Neurocognitive Foundations for the Learning Sciences

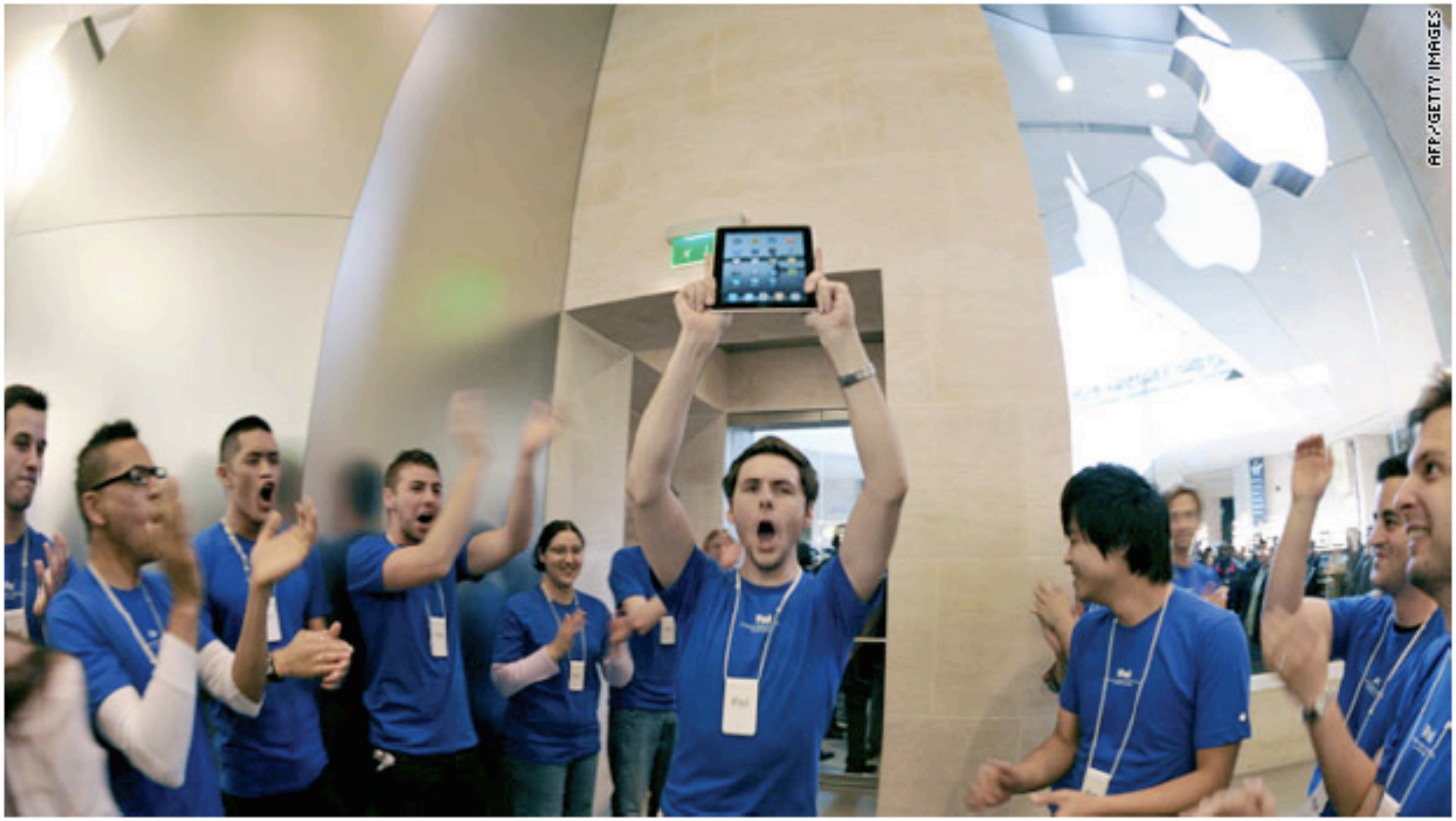
Sashank Varma
University of Minnesota

“The Cola Area”

McClure et al. (2004)

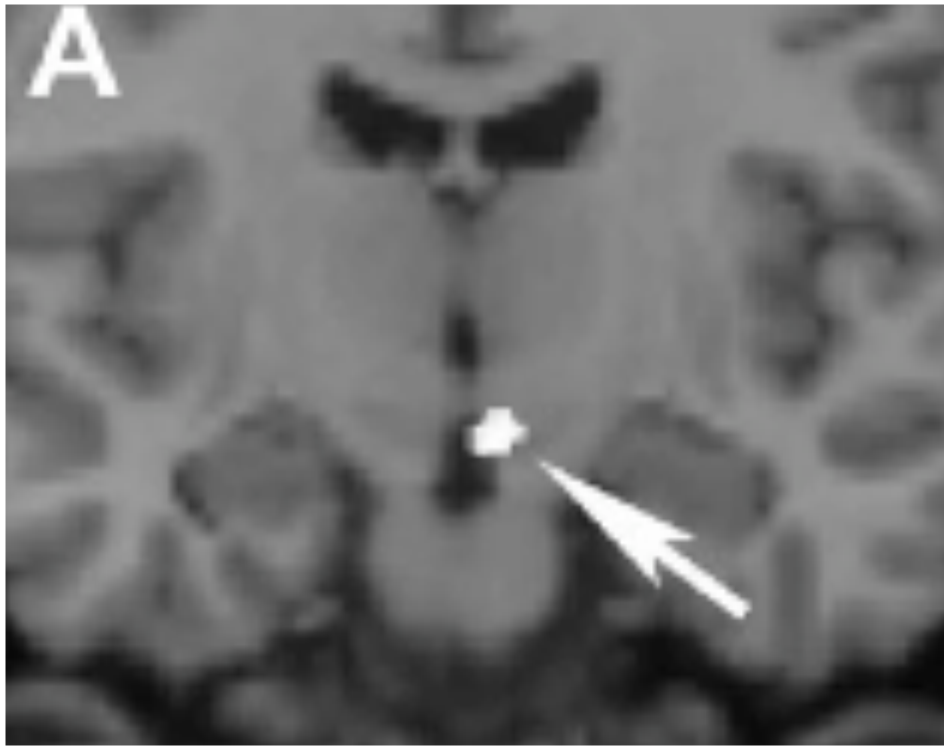
Apple triggers 'religious' reaction in fans' brains, report says

By **Mark Milian**, CNN
May 19, 2011 6:33 p.m. EDT | Filed under: Gaming & Gadgets

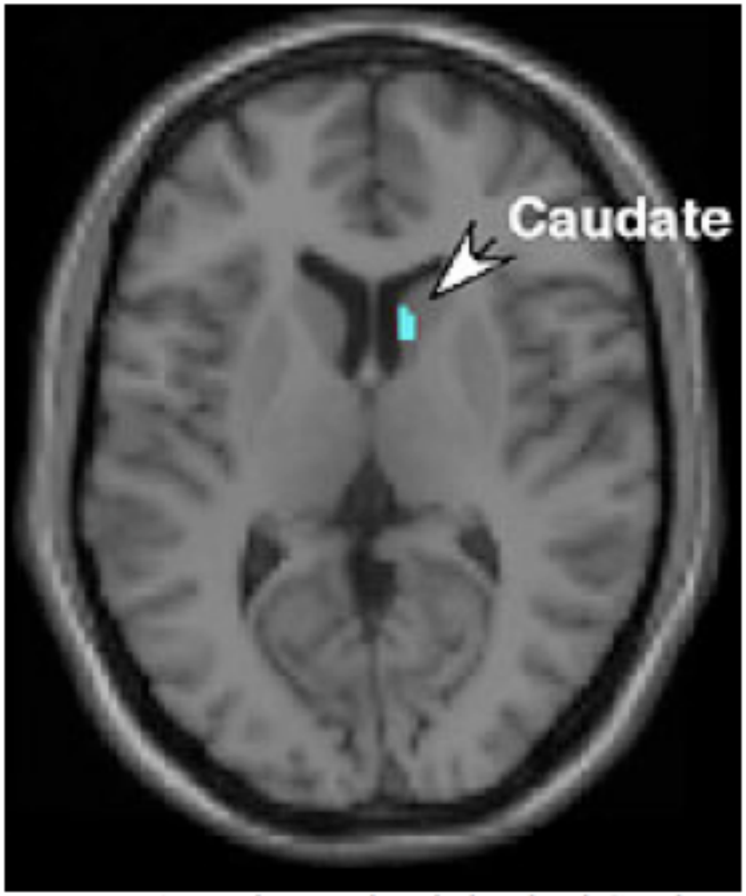


At product launches, Apple store employees cheer for the first customers to buy the company's latest gadgets.

“The Love Area”



Fisher et al. (2005)



American Physiological Society

A new study suggests that an area of the brain known as the caudate is associated with passion.

The New York Times — Fashion & Style

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS

FASHION & STYLE | DINING & WINE | HOME & GARDEN | WEDI

What Brain Scans Can Tell Us About Marriage

Luke Frazza/Agence France-Presse —

LAKE IDYLL In 2000, Tipper and Al Gore gave no sign of problems. More Photos »

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Watching New Love as It Sears the Brain

By BENEDICT CAREY

Published: May 31, 2005

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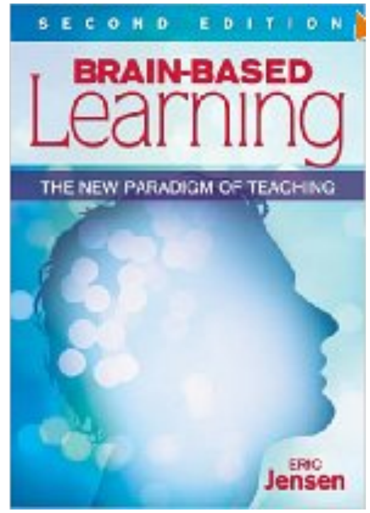
What is your best rhythm and timing for learning?
Find your PACE
energetic
Water
clear
Brain Buttons
active
The Cross Crawl
positive
Hook-ups


SECOND EDITION
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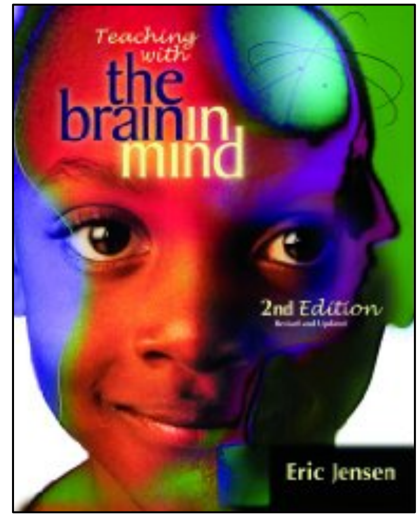
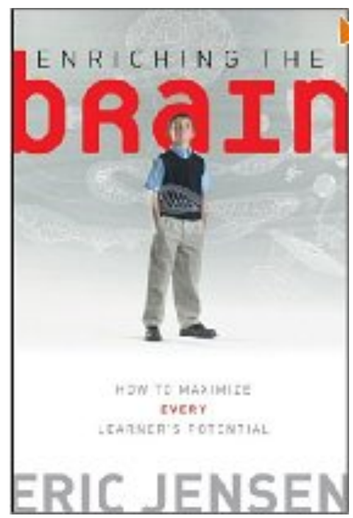
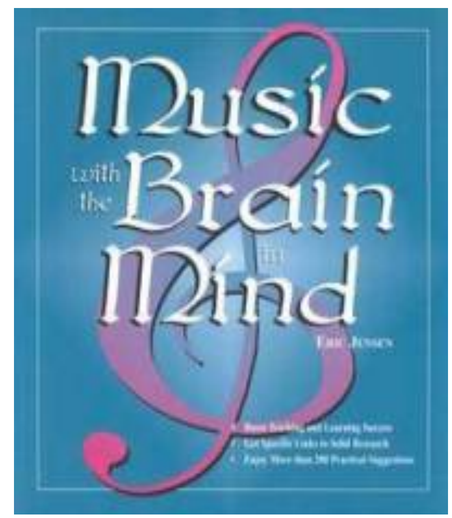
Learning
THE NEW PARADIGM OF TEACHING
ERIC
Jensen


Teaching with
the brain in mind
2nd Edition
Eric Jensen


ENRICHING THE
brain
HOW TO MAXIMIZE
EVERY
LEARNER'S POTENTIAL
ERIC JENSEN


Music
with the
Brain
in
Mind
Eric Jensen

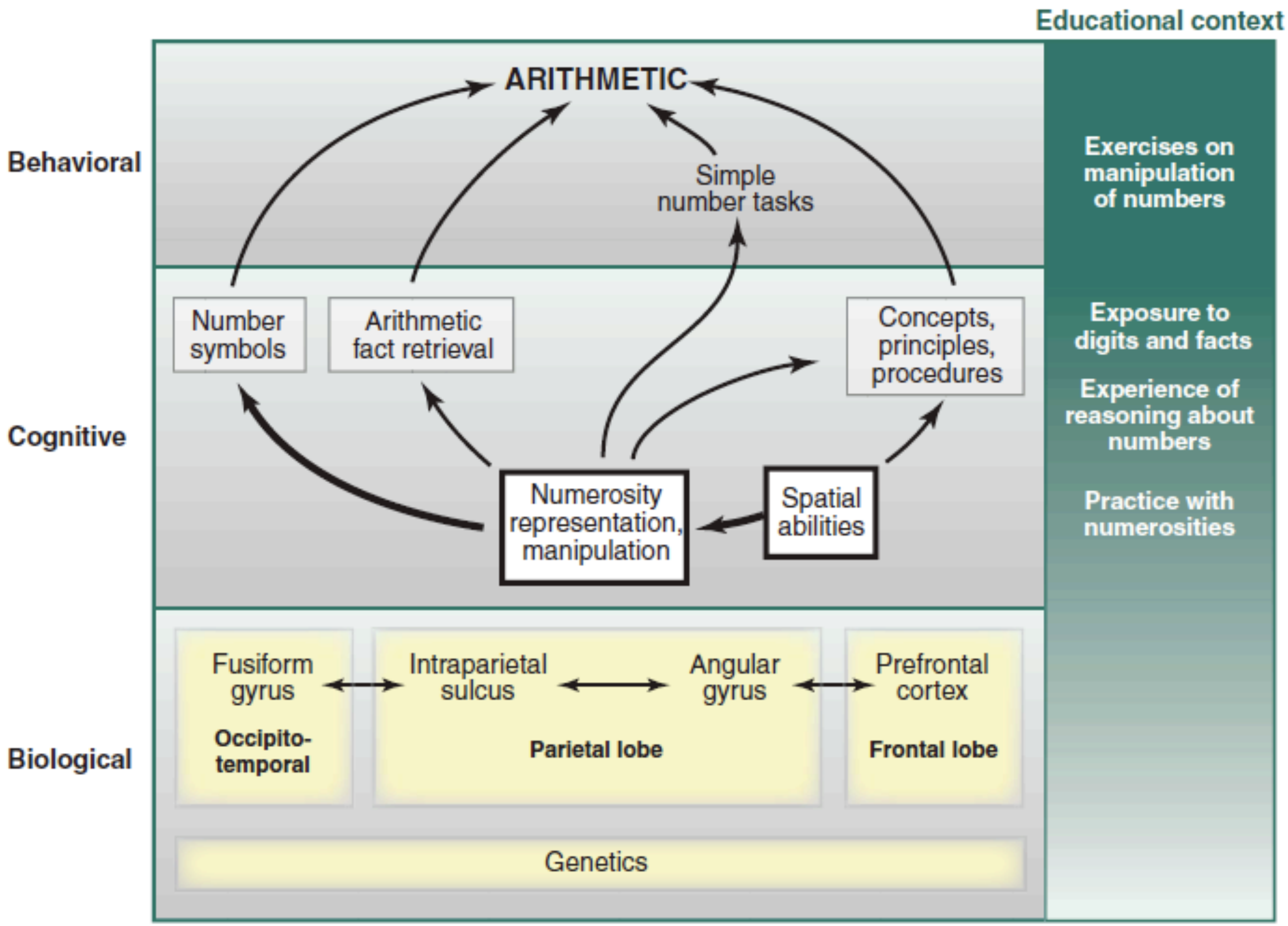
Neuro(cognitive) Topics

- Mathematics
- Language and embodiment
- Social processing
- Affective processing

- Learning

- Scientific reasoning
- Intelligence
- Motivation and reward
- Moral reasoning
- Media and the arts

Mathematics Across Contexts

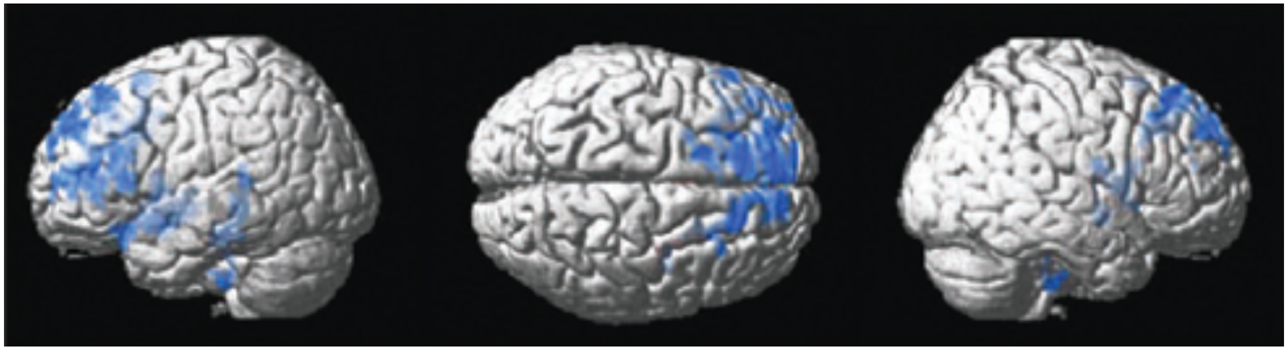


Butterworth et al. (2011)

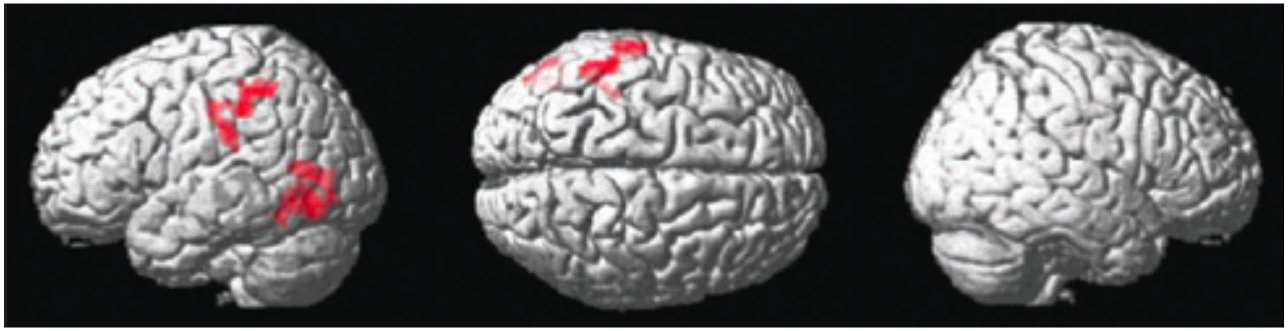
Mock Scanner

Arithmetic Across Development

Decreasing
w/
Development

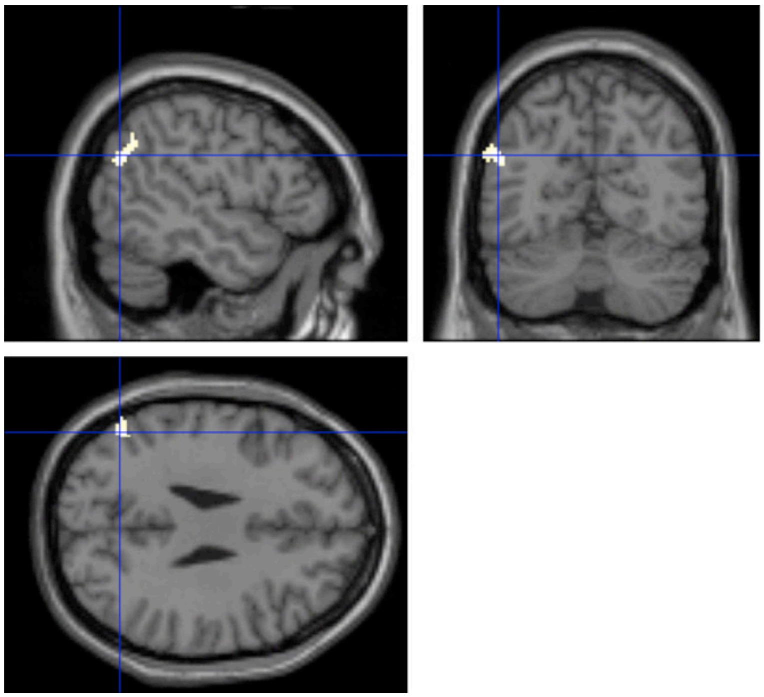


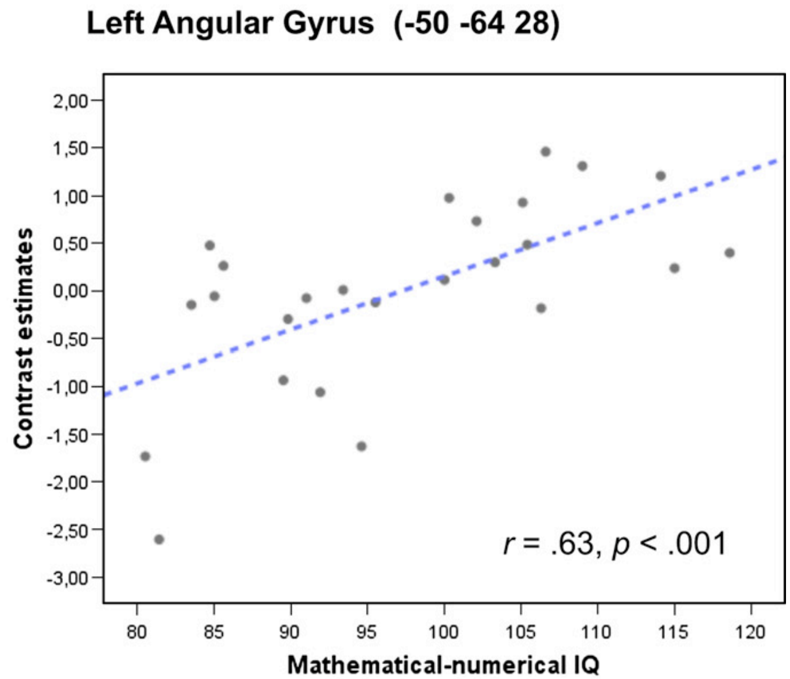
Increasing
w/
Development



Rivera et al. (2005)

Arithmetic Across Individuals

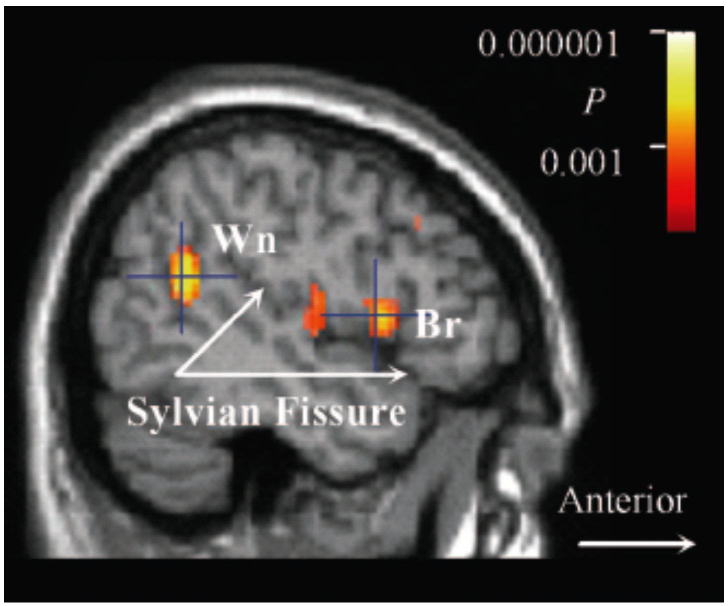




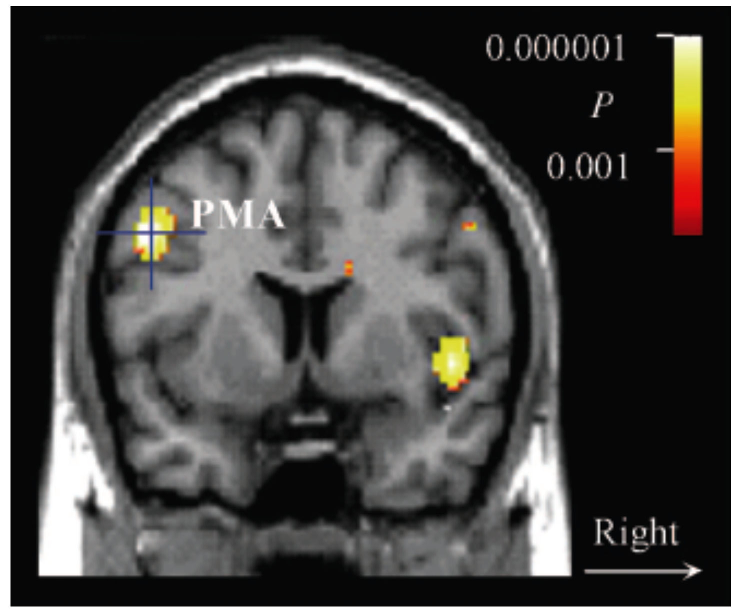
Grabner et al. (2007)

Arithmetic Across Cultures

English Speakers



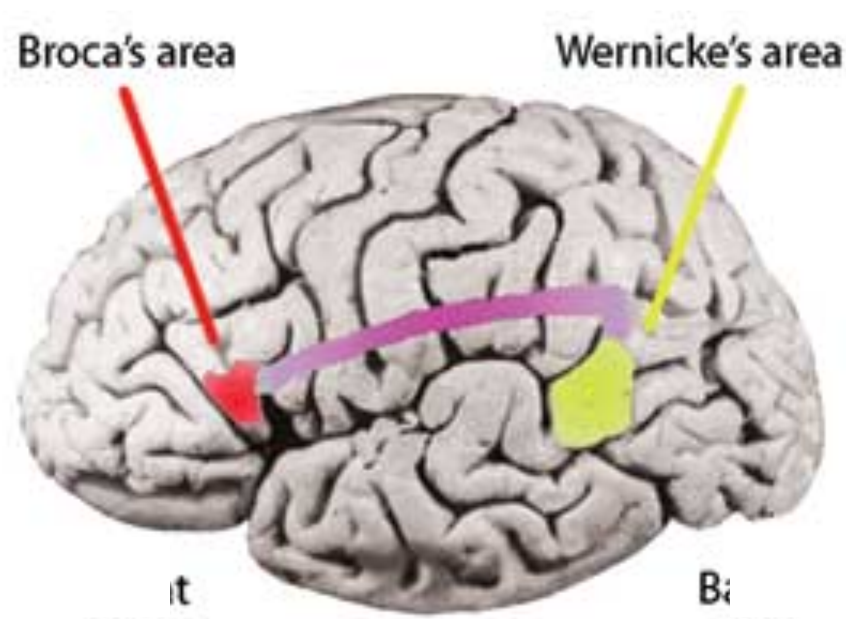
Chinese Speakers

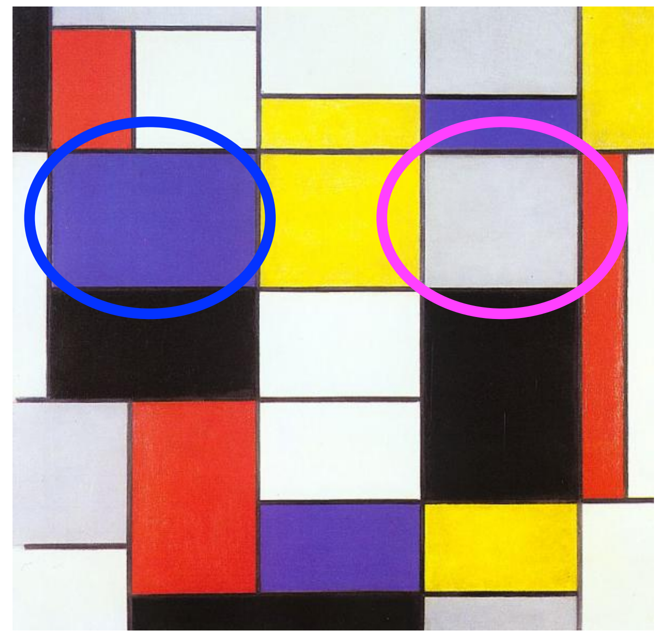


Broca, Wernicke; PMA, SMA

Tang et al. (2006)

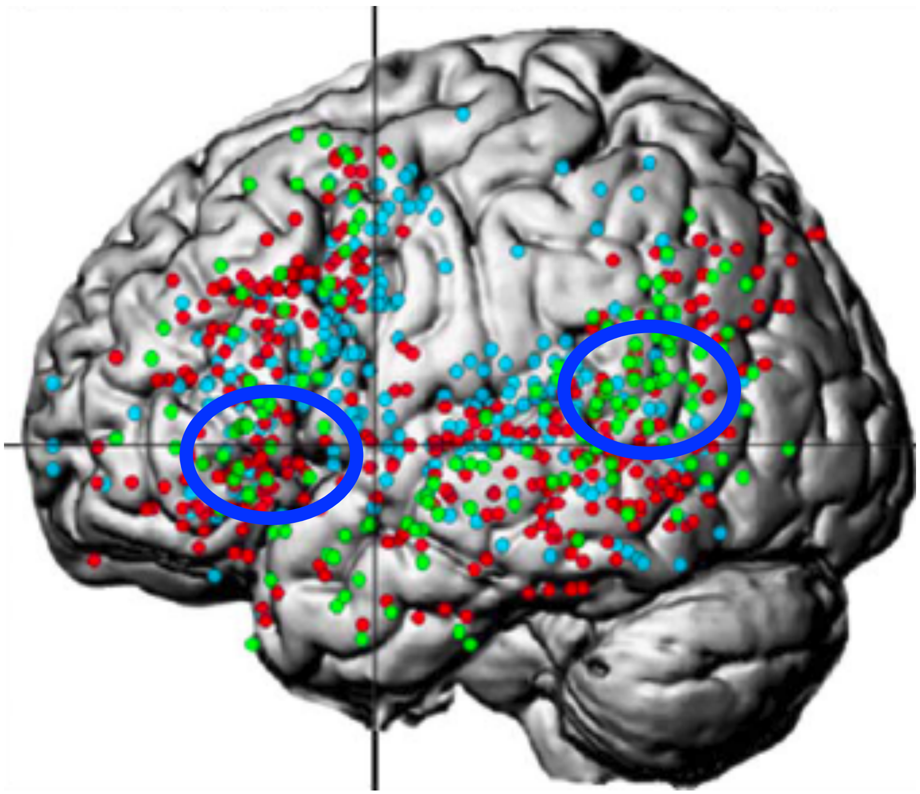
The Language Network (Classical)

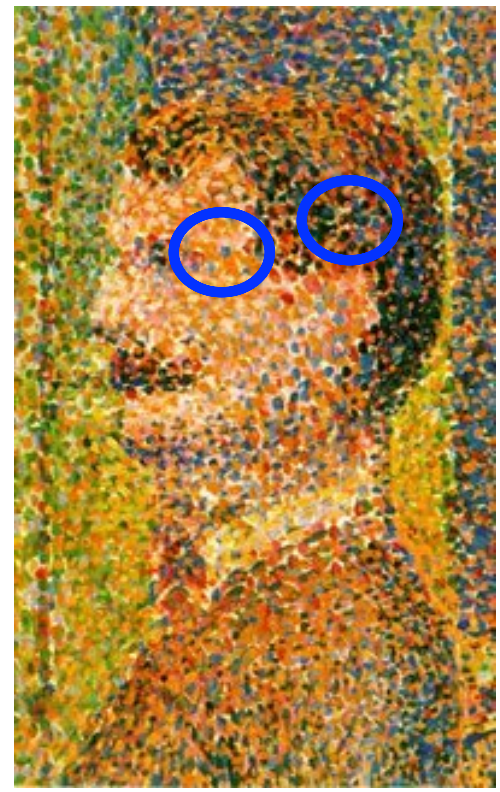




Mondrian (1923) *Composition A*

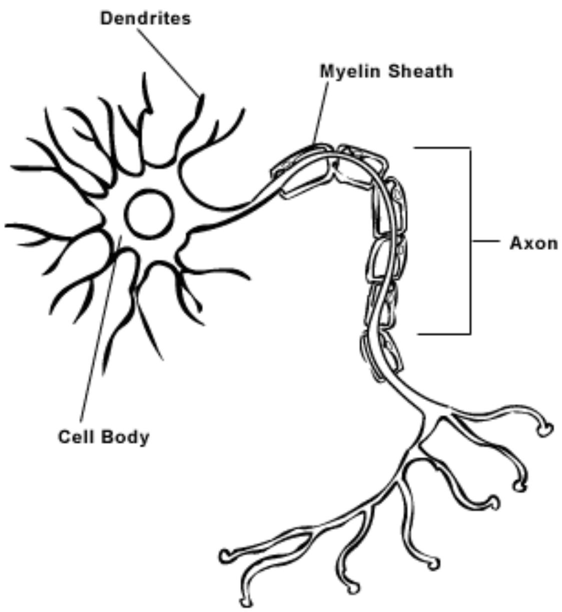
Meta-Analysis of fMRI Studies

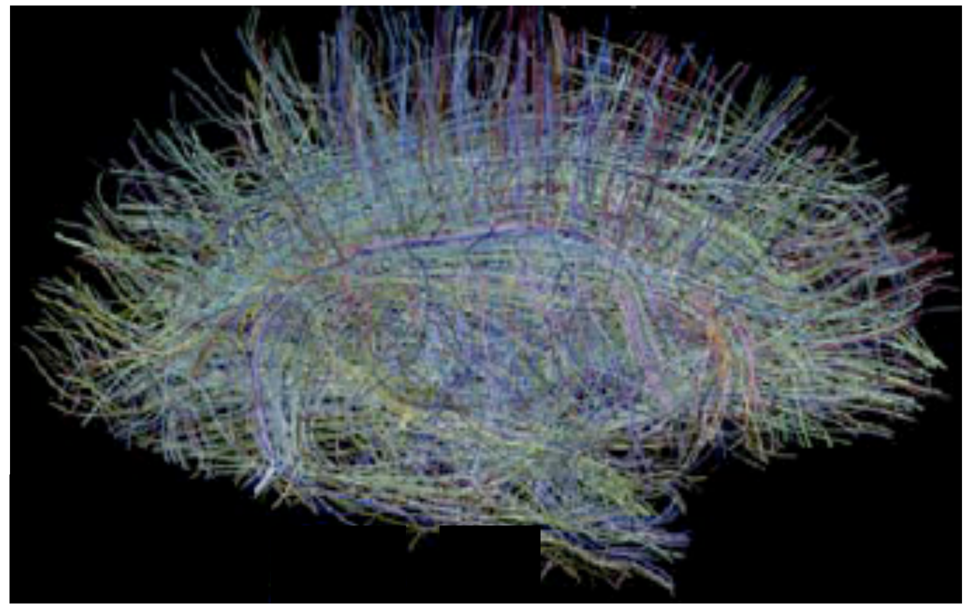




Vigneau et al. (2006); Seurat (1989) *La Parade*

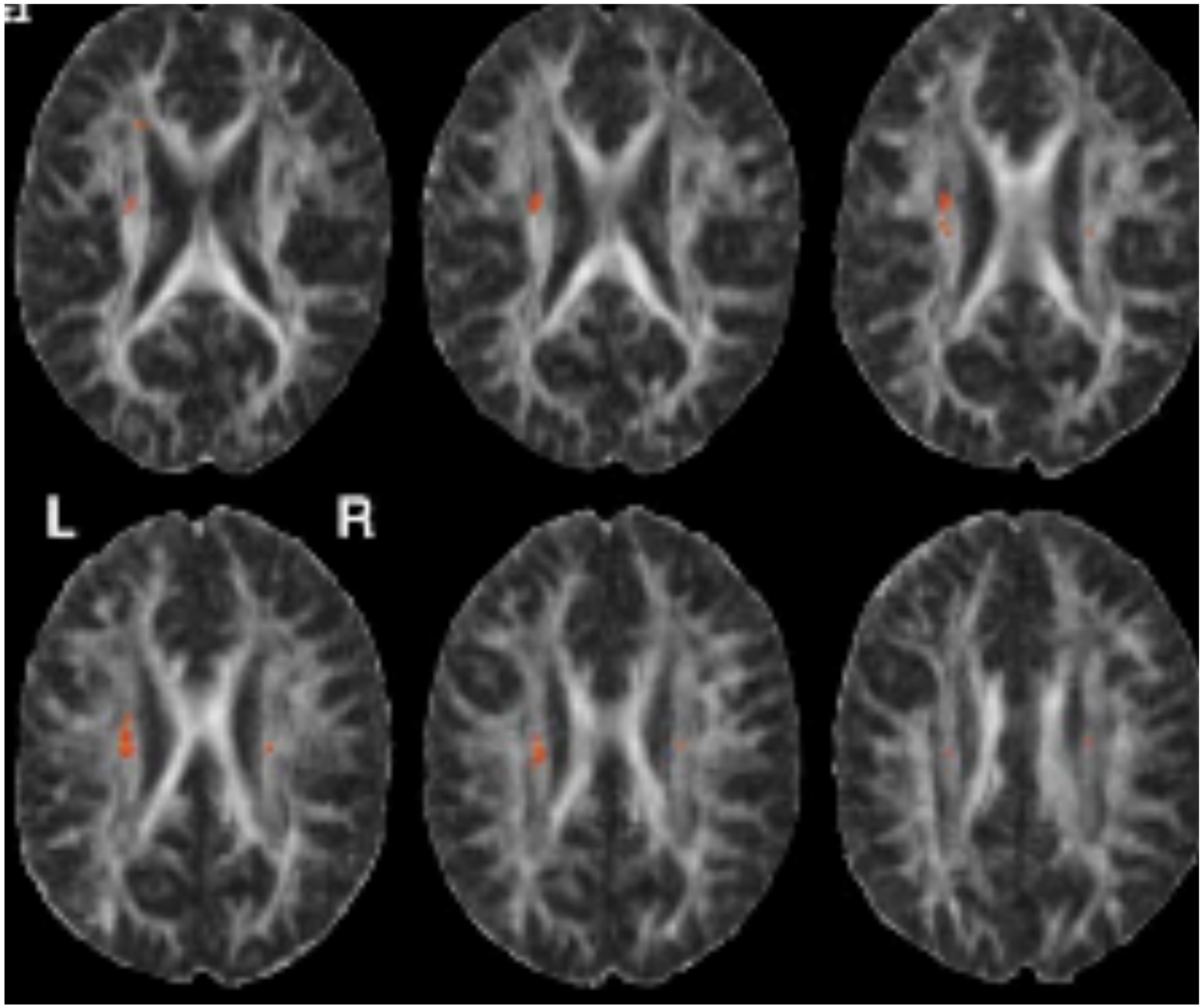
White Matter Tracts, DTI, and Fiber Tracking





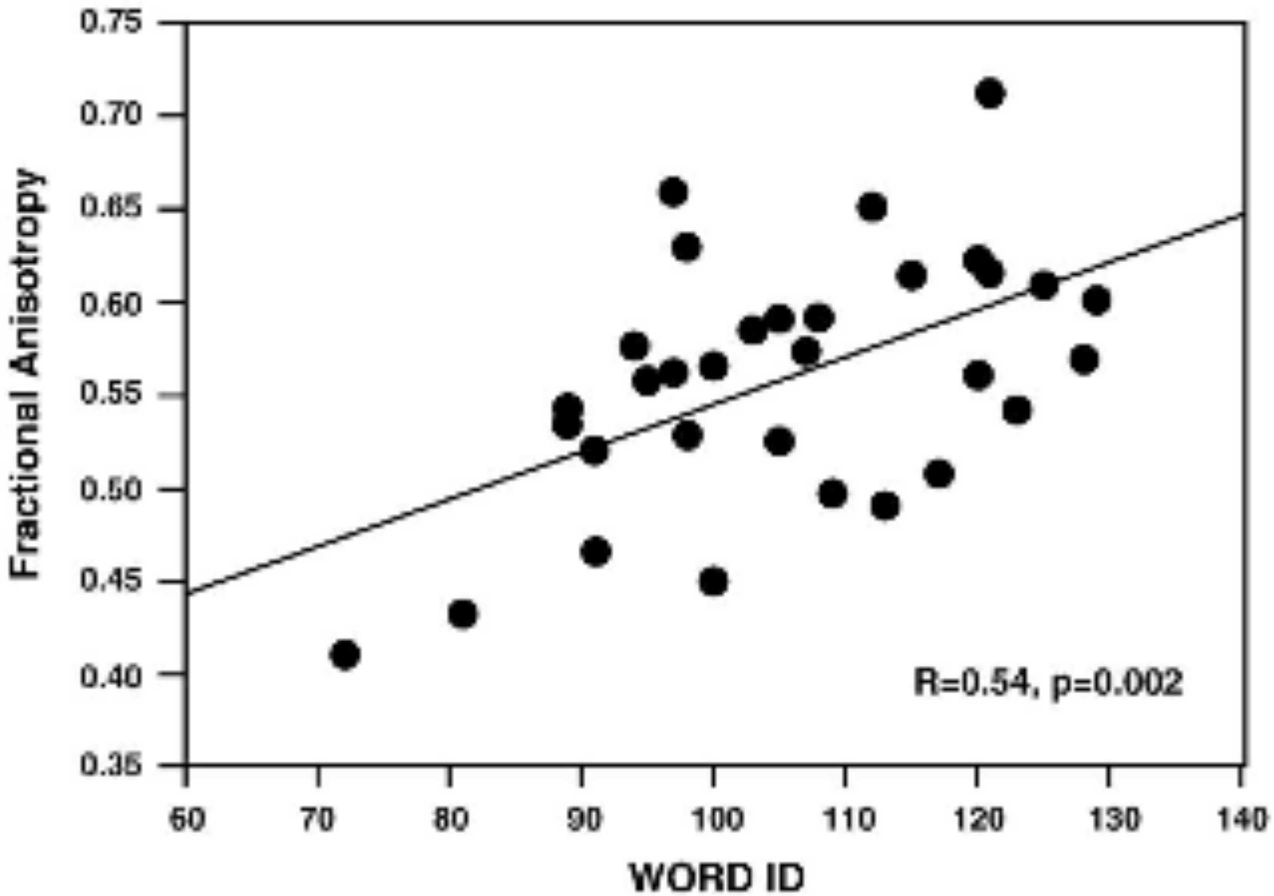
Hagmann et al. (2008)

Network Connectivity Predicts Individual Differences



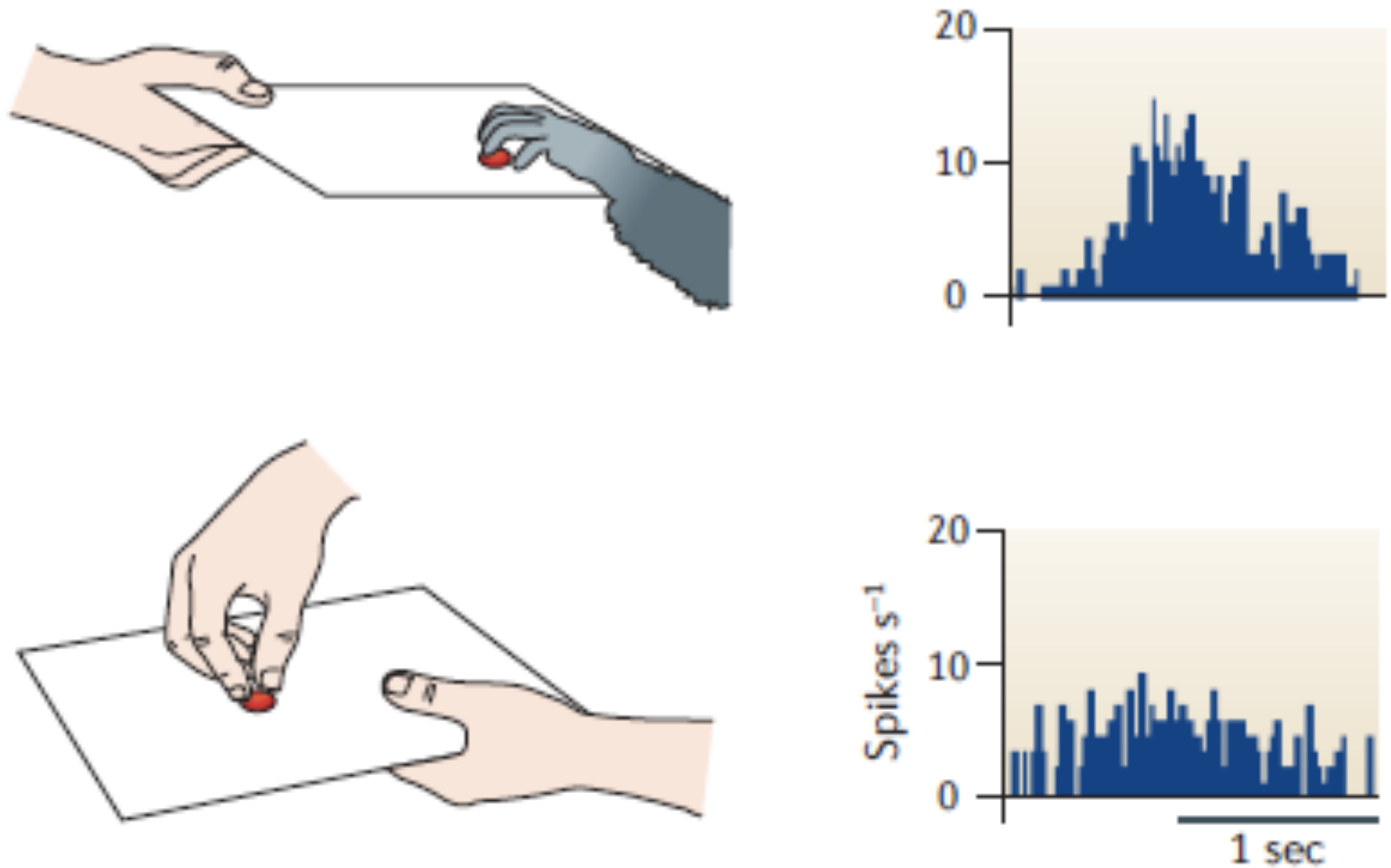
Beaulieu et al. (2005)

Network Connectivity Predicts Individual Differences



Beaulieu et al. (2005)

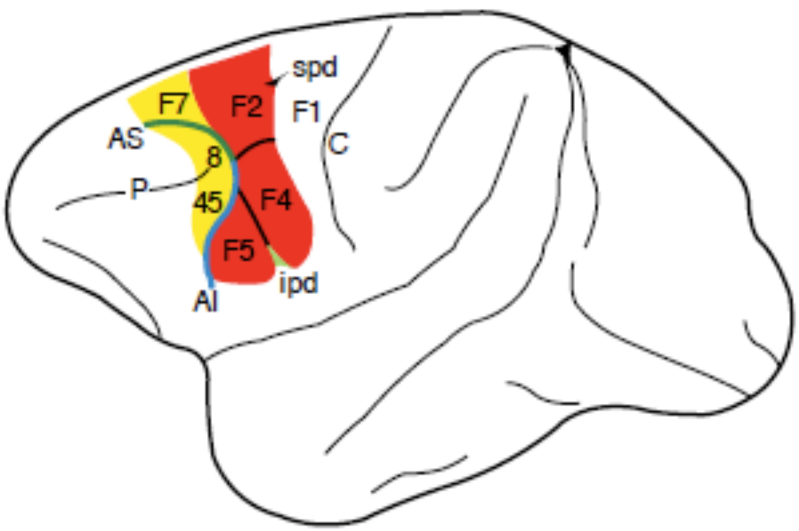
Mirror Neurons in Monkeys



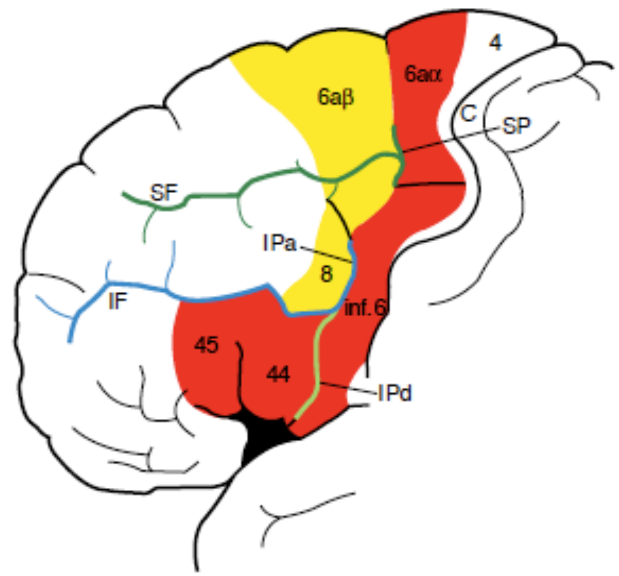
Iacoboni & Dapretto (2006)

Mirror Neurons in Monkeys and Humans

Monkey

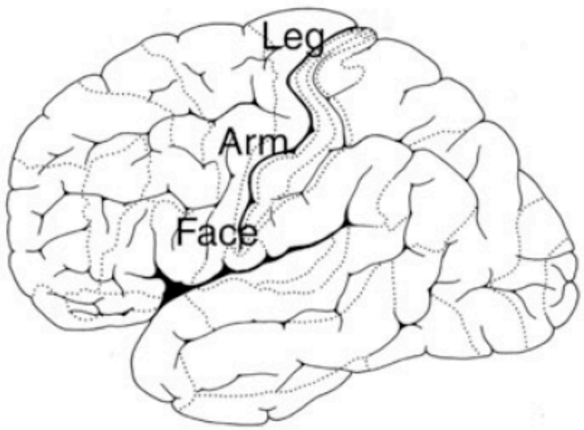


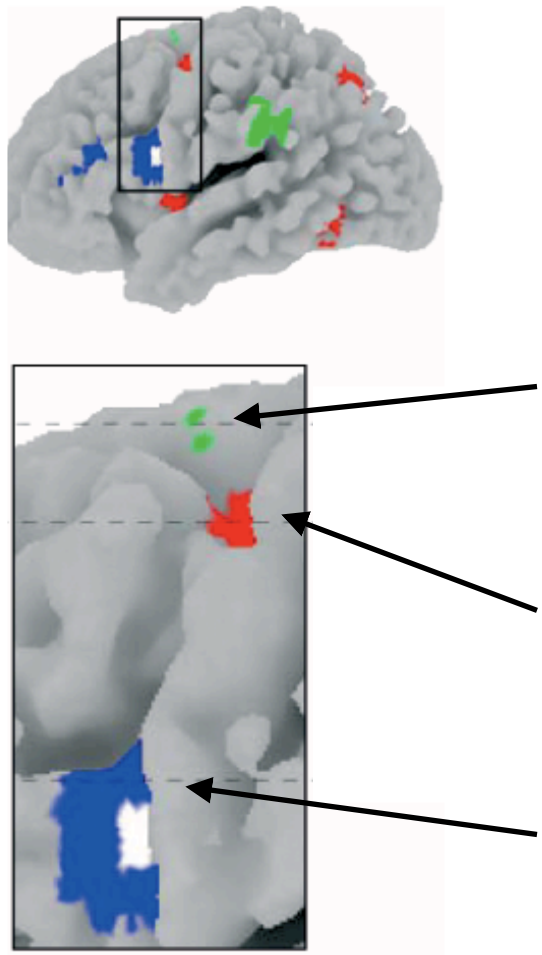
Human



Rizzolatti & Arbib (1998)

Motor Representations of Sentences





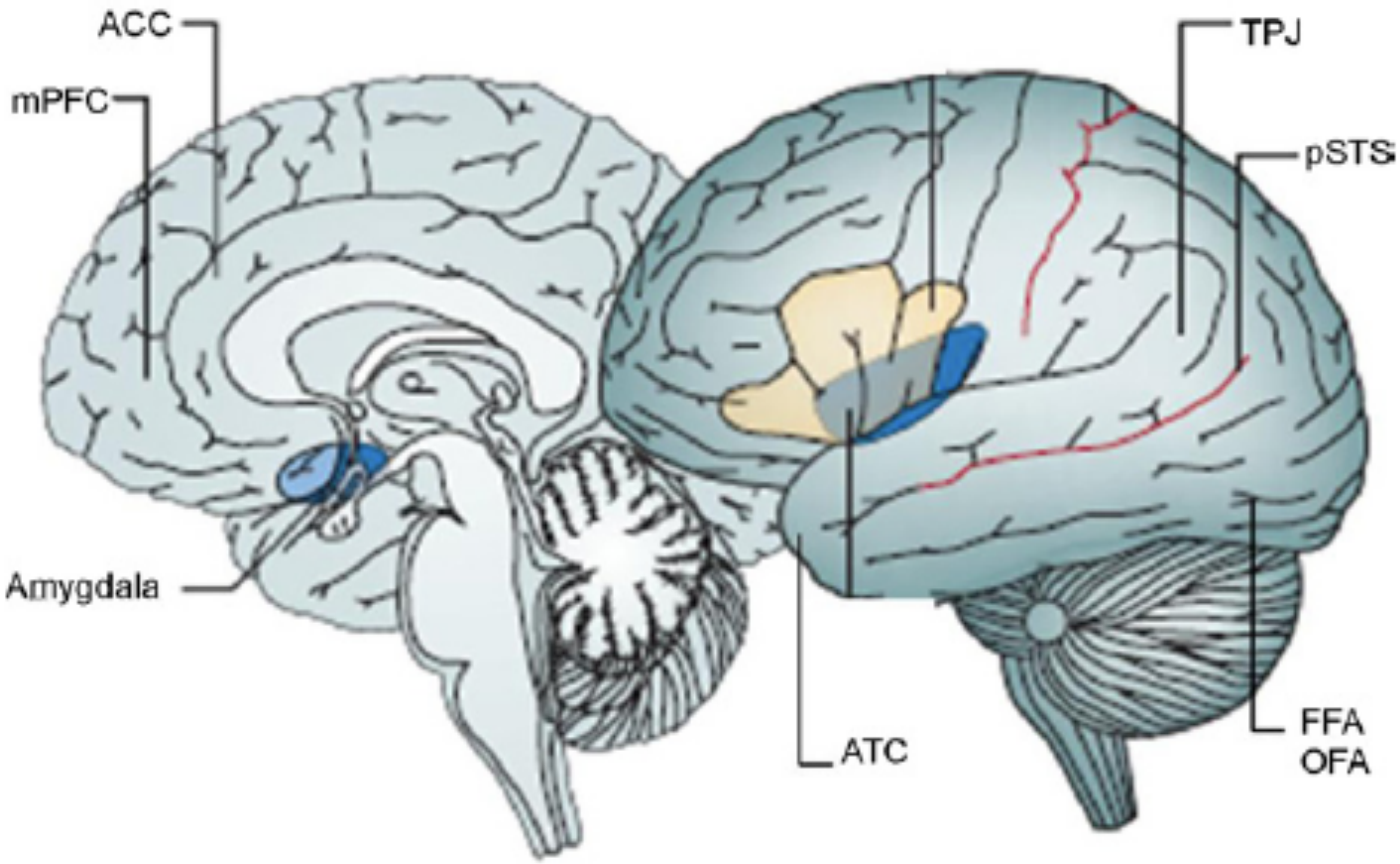
Leg sentence:
I kick the ball.

Arm sentence:
I grasp a knife.

Face sentence:
I bite an apple.

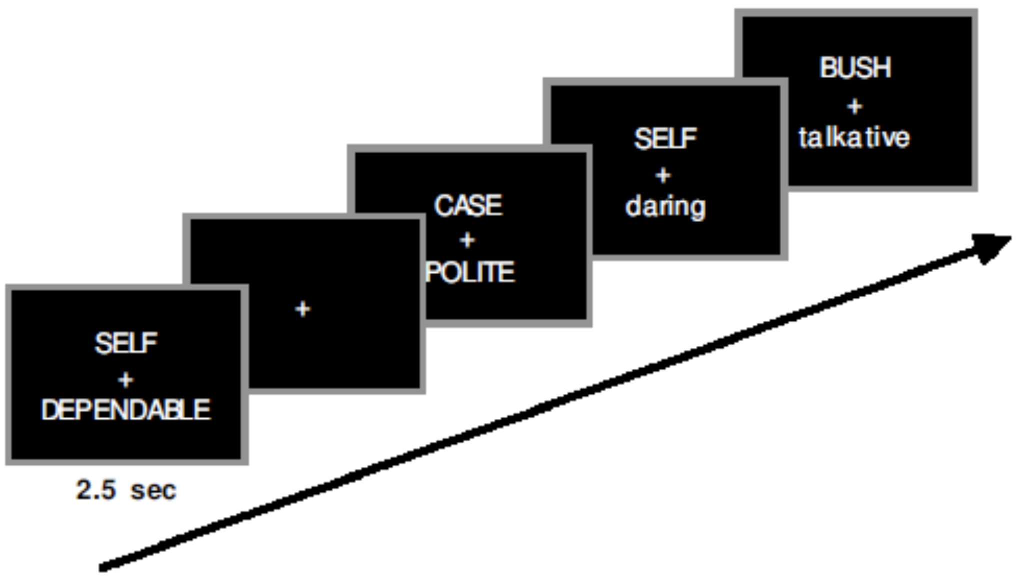
Tettamanti et al. (2005); Pulvermuller et al. (2005)

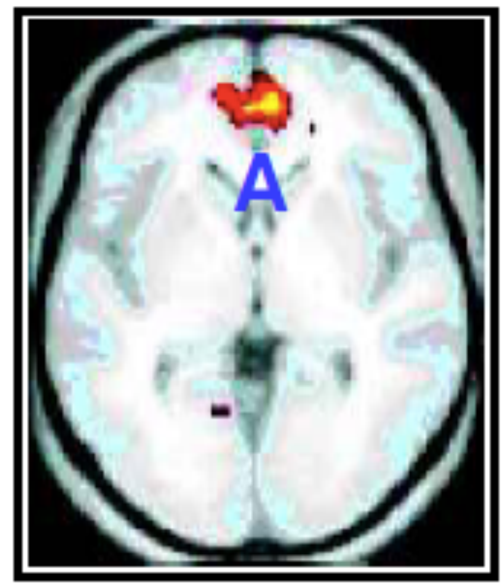
The Social Network



Burnett et al. (2011)

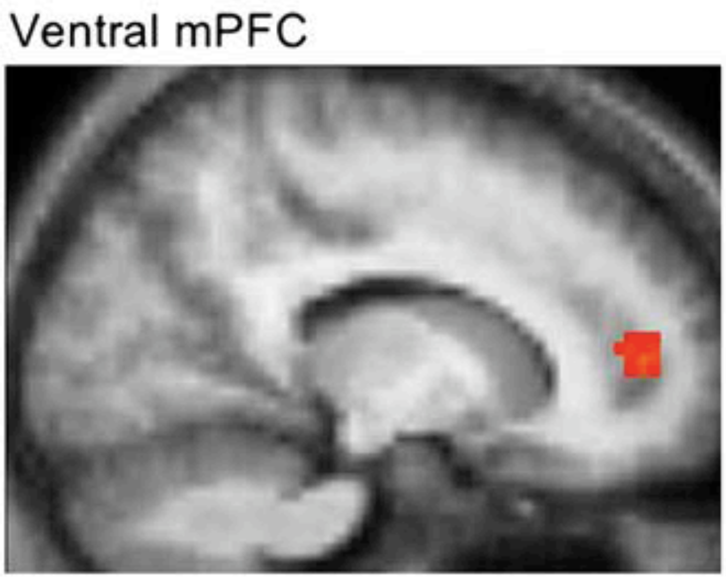
Self-Perception and mPFC



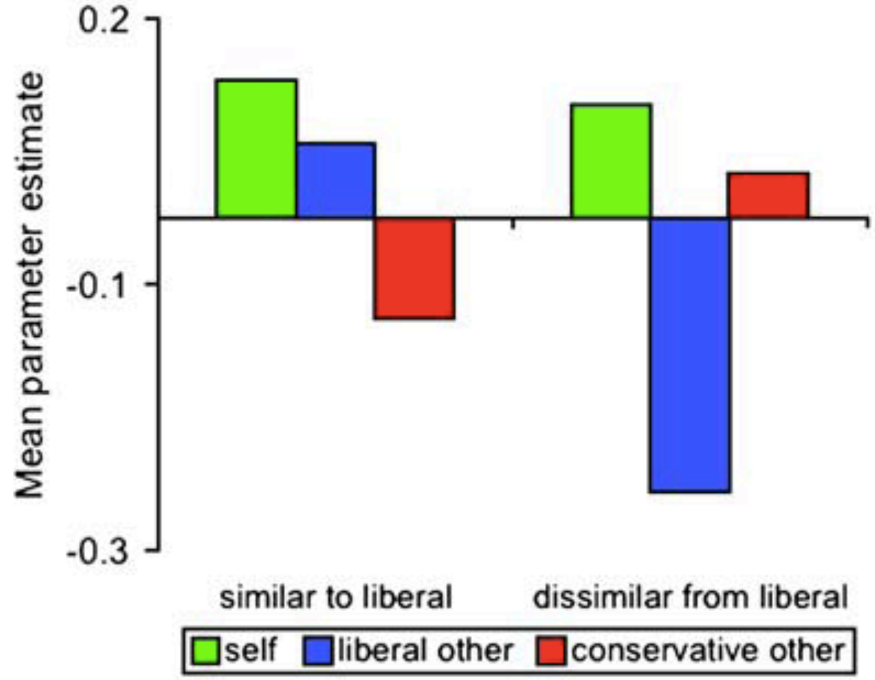


Kelley et al. (2002)

Close Other vs. Far Other and mPFC

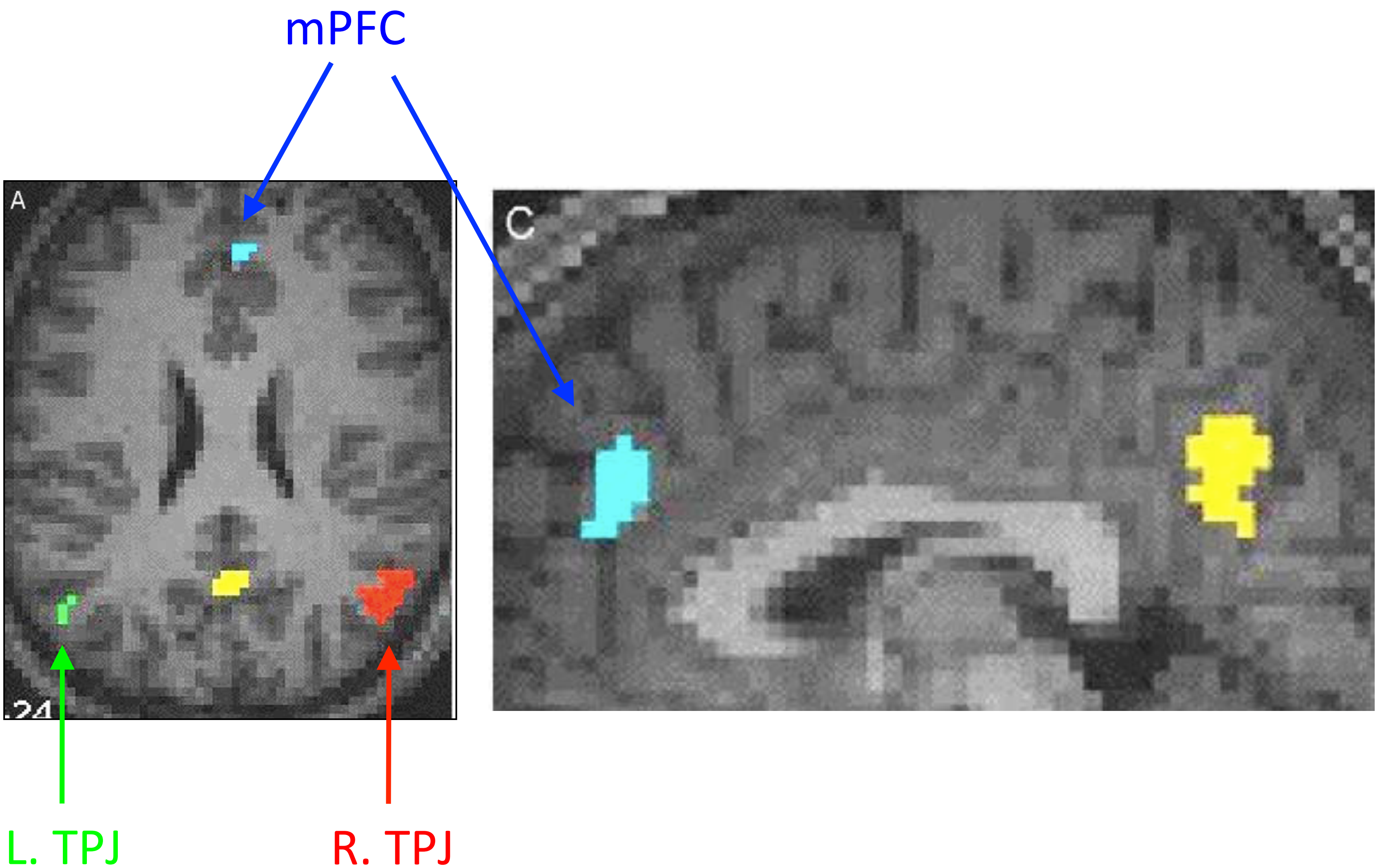


self liberal self conservative



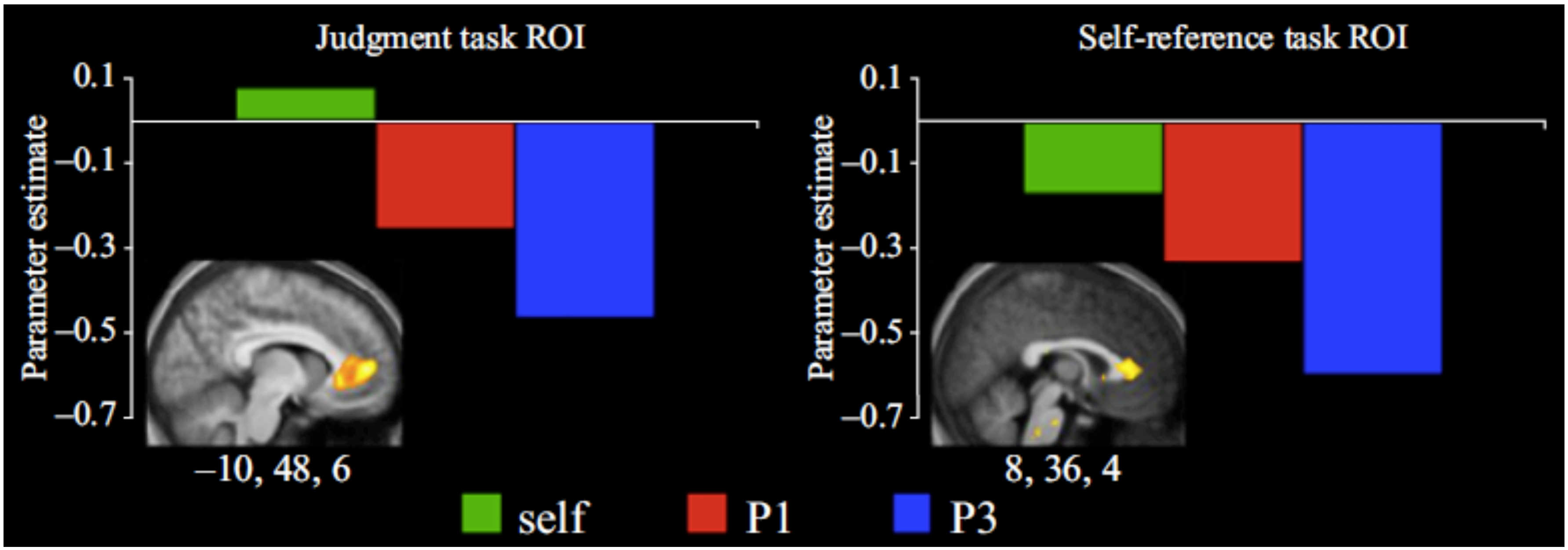
Mitchell et al. (2006)

Theory of Mind and R. TPJ



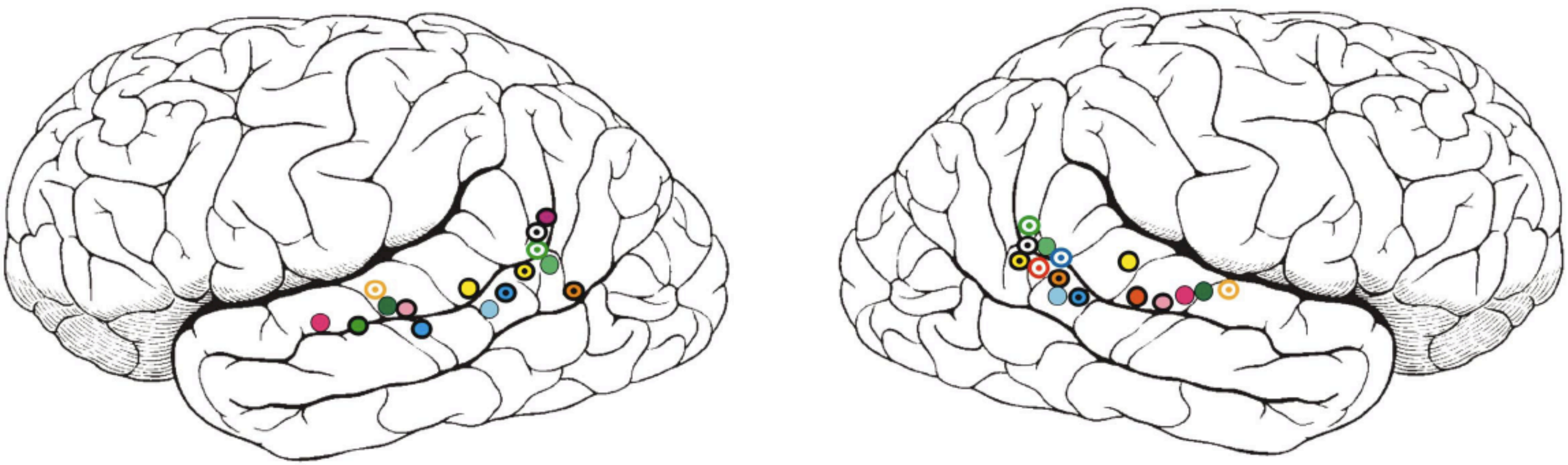
Saxe & Wexler (2005)

Empathy and mPFC



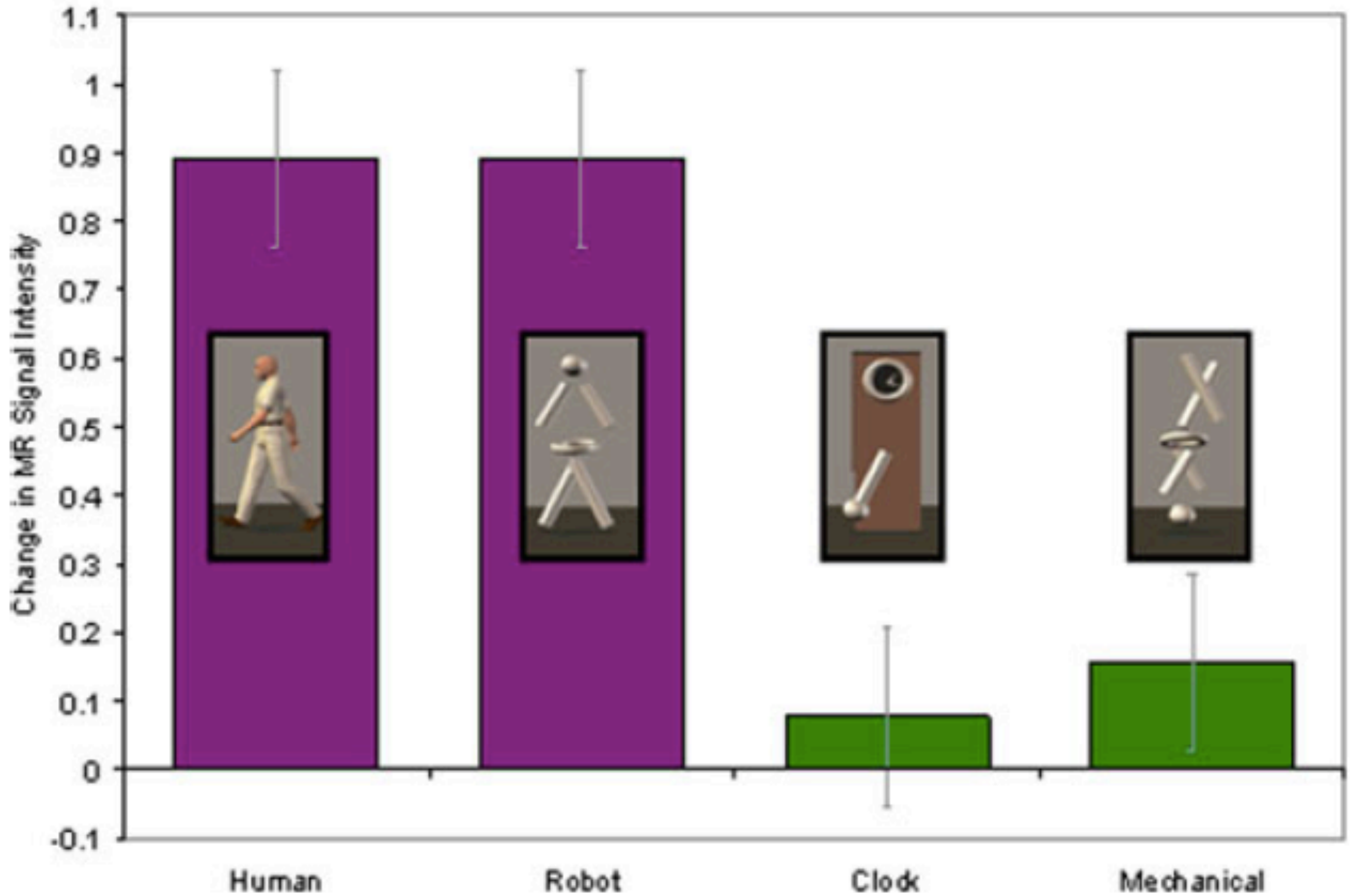
Ames et al. (2008)

Biological Movement and STS



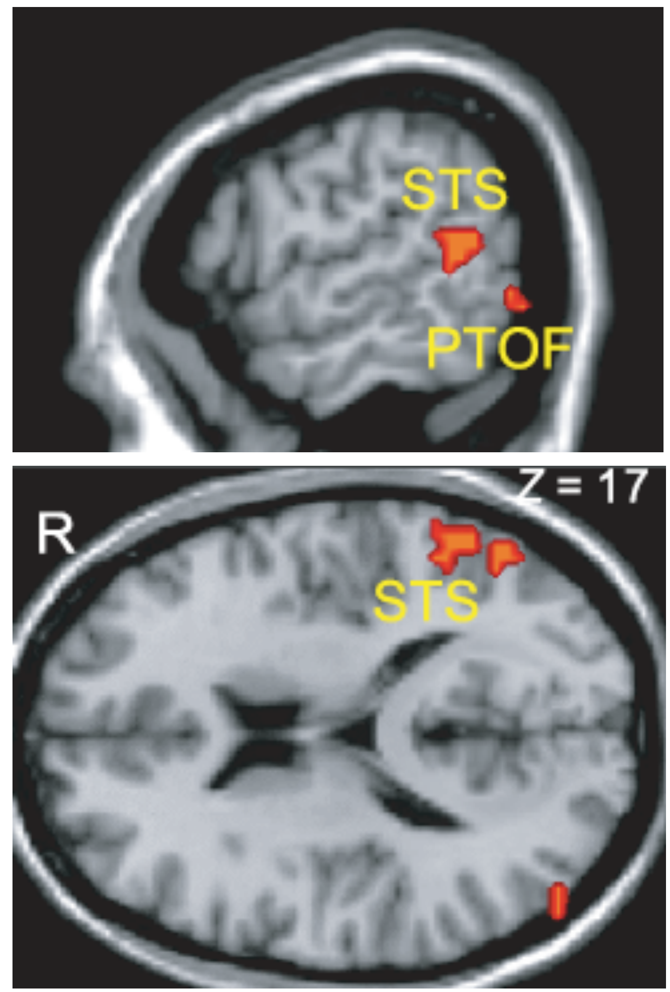
Allison et al. (2000)

Walking and R. STS



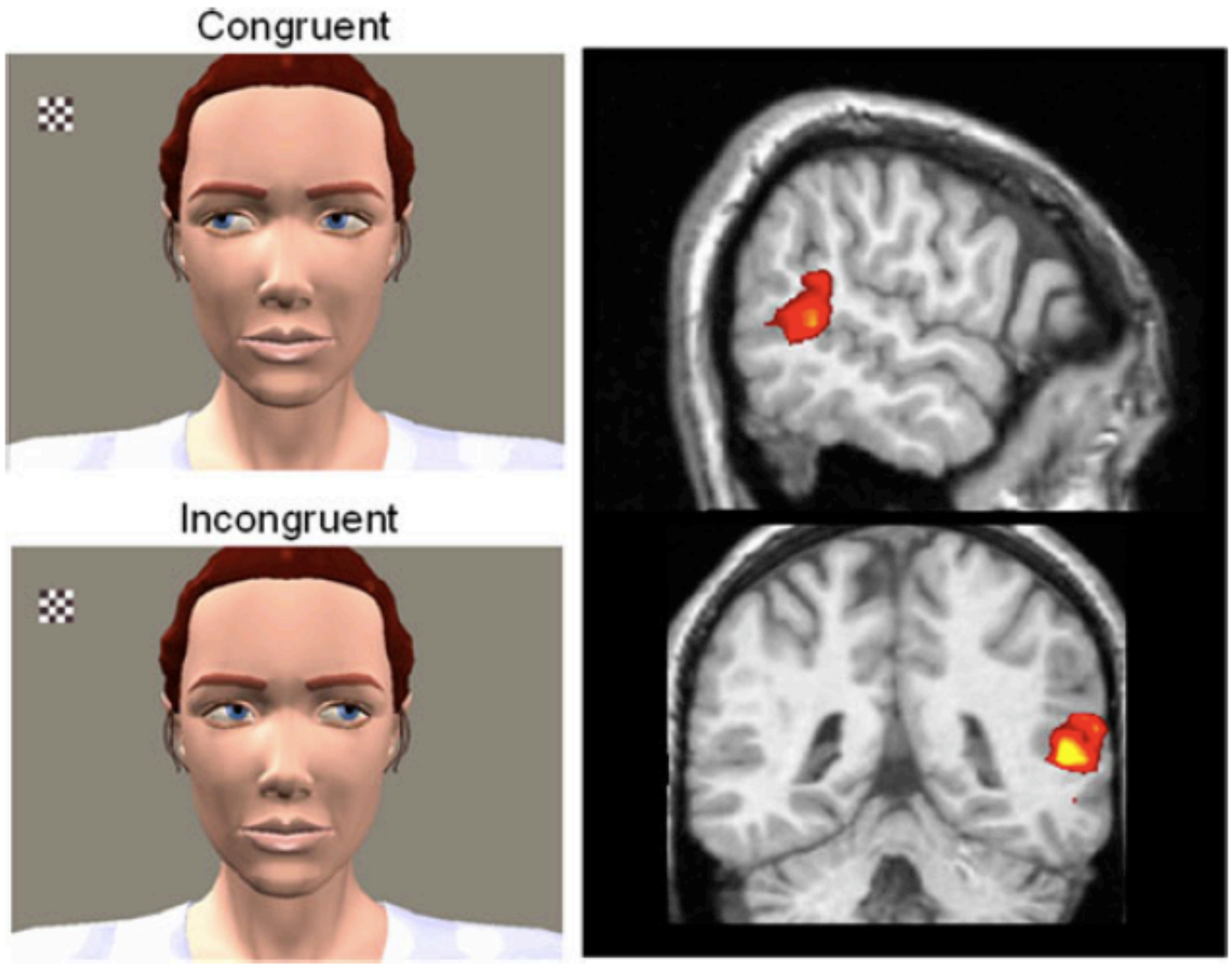
Pelphrey et al. (2003)

Grasping and R. pSTS



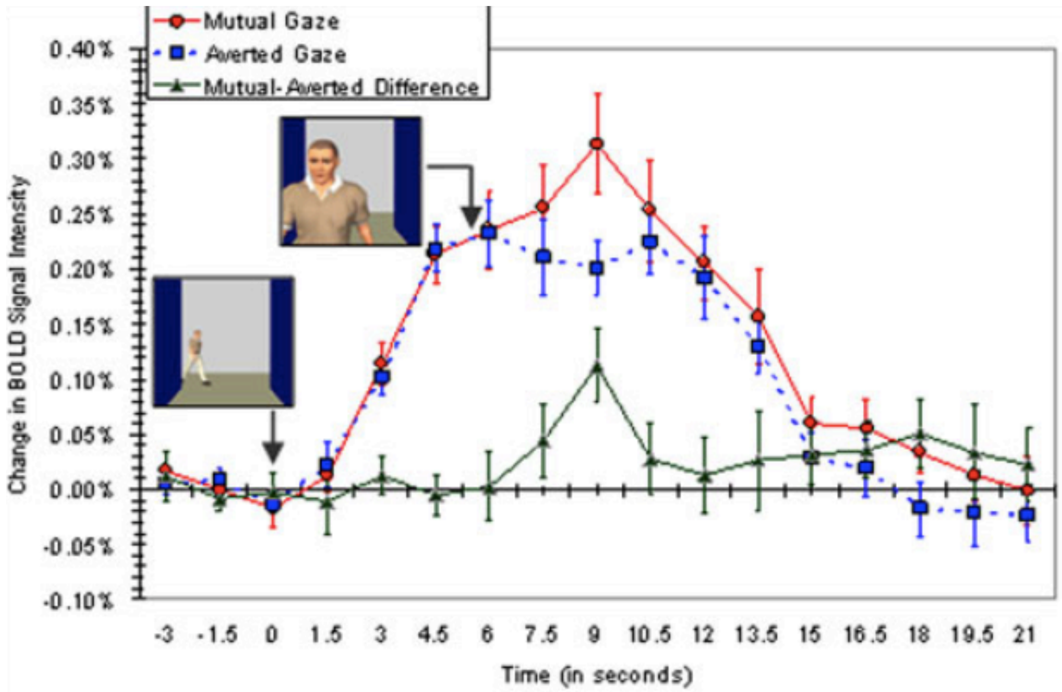
Pelphrey et al. (2004)

Intentional Eye Gaze and R. pSTS



Pelphrey et al. (2004)

Mutual Eye Gaze and R. pSTS

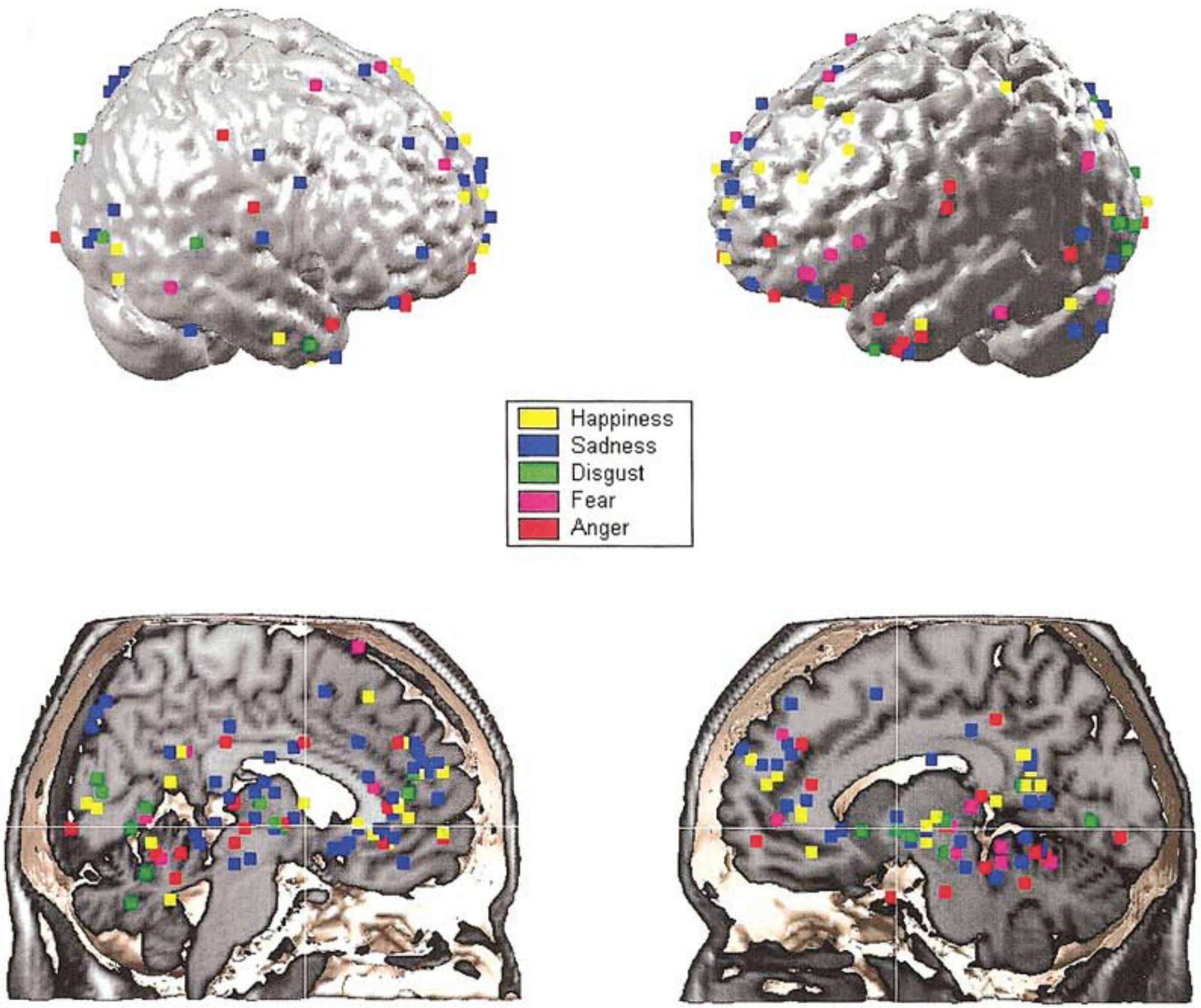


Pelphrey et al. (2004b)

Basic Facial Emotions

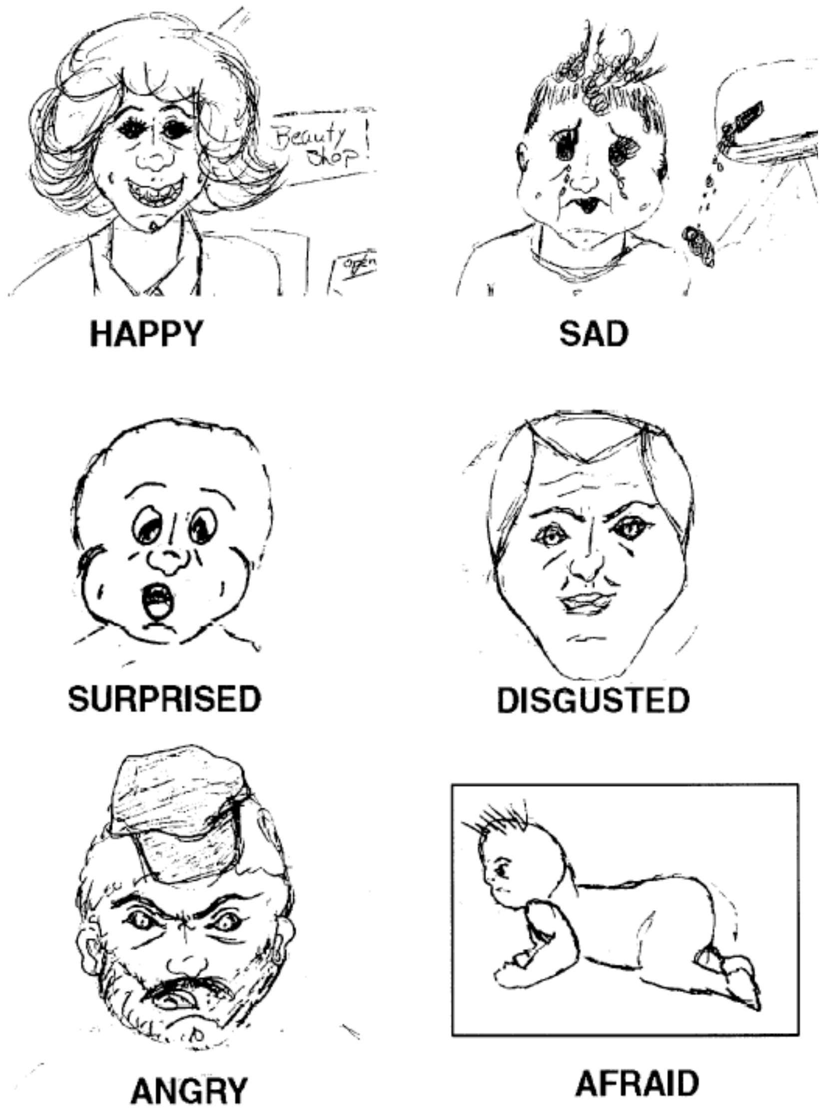
Ekman & Friesen (1971)

Affect in the Brain



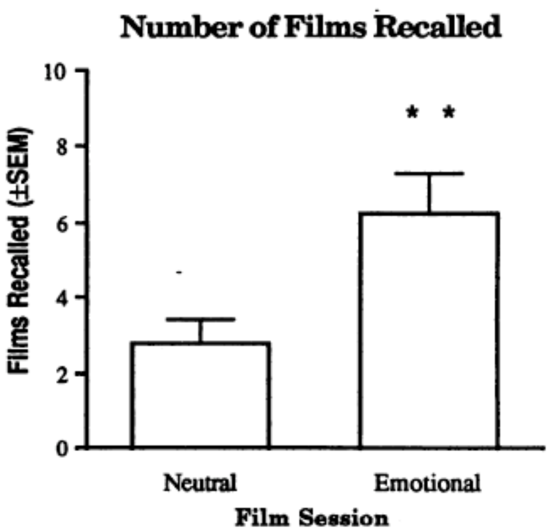
Phan et al. (2002)

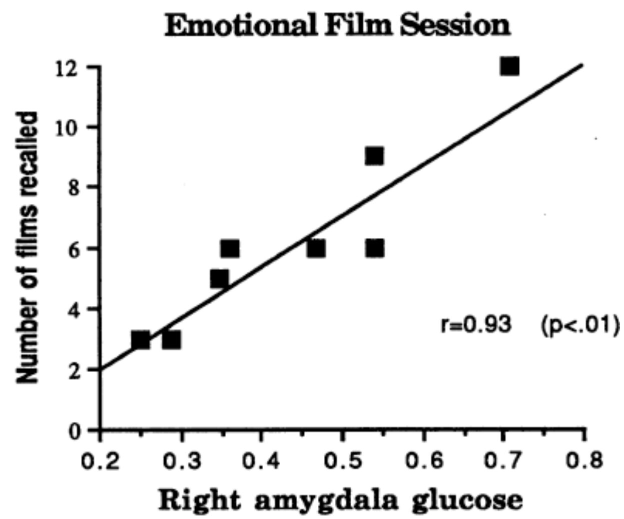
Amygdala Lesions and Facial Fear Production

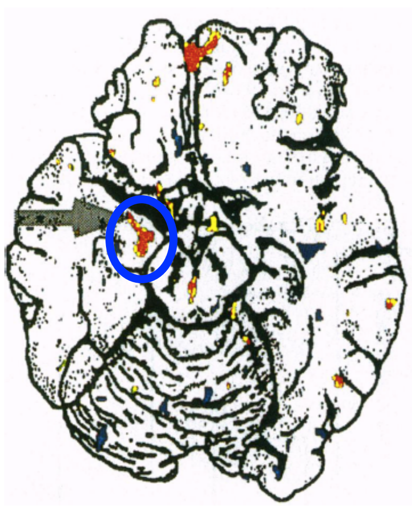


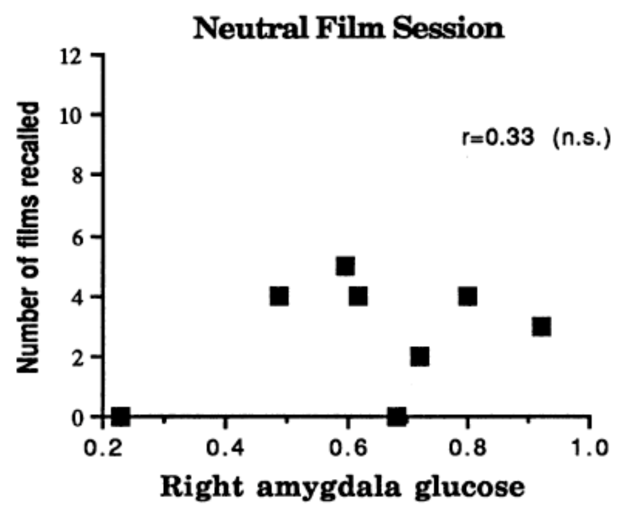
Adolphs et al. (1995)

Amygdala and Memory for Emotion





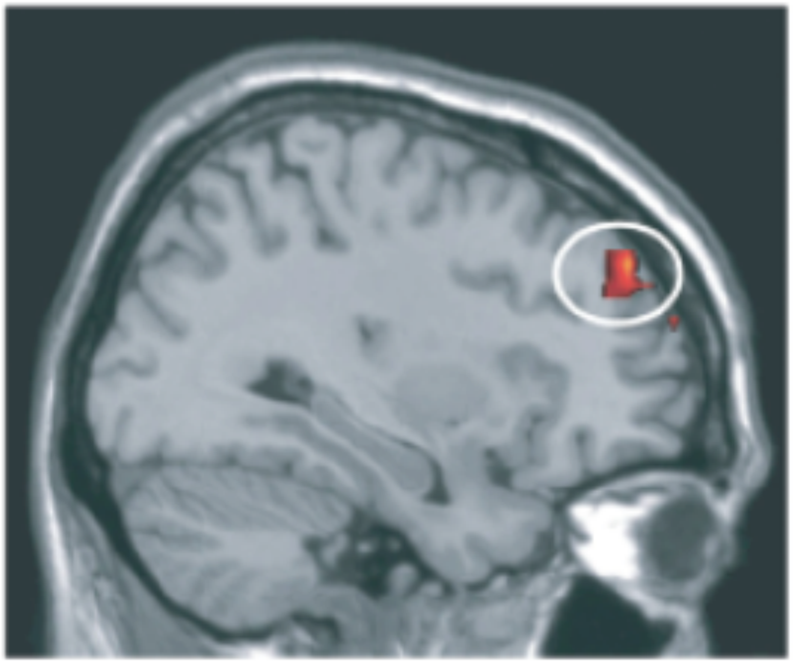




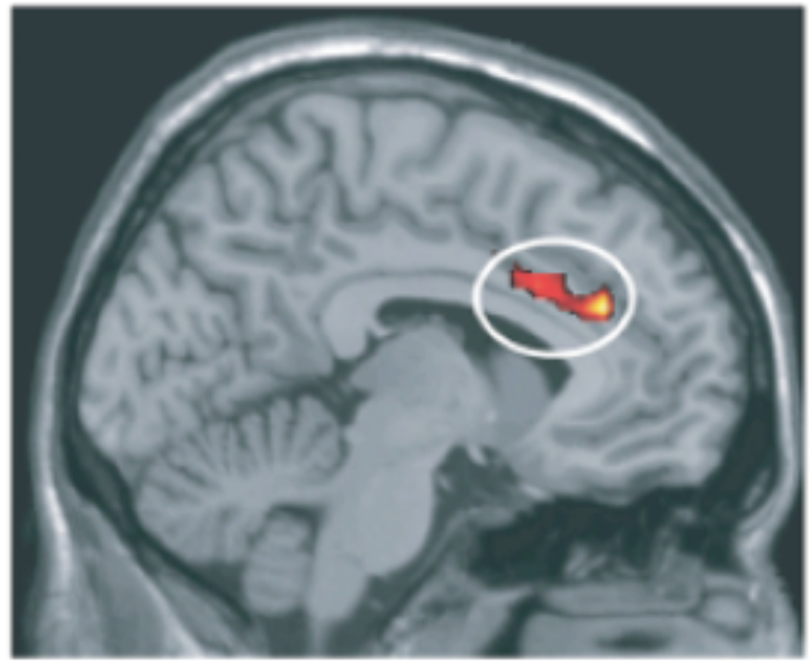
Cahill et al. (1996); Hamann et al. (1999)

Stereotypes: Automatic and Controlled Processing

R. DLPFC

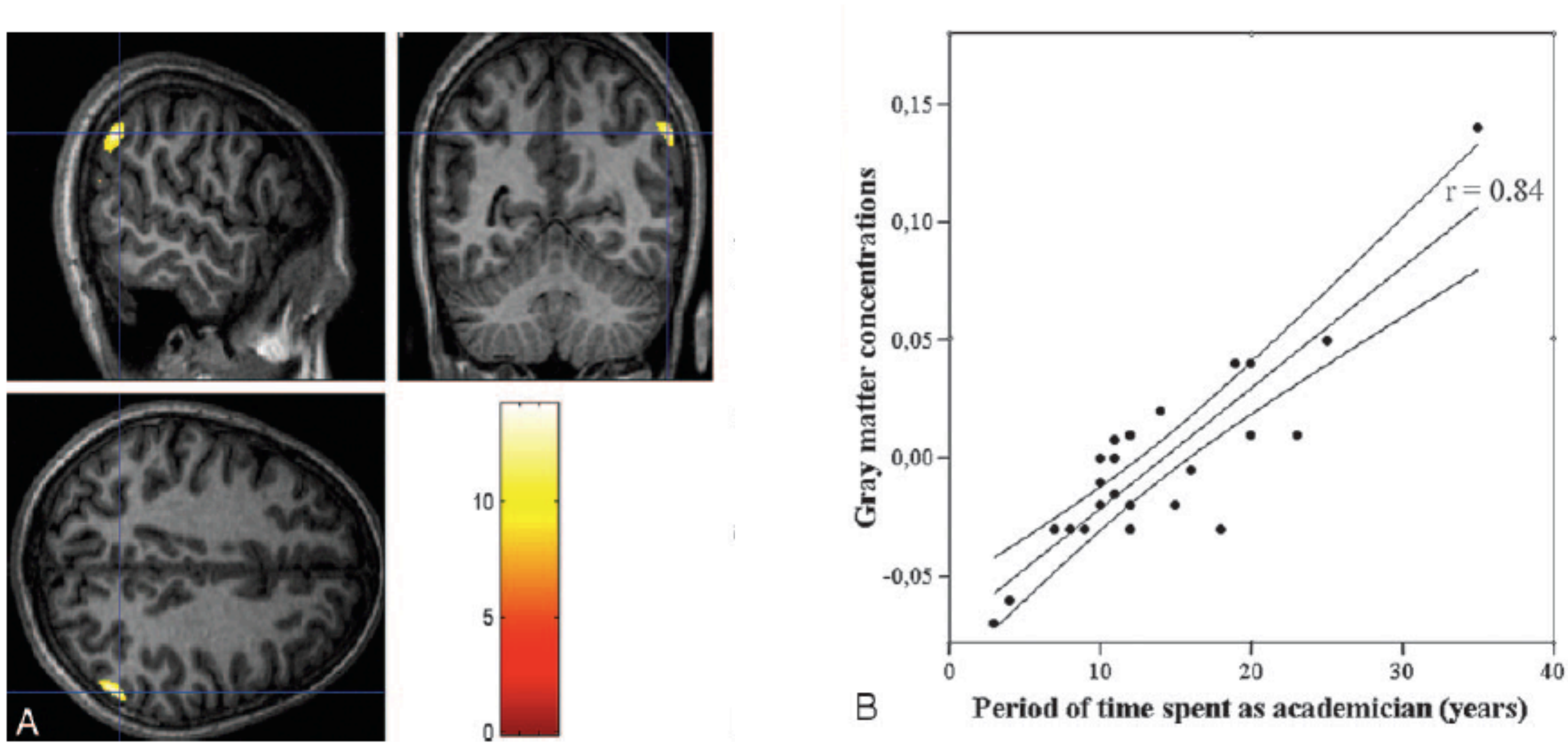


ACC



Cunningham et al. (2004)

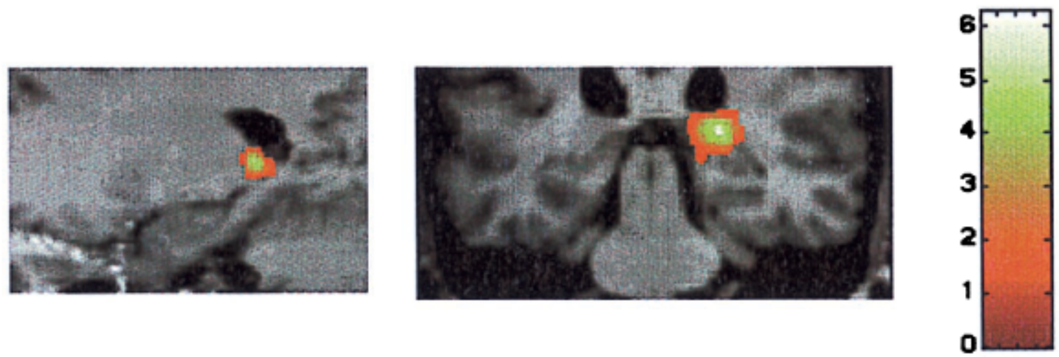
Mathematics Learning and R. IPS

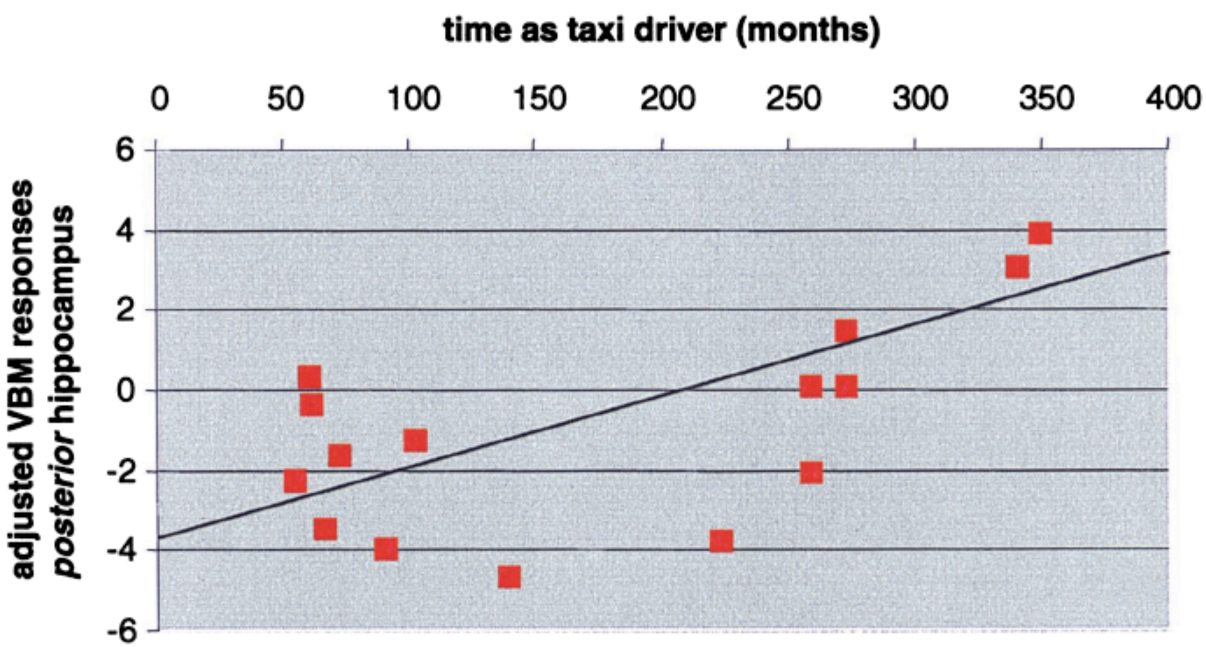


sample: mathematicians; R. IPS

Aydin et al. (2007)

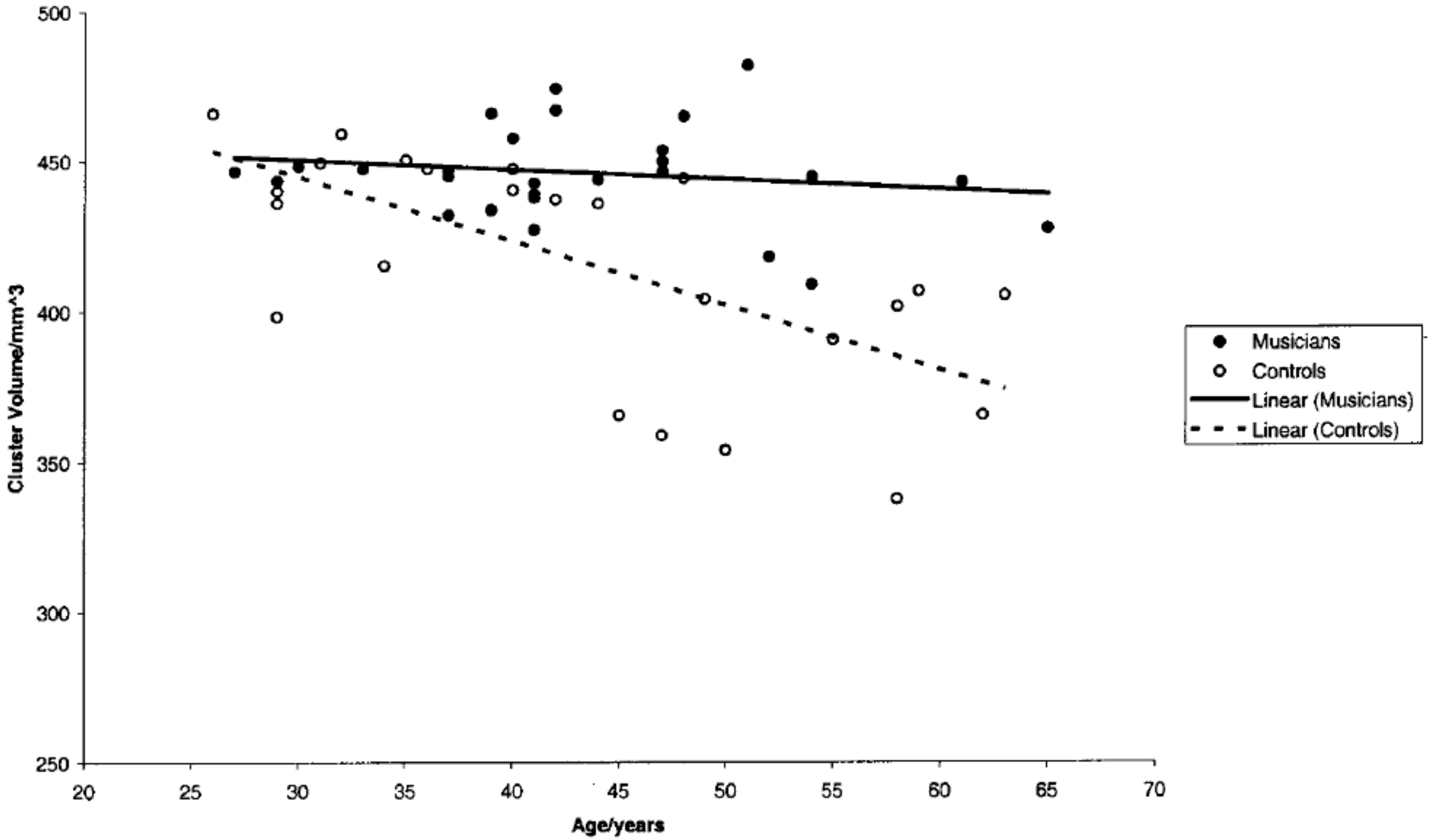
Spatial Learning and HIP





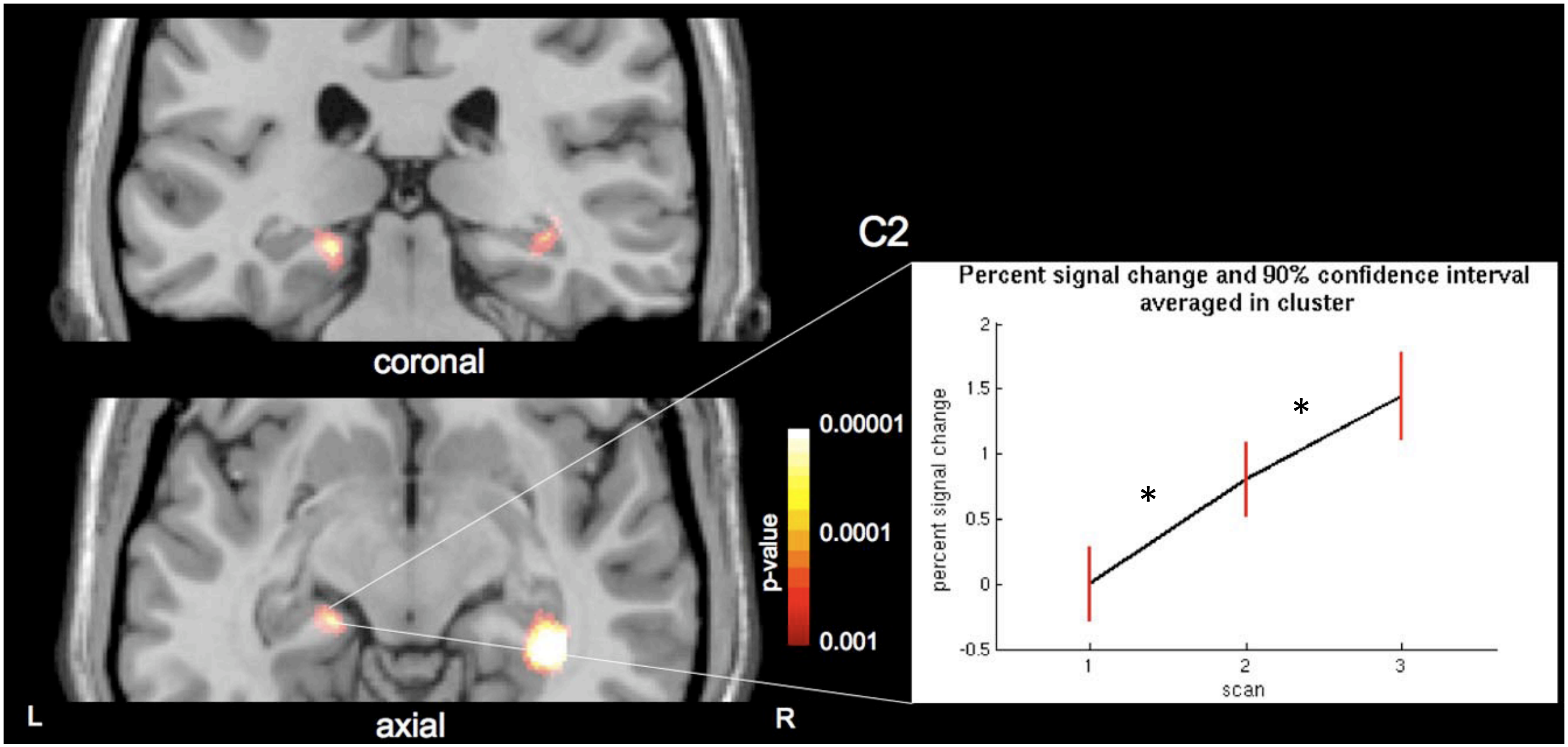
Maguire et al. (2000)

Music Learning and L. IFG



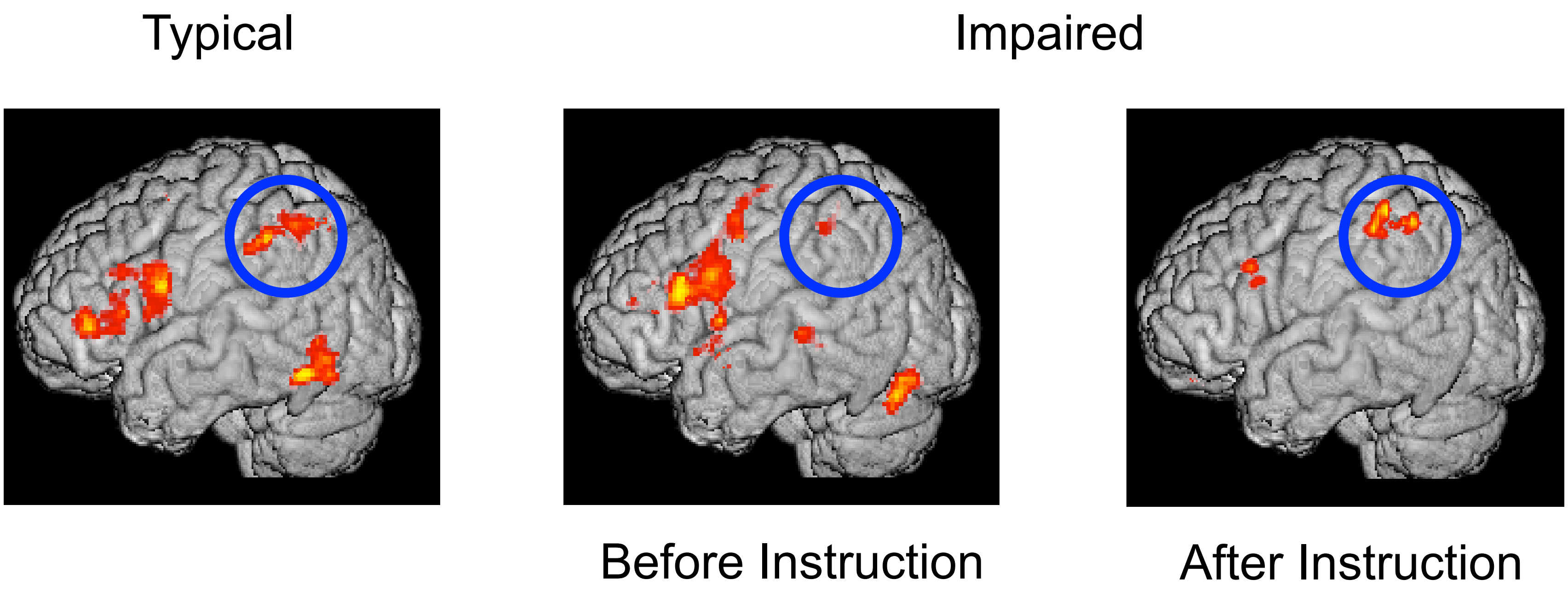
Sluming et al. (2002)

Science Learning and R. HIP



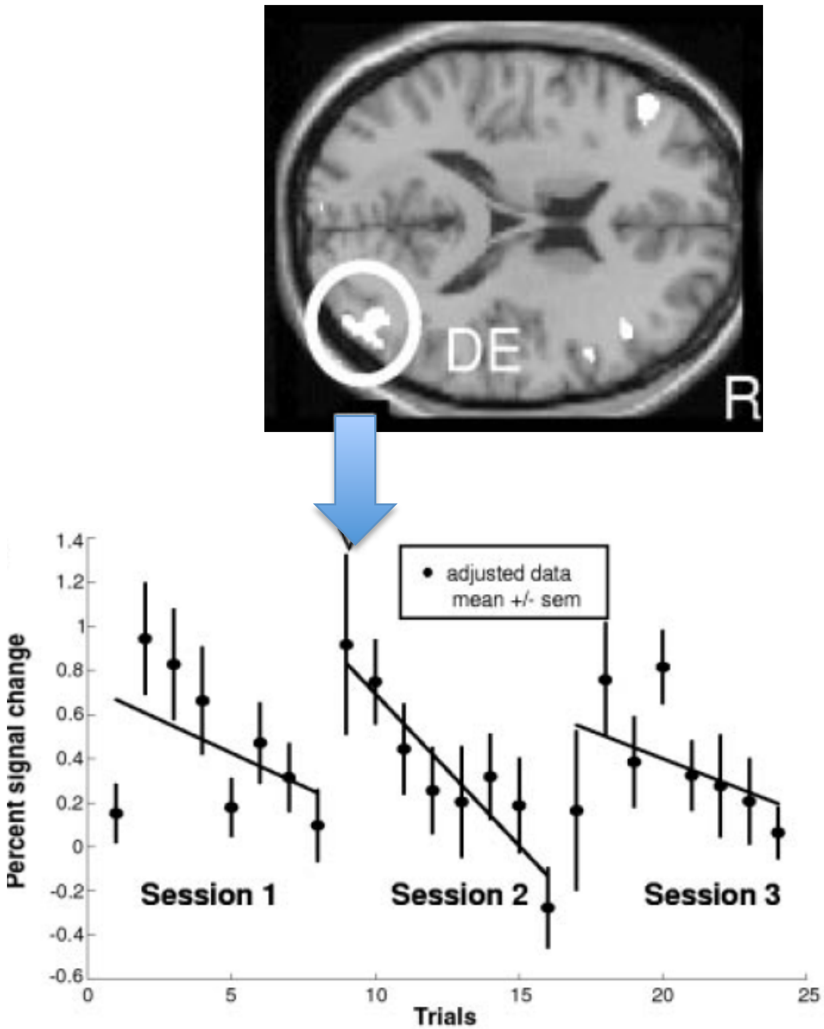
Draganski et al. (2006)

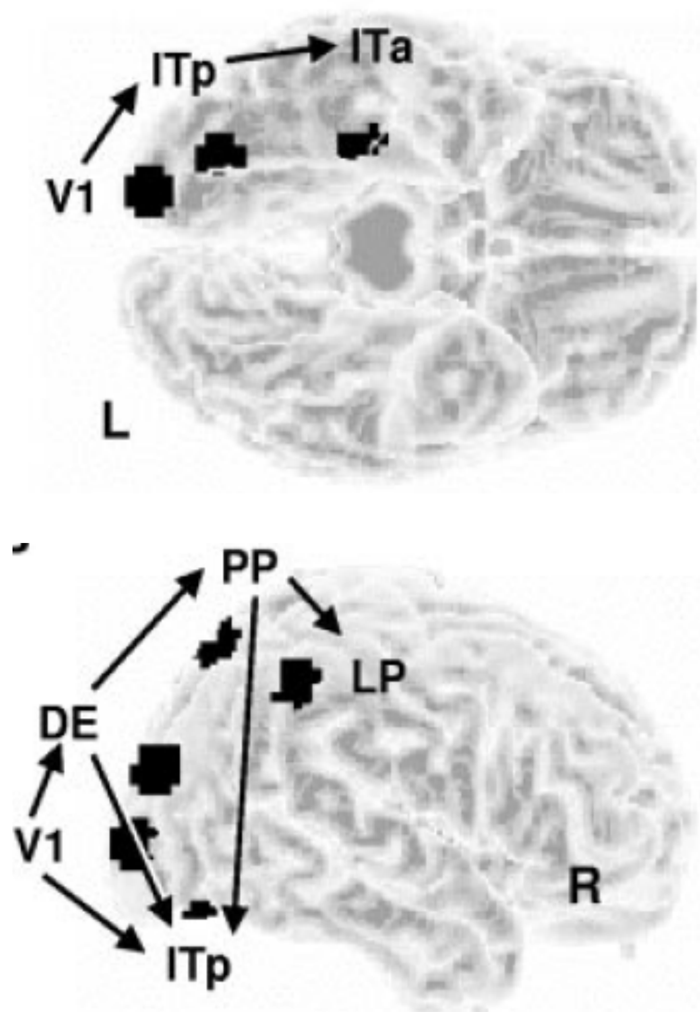
Language Instruction and L. SMG/AG



Eden et al. (2004)

Visual Learning and Effective Connectivity





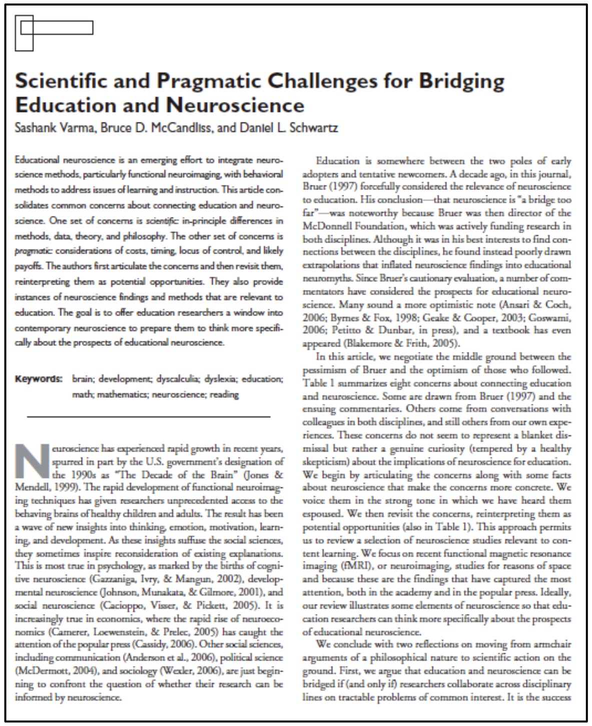
Büchel et al. (1999)

Neurocognitive Foundations for the Learning Sciences

- A new perspective on psychology and education

- Learning / training / instruction / remediation
- Development
- Individual differences
- Group differences

- Revealing surprises
- Revealing undetected differences



Scientific and Pragmatic Challenges for Bridging Education and Neuroscience

Sashank Varma, Bruce D. McCandliss, and Daniel L. Schwartz

Educational neuroscience is an emerging effort to integrate neuroscience methods, particularly functional neuroimaging, with behavioral methods to address issues of learning and instruction. This article consolidates common concerns about connecting education and neuroscience. One set of concerns is scientific: in-principle differences in methods, data, theory, and philosophy. The other set of concerns is *pragmatic*: considerations of costs, timing, locus of control, and likely payoffs. The authors first articulate the concerns and then revisit them, reinterpreting them as potential opportunities. They also provide instances of neuroscience findings and methods that are relevant to education. The goal is to offer education researchers a window into contemporary neuroscience to prepare them to think more specifically about the prospects of educational neuroscience.

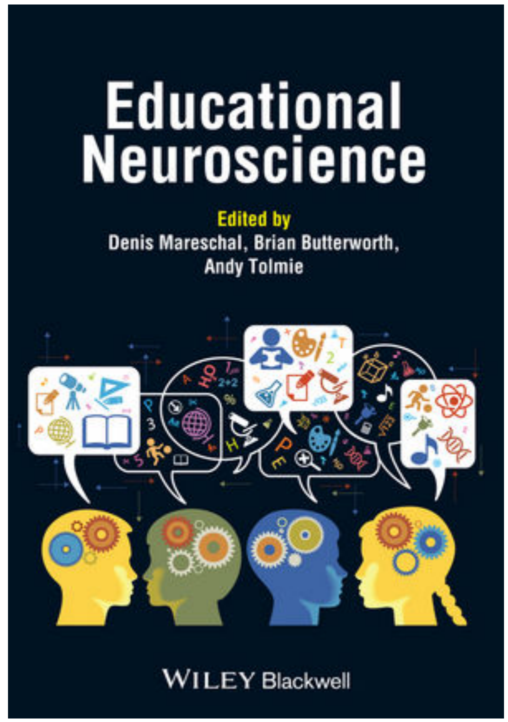
Keywords: brain; development; dyscalculia; dyslexia; education; math; mathematics; neuroscience; reading

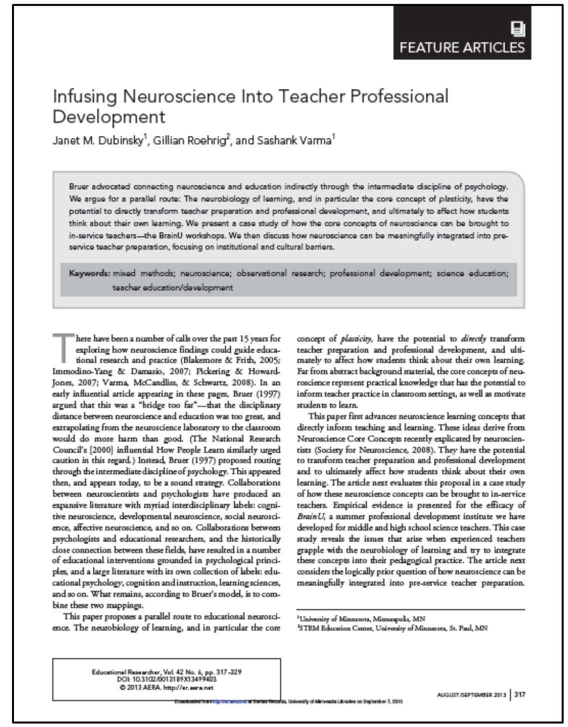
Neuroscience has experienced rapid growth in recent years, spurred in part by the U.S. government's designation of the 1990s as "The Decade of the Brain" (Jones & Mendell, 1999). The rapid development of functional neuroimaging techniques has given researchers unprecedented access to the behaving brains of healthy children and adults. The result has been a wave of new insights into thinking, emotion, motivation, learning, and development. As these insights suffuse the social sciences, they sometimes inspire reconsideration of existing explanations. This is most true in psychology, as marked by the births of cognitive neuroscience (Gazzaniga, Ivry, & Mangun, 2002), developmental neuroscience (Johnson, Munakata, & Gilmore, 2001), and social neuroscience (Cacioppo, Visser, & Pickett, 2005). It is increasingly true in economics, where the rapid rise of neuroeconomics (Camerer, Loewenstein, & Prelec, 2005) has caught the attention of the popular press (Cassidy, 2006). Other social sciences, including communication (Anderson et al., 2006), political science (McDermott, 2004), and sociology (Wexler, 2006), are just beginning to confront the question of whether their research can be informed by neuroscience.

Education is somewhere between the two poles of early adopters and tentative newcomers. A decade ago, in this journal, Bruer (1997) forcefully considered the relevance of neuroscience to education. His conclusion—that neuroscience is "a bridge too far"—was noteworthy because Bruer was then director of the McDonnell Foundation, which was actively funding research in both disciplines. Although it was in his best interests to find connections between the disciplines, he found instead poorly drawn extrapolations that inflated neuroscience findings into educational neuromyths. Since Bruer's cautionary evaluation, a number of commentators have considered the prospects for educational neuroscience. Many sound a more optimistic note (Ansari & Coch, 2006; Byrnes & Fox, 1998; Geake & Cooper, 2003; Goswami, 2006; Petitto & Dunbar, in press), and a textbook has even appeared (Blakemore & Frith, 2005).

In this article, we negotiate the middle ground between the pessimism of Bruer and the optimism of those who followed. Table 1 summarizes eight concerns about connecting education and neuroscience. Some are drawn from Bruer (1997) and the ensuing commentaries. Others come from conversations with colleagues in both disciplines, and still others from our own experiences. These concerns do not seem to represent a blanket dismissal but rather a genuine curiosity (tempered by a healthy skepticism) about the implications of neuroscience for education. We begin by articulating the concerns along with some facts about neuroscience that make the concerns more concrete. We voice them in the strong tone in which we have heard them espoused. We then revisit the concerns, reinterpreting them as potential opportunities (also in Table 1). This approach permits us to review a selection of neuroscience studies relevant to content learning. We focus on recent functional magnetic resonance imaging (fMRI), or neuroimaging, studies for reasons of space and because these are the findings that have captured the most attention, both in the academy and in the popular press. Ideally, our review illustrates some elements of neuroscience so that education researchers can think more specifically about the prospects of educational neuroscience.

We conclude with two reflections on moving from armchair arguments of a philosophical nature to scientific action on the ground. First, we argue that education and neuroscience can be bridged if (and only if) researchers collaborate across disciplinary lines on tractable problems of common interest. It is the success





FEATURE ARTICLES

Infusing Neuroscience Into Teacher Professional Development

Janet M. Dubinsky[1], Gillian Roehrig[2], and Sashank Varma[1]

Bruer advocated connecting neuroscience and education indirectly through the intermediate discipline of psychology. We argue for a parallel route: The neurobiology of learning, and in particular the core concept of plasticity, have the potential to directly transform teacher preparation and professional development, and ultimately to affect how students think about their own learning. We present a case study of how the core concepts of neuroscience can be brought to in-service teachers—the BrainU workshops. We then discuss how neuroscience can be meaningfully integrated into pre-service teacher preparation, focusing on institutional and cultural barriers.

Keywords: mixed methods; neuroscience; observational research; professional development; science education; teacher education/development

There have been a number of calls over the past 15 years for exploring how neuroscience findings could guide educational research and practice (Blakemore & Frith, 2005; Immodino-Yang & Damasio, 2007; Pickering & Howard-Jones, 2007; Varma, McCandliss, & Schwartz, 2008). In an early influential article appearing in these pages, Bruer (1997) argued that this was a "bridge too far"—that the disciplinary distance between neuroscience and education was too great, and extrapolating from the neuroscience laboratory to the classroom would do more harm than good. (The National Research Council's [2000] influential How People Learn similarly urged caution in this regard.) Instead, Bruer (1997) proposed routing through the intermediate discipline of psychology. This appeared then, and appears today, to be a sound strategy. Collaborations between neuroscientists and psychologists have produced an expansive literature with myriad interdisciplinary labels: cognitive neuroscience, developmental neuroscience, social neuroscience, affective neuroscience, and so on. Collaborations between psychologists and educational researchers, and the historically close connection between these fields, have resulted in a number of educational interventions grounded in psychological principles, and a large literature with its own collection of labels: educational psychology, cognition and instruction, learning sciences, and so on. What remains, according to Bruer's model, is to combine these two mappings.

This paper proposes a parallel route to educational neuroscience. The neurobiology of learning, and in particular the core concept of *plasticity*, have the potential to *directly* transform teacher preparation and professional development, and ultimately to affect how students think about their own learning. Far from abstract background material, the core concepts of neuroscience represent practical knowledge that has the potential to inform teacher practice in classroom settings, as well as motivate students to learn.

This paper first advances neuroscience learning concepts that directly inform teaching and learning. These ideas derive from Neuroscience Core Concepts recently explicated by neuroscientists (Society for Neuroscience, 2008). They have the potential to transform teacher preparation and professional development and to ultimately affect how students think about their own learning. The article next evaluates this proposal in a case study of how these neuroscience concepts can be brought to in-service teachers. Empirical evidence is presented for the efficacy of *BrainU*, a summer professional development institute we have developed for middle and high school science teachers. This case study reveals the issues that arise when experienced teachers grapple with the neurobiology of learning and try to integrate these concepts into their pedagogical practice. The article next considers the logically prior question of how neuroscience can be meaningfully integrated into pre-service teacher preparation.

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