Proprioception, our imperceptible sixth sense

17 February 2021, by Fabrice Sarlegna, Chris Miall, Jonathan Cole and Robert Sainburg

Proprioception makes it possible to situate the body in space. Credit: Pixabay, CC BY

Vision. Hearing. Smell. Taste. Touch. Proprioception. Proprioception? Few people are familiar with this sense, although its pioneer studies in the 19th century were by some of the giants of neuroscience: Claude Bernard who had a French university named after him, Sir Charles Bell, and Sir Charles Sherrington who won the Nobel Prize in Physiology/Medicine in 1932 and who coined the term proprioception.

So what is proprioception? It is the sense allowing us to feel and locate our body parts. Close your eyes, ask someone to move your right foot, and you will still know where it is. In fact, you can describe your body posture thanks to the integration by the nervous system of neurophysiological signals from receptors—proprioceptors—in the muscles, tendons, joints and skin that are sensitive to muscle length and force, to joint rotation, and to local bending of the skin. Proprioception is a key component of our "global positioning system," which is essential in our daily life because we need to know where we are in order to move somewhere. Proprioception enables us to determine each body part's position, speed and direction, whether we see it or not, and so enables the brain to guide our movements.

To understand the role of proprioception, researchers have studied rare patients who are deprived of it by disease of their peripheral nerves. Those individuals are unable to perform coordinated movements. The reason for the motor impairment is made clear when a patient, asked to move the legs by a neurologist, answers "Sure, Doc, as soon as I find them." Oliver Sacks described such a subject in the chapter, "The disembodied lady," in the best-seller "The Man Who Mistook His Wife for a Hat" (1985). There, Christina is a young woman who has lost proprioception. She can hardly stand and even if she observes her hands carefully, she can barely use them. Other related cases were studied by scientists: Ian Waterman's story about his "missing body" was the basis of a 1997 BBC documentary, "The Man Who Lost His Body." It also appeared in two of Peter Brook's plays, "The Man Who" (1993) and "The Valley of Astonishment" (2014), as well as Jonathan Cole's books "Pride and a Daily Marathon" (1995) and "Losing Touch: A Man without His Body" (2016).

Ian was 19 when he lost proprioception and touch as a result of an autoimmune reaction to a viral infection. It is difficult to understand his sensory deficit, since his loss cannot be simulated like a visual or hearing loss can be, by blindfolding or plugging one's ears. The closest we come to it is in anaesthesia, in really cold weather when we cannot feel our fingers, or when we experience a "dead limb" from awkward positioning and cutting off the blood supply to the sensors. But none of these really match Ian's permanent loss. Our inability to conceive of its absence may be one reason proprioception remains such a poorly known sense. Another is that much of its activity occurs automatically and unconsciously. But studying participants like Ian can highlight how crucial

proprioception is in everyday life.

When Ian was deprived of proprioception and touch, he also lost his ability to control his body. He spent 17 months in a rehabilitation center learning to move, sit, feed himself, dress and then stand and walk, all the time looking at each moving part and having to think his way into actions. His need for vision and mental concentration was absolute; if he sneezed he would fall over, daydreaming was out of the question, and a head cold sent him to bed. Forty years later, Ian still has to think out each action. Though his functional recovery amazed researchers, all his everyday actions still depend on attention and vision, and neither can completely compensate for the loss.

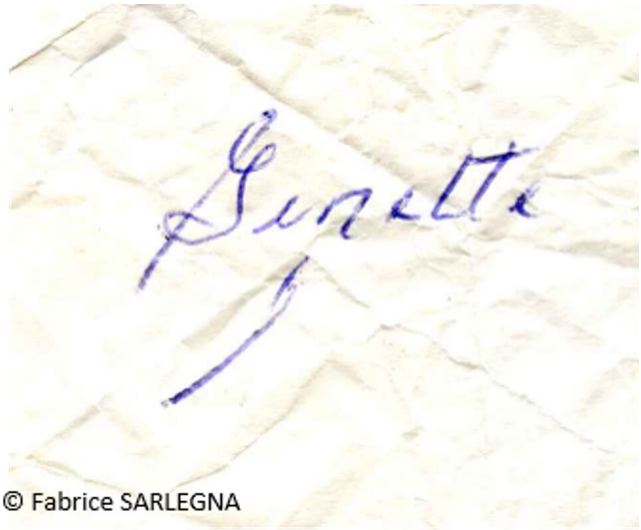
For the handful of similar cases known across the globe, standing and walking has been too perilous, so they live from a wheelchair. We are fortunate that several of them have collaborated with scientists, mostly in Europe and North America, to help uncover the effects of proprioceptive and tactile loss and exploring their ingenuity in recovering movement. Ginette and Wenche-Lise have a severe sensory neuropathy similar to Ian's: they may need an hour to peel a few potatoes as their manual dexterity is impaired.

Ginette, who has lost proprioception, was asked to hold a coffee cup. With eyes open (at left), the cup was well stabilized. When she closed her eyes (at right), she did not feel her arm descending and her wrist rotating.

Author provided, Author provided

Sana was born with a severe proprioceptive and tactile deficit and, at 31, has coordination issues as well. Movement is possible but far from normal when proprioceptive signals are missing.

Research has shown that the nervous system is a fairly slow processor and a critical aspect of movement is devoted to making predictions about the state of the body in the near future. Consider that when you interact with a friend, your perception of their words and movements occurs at least ¼ second after they act. Thus, we are always "behind the times," and we solve this delay by making predictions of future events, using current information and stored memories. When someone throws you a ball, you predict where it will fall to place your hand at the right place at the right time to catch it.



Two signatures of Ginette, top and bottom. Above, with eyes open (thus with visual feedback), the signature is well done. Below, with her eyes closed, we can see the beginning of the signature: the patient did not feel that her arm was rising, that she was no longer writing on the paper. Author provided

It turns out that a big role of proprioception is to be

able to quickly determine where our body parts are, so that we can make an appropriate motor plan. When you reach for your coffee cup, you don't need to look at where you hand is before you move, you simply look at the cup and reach, employing an unconscious process to plan your movement. In contrast, Ian and Ginette must use vision to inform their brain of the state of their hand and body parts every time they move. Among other problems, this cognitive process is exhausting. Nor does it fully allow individuals deprived of proprioception to produce as accurate movements as those we produce with proprioception.

These participants' efforts in laboratories have allowed researchers to unveil the paramount role of proprioception for motor coordination and can teach us not only about proprioception, but about the limits to rehabilitation for others too. For example, some of those with stroke, Parkinson's and various neuropathies have proprioceptive deficits which contribute to their impairments and which are not always identified.

Society richly rewards those with the best motor coordination, whether they are athletes or artists. To achieve excellence, performers practice many hours per day. Ginette, Ian, Sana, Wenche-Lise and others have much in common with elite performers, practicing and thinking about movement all day long, but are appreciated by a far smaller group of people—neuroscientists. While the loss of proprioception causes persistent deficits in posture and movement, the ingenuity and mental effort of these extraordinary people also reveals much about our capacity to explore the limits of what is possible in the face of previously unimagined impairment.

Provided by The Conversation