Chapter 12

MRI–Compatible Haptic Stimuli Delivery Systems for Investigating Neural Substrates of Touch

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ABSTRACT

Functional magnetic resonance imaging (fMRI) has been widely used to study human tactile perception. To reveal many unsolved problems to human tactile perception, developing complex and fMRI-compatible stimulation devices are crucial for tactile perception research. These stimulation devices, combined with functional magnetic resonance imaging (fMRI), can assist researchers in analyzing human brain activity. Through analyzing human brain activity, researchers can clarify how the human brain controls the body. Meanwhile, these device scan provide the best rehabilitation program for patients. This chapter presents previous fMRI-compatible stimulation devices, including texture stimulation, shape stimulation, vibrotactile stimulation, etc., which involve the hands, face, ears, legs and other parts of the body. In this chapter, we examine the design of the devices in greater detail. Finally, we summarize the characteristics of these devices and create an outlook for future fMRI-compatible devices.
Functional magnetic resonance imaging is a functional neuroimaging technique that uses MRI technology to measure brain activity by detecting changes in oxygen levels in the blood (Huettel, S. A, et al., 2009). Neuronal activation and cerebral blood flow are coupled. When an area of the brain is activated and requires energy, blood flow to this region also increases. Therefore, the primary form of this technique depends on the principle of blood-oxygen-level dependent (BOLD) contrast (Huettel, S. A, et al., 2009), which was discovered by Seiji Ogawa.

This procedure is similar to MRI but uses the change in magnetization between oxygen-poor and oxygen-rich blood, which can be detected on the basis of differential magnetic susceptibility. Although this measure is always disturbed by noise from various sources, statistical methods are used to extract the underlying signal. Then, the activation in the brain can be presented graphically by color-coding the strength of activation across the brain; thus, this technique can localize activity to within millimeters.

When neurons are activated, they require more energy in the form of sugar and oxygen. This process is called the hemodynamic response, and blood will bring oxygen to the activated neurons. This technology uses a type of specialized brain scan to map neural activity in the brain by imaging changes in the hemodynamic response as a result of energy use by brain cells (Huettel, S. A, et al., 2009).

Since the early 1990s, fMRI has dominated brain mapping research because it does not require people to undergo surgery, shots, be exposed to ionizing radiation, etc. (Huettel, S. A, et al., 2009). During the late 19th century, Angelo Mosso invented the ‘human circulation balance’, which worked like a seesaw to measure blood flow changes in the brain (Sandrone S, et al., 2012).

However, although briefly mentioned by William James in 1890, the precise workings of this balance and the experiments remained unclear until the discovery of the original instrument as well as Mosso’s reports by Stefano Sandrone and colleagues (Sandrone S, et al., 2014). In 1890, Charles Roy and Charles Sherrington first experimentally linked brain function to its blood flow at Cambridge University (Raichle, M. E, et al., 2000). In 1936, Linus Pauling and Charles Coryell discovered solutions to measure blood flow to the brain. They found that oxygen-depleted blood with dHb was attracted to a magnetic field, although less so than ferromagnetic elements, such as iron, whereas oxygen-rich blood with Hb was weakly repelled by magnetic fields. As Seiji Ogawaat At&T Ball labs recognized, this could be used to
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