Making sense

Proprioception: is the sensory system that supports body posture and movement also the root of our understanding of physical laws?

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Effortless grace? A body's fine-tuned actions belie inner complexities.

Aristotle argued that human beings have five senses at their disposal. Although various other sense organs have come to light since then, this antique dogma still constrains popular imagination. The term 'sixth sense' resonates with instinct and metaphysics, implying that although the five 'regular' senses represent reality adequately, there is something else lurking in the subconscious. The search for the sensory system with which the blind guide their movements revealed that the body's sense of posture and movement relies on different types of tiny receptors densely packed in the muscles and tendons. In 1906 Charles Sherrington coined the term proprioception (perception of one's own) for the sensory modality based on these receptors and called it our 'secret sixth sense'. But this concept of the body as a major sense organ has failed to arouse the interest it deserves.

Proprioception functions in much the same way as the conventional senses. Proprioceptors precisely measure physical properties, such as muscle length, tendon tension, joint angle or deep pressure. Signals from this sensory orchestra are sent by afferent nerves through the spinal cord to the somatosensory, motor and parietal cortices of the brain, where they continuously feed and update dynamic sensory-motor maps of the body. So proprioception provides information on the physics of the body, the momentary distribution and dynamics of masses, forces acting on the limbs and their highly nonlinear interactions. The maps derived from these complex calculations not only guide body movement, they also (together with touch) sense the size and shape of objects and measure the geometry of external space. Weight — one's own and that of objects — is measured independently by pressure sensors and muscular tension. So subjective body consciousness provided by myriad networking proprioceptors is the basis of objective knowledge of fundamental physical properties — space, time and weight — of external reality.

Our daily doings are coordinated and run by a trinity of independent sensory systems: proprioception, vision and the vestibular organs of the inner ear (which sense balance, momentum and guide the eyes). Their signals are so tightly integrated that it is impossible to unravel them through introspection, a view which seems to favour vision as the primary sense organ of the mind. But whereas in the congenitally blind other senses more or less compensate for the loss, a child born without proprioception would not know it had a body and would be physically and mentally retarded as a result.

Selective loss of proprioception in adults is rare. In the case of Ian Waterman, a rare disease caused degeneration of sensory nerves relaying information from the body to the brain from the neck down, but spared the motor nerves conveying signals in the other direction. He could see, but not feel, where his body was or whether it was moving or not. At the age of 19, he was left a helpless 'rag doll', who had to be fed, washed and dressed — attempts at movement elicited only uncontrolled jerks. However, his strong will and memory of his body enabled him to learn to gradually control and guide his movements with his eyes. But even after 30 years of intense practice, the simplest movement has not been automated, but requires concentrated visual attention so strenuous that he likens it to a daily marathon, and in the dark he still collapses like a rag doll. His case, and a few others, demonstrate that all purposeful movements, both conscious and unconscious, are controlled by proprioception.

The proprioceptive system is so efficient and reliable at granting us the freedom of movement we expect from our bodies that we unconsciously relegate it to a subconscious, background realm of reflexes below the sphere of the five 'primary' senses. This attitude is unjustified. Most of our movements are indeed automated and run, as in animals, by the more basic and evolutionarily older parts of the brain. But we easily forget, for good reason, the intense conscious attention required to learn complex skills, such as writing, skiing or driving. Learning a skill implies developing new patterns of movement by screening, coordinating and calibrating relevant information from the orchestra of signals supplied to the neocortex by the trinity of sensory systems. New neural programmes are computed, memorized by repetition and transferred to the more fundamental regions of the brain, from where they are run with less effort and relayed much faster than from the seat of conscious awareness. So mastering a skill amounts to automating it.

Human proprioceptive ability is far superior to that of animals, reflected in the range, variety and precision of our automated skills, and manifest in the tools we make and what we achieve with them. Just as tools are extensions of the body, so basic scientific instruments — the balance, pendulum and measuring rod — are extensions of body sense. Evolution of these instruments, together with optical ones, launched the scientific exploration of space and time domains outside those of the body experience. Interestingly, the models of external space based on mathematical language made sense before their confirmation by precise measurements. From where else could these models have come, if not from the neural correlates of internal models of the physical laws of motion which run our bodies automatically? So the rules and laws of science were in place, and obeyed blindly, before they were rediscovered in the external world. In short, the neural correlates of physics and mathematics did not evolve *de novo*, but are rooted in our 'subconscious' body sense. ■

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FURTHER READING

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