Warning! Collision imminent! The brain's quick interceptions help you navigate the world

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When you are about to collide into something and manage to swerve away just in the nick of time, what exactly is happening in your brain? A new study from the Montreal Neurological Institute and Hospital – The Neuro, McGill University shows how the brain processes visual information to figure out when something is moving towards you or when you are about to head into a collision. The study, published in the *Proceedings of the National Academy of Sciences* (*PNAS*), provides vital insight into our sense of vision and a greater understanding of the brain.

Researchers at The Neuro and the University of Maryland have figured out the mathematical calculations that specific neurons employ in order to inform us of our distance from an object and the 3D velocities of moving objects and surfaces relative to ourselves. Highly specialized neurons located in the brain's visual cortex, in an area known as MST, respond selectively to motion patterns such as expansion, rotation, and deformation. However, the computations underlying such selectivity were unknown until now.

Using mathematical models and sophisticated recording techniques, researchers have discovered how individual MST neurons function. "Area MST is typical of high-level visual cortex, in that information about important aspects of vision can be seen in the firing patterns of single neurons. A classic example is a neuron that only fires when the subject is looking at the image of a particular face. This type of neuron has to gather information from other neurons that are selective to simpler features, like lines, colors, and textures, and combine these pieces of information in a fairly sophisticated way," says Dr. Christopher Pack, neuroscientist at The Neuro and senior author. "Similarly, for motion detection, neurons have to combine input from many other neurons earlier in the visual pathway, in order to determine whether something is moving toward you or just drifting past." The brain's visual pathway is made up of building blocks. For example, neurons in the retina respond to very simple stimuli, such as small spots of light. Further along the visual pathway, neurons respond to more complex stimulus such as straight lines, by combining inputs from neurons earlier on. Neurons further along respond to even more complex stimulus such as combinations of lines (angles), ultimately leading to neurons that can respond to, or recognize, faces and objects for example.

The research team found that a remarkably simple computation lies at the heart of this sophisticated neural selectivity: MST neurons appear to be capable of performing a multiplicative operation on their inputs. These inputs come from neurons one step earlier in the visual pathway, in a well-studied area known as MT. In other words, the inputs of MT neurons are multiplied in order to get the output of MST neurons. This turns out to be remarkably similar to what has been observed in other brain areas and in other species, suggesting it may reflect a general strategy by which brains process sensory information. "One interesting aspect of the computation is that it appears to be about the same as what other people have found in flies and beetles, suggesting that evolution solved this problem once, at least a few hundred million years ago."

"We developed a new motion stimulus with a morphing pattern flow (e.g. dots on a screen that are expansive, swirl around, circle to the right, contract etc) and recorded MST neurons responding to these stimuli," says Patrick Mineault, Ph.D. candidate at The Neuro and primary author on the study. "We circumvented the issue of increasing complexities of calculations along the various steps of the visual pathway by incorporating known data from neurons just one step earlier in the pathway - area MT, which precedes MST. As we now had measurements of the output of the MST neurons from the study's recordings, and already knew the input of MT neurons, we could calculate the math linking these two functions – and it turns out to be a multiplicative function." The mathematical models successfully account for the stimulus selectivity of some of the brain's complex motion neurons - which are vitally important in helping navigate us through the world.

Provided by McGill University

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