At arm's length: The plasticity of depth judgment

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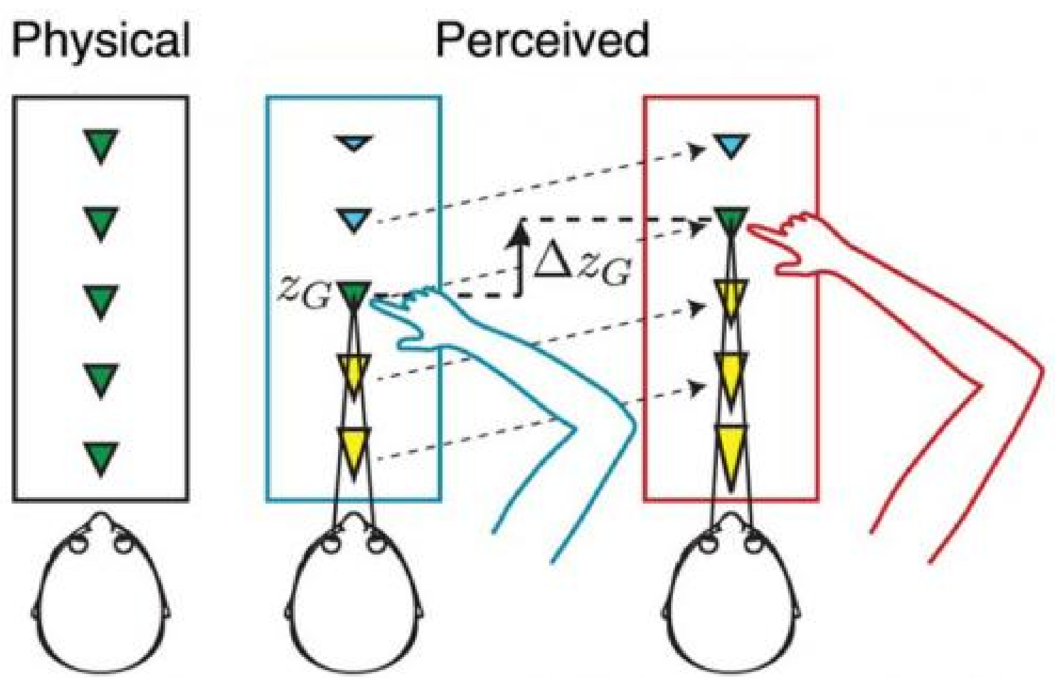


People judge depth most accurately at a distance that corresponds with their arm length (green triangle). Too close and they overestimate depth (yellow); too far leads and they underestimate (blue). If they perceive their arm to be longer, researchers found, the whole continuum shifts farther away. Credit: Istituto Italiano di Tecnologia

(Medical Xpress)—People have a distance at which they are best able to judge depth. That distance, it turns out, is dictated by how long people understand their arms to be. Researchers showed this in the *Journal of*

Neuroscience by tricking subjects with virtual reality into thinking their reach was longer than it really was. The result? Their accurate perception of depth via sight moved outward and touch became more sensitive.

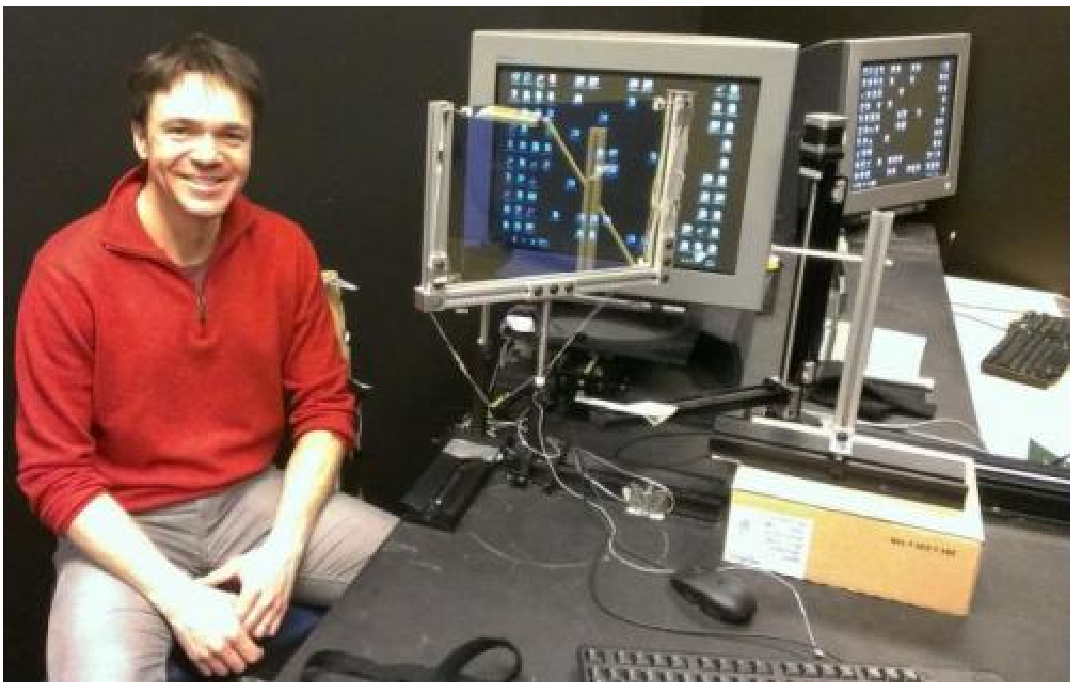
We need to reach for things, so a connection between arm length and our ability to judge depth accurately may make sense. Given that we grow throughout childhood, it may also seem reasonable that such an optimal depth perception distance should be flexible enough to change with a lengthening arm. Recent research in the *Journal of Neuroscience* provides evidence for these ideas with surprising findings: Scientists showed that they could manipulate the distance at which adult volunteers accurately perceived depth, both through sight and touch, by tricking them into thinking they had a longer reach than they really do.

In their research on depth perception, the research team, coordinated by Fulvio Domini, professor of cognitive linguistic and psychological sciences at Brown University and senior scientist collaborator at the Istituto Italiano di Tecnologia (IIT) in Italy, has found that people have a preferred distance at which they judge depth most accurately. People overestimate depth when objects are closer and underestimate depth when objects are farther away.

"When children start touching and playing with things, they don't just do it at any distance. They do it at a small range of distances," Domini said. "Our thought is maybe what the brain does is figure out a metric at that distance and the rest is all heuristic."

That optimal distance where people are most accurate, it turns out, depends on their mind's perception of arm length. In the experiments first published Oct. 23 in the journal, lead author Robert Volcic of IIT, Domini, and their co-authors demonstrated the importance in depth perception of arm length by manipulating it.

In experiments conducted at IIT with 41 volunteers, those they "trained" to think their arms were reaching farther than they really were subconsciously accepted that fiction and shifted the distance at which they best judge depth farther away. They also had a finer ability to discriminate between two separate tactile stimuli, in that they could perceive them as distinct with less distance between them than before.



“When children start touching and playing with things, they don’t just do it at any distance. They do it at a small range of distances. ... Maybe what the brain does is figure out a metric at (arm’s length).” Credit: Fulvio Domini

Virtual games, real effects

For their experiments, Volcic and colleagues asked volunteers to engage in three depth perception tasks—two visual and one tactile—both before and after a reach "training" exercise.

All the experiments were done in darkness so that the subjects couldn't see their actual arms or hands. Instead, one visual task group was presented with a 3-D computer-generated image of three rods in a triangle configuration (like the front three pins in bowling) at various distances away from their eyes. Their task was to use a computer mouse to indicate how far apart the rods appeared to them. Another visual group, this time equipped with motion tracking markers, indicated the spacing of the rods at various distances with their index finger and thumb, ,like the pinch one does on a smartphone.

The tactile task group was given either a single or a pair of little pokes on the forearm. The pairs of pokes started very close together and slowly moved farther and farther apart in space. The subjects were asked to report when, if ever, they felt two pokes instead of one. In so doing they revealed how far apart the pokes had to be for them to feel distinct.

The training at the intermission of each of these tasks was where the scientists tricked a random subset of the subjects into thinking their reach was longer than it was. With motion capture tags on their arms and fingers, the volunteers reached out for a virtual 3-D cylinder with their right arm. The position of their right index finger relative to the virtual rod was presented to them as a red dot in front of them. Some of the participants were given accurate information about the position of their finger and some were given information that presented their finger as 15 centimeters (about 6 inches) closer to the object than they really were—as if they had longer arms.

After the training, the subjects who were tricked into perceiving longer arms also shifted the distance at which they judged depth best. They also required less distance between pokes on their forearm before they could distinguish them. People whose reach was presented accurately—who were not "retrained"—continued with the same accurate depth perception distance and distance for discriminating the pokes.

Not only did the retrained subjects' perceptions change, Domini said, but also the precise degree of the changes could be accurately predicted ahead of time by mathematical models that incorporate perceived arm length and depth perception at that distance.

How we perceive

The findings of a role for arm length may help to explain depth perception and the limits of its accuracy, Domini said. In addition, the finding that depth perception can be predictably manipulated by changing perceived arm length could also matter to designers of robotic proxies, exoskeletons, and robotic surgery.

The research also raises a fundamental neuroscience question about how two different senses—vision and touch—are both influenced by perception of the arm.

The researchers conclude, "Even in adulthood sensory systems are not fixed structures with immutable functions. ... We have instead found strong sensory plasticity that can be evoked within minutes in adults."

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