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EDITED BY
Antonio Mattia Grande,
Polytechnic University of Milan, Italy

REVIEWED BY
Lachlan Kent,
RMIT University, Australia
Mark Harvey,
University of North Carolina at Asheville, United States

*CORRESPONDENCE
Elisa Raffaella Ferré,
elisa.ferre@bbk.ac.uk

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Gravity shapes the self: experimental evidence from simulated weightlessness

Maryam Haq[1], Héléne Grandchamp Des Raux[1], Emily Canella Perry[2], Isabel Risco Narvaez[1], Milena Da Silva Baiao[1], Maria Gallagher[2] and Elisa Raffaella Ferré[1]*

[1]School of Psychological Sciences, Birkbeck, University of London, London, United Kingdom, [2]School of Psychology, University of Kent, Canterbury, United Kingdom

Gravity is a constant of life on Earth, yet its role in shaping the sense of self remains poorly understood. Here, we tested the hypothesis that bodily self-consciousness depends on the continuous alignment between vestibular signals and an internal model of gravity. Using the European Space Agency (ESA)'s frictionless air-bearing platform, we simulated weightlessness in healthy participants. Depersonalisation, characterised by a sense of detachment from one's body or self, was assessed before and after exposure using the Cambridge Depersonalisation Scale. Results revealed a significant increase in depersonalisation scores following simulated weightlessness, indicating that even brief disruption of vestibular-gravity signals alter the sense of self. These findings provide the first experimental evidence linking altered gravity conditions to depersonalisation in healthy individuals. We propose that gravity acts as a strong prior constraining multisensory integration and anchoring bodily self-consciousness. When this prior is violated, sensory conflict emerges, leading to altered self-consciousness. Neuroanatomical overlap between vestibular and self-processing networks further supports this mechanism. Our results demonstrate that gravity is not merely a physical constraint, but a fundamental determinant of conscious experience.

KEYWORDS
depersonalisation, gravity, multisensory integration, self-consciousness, simulated weightlessness, vestibular system

Introduction

"Up there you feel weightless . . . yet somehow bodiless" observed Edgar Mitchell during his time in space (Mitchell, 2011). Accounts like this highlight a striking but poorly understood consequence of spaceflight: disruption of the normally stable experience of the self as an embodied, spatially located individual. The sense of self is not a unitary construct, but encompasses multiple interacting dimensions, including the experience of owning one's body, being located within it, acting through it, and experiencing the world from a first-person perspective (Blanke, 2012). These aspects of self-consciousness emerge from the continuous integration of visual, vestibular, somatosensory, proprioceptive and interoceptive signals, which together provide the brain with a coherent representation of the body and its relationship to the surrounding environment (Ferré et al., 2014).

Gravity is a fundamental constraint on this experience. On Earth, gravitational acceleration is approximately 9.81 m/s^2 (1 g), providing a highly stable directional constraint on bodily orientation, movement and perception. The brain has therefore evolved within, and is continuously calibrated to, a gravitational environment in which

the direction and magnitude of this force remain remarkably consistent. Across evolution, this unchanging force has shaped how the nervous system encodes the body and the environment, calibrates perception, coordinates movement and sustains a coherent sense of self (Arshad and Ferré, 2023). The vestibular system provides the primary interface with gravity, continuously signalling head motion and orientation through the semicircular canals and otolith organs. These signals are first relayed through the brainstem and thalamic nuclei before being integrated within a distributed cortical network, including the parieto-insular vestibular cortex, temporoparietal junction and somatosensory regions, where they converge with visual, somatosensory and proprioceptive inputs. Within this architecture, gravity is not merely detected but internalised as a predictive model that constrains sensory inference (Lacquaniti et al., 2014). From a Bayesian perspective, gravity functions as a strong prior that shapes the interpretation of incoming sensory signals. The brain combines this prior with sensory evidence from vestibular, visual, somatosensory and proprioceptive systems, weighting each source according to its reliability to generate the most probable estimate of the body's position and orientation in space (Jörges and López-Moliner, 2017). Under normal terrestrial gravitational conditions, this process provides a stable reference against which sensory information is calibrated, supporting a coherent experience of the self.

Spaceflight challenges this fundamental constraint. When gravitational input becomes unreliable, vestibular signals no longer align with their expected meaning, creating a conflict between sensory evidence and internal predictions. Astronauts during spaceflight exhibit several sensorimotor disturbances (Reschke and Clément, 2018), including impairments in spatial orientation (Reschke and Clément, 2018), postural stability (Ozdemir et al., 2018) and both fine and gross motor coordination (Holden et al., 2023; Gaveau et al., 2011). These deficits are accompanied by perceptual distortions, such as misjudgements of distance and verticality (Clément et al., 2013), as well as illusions of self-motion (Kornilova, 1997) and altered body orientation (Clement et al., 1987). Bodily self-consciousness refers to the experience of being an embodied self, encompassing the sense that a body belongs to oneself (body ownership) and that one is spatially located within it (self-location) (Serino et al., 2013). Beyond the aforementioned effects, astronauts frequently report changes in self-consciousness, including feelings of detachment from their body or a sense of observing themselves from the outside (Hoffman, 2009; Mitchell, 2011). Such experiences are characteristic of depersonalisation, a disruption in the normal sense of self in which individuals feel detached or estranged from their body or mental processes (Cahill and Murphy, 2004). Given that a component of bodily self-consciousness is body ownership, Edgar Mitchell's description of feeling "weightless" yet "bodiless" (Mitchell, 2011) provides a striking phenomenological illustration of how altered gravitational conditions may affect the experience of the embodied self (Serino et al., 2013). Crucially, regions such as the temporoparietal junction have been established as dual-role in nature, with associations with both bodily self-consciousness and vestibular processing (Serino et al., 2013; Ferrè et al., 2014). Consequently, in considering gravity as a stable reference frame, the disruption to vestibular-gravitational signals and thereby the resulting impact on the weighting of sensory information is suggested to propagate to representations of the self, influencing bodily self-consciousness. Closely related to depersonalisation is derealisation, in which the external environment is experienced as unreal, distant, or perceptually altered (Hunter et al., 2004). Together, these observations suggest that the brain's internal model of gravity may contribute not only to movement coordination and sensory integration, but also to the maintenance of a stable sense of self. Evidence from patients with peripheral vestibular lesions reinforces this link, demonstrating that disruption of vestibular signalling is associated with depersonalisation and derealisation experiences (Sang et al., 2006).

Here, we investigated whether the sense of self depends on the continuous alignment between vestibular signals and the brain's internal model of gravity. To test this, we simulated weightlessness using the European Space Agency (ESA)'s frictionless air-bearing platform, which enables controlled multi-axis motion to induce a weightless-like sensation. This air-bearing platform is utilised within the ESA Orbital Robotics Laboratory (ORL) on its flat floor enabling an air gap to be maintained within two translational and one rotational dimension. It is these key features which allows its use as an analogue to microgravity environment within the present experiment. Particularly, this simulated weightlessness disrupts incoming vestibular-gravitational signals, similar to spaceflight, resulting in a conflict with internal predictions based in the gravity prior. When considering the Bayesian perspective, this produces a prediction error which must be overcome through updating estimates and reweighting based on sensory evidence. Depersonalisation was measured using the Cambridge Depersonalisation Scale before and after exposure to simulated weightlessness (CDS-S; Michal et al., 2004). By experimentally inducing a mismatch between incoming vestibular-gravity signals and the brain's internalised gravity prior, this study provides evidence that briefly disrupting the normally stable relationship between gravitational expectations and sensory evidence can transiently alter the sense of self. These findings point to a potential mechanistic link between gravity-based predictive processing, vestibular signalling and higher-order self-consciousness.

Methods

Participants

Twenty-two participants (11 females; mean age 27.6 ± 5.05 years, mean ± SD) were recruited on a volunteer basis. The sample had a mean Edinburgh Handedness Inventory score of 68.38 ± 49.55 (Oldfield, 1971). All participants reported no history of psychiatric or neurological disorders. Experimental procedures were approved by the School of Psychological Sciences Research Ethics Committee at Birkbeck, University of London and the ESA Medical Board, and were conducted in accordance with the Declaration of Helsinki.

Experimental Procedure

The ESA Orbital Robotics Laboratory (ORL) was used to simulate weightlessness in human participants. Controlled



FIGURE 1
Experimental setup and results.

simulated weightlessness was achieved using the ORBIT flat floor in combination with the Standing Floating Platform (SFP), enabling human experimentation for the first time. The ORBIT facility (ESTEC, Netherlands) features a 43 m^2 ultra-flat surface with height variations of less than 1 mm (Figure 1). Platforms are mounted on air bearings, generating a stable, frictionless interface that permits motion across the floor without resistance, effectively reproducing two-dimensional free-floating conditions. The SFP extends this functionality to three degrees of freedom, providing frictionless motion in two-dimensional translation and one-dimensional rotation, simulating microgravity relevant for orbital manoeuvring. The platform was adapted for human use with a seat, accommodating participants up to 200 cm in height and 100 kg in weight. The SFP was utilised in its tethered form, enabling for the continuous use of the platform unrestrained by time limits. This tethered form of the SFP also ensured the platform would maintain frictionless movement across the flat floor. Platform kinematics were recorded using a VICON motion capture system. Velocity and acceleration were recorded at a sampling frequency of 100 Hz (sampling interval: 0.01 s). Median acceleration was computed for each participant. Movement velocities did not exceed 10 cm/s as advised by the ESA ORL Team. As such, randomised movement directions and accelerations were guided by the experimenter within this velocity limit. Together, the randomised frictionless movements of the SFP altered the reliability of vestibular signals and reduced the perceived impact of gravity, with participants experiencing simulated weightlessness for 30 min.

Participants were seated on the SFP and instructed to maintain an upright posture throughout the session; a soft chin support was worn around the neck to help stabilise the head in an upright position. To minimise proprioceptive cues, the participants legs were passively floating throughout testing. Visual cues were obscured by a Meta Quest 3 headset worn for the duration of the experiment, which displayed a uniform black background to minimise visual references (Figure 1). Depersonalisation experiences were assessed using the Cambridge Depersonalisation Scale State Version (CDS-S; Michal et al., 2004), a 22-item self-report questionnaire measuring the intensity of depersonalisation and derealisation experiences. Items are rated on a 0%–100% scale, where 0 indicates no experience and 100 indicates maximal intensity. Individual item weightings were summed to produce a total score. Participants completed the CDS-S immediately before and after exposure to the SFP to evaluate the impact of frictionless, weightless-like motion on self-experience. To preserve the immersive nature of the task, communication with participants was minimised and occurred only before and after the simulated weightlessness session. These lab-controlled settings were crucial in enabling the effects of simulated weightlessness to be understood within the context of altered vestibular-gravitational signals.

Participants were seated on the air-bearing Standing Floating Platform (SFP), which incorporates air bearings and a pneumatic system. Friction is minimized by thin air gaps formed between the air bearings and the flat floor, allowing the platform to glide freely and thereby simulate weightlessness. A continuous air supply ensured that this friction reduction was maintained throughout the experiment. Participants sat on the platform wearing a head-mounted display and a soft neck rest, which supported a comfortable upright posture. Results showed a significant increase in total scores on the Cambridge Depersonalisation Scale–State Version (CDS-S; Michal et al., 2004) after exposure to simulated weightlessness via the SFP platform, compared with scores obtained before exposure.

Results

Total CDS-S scores were calculated for each participant before and after exposure to simulated weightlessness via the SFP platform. One participant was excluded as an outlier due to an exceptionally high post-platform score (total score = 1,521). A paired-samples t-test revealed a significant increase in CDS-S scores following exposure to the SFP (mean = 148.95, SD = 199.01) compared to the pre-platform baseline (mean = 69.52, SD = 85.36), $t(20) = -2.596$, $p = 0.017$, Cohen's d = 0.57 (Figure 1). These findings indicate that simulated weightlessness, induced by the SFP's frictionless movements, heightened participants' experience of depersonalisation.

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TABLE 1 Cambridge Depersonalisation Scale state version Items and scores before and after simulated weightlessness exposure.

Item	Before weightlessness mean (SD)	After weightlessness mean (SD)	t-value	p-value	Cohen's d	Bayes factor
1. I'm feeling strange, as if I were not real or as if I were cut off from the world	8.95 (20.51)	13.05 (22.20)	−2.161	0.043	−0.472	1.54
2. Things around me are now looking 'flat' or 'lifeless', as if I were looking at a picture	2.48 (4.37)	5.00 (10.53)	−1.232	0.232	−0.269	0.44
3. I am feeling as if parts of my body don't belong to me	2.57 (3.96)	4.33 (9.59)	−1.029	0.316	−0.225	0.36
4. I'm now having the feeling of being a 'detached observer' of myself	3.43 (6.63)	6.29 (13.54)	−1.392	0.179	−0.304	0.53
5. My body is feeling very light now, as if I were floating on air	4.81 (9.92)	12.43 (19.03)	−1.542	0.139	−0.336	0.63
6. I am not feeling any emotions at all	16.71 (30.28)	9.10 (16.27)	1.009	0.325	0.220	0.36
7. If I read this sentence aloud, my voice sounds remote and unreal	1.38 (3.17)	2.48 (4.71)	−1.255	0.224	−0.274	0.45
8. I am having a feeling of complete emptiness in my head so that I am not having any thoughts at all	6.10 (14.11)	12.86 (23.19)	−1.289	0.212	−0.281	0.47
9. I'm having the feeling that my hands or my feet have become larger or smaller	0.71 (2.41)	7.38 (20.45)	−1.564	0.133	−0.341	0.65
10. My surroundings are feeling detached or unreal, as if there was a veil or a fog between me and the outside world	6.76 (14.19)	11.29 (18.07)	−1.341	0.195	−0.293	0.50
11. It seems now as if things that I have recently done took place a long time ago. For example, anything which I have done this morning feels as if it were done weeks ago	3.14 (6.50)	7.86 (16.60)	−1.677	0.109	−0.366	0.75
12. If I try to remember important events in my life (e.g., graduation, wedding, *etc.*), I feel so detached from the memories that it seems as if I had not been involved in them	2.43 (4.81)	3.86 (9.96)	−1.071	0.297	−0.234	0.38
13. I don't seem to be feeling any affection towards my family or close friends	0.43 (1.33)	3.52 (7.72)	−2.024	0.056	−0.442	1.24
14. Objects around me are looking smaller or further away	1.33 (4.79)	7.90 (22.78)	−1.510	0.147	−0.330	0.61
15. I cannot feel properly the pencil that I have in my hand, as if it were not me who were holding it	0.90 (2.66)	1.76 (4.79)	−0.742	0.467	−0.162	0.29
16. If I now try to imagine the face of a relative or friend whom I frequently see (but who is not with me at the present), I do not seem able to picture it in my mind	1.00 (2.98)	2.33 (8.11)	−1.102	0.283	−0.241	0.39
17. If I pinch myself in my own arm now, I feel so detached from the pain that it feels as if it were 'somebody else's pain'	0.48 (1.44)	2.71 (6.78)	−1.696	0.105	−0.370	0.77
18. I am now having the feeling of being outside of my body	0.95 (2.42)	5.52 (8.20)	−2.647	0.015	−0.578	3.51

(*Continued*)

TABLE 1 Continued

Item	Before weightlessness mean (SD)	After weightlessness mean (SD)	t-value	p-value	Cohen's d	Bayes factor
19. I am feeling as if I were not in charge of my movements, so that I feel 'automatic' and mechanical, as if I were a 'robot'	2.00 (5.66)	11.76 (25.73)	−2.039	0.055	−0.445	1.27
20. I am feeling so detached from my thoughts that they seem to have a 'life' on their own	0.71 (1.82)	7.57 (20.69)	−1.527	0.142	−0.333	0.62
21. I feel like touching myself to make sure that I have a body or a real existence	1.10 (3.18)	3.29 (7.53)	−2.104	0.048	−0.459	1.40
22. I am still having the same strange feelings as when I stated to answer this questionnaire	1.14 (2.73)	6.67 (12.86)	−2.313	0.031	−0.505	1.97

While t-tests are generally robust against non-normality, particularly when sample sizes exceed n > 15 (Ratcliffe, 1968), our data nonetheless exhibited non-normality ($W = 0.79$, $p < 0.001$). Accordingly, we also conducted a Wilcoxon signed rank test as a non-parametric equivalent test robust against such violations of normality. This test also revealed a significant increase in CDS-S scores following exposure to the SFP ($V = 29.5$, $p = 0.016$), supporting the robustness of the result.

Paired-samples t-tests were conducted to compare before and after-weightlessness exposure scores on each item of the CDS-S (Table 1). We treated each CDS-S item as a distinct inquiry into the specific symptom profile observed in participants as a basis for future study, and accordingly avoided artificially inflating Type II error rates by applying conservative corrections for multiple comparisons (Saville, 1990). However, to aid in interpretation of results given the potential for increased Type I familywise error, we also calculated Bayes Factors (using a standard prior of 0.707). Significant increases were observed in several items following platform exposure. Specifically, participants reported higher levels of feeling strange or cut off from the world (Item 1: $t(20) = -2.161$, $p = 0.043$, Cohen's $d = -0.472$, $BF_{10} = 1.54$), out-of-body experiences (Item 18: $t(20) = -2.647$, $p = 0.015$, Cohen's $d = -0.578$, $BF_{10} = 3.51$), urge to verify bodily existence (Item 21: $t(20) = -2.104$, $p = 0.048$, Cohen's $d = -0.459$, $BF_{10} = 1.40$), and persistence of unusual feelings (Item 22: $t(20) = -2.313$, $p = 0.031$, Cohen's $d = -0.505$, $BF_{10} = 1.97$). All significant effects reflected an increase in depersonalisation/derealisation-related experiences following weightlessness exposure. Effect sizes were in the small-to-moderate range. No other items reached statistical significance ($p > 0.05$), although several showed trends towards increased depersonalisation (e.g., Items 13 and 19). Accordingly, the impact of weightlessness exposure on specific body-related depersonalisation/derealisation experiences is a promising line for future research.

Discussion

Depersonalisation is defined as a disruption of the normal sense of self, characterised by feelings of detachment from one's body or a sense of observing oneself from an external perspective. While it is most commonly associated with neurological and psychiatric conditions, such as temporal lobe epilepsy, migraine, or anxiety and depressive disorders (Kenna and Sedman, 1965; Cahill and Murphy, 2004; Sedman and Reed, 1963), transient depersonalisation can also occur in healthy individuals under a variety of circumstances, including Virtual Reality, pharmacological interventions or extreme environmental perturbations, such as spaceflight (Aardema et al., 2010; Peckmann et al., 2022; Mundy-Castle, 1958).

Our study provides the first experimental evidence that transient, simulated weightlessness can systematically induce depersonalisation in healthy participants. Using the ESA frictionless air-bearing platform, we experimentally disrupted the normally stable relationship between vestibular signals and gravitational expectations while minimising visual cues, thereby reproducing key sensory features of weightlessness. Following exposure, participants showed increased depersonalisation and derealisation, supporting the hypothesis that vestibular-gravitational signals contribute to the maintenance of a stable sense of self. Importantly, these effects were selective rather than global, with significant increases in feelings of unreality, out-of-body experiences, and the urge to verify one's own bodily existence. Thus, the significant changes were concentrated on experiences reflecting an alteration in the relationship between the self and the body or surrounding reality, with effect sizes in the small-to-moderate range. Although not all items reached statistical significance, several showed consistent trends in the same direction, suggesting that the effects may reflect a broader, albeit variable, modulation of depersonalisation-related experiences. These findings extend previous observational reports from astronauts, who frequently describe alterations in bodily self-consciousness during spaceflight, and converge with clinical evidence from vestibular patients on Earth, in whom disrupted vestibular input is associated with similar experiences. Taken together, experimental evidence from the present study, clinical observations and reports from astronauts converge on the possibility that vestibular-gravitational signals contribute not only to spatial orientation during rest and movement, but also to the grounding of the self as an embodied and temporally situated experience. Gravity may therefore provide a fundamental sensory reference against which the brain continuously calibrates the representation of the body, helping to maintain a stable experience of oneself as a physical individual

located in space and embedded within the surrounding environment.

Our results suggest that the brain's internal model of gravity functions as a strong prior, constraining multisensory integration and anchoring the perception of the body in space. This interpretation is consistent with Bayesian models of perception, in which the brain continuously combines prior expectations with incoming sensory evidence to infer the most probable state of the body and its environment. Within this framework, gravity provides a particularly stable and reliable source of prior information: under terrestrial conditions, vestibular, visual, somatosensory and proprioceptive signals are interpreted against an internalised expectation of the direction and magnitude of gravitational force. Gravity therefore provides a fundamental reference for perceptual inference (Jörges and López-Moliner, 2017), with the brain weighting prior expectations and incoming sensory evidence according to their relative reliability to minimise uncertainty and maintain a stable estimate of orientation and motion (Torok et al., 2019; Gallagher et al., 2020; Nezami and Ferre, 2026). Disruption of vestibular-gravitational signals, as occurs during weightlessness or simulated weightlessness, introduces a discrepancy between this internalised gravitational prior and incoming sensory evidence. From a Bayesian perspective, this discrepancy generates prediction error and requires the perceptual system to update its estimate of the current state. Such updating may involve changes in the precision-weighting of sensory evidence and, with sustained exposure, potentially recalibration of the underlying prior itself. Importantly, because gravity provides a pervasive and highly stable reference for interpreting multisensory information, disruption of this relationship may have consequences beyond sensorimotor calibration and spatial orientation. Our findings raise the possibility that altered precision-weighting of vestibular-gravitational signals can propagate to higher-order representations of the self, contributing to the changes in embodiment and reality observed following simulated weightlessness.

This interpretation is further supported by the anatomical convergence between regions involved in vestibular-gravitational processing and those implicated in depersonalisation, including the temporoparietal junction, posterior insula and superior parietal cortex (Jay et al., 2014; Phillips et al., 2001). These regions form part of a distributed multisensory network that combines vestibular, visual, somatosensory and proprioceptive signals to construct representations of the body and its spatial relationship with the surrounding world. The temporoparietal junction, in particular, has been implicated in the integration of multisensory information underlying the distinction between the self and the external world, as well as in alterations of bodily self-consciousness and out-of-body experiences (Ferrè et al., 2014). The posterior insula contributes to the representation of vestibular and interoceptive signals, while superior parietal regions support spatial and egocentric representations of the body. Perturbation of vestibular-gravitational input may therefore alter the balance of multisensory information within this partially overlapping network, with consequences extending to bodily self-location and embodiment. Specifically, a mismatch between incoming sensory signals and the brain's internal model of the body in space may increase uncertainty about the current state of the body, thereby affecting the perceptual inference that underpins bodily self-consciousness. This provides a potential mechanistic account of how transient changes in vestibular-gravitational signalling could influence self-consciousness and contribute to depersonalisation and derealisation during weightlessness or simulated weightlessness.

Interestingly, our findings also converge with research on psychedelic states, which provides a complementary context for understanding how disruptions to normally stable representations of the self may arise. Psychedelic compounds such as LSD and psilocybin can produce profound alterations in self-consciousness, including depersonalisation-like experiences and ego-dissolution, accompanied by changes in the functional organisation of brain networks involved in self-related processing (Lebedev et al., 2015; Carhart-Harris et al., 2016). These effects have been interpreted as reflecting a disruption of normally stable high-level models of the self, suggesting that the sense of being a coherent and bounded individual depends on the integrity of distributed neural representations and their integration with ongoing sensory evidence. Notably, altered states of consciousness have also been reported in the context of spaceflight, where astronauts describe changes in bodily self-consciousness, perspective and the sense of connection between the self and its environment (Nezami and Ferre, 2026). Although psychedelic states and simulated weightlessness involve fundamentally different physiological and neurochemical mechanisms, the convergence of these findings raises the possibility that distinct perturbations of brain systems supporting multisensory integration and bodily self can produce partially overlapping changes in conscious self-experience.

Importantly, our findings indicate that even brief perturbations of vestibular input are sufficient to alter the sense of self, highlighting the vestibular system's central role in maintaining bodily self-consciousness. Distortions in the relationship between self and body in patients with vestibular disorders were first described by Bonnier (1905), and subsequent work has shown that vestibular stimulation can influence judgments about the orientation of visually presented bodies and perspective-taking (Vallar and Rode, 2009; Dilda et al., 2012). However, until now, no studies have experimentally investigated how vestibular signals contribute to depersonalisation under altered gravity conditions. Controlled simulation of microgravity thus provides a powerful paradigm to study the neurocognitive mechanisms underlying depersonalisation and related self-perceptual phenomena in healthy participants, without the confounds of pathology or prolonged spaceflight.

Limitations should be considered when interpreting these findings. First, the study did not include a control group, limiting the extent to which the observed pre-post changes can be attributed specifically to the vestibular-gravitational mismatch induced by the platform. A control condition would have allowed the effects of the experimental manipulation to be more directly distinguished from non-specific features of the procedure, including the novelty of the experience. Second, as with any pre-post design, potential threats to internal validity include testing effects, whereby repeated exposure to the depersonalisation scale may influence subsequent responses, and fatigue or other time-related effects associated with participation. Although the magnitude and direction of the pre-post changes, together with the controlled nature of the experimental exposure, provide evidence against these factors alone accounting for the findings, they cannot be

completely excluded. The absence of a control condition also means that a contribution from other aspects of the experimental experience cannot be definitively ruled out. Future studies should therefore incorporate appropriate control groups and control conditions, ideally with matched exposure to the experimental procedures, to provide stronger causal tests of the contribution of vestibular-gravitational mismatch to changes in the sense of self. Moreover, practicalities of accessing a specialised platform over a short time window of testing necessarily restricted the ultimate sample size we were able to gather in our study. Sensitivity analysis for a two-tailed paired t-test with $n = 21$ and $\alpha = 0.05$ indicated 80% power to detect effect sizes ≥ 0.64. Thus, given our observed effect size of 0.57, the reported t-test likely operated with ~69% power, slightly below the conventional threshold of 80%. Thus, this sample size constraint and slight underpower limited our ability to detect smaller effects. Nonetheless, we believe that the reported findings are robust and provide an interesting avenue for future research into the impact of weightlessness on the bodily self.

To conclude, our findings demonstrate that simulated weightlessness, achieved through frictionless, multi-axis motion, can transiently induce depersonalisation in healthy individuals. These results provide direct evidence that self-consciousness depends on the continuous alignment between vestibular signals and an internal model of gravity, supported by overlapping neuroanatomical substrates. More broadly, this work reveals a fundamental constraint on human experience: gravity is not merely a physical force acting on the body, but a foundational prior shaping perception, action, and the very construction of the self. Its absence does not simply alter how we move through space: it alters how we experience being a body at all.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the School of Psychological Sciences Research Ethics Committee at Birkbeck, University of London and the ESA Medical Board, and were conducted in accordance with the Declaration of Helsinki. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MH: Conceptualization, Data curation, Formal Analysis, Methodology, Writing – original draft. HG: Data curation, Formal Analysis, Methodology, Writing – original draft. EC: Data curation, Formal Analysis, Methodology, Writing – original draft. IR: Data curation, Formal Analysis, Methodology, Writing – original draft. MD: Data curation, Formal Analysis, Methodology, Writing – original draft. MG: Conceptualization, Formal Analysis, Methodology, Supervision, Writing – review and editing. EF: Conceptualization, Formal Analysis, Methodology, Supervision, Writing – review and editing.

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