body Ownership in Humans. *International Journal of Neuropsychopharmacology*, 18(12). <https://doi.org/10.1093/ijnp/pyv065>
- Martin, M. G. F. (1995). Bodily Awareness: A Sense of Ownership. In J. L. Bermudez, A. J. Marcel, & N. M. Eilan (Eds.), *The Body and the Self* (pp. 267–289). Cambridge, MA: MIT Press.
- McGeoch, P. D., Brang, D., Song, T., Lee, R. R., Huang, M., & Ramachandran, V. S. (2011). Xenomelia: A new right parietal lobe syndrome. *Journal of Neurology, Neurosurgery & Psychiatry*, 82(12), 1314–1319. <https://doi.org/10.1136/jnnp-2011-300224>
- Medical Writers, A. (2017). Medications that affect CNS neurotransmitter levels may induce tactile hallucinations. *Drugs & Therapy Perspectives*, 33(6), 279–282. <https://doi.org/10.1007/s40267-017-0394-x>
- Merleau-Ponty, M. (1968). *The Visible and the Invisible*. Northwestern University Press.
- Millière, R. (2017). Looking For The Self: Phenomenology, Neurophysiology and Philosophical Significance of Drug-induced Ego Dissolution. *Frontiers in Human Neuroscience*, 11(245), 1–22. <https://doi.org/10.3389/fnhum.2017.00245>
- Millière, R. (2020). The varieties of selflessness. *Philosophy and the Mind Sciences*, 1(1), 8. <https://doi.org/10.33735/phimisci.2020.I.48>
- Millière, R. (forthcoming). Drug-induced bodily disownership. In C. Letheby & P. Gerrans (Eds.), *Philosophical perspectives on the psychedelic renaissance*. Oxford: Oxford University Press.
- Millière, R., Carhart-Harris, R. L., Roseman, L., Trautwein, F.-M., & Berkovich-Ohana, A. (2018).

- Psychedelics, Meditation and Self-Consciousness. *Frontiers in Psychology*, 9(1475), 1–29. <https://doi.org/10.3389/fpsyg.2018.01475>
- Nair, N., Tee Chun Keat, Devadas, S., Choo Shell Pinn, Rahaiza, E., & Kaur, B. (2016). An Intriguing Case of Heroin Induced Delusion of Parasitosis. *ASEAN Journal of Psychiatry*, 17(1), 116–119.
- Nakamura, M., & Koo, J. (2016). Drug-Induced Tactile Hallucinations Beyond Recreational Drugs. *American Journal of Clinical Dermatology*, 17(6), 643–652. <https://doi.org/10.1007/s40257-016-0219-z>
- Nichols, D. E., Johnson, M. W., & Nichols, C. D. (2017). Psychedelics as Medicines: An Emerging New Paradigm. *Clinical Pharmacology and Therapeutics*, 101(2), 209–219. <https://doi.org/10.1002/cpt.557>
- Occhionero, M., & Cicogna, P. C. (2011). Autoscopical phenomena and one's own body representation in dreams. *Consciousness and Cognition*, 20(4), 1009–1015. <https://doi.org/10.1016/j.concog.2011.01.004>
- Orsolini, L., Gentilotti, A., Giordani, M., & Volpe, U. (2020). Historical and clinical considerations on Ekblom's syndrome. *International Review of Psychiatry*, 32(5-6), 424–436. <https://doi.org/10.1080/09540261.2020.1757306>
- Paillard, J. (1999). Body Schema and body image—a double dissociation. In G. N. Gantchev, S. Mori, & J. Massion (Eds.), *Motor control, today and tomorrow* (pp. 197–214). Sofia: Professor Marius Drinov Academic Publishing House.
- Panenka, W. J., Procyshyn, R. M., Lecomte, T., MacEwan, G. W., Flynn, S. W., Honer, W. G., & Barr, A. M. (2013). Methamphetamine use: A comprehensive review of molecular, preclinical and clinical findings. *Drug and Alcohol Dependence*, 129(3), 167–179. <https://doi.org/10.1016/j.drugalcdep.2012.11.016>
- Park, T. (2019). On the alleged evidence for non-unpleasant pains. *Inquiry*, 0(0), 1–19. <https://doi.org/10.1080/0020174X.2019.1658625>
- Pfeifer, L. (1970). A subjective report of tactile hallucinations in schizophrenia. *Journal of Clinical Psychology*, 26(1), 57–60. [https://doi.org/10.1002/1097-4679\(197001\)26:1%3C57::AID-JCLP2270260113%3E3.0.CO;2-5](https://doi.org/10.1002/1097-4679(197001)26:1%3C57::AID-JCLP2270260113%3E3.0.CO;2-5)
- Pitron, V., Alsmith, A., & de Vignemont, F. (2018). How do the body schema and the body image interact? *Consciousness and Cognition*, 65, 352–358. <https://doi.org/10.1016/j.concog.2018.08.007>
- Pitron, V., & de Vignemont, F. (2017). Beyond differences between the body schema and the body image: Insights from body hallucinations. *Consciousness and Cognition*, 53, 115–121. <https://doi.org/10.1016/j.concog.2017.06.006>
- Podoll, K., & Robinson, D. (2002). Splitting of the Body Image as Somesthetic Aura Symptom in Migraine. *Cephalalgia*, 22(1), 62–65. <https://doi.org/10.1046/j.1468-2982.2002.00316.x>
- Rashid, J., & Mitelman, S. (2007). Methylphenidate and somatic hallucinations. *Journal of the American Academy of Child and Adolescent Psychiatry*, 46(8), 945–946. <https://doi.org/10.1097/CHI.0b013e318067fd7c>
- Reimers, N., & Gurevych, I. (2019). Sentence-BERT: Sentence Embeddings using Siamese BERT-Networks. *Proceedings of the 2019 Conference on Empirical Methods in Natural Language Processing and the 9th International Joint Conference on Natural Language Processing (EMNLP-IJCNLP)*, 3982–3992. Hong Kong, China: Association for Computational Linguistics. <https://doi.org/10.18653/v1/D19-1410>
- Roncero, C., Grau-López, L., Palma-Álvarez, R. F., Rodríguez-Cintas, L., Ros-Cucurull, E., Esojo, A., & Daigre, C. (2017). Higher severity of cocaine addiction is associated with tactile and somatic hallucinations. *European Psychiatry: The Journal of the Association of European Psychiatrists*, 42, 63–69. <https://doi.org/10.1016/j.eurpsy.2016.11.006>

- Sarff, M., & Gold, J. A. (2010). Alcohol withdrawal syndromes in the intensive care unit. *Critical Care Medicine*, 38(9 Suppl), S494–501. <https://doi.org/10.1097/CCM.0b013e3181ec5412>
- Schütz-Bosbach, S., Musil, J. J., & Haggard, P. (2009). Touchant-touché: The role of self-touch in the representation of body structure. *Consciousness and Cognition*, 18(1), 2–11. <https://doi.org/10.1016/j.concog.2008.08.003>
- Schwoebel, J., Coslett, H. B., & Buxbaum, L. J. (2001). Compensatory coding of body part location in autotopagnosia: Evidence for extrinsic egocentric coding. *Cognitive Neuropsychology*, 18(4), 363–381. <https://doi.org/10.1080/02643290126218>
- Seth, A. K., & Tsakiris, M. (2018). Being a Beast Machine: The Somatic Basis of Selfhood. *Trends in Cognitive Sciences*, 22(11), 969–981. <https://doi.org/10.1016/j.tics.2018.08.008>
- Sierra-Hidalgo, F., de Pablo-Fernández, E., Herrero-San Martín, A., Correas-Callero, E., Herreros-Rodríguez, J., Romero-Muñoz, J. P., & Martín-Gil, L. (2012). Clinical and imaging features of the room tilt illusion. *Journal of Neurology*, 259(12), 2555–2564. <https://doi.org/10.1007/s00415-012-6536-0>
- Sofuoglu, M., DeVito, E. E., & Kosten, T. R. (2021). Neurobiology of Stimulants. In K. T. Brady, F. R. Levin, M. Galanter, & H. D. Kleber (Eds.), *The American Psychiatric Association Publishing Textbook of Substance Use Disorder Treatment* (Sixth edition). Washington, DC: American Psychiatric Association Publishing.
- Soto, E., & Vega, R. (2010). Neuropharmacology of Vestibular System Disorders. *Current Neuropharmacology*, 8(1), 26–40. <https://doi.org/10.2174/157015910790909511>
- Stevenson, R., & Tuddenham, L. (2014). Novel psychoactive substance intoxication resulting in attempted murder. *Journal of Forensic and Legal Medicine*, 25, 60–61. <https://doi.org/10.1016/j.jflm.2014.04.007>
- Timmermann, C., Roseman, L., Schartner, M., Milliere, R., Williams, L. T. J., Erritzoe, D., ... Carhart-Harris, R. L. (2019). Neural correlates of the DMT experience assessed with multivariate EEG. *Scientific Reports*, 9(1), 1–13. <https://doi.org/10.1038/s41598-019-51974-4>
- Ukai, K. (2019). Tactile hallucinations in dementia with Lewy bodies. *Psychogeriatrics*, 19(5), 435–439. <https://doi.org/10.1111/psyg.12407>
- Vallar, G., & Ronchi, R. (2009). Somatoparaphrenia: A body delusion. A review of the neuropsychological literature. *Experimental Brain Research*, 192(3), 533–551. <https://doi.org/10.1007/s00221-008-1562-y>
- Vari, M. R., Pichini, S., Giorgetti, R., & Busardò, F. P. (2019). New psychoactive substances—Synthetic stimulants. *WIREs Forensic Science*, 1(2), e1197. <https://doi.org/10.1002/wfs2.1197>
- Williams, A., Nangia, N., & Bowman, S. (2018). A broad-coverage challenge corpus for sentence understanding through inference. *Proceedings of the 2018 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, Volume 1 (Long Papers)*, 1112–1122. New Orleans, Louisiana: Association for Computational Linguistics.