When the brain lies: Body posture alters neural activity

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Imagine if researchers were up front about what awaits the subject of a typical brain imaging session: "Welcome to the lab, please lie down and keep your head absolutely still. We'll slide you into this tube here and be back in an hour. These earbuds will help block out any sudden screeches and thumps—of which there will be plenty. Good luck."

Now, for many clinical and research purposes, this situation poses only negligible problems. But what if we aim to understand the brain processes of everyday human functioning? How likely is it that a typical person will respond to the contrived environment of a magnetic resonance imaging (MRI) session in a similar manner as they would to a more familiar, ecological context? For researchers looking to model brain processes associated with day-to-day activity, such questions point toward a serious concern—we must treat the brain not as a jumble of neurons in a vat, but as a component of a body that interacts with its environment.

Lying motionless in a cramped tube or sitting alone in a silent and dimly lit room remains far from a run-of-the-mill afternoon. And yet, much of our knowledge of the functioning human brain stems from such settings. If we closely examine the constraints that neuroimaging experiments impose, we can start to understand how these experimental settings affect us. One oft-overlooked source of discrepancy between experimental and everyday contexts—namely, body posture—not only changes the way our neurons fire, but also alters the way we feel pain, breathe, think, and even see. It turns out that whether participants sit, stand, or lie down can dramatically impact the results of a brain imaging study.

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To better appreciate how brain imaging environments alter our mental and physical states, we must first examine what these environments look like. Today, most functional neuroimaging—that is to say, measures of brain function rather than brain structure—record either electromagnetic signals or the level of oxygen in the blood circulating throughout the brain. The physical constraints vary with the method. For example, in a typical electroencephalography (EEG) experiment (see Chapter 7), participants sit alone in an eerily quiet room and stare at a computer screen for extended periods of time. In a standard functional MRI (fMRI) experiment (see Chapter 8), participants lie motionless in a narrow cylinder while loud hums and thumps revolve around their head for up to an hour. While functional neuroimaging generally draws on these two technologies, researchers sometimes opt for other techniques such as magnetoencephalography (MEG) and functional near infrared spectroscopy (fNIRS).

Each imaging modality permits a subset of body positions. Participants can wear EEG and fNIRS caps throughout a wide range of postures and, with proper equipment, can move and interact with their environment; MEG machines often restrict participants to an adjustable seat that can adopt any position between an upright chair and a horizontal bench; and most fMRI options constrain participants to horizontal positions. Compared to portable technologies (EEG and fNIRS) the large and static imaging devices (fMRI and MEG) permit fewer postures, yet provide higher quality data. These intrinsic differences make certain imaging modalities more advantageous for specific applications and research questions but less so for others. For example, the postural constraints of most MRI scanners would make fMRI a good way to explore the resting brain, but less ideal to study the brain of a motorist at the wheel.

The truth, which many studies avoid addressing directly, is that the imaging environment, by restricting the range of available postures, can alter the very mental phenomena researchers aim to study. Take the simple difference between upright and lying subjects. Not only do we perform motor tasks better when sitting upright but we also smell certain odors better, feel pain more intensely, and asses our visual field differently [1−4]. Sitting amplifies our anxiety, increases motivation, hinders conflicting thoughts, and improves nonverbal intelligence compared to lying down [4,5]. On the flip side, whereas upright postures can improve our selective attention [6], they can compromise performance on problems requiring a burst of insight [7].

Sitting and standing also affect physiology and increase our heart rate, respiratory volume, oxygen consumption, core body temperature, and the release of a stress hormone known as cortisol [8−11]. Body posture further regulates the volume and flow of blood throughout the brain [12]. Notably, these processes represent the very signal that fMRI measures: blood-oxygen concentrations—not, as is often presumed, neural activity itself (see Chapter 8). Thus posture can influence the fMRI signal via mechanisms independent of the activity of neurons [13].

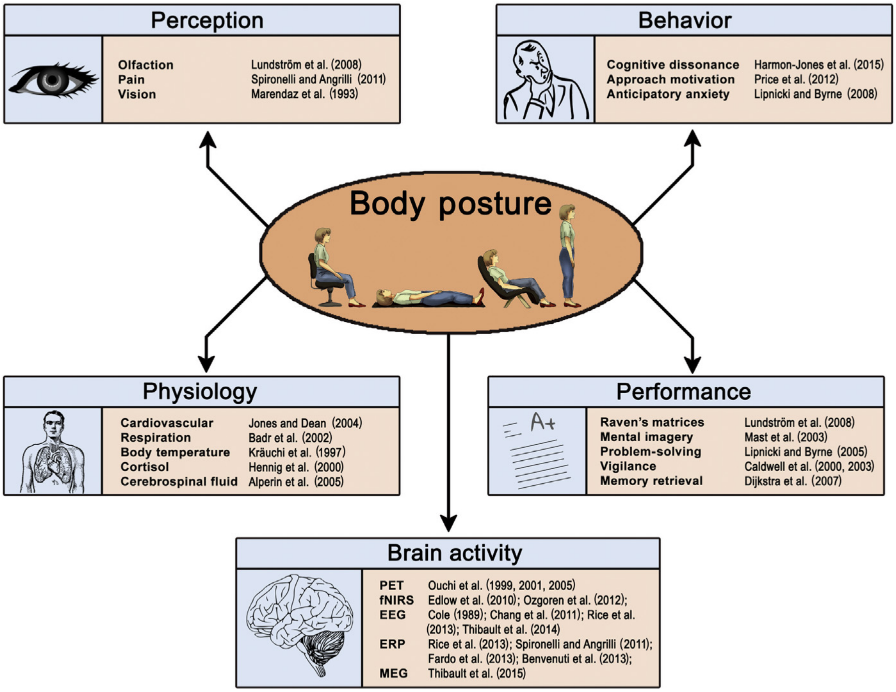

Figure 10.1 Posture modulates physiology and cognition: Select experimental findings. From Thibault, R. T., & Raz, A. (2016). Imaging posture veils neural signals. Frontiers in human neuroscience, 10, 520.

Beyond the psychological and basic physiological measures, posture also exerts a quantifiable and direct impact on brain activity. When we sit upright, our brains assume a different baseline state than when we lie down. Sitting amplifies high-frequency brain waves, associated with alertness and sensory processing, and dampens down low-frequency waves, associated with relaxed or drowsy states [14]. Further studies suggest that posture can influence a core brain system known as the default mode network [15]. Depending on body position, our neurons also respond differently to visual presentations [16], painful stimuli [3], and emotional events [17]. Whereas the majority of these studies employ healthy young adults, posture may exert a particularly strong influence on brain function in the elderly and specific patient groups. Taken together, these insights raise the question: How do we better account for the brain as a component of a body in an environment, thus interpreting neuroimaging results in a fuller context?

By looking at posture in particular, scientists have already made headway on this issue and identified at least three mechanisms by which posture influences brain data. First, lying down may hinder the brain from releasing the chemical precursor to adrenalin. Gravitational loads redistribute when lying down, stimulating receptors in our circulatory system and initiating a physiological cascade that reduces the excitability of neurons. A cleverly designed experiment supports this explanation.

Researchers used inflatable pants to apply leg pressure to participants in order to stabilize circulatory receptor activity and found that postural effects on brain waves were partially negated [9].

Second, the distribution of the highly conductive fluid, in which our brain bathes, differs based on the posture we assume. This substance, known as cerebrospinal fluid, drastically alters electrical signals as they pass from brain to imaging sensor [18]. One study found that when lying face-up, rather than lying face-down, gravity draws the brain downward, thins out the cerebrospinal fluid under posterior brain regions, and in turn, amplifies the electrical signals recorded from the back of the brain [16].

Third, our brains may only be prepared to act on the subset of possible interactions we can have with the surrounding environment based on our current body position. Planning movements depend on the configuration of our limbs [19] and we react more quickly to moving visual fields when upright [20]. Lying down, moreover, decreases social behaviors [21] and hardly invites typical social interactions known to modulate brain activity, such as eye contact [22].

Adopting experimental designs that evaluate and integrate these three mechanisms will refine our ability to use experimental contexts to understand human brain function during everyday life. For example, to help maintain a more “upright” brain state when participants lie down, researchers could entertain the possibility of applying pressure to the body to maintain circulatory receptor activity, pharmacologically sustaining adrenalin levels, or providing periodic stimulation via conversation or sensory input. To overcome variations in the distribution of cerebrospinal fluid, we may require anatomical brain scans from each participant alongside novel compensatory algorithms that cancel out the influence this fluid has on brain signals. Researchers could furthermore weed out participants suffering from sleep-deprivation or other conditions that may cause their brain and body to react differently when upright compared with when lying down. With diligence, neuroimagers can improve current research paradigms to account for a number of these postural discrepancies.

Researchers can also leverage smaller, lighter, and more mobile imaging devices. With the use of overhead tracks, participants undergoing EEG and fNIRS can now move and interact in a laboratory environment. Recent developments, moreover, permit individuals to connect EEG electrodes to their smartphone and record brain activity in everyday contexts [23]. Moving while recording EEG, however, comes with caveats and raises the concern that researchers who are not careful may mistake artifacts for brain oscillations themselves. These portable devices currently sacrifice signal quality for ecological human functioning. Fortunately, technologies can also be used in tandem with one another. In a single experiment, we can combine concurrent data from the more precise and static imaging modalities with data from ecological yet coarser resolution measurements. Similar to how portable devices transformed the field of eye-tracking, wearable neuroimaging technologies may revolutionize how we study the living human brain.

In summary, posture reliably influences brain, body, and mind. This reality rings alarm bells in a field that rarely considers postural constraints. Whereas humans perform the largest diversity of their interactions with the world when standing and moving, most neuroimaging studies demand that participants sit up or lie down and remain motionless. This state of affairs points toward a critical question to ask when interpreting *any* research: How generalizable are the findings? Does the experimental context diverge substantially from an everyday setting? If so, we best interpret the results with due diligence.

Additional readings

A proposal for an embodied approach to neuroscience: Kiverstein J, Miller M. The embodied brain: towards a radical embodied cognitive neuroscience. Front Hum Neurosci 2015;9:1–11.

A landmark research experiment on posture and EEG: Rice JK, Rorden C, Little JS, Parra LC. Subject position affects EEG magnitudes. NeuroImage 2013;64:476–84.

A more in-depth review: Thibault RT, Raz A. Imaging posture veils neural signals. Front Hum Neurosci 2016;10:520.