Chapter 9
Cognitive Neuroscience in Information Systems Research

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ABSTRACT

This paper reviews cognitive neuroscience and several neurophysiological tools (e.g., fMRI, PET, EEG, MEG, and eye tracking). The strengths and weaknesses of such tools for information systems research are presented. The paper provides examples of existing cognitive neuroscience studies in varies areas, such as neuroeconomics, neuromarketing, and eye tracking. In addition, this paper provides an overview of brain areas that response to various mental processes, and discusses the localization and functionality of each brain area. Because of the popularity of eye-tracking research in information systems, measurements and metrics related and derived from eye-tracking technique (e.g., fixation, saccades and scanpath) are described and discussed in this paper. Opportunities for applying cognitive neuroscience techniques to IS research as well as future research directions are also discussed.

INTRODUCTION

Neuroscience is the scientific study of the nervous system. As a branch of science, neuroscience covers the fields of anatomy, physiology, biochemistry, or molecular biology of nerves and nervous tissue. Cognitive neuroscience spans over and overlaps many disciplines such as neuroscience, physiological psychology, cognitive psychology, and neuropsychology.

Cognitive neuroscience aims to find the causal relationship between neural circuits in the brain and their corresponding psychological or cognitive functions. The use of neuroimaging functional tools (e.g., fMRI) enables the examination of brain mechanisms and brain activations while the subject performs mental tasks. In order to identify the brain area activated by a specific mental task, researchers have studied different research topics such as consciousness, cognition, memory, attention, emotion, decision making and others.

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Basics of Cognitive Neuroscience

The human brain contains about one hundred billion (10^{11}) neurons and 100 trillion (10^{14}) synapses, making it the most complex organ in human body. There are two major brain systems that control and influence our daily behaviors, namely the prefrontal cortex (PFC) and the limbic system. The prefrontal cortex is the brain's outer layer (cerebral cortex) that covers the front part of the prefrontal lobe. It is associated with higher cognitive processing such as reasoning, planning, problem solving, decision-making, and movements. The limbic system deals mainly with emotions and memories. Specific brain areas and their subdivisions are responsible for different behaviors. Table 1 summarizes the existing understanding of different parts of the brain and their associated cognitive behaviors.

OVERVIEW OF NEUROPHYSIOLOGICAL TOOLS

Functional Neuroimaging Techniques

In order to interpret the association between brain activation and corresponding stimulus, we need to identify which area is activated when the subject performs a particular task. Usually, there are four functional neuroimaging techniques that are commonly used to observe brain activation and they are fMRI, PET, EEG and MEG. fMRI and PET detect changes associated with cerebral blood flow whilst EEG and MEG are electrophysiological techniques that monitor electromagnetic brain activity.

Functional Magnetic Resonance Imaging or Functional MRI (fMRI)

fMRI is probably the most commonly used functional neuroimaging procedure using MRI technology. Based on the fact that regional cerebral blood flow always associate with neuronal activation during cognition, fMRI is able to localize and track changes in blood oxygenation, which is a reasonable proxy for neural activity. fMRI studies range from the examination of familiar cognitive processes (e.g., human

Table 1. Brain systems and responsive cognitive behaviors

Brain system and Functions	Key Area	Cognitive Behaviors
Prefrontal cortex - Problem solving - Personality expression - Calculation - Short-term memory - Moderating acceptable behavior - Decision making	Dorsal prefrontal cortex	Attention, cognition and action (Goldman, Rokic, 1988) Working memory (Braver et al., 1997; Cohen et al., 1997) Cognitive effort (Owen et al., 2005; Van der Linden et al., 2003)
	Ventral prefrontal cortex	Emotion (Price, 1999)
	Medial prefrontal cortex	Slow-wave sleep (SWS) (Mander et al., 2013)
Limbic System - Emotion - Behavior - Motivation - Long-term memory - Olfaction	Hypothalamus	Motivation, emotion, learning, and memory
	Hippocampus	- Spatial memory (Kheirbeck & Hen, 2011) - Learning (CurlikShors & Shors, 2012)
	Amygdala	- Episodic-autobiographical memory (EAM) networks (Markowitsch & Staniloiu, 2011) - Attention and emotional process, social processing