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Pinning down the ticking of the neural clock

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Our innate ability to track time is important for our everyday lives. We would not be able to speak, or even walk properly if we were not able to get the timing of each action just right. How are we able to track time? Are there a bunch of neural clocks ticking away somewhere deep inside our brain, cuing us on when to perform different actions? Recent results by neuroscientists at the Champalimaud Centre for the Unknown in Lisbon provide support to current theories in the field advocating the existence of such clocks and demonstrate, for the first time, that they can be used to predict behaviour.

"We discovered that populations of neurons in a part of the brain called the Striatum, which is known to be important for timing behaviour, create sequences of activity that can be used to encode time and to predict timing behaviour." Says Dr. Joe Paton, Principal Investigator at the Champalimaud Centre for the Unknown and the head of this study.

The researchers were able to identify this mechanism by asking rats to decide whether two brief sounds were separated by a duration of more, or less than 1.5 seconds. At the same time, the researchers recorded the activity of multiple neurons in the Svtriatum.

"By analysing the activity of the neurons, we found that it could be used to encode time." Says Dr. Tiago Monteiro, a postdoctoral researcher in the lab of Dr. Paton and one of the authors of the study. "Specifically, we found that upon the presentation of the first sound, a stereotypical wave-like activity took place within the group of recorded neurons. Throughout this wave, certain neurons would always be active earlier and others later. In this way, we could tell how much time had passed since the first sound by simply following the progression of the wave."

The idea that a stereotypical wave of neural activity can work as a clock is a model that has had robust support in the scientific community. According to this model, some neurons would be active earlier, and some later, so the brain could tell how much time had passed by simply observing which neuron is active. But how can the researchers confirm that the rat actually uses this clock to estimate time?

"To answer this question, we always have to look at what happens when the animal has to make difficult decisions, ones that are close to the boundary. It is easy enough for the rat to know that 2.5 seconds are longer than 1.5, but what about 1.6? Both animals and humans find these types of tasks very challenging. That's when their behaviour becomes more variable. For the same duration, on some trials the animal might decide that it was long and on others, that it was short. We cannot predict when this will happen, but we can look at the neural activity and see if the neurons can." Explains Dr. Monteiro.

And that is precisely what the researchers observed. "When a rat had to decide whether a 1.6 seconds interval was shorter or longer than 1.5 seconds, we could see how the population clock stretched or shrunk in accordance with the decision of the animal." Explains Thiago Gouvêa, a doctoral student at the lab who also participated in this study. "If the wave would move faster, then the neurons that are usually active during the later part of the wave would already be active at the time the second sound happens and the rat would decide the duration was long. However, the wave would frequently move slower, leading the rat to believe erroneously that the duration was short."

These results strongly indicate that the behaviour of the rat may be driven by this population of neurons, which informs the animal how much time had passed, leading it to make corresponding decisions.

"This is the first time that the relation between the speed of the ´neural population clock' and the duration judgments made by the subject has been demonstrated. The question now is how is this timing information generated and how is it precisely used to guide the behaviour of the animal." Concludes Dr. Paton.

Finally, even though the rat was making mistakes when it had to make decisions about durations close to the boundary, the researchers "don't think this means that the clock isn't perfect exactly... It is perhaps variable relative to the time our watch provides, but this might actually be an optimal representation of time for the organism."

More information: Thiago S Gouvêa et al. Striatal dynamics explain duration judgments, *eLife* (2015). DOI: 10.7554/eLife.11386

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