Breathing modulates brain activity and mental function

New research shows that the rhythm of breathing directly impacts neural activity in a network of brain areas involved in smell, memory and emotions

The rhythm of breathing co-ordinates electrical activity across a network of brain regions associated with smell, memory, and emotions, and can enhance their functioning, according to a new study by researchers at North-western University. The findings, published in the *Journal of Neuroscience*, suggest that breathing does not merely supply oxygen to the brain and body, but may also organise the activity of populations of cells within multiple brain regions to help orchestrate complex behaviours.

Nearly 75 years ago, the British physiologist Edgar Adrian used electrodes to record brain activity in hedgehogs, and found that brain waves in the olfactory system were closely coupled to breathing, with their size and frequency being directly related to the speed at which air moves through the nose. Since then, this same activity has been observed in the olfactory bulb and other brain regions of rats, mice and other small animals, but until now it has not been investigated in humans.

In this new study, a research team led by Christina Zelano recorded electrical activity directly from the surface of the brain in seven patients being evaluated for surgery to treat drug-resistant temporal lobe epilepsy, focusing on three brain regions: the piriform cortex, which processes smell information from the olfactory bulbs, the hippocampus, which is critical for memory formation, and the amygdala, which plays an important role in emotional processing. At the same time, they monitored the patients' respiratory rates with either pressure sensors or an abdominal breathing belt.

The researchers found that slow brain wave oscillations in the piriform cortex, and higher frequency brain waves in the hippocampus and amygdala, were synchronised with the rate of natural, spontaneous breathing. Importantly, though, the brain wave oscillations in all three regions were most highly synchronised immediately after the patients breathed in, but less so while they were breathing out. And when the patients were asked to divert breathing to their mouths, the researchers observed a significant decrease in brain wave coupling.

Thus, the air plumes that periodically enter the nose during natural breathing appear to synchronise the activity of neurons in the piriform cortex, and this synchrony is then propagated to the hippocampus and amygdala.

Given the well-established respective roles of the hippocampus and amygdala in memory and emotions, the researchers conducted a series of behavioural tests to investigate whether breathing phase might influence thought processes. First, they recruited 21 healthy participants, and asked them to perform an emotion discrimination task. They were shown images of faces expressing either fear or surprise, in quick succession, and asked to identify the emotion in each one as quickly as they could. Another group of 75 healthy participants performed a visual memory task, in which they viewed a series of images and then identify the ones they had seen before from a second series presented to them 20 minutes later.

Participants in the emotion discrimination task identified the fearful faces, but not the surprised ones, more quickly when they saw them while breathing in compared to when breathing out. And those who performed the memory task were far better able to recall images that had been presented to them while breathing than those they saw while breathing out.

Breathing therefore modulates emotional recognition and memory recall, with both processes being more accurate during breathing in compared to breathing out. Once again, the route of breathing was critically important – the effects were seen when the participants were asked to breath in through their noses, but their performance on both tasks declined markedly when they breathed through their mouths.

Breathing is controlled unconsciously by the brainstem, and humans alter their breathing pattern in response to emotional stimuli and mental effort, suggesting that our thought processes affect the rate of breathing. These new findings suggest that breathing can also impact our mental function. For example, breathing rapidly when we are scared or highly aroused may optimise information processing in the brain so that we can think and act appropriately and quickly.

"When you breathe in… you are stimulating neurons in the olfactory cortex, amygdala and hippocampus," says Zelano. "In a panic state, your breathing rhythm becomes faster [and] as a result you'll spend proportionally more time inhaling," [This] could have a positive impact on brain function and result in faster response times to dangerous stimuli in the environment."

Reference

Zelano, C., *et al*. (2016). Nasal Respiration Entrains Human Limbic Oscillations and Modulates Cognitive Function. *J. Neurosci*., **6**: 12448 –12467 [Abstract]