

Brain Study Techniques

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Brain study techniques are used to understand how the brain processes information and manages behavior. They can establish which parts of the brain are responsible for different types of cognition and behavior. One technique, called *lesion studies*, involves conducting case studies of patients with brain injury and associating damage in specific regions or structures with loss or impairment of specific cognitive processes and behaviors. For example, in the mid-1800s, using post-mortem autopsy, Paul Broca observed that patients who had lost the ability to speak, but could understand language, had damage in the posterior sections of the inferior frontal gyrus; whereas, Carl Wernicke observed that patients who could speak, but could not understand language, had damage in a posterior section of the superior temporal gyrus, establishing a double dissociation between these structures and functions.

Since the 1990s, technological innovations have provided researchers with non-invasive methods for localizing cognitive functions in the brain. The most widely used modern brain study technique is *functional magnetic resonance imaging (fMRI)*, which measures changes in blood flow and oxygen content within the brain due to neuronal activity. In a fMRI study, a participant lies on a table, a coil is placed on the head, and the table is moved into a large, tube-shaped magnet. While in the magnet, a series of high spatial resolution digital photographs of the brain are taken while the participant processes stimuli and performs cognitive tasks, allowing researchers to identify brain structures and regions that are active during specific types of processing. Inside the scanner, auditory stimuli can be presented through headphones and visual stimuli can be presented using projection onto specialized goggles. Participants use hand-held

button boxes to select responses, which also record accuracy and response times. Experimental and control trials, which allow researchers to subtract activation due to button presses, visual processing, and other cognitive functions, can be randomly presented in blocks or interleaved in an event-related design. Correlations between brain activation in structures or regions and cognitive processing or responses can be represented on standardized brain templates using colored pixels. fMRI has several limitations: participants cannot have iron-containing metal on or in their bodies (e.g., jewelry, orthodontic braces); participants must remain still during scanning, limiting usefulness for infants and young children; tasks must minimize movement and talking; and measurement of the timing of blood flow is on the scale of seconds, rather than milliseconds (i.e., low temporal resolution).

fMRI procedures often also include *diffusion tensor imaging (DTI)*. DTI measures the diffusion process of water within brain tissue to generate images of white matter tracts, which are the axons of neurons insulated by a fatty substance, called *myelin*. DTI can be used to gauge the organization and integrity (i.e., density and myelination) of connections between brain regions. Some DTI studies have established associations between developmental maturation, white matter organization, cognitive function, and disorders.

Another brain study technique uses *electroencephalography (EEG)* to identify neural networks associated with cognitive processing by measuring the time course of electrical activity as information is transferred from region to region across the brain. In an EEG study, a participant wears an elastic cap that has between 20 to 256 sensors placed in standard positions on the scalp to record electrical activity generated by neurons in the brain. The participant listens to or watches a large number of trials of stimuli presented by a computer system and may respond by clicking buttons on a mouse. Researchers use experimental and control condition

trials to extract *event-related potential (ERP)* components from waveforms by averaging electrical activity at each sensor site, time-locked to the onset of the target stimulus and isolating them from other brain activity. These components are typically labeled according to the polarity of the peak (Positive or Negative) and order (1st, 2nd, 3rd) or timing in milliseconds. For example, a negative peak that occurs at 100 milliseconds, called *N1*, is associated with processing in the visual cortex; while a positive peak at 200 milliseconds, called *P200*, is associated with pattern recognition in parieto-occipital and frontal regions. Scalp distribution maps and time-lapse video can be used to present results. ERP can be used with all ages, including infants, but localization is limited to general brain regions, rather than specific structures (i.e., low spatial resolution).

Further Reading

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