

Mind Over Body

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We categorize as we do because we have the brains and bodies we have and because we interact in the world as we do,” wrote cognitive linguist George Lakoff in his 1999 book, *Philosophy in the Flesh: The Embodied Mind and Its Challenge to Western Thought*. Lakoff is renowned as a leading voice in the field of embodied cognition, an interdisciplinary area of cognitive science that is often called “radical” for pushing the boundaries of our understanding of the relationship between our minds and bodies.

Integrating methods from neuroscience, psychology, and computer science, embodied-cognition researchers are delving into groundbreaking new technologies such as virtual reality to observe how modifying our bodies can also lead to profound changes in our sense of self, identity, and cognitive processes.

Invasion of the Body Swappers

You won’t find mannequins with head-mounted video cameras or kitchen knives in the labs of most cognitive neuroscientists, but Henrik Ehrsson and his lab rely on these unusual props to study fundamental questions about how our minds construct a sense of ownership over our bodies.

For decades, researchers have relied on optical illusions to gain insights into the ways that the eyes, mind, and brain work together to create our experience of the world. But Ehrsson, a professor of neuroscience at the Karolinska Institutet in Sweden, has pioneered the use of mind-bending illusions using the body itself to study the perception of body ownership.



In

one experiment by Ehrsson and Petkova, participants wore head-mounted display goggles while facing a mannequin wearing a pair of eye-level video cameras. When participants looked down at their own bodies, what they actually saw, via the video from the goggles, was the mannequin's body.

Although we might take it for granted that we perceive our bodies as our own, Ehrsson's bodily illusions have shown that this perception is actually the product of a multisensory orchestra playing in sync.

"If these signals are congruent, if they happen at the same time and same place, the signals are integrated, infused into a coherent representation of your own body," Ehrsson explained at the 2019 *Integrative Science Symposium at the International Convention of Psychological Science (ICPS)*. "If the signals don't match, if they are out of sync or different in places, the signals are not integrated."

Even minor tweaks to our position in space, visual perspective, and tactile sensations can dramatically skew our sense of ownership over our bodies.

In a 2008 study published in *PLOS ONE*, Ehrsson and Valeria Petkova, at the time a colleague at the Karolinska Institutet, found that with a mannequin and a few other props, they could create a vivid illusion of swapping bodies. In one experiment, participants wore head-mounted display goggles while facing a mannequin wearing a pair of eye-level video cameras. When participants looked down at their own bodies, what they actually saw, via the video from the goggles, was the mannequin's body.

This bodily illusion was so vivid that "threatening" the mannequin's body with a kitchen knife caused a spike in evoked skin-conductance response, which was used as an objective measure of anxiety.

“We think this is a multi-sensory perception phenomenon,” Ehrsson said at ICPS. “We think it happens because the brain continues to integrate what you see and what you feel. That elicits a very vivid illusion that the mannequin’s body is your own body—it’s a perceptual illusion.”

Not all participants experienced these body-ownership illusions; neuroimaging studies have found that people who experience full-body ownership illusions demonstrate activity in brain areas that integrate multisensory and visual information in the frontal and parietal cortex.

Ehrsson is currently pursuing a new line of research on how body perception itself can influence various high-level cognitive functions, such as gender identity. His lab’s new research suggests that experiencing the illusion of having an opposite-sex body, even for a brief amount of time, can shift participants’ self-assessment to being less stereotypically gendered.

“Another way of thinking about this is self-coherence, that the mind and the brain are trying to keep these different self-representations somewhat coherent; and, if there are inconsistencies, there will be adjustment,” Ehrsson explained. “So, if you change the bodily self, that could then lead to changes in self-concept.”

Virtual Skin

In the classic novel *To Kill a Mockingbird*, Atticus Finch advises his daughter that truly understanding other people requires taking on their experience of the world: “You never really understand a person until you consider things from his point of view, until you climb inside of his skin and walk around in it.”



Pressure Sensors

Atticus Finch may have been speaking metaphorically, but Domna Banakou, a postdoc at the University

of Barcelona, is using virtual reality as a new tool to show that inhabiting another person's skin really can lead to positive changes in our perceptions of others.

Through virtual reality, Banakou has measured how people's beliefs, attitudes, and abilities change after they experience the illusion of inhabiting a body that is dramatically different from their own—swapping race, age, sex, and gender.

To experience this body swapping technology, participants wear a virtual-reality headset and motion sensors that match their body's movements to those of their virtual body. Mirrors are often included within the virtual environment, further enhancing the sensation that the virtual body is actually their own.

In a 2016 study published in *Frontiers in Human Neuroscience*, Banakou and coauthors Parasuram Hanumanthu and Mel Slater found that experiencing virtual embodiment has the potential to reduce racial bias. In the study, White participants completed an Implicit Association Test on racial bias a week before their virtual-reality sessions, in which they took a Tai Chi lesson while inhabiting either a Black or White virtual body. A week later, participants retook the Implicit Association Test. Those who had experienced a Black virtual body had reduced racial bias scores compared with those who had experienced White virtual bodies.

In addition to influencing bias, there is also evidence that the illusion of ownership over a different body can lead to changes in cognition.

In a 2018 study published in *Frontiers in Psychology*, Banakou was interested in the flexibility of the relationship between embodiment and the brain: If we gave someone a recognizable virtual body that represents intelligence, would they perform better on a cognitive task than people in a normal body?

To explore that question, participants were virtually embodied as the iconic physicist Albert Einstein. First, participants completed an IQ test, an Implicit Association Test on age bias, and the Tower of London test of executive functioning. A week later they returned to the lab, where they completed a series of embodiment exercises in virtual reality using either Einstein's body or a normal adult body. Afterward, participants again completed the Tower of London task and the Implicit Association Test.

Those who had been embodied as Einstein showed decreased bias toward the elderly as well as more improvement on the cognitive task compared with the control group. However, participants who reported low self-esteem showed the biggest improvement in cognitive skills.

“There could therefore be the possibility that embodying the Einstein body led low self-esteem participants to increase their self-confidence—thus decreasing any experienced task-related stress—which in turn led to better performance,” Banakou and colleagues wrote.

New Sensation

Our mental representations of our own bodies are not fixed—they are continuously being attended and updated. And, as psychoacoustics researcher Ana Tajadura-Jiménez's team at Universidad Carlos III de Madrid and University College London has shown, the sensory cues we rely on to build our sense of self can include things as mundane as the sound of our own footsteps.

Tajadura-Jiménez has shown how modifying these self-generated sounds can lead to surprisingly wide-ranging shifts in perceptions, attitudes towards the self, and emotion.

With every movement, we interact with the environment and generate sounds with our bodies, Tajadura-Jiménez explained at ICPS. These sounds, which we often fail to even notice, provide us with a lot of feedback information about our bodies and our environment. Our bodies are constantly using sounds generated by the body and the environment to build our shifting sense of self; every time our feet touch the ground our bodies are processing a wealth of information.

Tajadura-Jiménez noted the experience of hearing someone walking behind you. From the sound of their footsteps, you can surmise a lot of information—something about their size, their posture, their pace, the type of surface they're walking on. This is because, in general, heavy-hitting objects produce sounds with lower frequencies compared with lighter-hitting objects.

“Even if we are not aware of this relationship with sound frequencies, people are actually quite good at detecting it, when they are asked to make judgments about the body of a walker just on the basis of their footstep sounds,” she said.

To study how our bodies use and interpret sensory inputs to form self-perceptions, Tajadura-Jiménez's team created a pair of “magic shoes.” The shoes are wired up with microphones and motion sensors to track the wearer's movement and gait. The sounds picked up from the microphones can be modified to emphasize different frequencies before hitting participants' ears through a pair of headphones.

In a conference paper, Tajadura-Jiménez and colleagues (2015) reported that changes to the sound of footsteps could lead to a cascade of other perceptual and affective effects. For example, when the sounds generated while walking in the magic shoes were altered to boost high frequencies, participants began to perceive their bodies differently: They changed their gait to correspond to the mechanics of feeling lighter—their feet had less contact with the floor. Manipulating walking sounds to emphasize lower frequencies appears to have the opposite effect; participants start moving as though their feet and legs were heavier than they were before.

When asked how they felt, participants in the high-frequency condition report feeling faster, more positive, and happier.

Tajadura-Jiménez is now investigating whether these findings could have applications to support well-being or therapy by enhancing individuals' perceptions of their own bodies.

This could involve finding a tool to encourage people to be more physically active and exercise more, but it could also have clinical implications in settings where participants experienced dysphoric or negative body perceptions. They have conducted proof-of-concept pilot studies with populations with chronic pain and stroke and are currently extending these findings to other populations.

Ghosts in the Machine

Andrea Serino, a professor in the department of clinical neurosciences at the University Hospital of Lausanne (École Polytechnique Fédérale de Lausanne, or EPFL) in Switzerland, runs a lab that

investigates how our brains represent our bodies in space to create our experience of self. Serino is also the head of the MySpace Lab in Lausanne, where his research focus is “really about finding the neural basis of peripersonal space,” he said at ICPS.

Understanding how our bodies interpret “peripersonal” space, the space immediately surrounding our bodies, helps inform how many of these embodiment illusions work.

Body illusions rely on physical proximity and the mechanisms of peripersonal space, Serino said. Neurons that respond to touch on a part of the body—tactile neurons—can also respond to visual or auditory stimuli that occur in close proximity to that body part. Whether these tactile neurons respond to stimuli depends on whether it occurs within our “personal bubble” of peripersonal space.

Normally, our senses operate in synchrony and are linked to our movement—we move our hands, we see an object near our hands, and at the same time we feel the tactile sensation. However, as Ehrsson’s research with mannequins demonstrates, when we experience sensorimotor conflicts, our brains may perceive an internal sensation as coming from outside of our bodies, leading to body illusions or even, in some cases, perceptions of a foreign presence like a spirit or a ghost.

These body illusions may help scientists understand the causes of some of the symptoms of conditions like schizophrenia and epilepsy. Patients with schizophrenia may experience hallucinations or delusions of alien voices or presences. These hallucinations may be caused when the brain misattributes sounds and movements generated by the body as being generated by an external agent.

In a 2014 study published in *Current Biology*, Serino and colleagues, in the lab of Olaf Blanke at the EPFL, used a robotic device synchronized to touch participants’ backs as they moved their hands in front of their bodies. When the device’s movements matched participants in real time, they perceived the touch sensation as their own. However, introducing a time delay of just a few milliseconds produced enough sensory asynchrony to induce the sensation that participants were being touched by an invisible presence behind them.

A few participants found the illusion of a foreign presence to be so vivid and disturbing that they asked whether there was really someone close to them.

“Whenever we complete a movement without our bodies, our brains generate a prediction of what’s going on in terms of sensory consequences,” Serino said. “If our prediction corresponds to the sensory feedback that we get, there is no problem—I know that it’s me and my body. But if my brain generates a prediction and then the sensory feedback contradicts these predictions, then my brain decides that this must not be me.” Currently this research is evolving to study how these sensory-motor conflicts, and the associated changes in experience, affect high-order cognitive processes, such as self-monitoring and thought insertion.

Studies like his elegantly demonstrate how even very simple manipulations of congruency between sensory and motor inputs can have profound effects on our cognition and sense of self.

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