Mind Over Body

March 24, 2020

Wecategorize as we do because we have the brains and bodies we have and becausewe interact in the world as we do," wrote cognitive linguist George Lakoff inhis 1999 book, *Philosophy in the Flesh:The Embodied Mind and Its Challenge to Western Thought*. Lakoff is renownedas a leading voice in the field of embodied cognition, an interdisciplinaryarea of cognitive science that is often called "radical" for pushing theboundaries of our understanding of the relationship between our minds andbodies.

Integrating methods fromneuroscience, psychology, and computer science, embodied-cognition researchersare delving into groundbreaking new technologies such as virtual reality toobserve how modifying our bodies can also lead to profound changes in our senseof 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 reliedon optical illusions to gain insights into the ways that the eyes, mind, andbrain work together to create our experience of the world. But Ehrsson, aprofessor of neuroscience at the Karolinska Institutet in Sweden, has pioneeredthe use of mind-bending illusions using the body itself to study the perceptionof body ownership.


In one experiment by Ehrsson and Petkova, participants wore head-mounted display goggleswhile facing a mannequin wearing a pair of eye-level video cameras. When participantslooked down at their own bodies, what they actually saw, via the video from the goggles, wasthe 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, ifthey happen at the same time and same place, the signals are integrated,infused into a coherent representation of your own body," Ehrsson explained atthe 2019 *Integrative Science Symposium at the International Convention ofPsychological 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 inspace, visual perspective, and tactile sensations can dramatically skew oursense of ownership over our bodies.

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

This bodily illusion was so vividthat "threatening" the mannequin's body with a kitchen knife caused a spike inevoked skin-conductance response, which was used as an objective measure ofanxiety.

“We think this is a multi-sensory perceptionphenomenon,” Ehrsson said at ICPS. “We think it happens because the braincontinues to integrate what you see and what you feel. That elicits a veryvivid illusion that the mannequin’s body is your own body—it’s a perceptualillusion.”

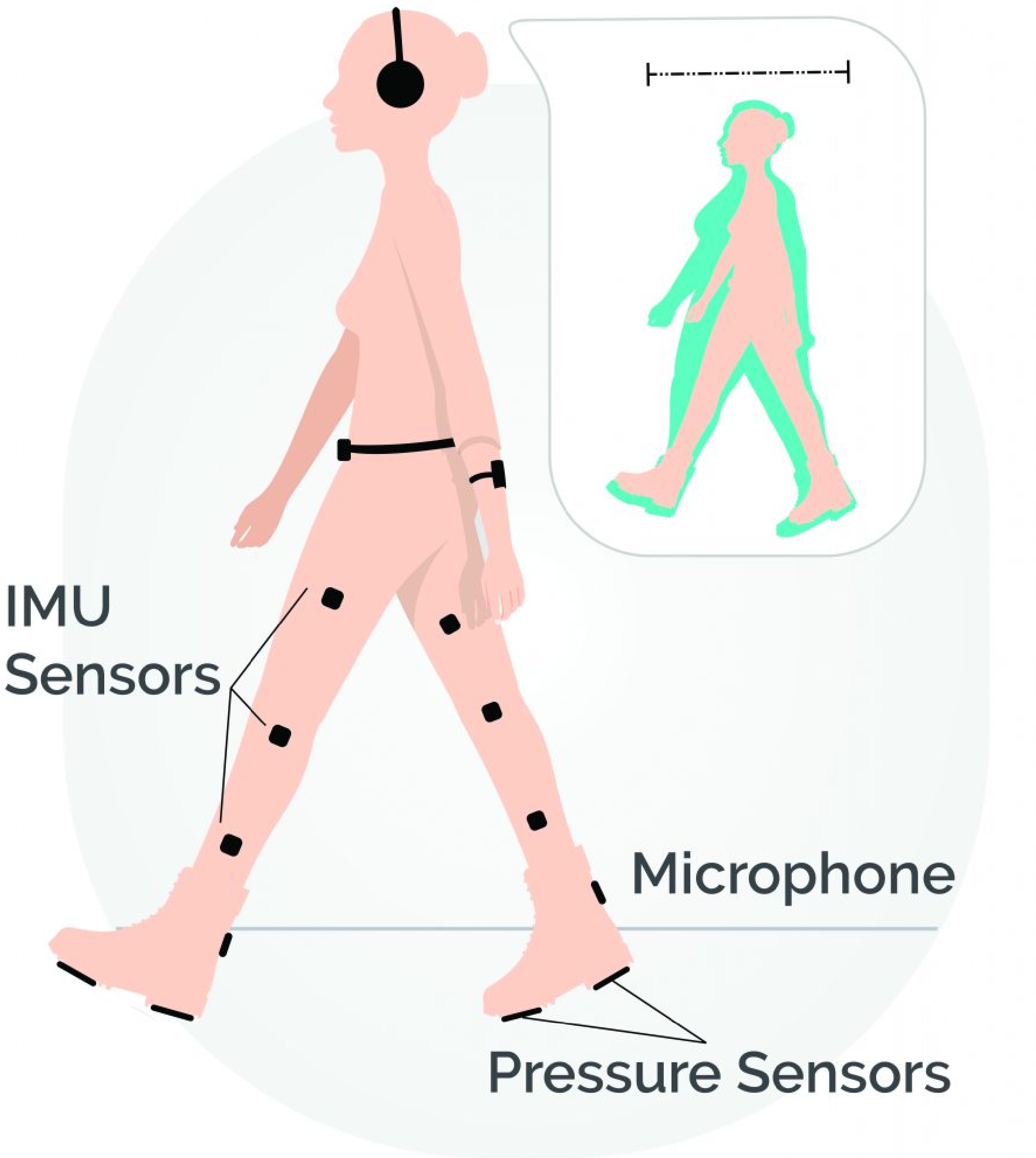
Not all participants experiencedthese body-ownership illusions; neuroimaging studies have found that people whoexperience full-body ownership illusions demonstrate activity in brain areasthat integrate multisensory and visual information in the frontal and parietalcortex.

Ehrsson is currently pursuing a newline of research on how body perception itself can influence various high-levelcognitive functions, such as gender identity. His lab’s new research suggeststhat experiencing the illusion of having an opposite-sex body, even for a briefamount of time, can shift participants’ self-assessment to being lessstereotypically gendered.

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

Virtual Skin

In the classicnovel *To Kill a Mockingbird*, AtticusFinch advises his daughter that truly understanding other people requirestaking on their experience of the world: “You never really understand a personuntil you consider things from his point of view, until you climb inside of hisskin and walk around in it.”



To study how our bodies use and interpret sensory inputs to form self-perceptions,a team led by Ana Tajadura-Jiménez (next page) created a pair of “magic shoes” wiredwith microphones and inertial measurement unit (IMU) motion sensors to track thewearer’s movement and gait. The sounds picked up from the microphones can bemodified to emphasize different frequencies before hitting the wearer’s ears througha pair of headphones.

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 hasmeasured how people’s beliefs, attitudes, and abilities change after theyexperience the illusion of inhabiting a body that is dramatically differentfrom their own—swapping race, age, sex, and gender.

To experience this body swappingtechnology, participants wear a virtual-reality headset and motion sensors thatmatch their body’s movements to those of their virtual body. Mirrors are oftenincluded within the virtual environment, further enhancing the sensation thatthe virtual body is actually their own.

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

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

In a 2018 study published in *Frontiers in Psychology*, Banakou wasinterested in the flexibility of the relationship between embodiment and thebrain: If we gave someone a recognizable virtual body that representsintelligence, would they perform better on a cognitive task than people in anormal 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 agebias, and the Tower of London test of executive functioning. A week later theyreturned to the lab, where they completed a series of embodiment exercises invirtual reality using either Einstein’s body or a normal adult body. Afterward,participants again completed the Tower of London task and the ImplicitAssociation Test.

Those who had been embodied asEinstein showed decreased bias toward the elderly as well as more improvementon the cognitive task compared with the control group. However, participantswho reported low self-esteem showed the biggest improvement in cognitiveskills.

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

New Sensation

Our mentalrepresentations of our own bodies are not fixed—they are continuously beingattended and updated. And, as psychoacoustics researcher Ana Tajadura-Jiménez’s team at Universidad Carlos III deMadrid and University College London has shown, the sensory cues we rely on tobuild our sense of self can include things as mundane as the sound of our ownfootsteps.

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

With every movement, we interact withthe 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 feedbackinformation about our bodies and our environment. Our bodies are constantlyusing sounds generated by the body and the environment to build our shiftingsense of self; every time our feet touch the ground our bodies are processing awealth of information.

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

"Even if we are not aware of thisrelationship with sound frequencies, people are actually quite good atdetecting it, when they are asked to make judgments about the body of a walkerjust on the basis of their footstep sounds," she said.

To study how our bodies use andinterpret sensory inputs to form self-perceptions, Tajadura-Jiménez's team created a pair of "magicshoes." The shoes are wired up with microphones and motion sensors to track thewearer's movement and gait. The sounds picked up from the microphones can bemodified to emphasize different frequencies before hitting participants' earsthrough a pair of headphones.

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

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

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

This could involve finding a tool toencourage people to be more physically active and exercise more, but it couldalso have clinical implications in settings where participants experiencedysphoric or negative body perceptions. They have conducted proof-of-conceptpilot studies with populations with chronic pain and stroke and are currentlyextending these findings to other populations.

Ghosts in the Machine

Andrea Serino, aprofessor in the department of clinical neurosciences at the UniversityHospital of Lausanne (École Polytechnique Fédérale de Lausanne, or EPFL) inSwitzerland, runs a lab that investigates how our brains represent our bodiesin space to create our experience of self. Serino is also the head of theMySpace Lab in Lausanne, where his research focus is “really about finding theneural basis of peripersonal space,” he said at ICPS.

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

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

Normally, our senses operate insynchrony and are linked to our movement—we move our hands, we see an objectnear our hands, and at the same time we feel the tactile sensation. However, asEhrsson’s research with mannequins demonstrates, when we experiencesensorimotor conflicts, our brains may perceive an internal sensation as comingfrom outside of our bodies, leading to body illusions or even, in some cases, perceptionsof a foreign presence like a spirit or a ghost.

These body illusions may helpscientists understand the causes of some of the symptoms of conditions likeschizophrenia and epilepsy. Patients with schizophrenia may experiencehallucinations or delusions of alien voices or presences. These hallucinationsmay be caused when the brain misattributes sounds and movements generated bythe body as being generated by an external agent.

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

A few participants found the illusionof a foreign presence to be so vivid and disturbing that they asked whetherthere was really someone close to them.

“Whenever we complete a movement withour bodies, our brains generate a prediction of what’s going on in terms ofsensory consequences,” Serino said. “If our prediction corresponds to thesensory feedback that we get, there is no problem—I know that it’s me and mybody. But if my brain generates a prediction and then the sensory feedbackcontradicts 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 cognitiveprocesses, 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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