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Alpha, beta, theta: What are brain states and brain waves? And can we control them?

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There's no shortage of apps and technology that claim to shift the brain into a "theta" state—said to help with relaxation, inward focus and sleep.

But what exactly does it mean to change one's "mental state"? And is that even possible? For now, the evidence remains murky. But our understanding of the brain is growing exponentially as our methods of investigation improve.

Brain-measuring tech is evolving

Currently, no single approach to imaging or measuring brain activity gives us the whole picture. What we "see" in the brain depends on which tool we use to "look." There are myriad ways to do this, but each one comes with trade-offs.

We learnt a lot about brain activity in the 1980s thanks to the advent of magnetic resonance imaging (MRI).

Eventually we invented "functional MRI," which allows us to link brain activity with certain functions or behaviors in real time by measuring the brain's use of oxygenated blood during a task.

We can also measure electrical activity using EEG (electroencephalography). This can accurately measure the timing of brain waves as they occur, but isn't very accurate at identifying which specific areas of the brain they occur in.

Alternatively, we can measure the brain's response to magnetic stimulation. This is very accurate in terms of area and timing, but only as long as it's close to the surface.

What are brain states?

All of our simple and complex behaviors, as well as our cognition (thoughts) have a foundation in brain activity, or "neural activity."

Neurons—the brain's nerve cells—communicate by a sequence of electrical impulses and chemical signals called "neurotransmitters."

Neurons are very greedy for fuel from the blood and require a lot of support from companion cells. Hence, a lot of measurement of the site, amount and timing of brain activity is done via measuring electrical activity, neurotransmitter levels or blood flow.

We can consider this activity at three levels. The first is a single-cell level, wherein individual neurons communicate. But measurement at this level is difficult (laboratory-based) and provides a limited picture.

As such, we rely more on measurements done on a network level, where a series of neurons or networks are activated. Or, we measure whole-of-brain activity patterns which can incorporate one or more so-called "brain states."

According to a recent definition, brain states are "recurring activity patterns distributed across the brain that emerge from physiological or cognitive processes." These states are functionally relevant, which means they are related to behavior.

Brain states involve the synchronization of different brain regions, something that's been most readily observed in animal models, usually rodents. Only now are we starting to see some evidence in human studies.

Various kinds of states

The most commonly-studied brain states in both rodents and humans are states of "arousal" and "resting." You can picture these as various levels of alertness.

Studies show environmental factors and activity influence our brain states. Activities or environments with high cognitive demands drive "attentional" brain states (so-called task-induced brain states) with increased connectivity. Examples of task-induced brain states include complex behaviors such as reward anticipation, mood, hunger and so on.

In contrast, a brain state such as "mind-wandering" seems to be divorced from one's environment and tasks. Dropping into daydreaming is, by definition, without connection to the real world.

We can't currently disentangle multiple "states" that exist in the brain at any given time and place. As mentioned earlier, this is because of the trade-offs that come with recording spatial (brain region) versus temporal (timing) brain activity.

Brain states vs. brain waves

Brain state work can be couched in terms such as alpha, delta and so forth. However, this is actually referring to brain waves which specifically come from measuring brain activity using EEG.

EEG picks up on changing electrical activity in the brain, which can be sorted into different frequencies (based on wavelength). Classically, these frequencies have had specific associations:

- gamma is linked with states or tasks that require more focused concentration
- beta is linked with higher anxiety and more active states, with attention often directed externally
- alpha is linked with being very relaxed, and passive attention (such as listening quietly but not engaging)
- theta is linked with deep relaxation and inward focus
- and delta is linked with deep sleep.

Brain wave patterns are used a lot to monitor sleep stages. When we fall asleep we go from drowsy, light attention that's easily roused (alpha), to being relaxed and no longer alert (theta), to being deeply asleep (delta).

Can we control our brain states?

The question on many people's minds is: can we judiciously and intentionally influence our brain states?

For now, it's likely too simplistic to suggest we can do this, as the actual mechanisms that influence brain states remain hard to detangle. Nonetheless, researchers are investigating everything from the use of drugs, to environmental cues, to practicing mindfulness, meditation and sensory manipulation.

Controversially, brain wave patterns are used in something called "neurofeedback" therapy. In these treatments, people are given feedback (such as visual or auditory) based on their brain wave activity and are then tasked with trying to maintain or change it. To stay in a required state they may be encouraged to control their thoughts, relax, or breathe in certain ways.

The applications of this work are predominantly around mental health, including for individuals who have experienced trauma, or who have difficulty self-regulating—which may manifest as poor attention or emotional turbulence.

However, although these techniques have intuitive appeal, they don't account for the issue of multiple brain states being present at any given time. Overall, clinical studies have been largely inconclusive, and proponents of neurofeedback therapy remain frustrated by a lack of orthodox support.

Other forms of neurofeedback are delivered by MRI-generated data. Participants engaging in mental tasks are given signals based on their neural activity, which they use to try and "up-regulate" (activate) regions of the brain involved in positive emotions. This could, for instance, be useful for helping people with depression.

Another potential method claimed to purportedly change brain states involves different sensory inputs. Binaural beats are perhaps the most popular example, wherein two different wavelengths of sound are played in each ear. But the evidence for such techniques is similarly mixed.

Treatments such as neurofeedback therapy are often very costly, and their success likely relies as much on the therapeutic relationship than the actual therapy.

On the bright side, there's no evidence these treatment do any harm—other than potentially delaying treatments which have been proven to be beneficial.