Applications of Neuroimaging in Information Science: Challenges and Opportunities

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ABSTRACT
This panel will discuss opportunities and challenges involved in applying cognitive neuroscience and neuroimaging in information science. The panelists will discuss lessons learned from related disciplines and will consider how neuroimaging tools, such as fMRI, fNIRS, and EEG, could contribute to information science.

Keywords
Neuroscience, neuroimaging, functional magnetic resonance imaging (fMRI), electroencephalography (EEG), Neuro-Information Science.

PANEL OVERVIEW AND MOTIVATION

The progress made in neuroscience in the last two decades allows one to expect that neuroscience will contribute to other disciplines. It has already happened in several social science disciplines, such as economics and marketing – neuroeconomics and neuromarketing have been established over a decade ago. The results from collaboration between behavioral economists and neuroscientists have supported advances in understanding of decision-making and human behavior (Camerer et al., 2004). More recently, information systems researchers started a new sub-field NeuroIS (Neuro Information Systems – Dimoka et al., 2010; NeuroIS.org, 2009). Information systems research studies the development and use of information and communication technologies in organizations and society. NeuroIS is "a subfield of information systems literature that relies on neuroscience and neurophysiological theories and tools to better understand the development, use, and impact of information technologies (IT)" (Riedl et al., 2010, p. 245).

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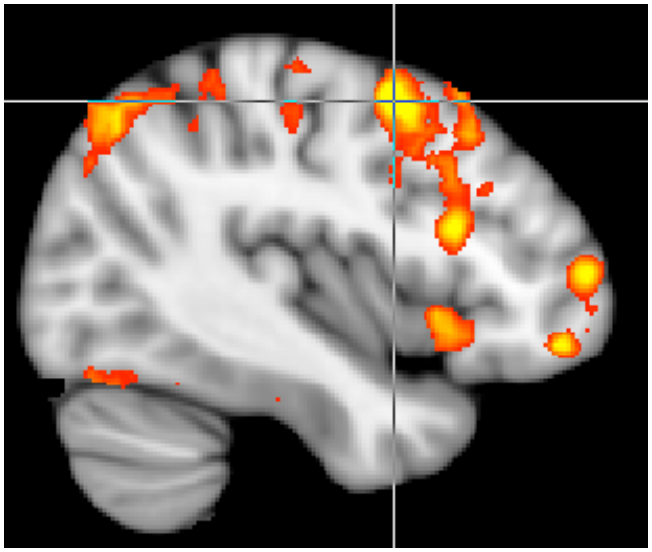

Figure 1. Example brain activations.

The cognitive aspects of human information interaction make information science (IS) a good candidate field that can take advantage of application of neuroscience theories and tools. These tools can provide a richer account of user cognition than that which is obtained from any other source. In addition, new technology developments in fMRI (stronger magnets and their wider availability) in eye-tracking (e.g., wider availability of high quality eye-trackers, new inexpensive eye-trackers, and a possibility of embedding high-resolution eye-tracking hardware in consumer laptops) and in EEG (e.g., low-cost consumer-level devices) enable wider use of these devices in research as well as raise the possibility of introducing some of them into the home environment as novel ways of collecting data about users.

The subfield that aims to take advantage of advances in cognitive neuroscience and neuroimaging techniques and apply them to answering information science and interactive information retrieval research questions has been termed *Neuro-Information Science* (Gwizdka, 2012; http://neuroinfoscience.org). The general motivation behind

this emerging field is a belief that an increasing familiarity with brain function should eventually lead to better information science theories and models. This potential for contributions of cognitive neuroscience to IS has been noted by other LIS scholars. For example, John Budd suggested that "a strain of research in IS could pay close attention to developments in neuroscience" (Budd, 2011).

This panel will discuss opportunities and challenges involved in applying neuroscience theories and tools. The panelists will discuss potential areas of their application in information science, and will highlight lessons learned from related disciplines as well as experiences from recent research projects (both completed and underway) that have employed fMRI (Moshfeghi et al., 2013; Gwizdka, 2013) and other tools. The panelists will also discuss potential future opportunities and areas where information science could benefit the most from application of neuroimaging tools.

Given that neuro-information science is in early stages of development we expect the panel to serve primarily as community building as well as awareness raising.

The opportunities and challenges that will be addressed by panelist include:

Opportunities

- *Objectivity* – Improve the measurement by complementing current sources of data with evidence from brain imaging data that can be taken as being objective and not subject to biases (e.g., subjectivity bias)
- *Localization* – Localize brain areas associated with information science constructs (such as information relevance, browsing vs. search).
- *Measurement of unobservable variables* (e.g., mental load, beliefs, emotions), and verification of hypothesized links between these variables and observable behavior (e.g., information source selection, choice of search tactic, stopping search) by mapping them on brain areas and their activation.
- *Verification* – Verify if information seeking behaviors considered as distinct are using similar brain areas.
- *Precision* - Add precision to information science models.

Challenges

- *Expertise* – the use of neuroscience tool requires expertise that goes beyond typical information science education and will thus require teaming up with neuroscientists.
- *Cost* – neuroscience tools can be very expensive In particular, fMRI equipment is particularly expensive (several million dollars) and thus conducting fMRI experiments requires access to neuroimaging centers and cooperation with neuroscientists.
- *Awareness* – the use of neuroimaging techniques in information science is new. Making progress will require increasing awareness of this new sub-area in the information science and information retrieval communities and gaining acceptance of funding agencies.
- *Limitations* – neuroimaging techniques come with their own limitations. We need to be aware that finding correlations between brain activities and information-behavior does not equate establishing causality (Ramsey et al., 2010) and that reverse inference (inferring engagement of a cognitive process from the activation of a brain region) should be used with great caution (Poldrack, 2006).

Potential areas of application (research questions)

- Better understanding of information relevance. Relevance is a fundamental concept in information science. It is a very complex and multi-dimensional construct. Neuroimaging tools can improve our understanding of this basic concept.
- Attempting to explain preferences for navigation over search in human-information interaction (including personal information management).
- Better understanding of cognitive demands imposed by search user interfaces and systems.

PANEL STRUCTURE

1. Introduction to the topic: 10 minutes, by the moderator;
2. Presentations by the panelists on work they have completed, on current projects and on their opinion on applications of neuroimaging to information science: each 10 minutes;
3. Discussion amongst the panelists based on questions posed to them by the moderator, both in advance of the panel, and based on the presentations, with contributions/questions from the audience. (30 minutes);
4. Summary discussion from the panel, led by the moderator: 10 minutes.

PANELISTS AND THEIR CONTRIBUTIONS

Jacek Gwizdka (Panel organizer and moderator)

Dr. Gwizdka is on the faculty of the School of Information at University of Texas, Austin. He conducts research in human-computer interaction with interests in information search processes and search interfaces, in application of cognitive psychology to interactive information retrieval, and in implicit assessment of mental states using psycho-physiological methods, such eye-tracking and EEG. His recent projects include application of cognitive neuroscience tools (fMRI) to the study of cognitive function engaged in human-information. More information on Dr. Gwizdka's research can be found at: http://gwizdka.com

Dr. Gwizdka will moderate the panel and present his experience with using fMRI and EEG with eye-tracking to explore the possibility of detecting brain activity related to relevance judgments of text.

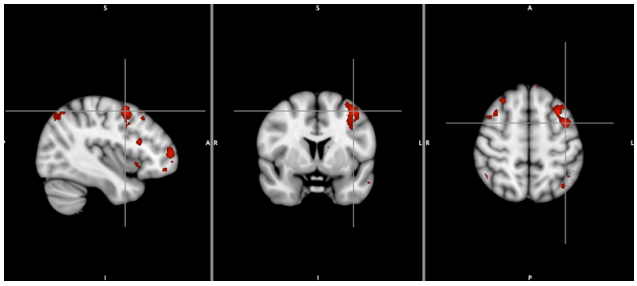

Figure 2. Differences in brain activation between judging relevance of a highly relevant vs. topically relevant vs. irrelevant text document - Middle Frontal Gyrus in left frontal lobe (group of eight participants – image from Dr. Gwizdka's fMRI experiment).

Yashar Moshfeghi (Panel participant)
Dr. Yashar Moshfeghi is a researcher in the School of Computing science at the University of Glasgow. He received a PhD in Information Retrieval from University of Glasgow. He has worked in different European projects in the filed of IR and is the author of several articles published in reputed conferences and is a member of different international working groups. His current research examines the brain regions activated during the explicit relevance judgement in an Information Retrieval process.

Frank E. Pollick (Panel participant)
Frank E. Pollick is a Professor of Psychology at the University of Glasgow. He received BS degrees in physics and biology from MIT, an MSc in biomedical engineering from Case Western Reserve University and a PhD in Psychology from The University of California, Irvine. From 1991–97 he was a researcher at the ATR Human Information Processing labs in Kyoto working on the topics of human perception and motor control. Since 1997 he has been in the School of Psychology at the University of Glasgow. His current research examines the information we use to perceive complex human activity and the underlying brain systems that process and evaluate this information.

From a theoretical perspective Dr. Moshfeghi and Prof. Pollick are interested in two issues. One issue is how best to characterize the concept of relevance within the psychological literature on working memory, executive function and attention. The other issue is how to address possible interactions between processing levels of perceptual representation and those of evaluation. On a practical level we are interested in how understanding brain mechanisms of relevance can be exploited in user feedback systems. Dr. Moshfeghi and Prof. Pollick will talk about their recent study, in which they investigated the connection between relevance and brain activity. fMRI was used to measure brain activity of 18 participants while they performed four topical relevance assessment tasks on relevant and non-relevant images. They will discuss their results from theoretical perspective of understanding the nature of information relevance and from applied perspective of utilizing it for more effective information retrieval.

Javed Mostafa (Panel participant)
Dr. Mostafa currently holds a joint position at the University of North Carolina at Chapel Hill. He is a Professor of information science in the School of Information and Library Science and a faculty member in the Biomedical Research Imaging Center of the School of Medicine. More information on Dr. Mostafa's research can be found here: http://lair.unc.edu

Dr. Mostafa is interested in investigating the possible relationship between locations in the brain that specialize in certain activities and information seeking tasks. Past studies on information seeking tasks, particularly on identifying task-typologies, have been primarily based on behavioral theories and evaluation methodologies. The research advances have been helpful and we now have a nuanced understanding of many typologies of information seeking tasks. However, there is a strong likelihood that certain types of information seeking tasks employ and activate specific brain regions. Hence, there is a possibility that localization or distribution patterns of activation can be used to analyze information seeking tasks and measure information seeking complexity. A related interest of Dr. Mostafa is information seeking evaluation methodologies that employ a broad spectrum of biological / physiological monitoring devices (e.g., fMRI, EEG, and skin conductance monitors).

Ofer Bergman (Panel participant)
Dr. Ofer Bergman is a lecturer (equivalent to Assistant Prof.) in the Dept. of Information Science at Bar-Ilan University. His main research interest is in Personal Information Management (PIM). One phenomenon that attracted his attention is preference for navigation over search in PIM. Some may disregard this simply as a learned habit, however there may be deeper reasons behind this. Using a dual task paradigm Bergman et al., (2013) found that searching for personal files requires more cognitive attention than navigation.

Another possible reason for navigation preference in PIM is that it involves the same brain structures used for physical navigation for millions of years (e.g. the hippocampus) while search demands the involvement of more 'advances' structures (e.g. pre-frontal lobe) thus requiring more attention. This is currently tested in an ongoing fMRI study with Dr. Yael Benn and Prof. Steve Whittaker.

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