How the brain helps us focus our attention

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How can we shift from a state of inattentiveness to one of highest attention? Scientists at the Max Planck Institute for Human Development and the University of Southern California have developed a novel framework describing the way the locus coeruleus regulates our brain’s sensitivity to relevant information in situations requiring attention. Credit: Anubhav Saxena on Unsplash

How can we shift from a state of inattentiveness to one of highest attention? The locus coeruleus, literally the "blue spot," is a tiny cluster of cells at the base of the brain. As the main source of the neurotransmitter noradrenaline, it helps us control our attentional focus. Synthesizing evidence from animal and human studies, scientists at the Max Planck Institute for Human Development and the University of Southern California have now developed a novel framework describing the way the blue spot regulates our brain's sensitivity to relevant information in situations requiring attention. Their findings have been published in an opinion article in the journal *Trends in Cognitive Sciences*.

Our attention fluctuates. Sometimes, we are distracted and things slip by our awareness, while at other times we can easily focus on what is important. Imagine you are walking home after a day at work; perhaps you are preparing the list of groceries to buy for dinner in your mind—you are in a state of inattentiveness. However, when a car you did not notice suddenly honks, you are readily able to redirect your attention and respond to this new situation. But how does the brain shift from a state of inattentiveness to one of focused attention?

During states of inattentiveness, our brains are governed by slow, rhythmic fluctuations of neural activity. In particular, neural rhythms at a frequency around 10 Hertz, termed alpha oscillations, are thought to suppress the active processing of sensory inputs during inattentiveness. Thus, alpha oscillations can be understood as a filter that regulates our brain's sensitivity for external information.

"While the link between the waxing and waning of alpha oscillations and attention has been established for some time, less is known about what makes these rhythmic firing patterns come and go," says Markus Werkle-Bergner, Senior Scientist at the Center for Lifespan Psychology at the Max Planck Institute for Human Development and coauthor on the opinion article.

To explore this question, the researchers focused on the blue spot (locus coeruleus), a tiny cell structure that is located in the brainstem, hidden deep under the cortex. This cell cluster is only about 15 millimeters in size, but it is connected to most of the brain via an extensive network of long-ranging nerve fibers. The blue spot is made up of neurons that are the main source of the neurotransmitter noradrenaline. By regulating neural communication, noradrenaline contributes to the control of stress, memory, and attention.

"Due to its small size and its location deep in the brainstem, it was previously almost impossible to investigate the noradrenergic nucleus non-invasively in living humans. Fortunately, over the past years, animal research has revealed that fluctuations in pupil size are linked to the activity of the blue spot. Thus, our eyes can be regarded as a window to a brain region that long seemed inaccessible," says Mara Mather, professor of Gerontology at the University of Southern California and coauthor on the opinion article.

To study whether the blue spot's noradrenaline could be one factor regulating alpha oscillations, the researchers combined recordings of pupil size and neural oscillations while participants solved a demanding attention task. As expected, during moments of larger pupil size, indicative of higher noradrenergic activity, alpha oscillations disappeared. Moreover, participants who showed stronger pupil and alpha responses were better at solving the attention task. These findings, that were published 2020 in an article in the *Journal of Neuroscience*, suggest that by modulating alpha oscillations, the blue spot can help us focus our attention.

What remained unanswered in this study is how noradrenaline influences alpha oscillations. To approach this question, the authors additionally turned to previous animal research that recorded neural activity directly from neurons in the thalamus, a region in the middle of the brain that functions as a pacemaker of the alpha rhythm. Importantly, the rhythmic firing of these neurons at rest gives rise to the cortical alpha oscillations seen during states of inattentiveness. However, adding noradrenaline to these neurons abolishes their rhythmicity.

"Assembling the findings across studies, we were able to describe how noradrenaline and the thalamus might interact to control alpha rhythmic activity. We suggest that the blue spot's noradrenaline regulates our brain's sensitivity to process relevant information by suppressing alpha generators in the thalamus," says Martin Dahl, postdoctoral researcher at the Center for Lifespan Psychology, Max Planck Institute for Human Development, and the University of Southern California and first author on the opinion article.

Thus, during situations requiring a sudden shift in attention, a surge of noradrenaline helps us refocus—and quickly dodge the approaching car.

Further long-term studies that assess both the locus coeruleus and thalamus in the same participants may be able to shed new light on the neural mechanisms of attention and its decline in aging and disease.

More information: Martin J. Dahl et al, Noradrenergic modulation of rhythmic neural activity shapes selective attention, *Trends in Cognitive Sciences* (2021). DOI: 10.1016/j.tics.2021.10.009

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