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The Evolution of C2

Extending Hypothesis Testing of Edge Organizations Using Functional Magnetic Resonance Imaging (fMRI) During ELICIT

Topics:
5 – Experimentation and Analysis
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Abstract

The Edge, appropriate for exploring contemporary military operations raises issues regarding comparative performance to traditional hierarchal configurations. Well-controlled experimental design offers insight about the internal workings of the Edge organization with high levels of reliability and internal validity. Leweling and Nissen (2007) reported results of an extension to a series of laboratory experiments using the ELICIT multiplayer intelligence game. This confirmed that Edge organizations outperform Hierarchy organizations in certain tasks, environmental contexts, and performance measures. Their findings answer questions and inform future experimentation. In particular, complementary research suggests that participants' tacit knowledge and contextual influence modulates those results. If so, then understanding tacit knowledge and contextual influence at the physiological level—and linking such understanding to individual and team performance—can reveal novel insight into how to organize, lead and perform in high-capability organizations (Kalbfleisch et al., 2006, 2007, Roberts et al., 2009, Kalbfleisch, in press). In this paper we explain the elements necessary to understand and employ during state-of-the-art functional magnetic resonance imaging (fMRI) to illuminate such physiological bases. Specifically, neuroimaging can be used to identify neural systems affiliated with behavior during meaningful moments of exchange to characterize tacit knowledge during ELICIT. Building upon previous work, this research extends the state of the art and opens new avenues for continued knowledge development.

Introduction

The Edge (Alberts and Hayes, 2003) represents a fresh approach to organizational design, one that is particularly powerful in the context of modern military operations; it capitalizes upon fully connected, geographically distributed, organizational participants by moving knowledge and power to the edges of organizations where they interact directly with their environments. Indeed, the Edge raises issues regarding comparative performance of individuals when performing within traditional hierarchical organizational configurations or others that function within alternative structures (Gateau et al., 2007). Well-controlled experimental design offers insight about the internal workings of the Edge organization with high levels of reliability and internal validity. Leweling and Nissen (2007) reported results of an extension to a series of laboratory experiments using the ELICIT (Experimental Laboratory for Investigating Collaboration, Information Sharing, and Trust) multiplayer counterterrorism intelligence game. This confirmed that Edge organizations outperform Hierarchy organizations in certain tasks, environmental contexts, and performance measures. In particular, complementary research suggests that participants' tacit knowledge and contextual influence on their reasoning may strongly affect such results. If so, then understanding people's tacit knowledge and contextual influences on their reasoning at the physiological level—and linking such understanding to individual and team performance—reveals novel insight into how to organize, lead and perform in high-capability organizations (Kalbfleisch et al., 2007, Kalbfleisch, in press).

In this paper we review some approaches to consider for experimental design examining how the environment changes neural systems of reasoning and how social interaction influences tacit knowledge and its influence on the formation of trust during ELICIT. Specifically, monitoring the neural basis of interoception, social awareness, and reasoning will permit a physiological understanding of behavior during meaningful moments of exchange. This research opens new avenues for the epistemological understanding of formal and informal dynamic influences on decision-making and trust during social interaction.

ELICITing Behavior

ELICIT is designed to explore social and cognitive impacts of the C2 approach within the context of organizational structures and situations such as information sharing, trust, shared awareness, and task performance. It consists of multiple features that permit flexibility in altering environmental context and supports social context between two individuals and also with software agents. Concretely, it involves players in a situational awareness task whose goal is the find the who, what, where, and when of a future terrorist attack. Information is distributed to multiple participants over time and no one participant will have all of the information needed to solve the problem. Dependent variables are things such as roles, responsibilities, and controlled access between and to other players (see Figure 1). Measures of effectiveness that lend themselves to behavioral characterization for neuroimaging experimentation fall under the headings Quality and Efficiency (see Table 1).

Quality of Awareness & Shared Awareness	Efficiency
Correctness (Authorized IDs)	Productivity (Total Correct Actions/ Time Stamp)
Timeliness (Minutes to Correct IDs)	Speed (Time of Earliest Correct ID)
Accuracy (Correct IDs & Total IDs)	

Table 1. ELICIT Effectiveness Indices

With these parameters, it is possible to synthesize the methodologies of ELICIT with functional magnetic resonance imaging (fMRI), correlating signal in imaging data to vectors tied to reaction time, response, and temporal contiguity, to approximate the neural systems that support key moments of choice and exchange during individual and social problem-solving. In doing so, there are important and necessary controls to apply to this examination that involve several layers of neural activity: (1) an account of a person's own self-awareness in the game experience, (2) their cognitive processes of reasoning, and (3) the modulation of uncertainty that primes the experience. Accounting for these variables sets the stage for the greatest resolution of knowledge construction processes (internal and social) that occur during ELICIT. The following section reasons for and outlines these constructs and discusses methodological issues associated with their accounting. Said succinctly, trust is not only a choice or the result of an intuitive or more intentional assessment, but a composite of other more basic processes occurring at a systemic level (as in Figure 1) and a physiological level. The next section outlines physiological requirements for exploring ELICIT dynamics.

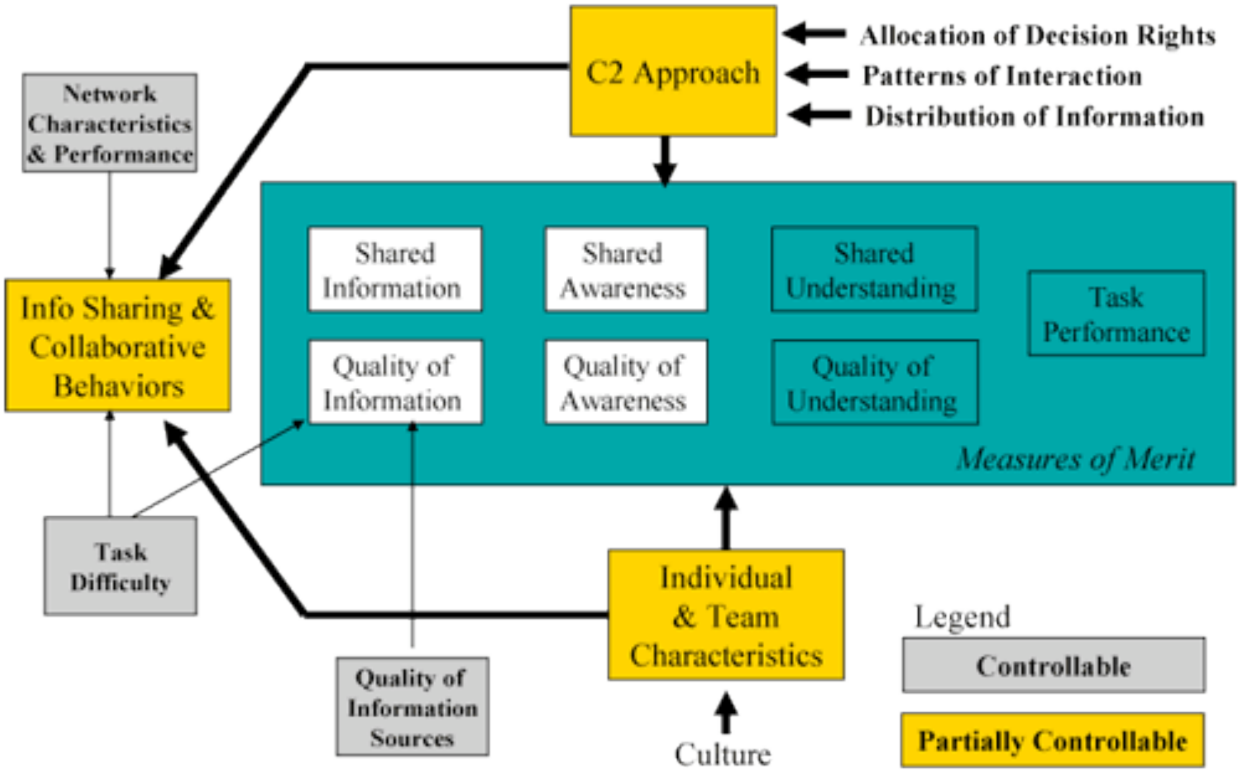

Figure 1. ELICIT Dependent Variables

Physiological Constructs Supporting the Assessment of Choice and Trust During ELICIT

Interoception

Studies of game interaction require an account for the influence of interoception, one's sense of the physiological condition of the body (Cameron and Minoshima, 2002; Longo et al., 2010) typically represented by activity in the right anterior insular cortex (Craig, 2003). When considering the role of context, an obvious but difficult relationship to characterize is the boundary between one's awareness of themselves and the impact of the social environment? To illustrate, it is known that emotions are associated with patterns of cardiorespiratory activity as measured by electrocardiogram (Rainville et al., 2006) and other studies of biofeedback and the autonomic nervous system. Another situation that rivals examining the complexity of social interactions and situated problem solving is the creative process. For instance, neurologist Kenneth Heilman and colleagues (2003) suggest that creative people, in addition to possessing a deep store of domain knowledge and the intellectual resources to mine it, may also have an ability to modulate their hormonal systems. They posit that because creativity is associated with low levels of arousal, sometimes called "flow" (Dietrich, 2004), that the ability to modulate the adrenalin system may be an additional enabling factor to influencing creative production.

They tested this hypothesis in a population of individuals who had been implanted with vagus nerve stimulators for treatment of intractable seizures (Ghacibeh et al., 2006). The vagus nerve is a cranial nerve (X) that serves as the main conduit between the body and the brain and its transmission of adrenaline. The vagus nerve travels from the gut and heart in the periphery through the solitary tract nucleus in the brainstem and up to the locus coeruleus, the part of cortex which holds the limbic system, an area heavily modulated by adrenalin. During stimulation of this nerve, Heilman and colleagues found that learning and retention were enhanced, while performance on measures of cognitive flexibility and creativity were impaired. They discuss the relationship between arousal and cognition lending insight into the dose response curve associated with subjective and objective forms of stress, a key variable in the ability to express talent (Kalbfleisch, 2009). This type of emotion regulation and how it organizes for successful goal-directed behavior is also suggested in the child development literature (Hoeksma et al., 2004) pointing to the fact that our nervous systems regulate cognition on simultaneous and multiple levels just as it does basic autonomic processes, and that the two are more closely entrained than we presently appreciate. Contemporary cognitive neuroscience presents a revised understanding of the posteromedial cortex (consisting of Brodmann areas 23, 29, 30, 31, and 7m) as a regional area that actively assesses interoceptive and state-related information (Parvizi et al., 2006) beyond examining basic systems of arousal. Separating the influences of task demand and the participant's sense of self in relationship to their progress or experience during ELICIT can illustrate how emotion regulation may relate to the formation of tacit knowledge and how it may be trained (Critchley et al., 2002). Furthermore, in regards to the "flow" state affiliated with discussions about creativity, leads me to consider the cognitive states of game participation. One could argue that players in game situations are also engaged in a state of flow entrained by the game environment itself.

Social Awareness

This section draws primarily from the chapter by Edward Hutchins on social learning processes during ship navigation (1996) where he draws heavily from writings of Lev Vygotsky to map out and in between the development of navigation skills and the designed spaces that facilitate that acquisition during social interaction. In this chapter he quotes heavily from Vygotsky (1960, 1981) who says, "*Any higher mental function necessarily goes through an external stage in its development because it is initially a social function. This is the center of the whole problem of internal and external behavior…. When we speak of a process, 'external' means 'social.' Any higher mental function was external because it was social at some point before becoming an internal, truly mental function. It was first a social relation between two people*" (p.162).

Drawing from that inspiration, Hutchins posits:

"*That leads one to wonder whether there might be intrapsychological processes that could not be transformations of processes that occurred in social interaction. Finding such a process would be a challenge to Vygotsky's position, but unless there are constraints on the possible transformations, then there is no way to identify such a process*" (p. 61).

An a priori design to monitor aspects of interoception and social awareness provides the ability to triangulate more than just the cognitive processes affiliated with problem solving during ELICIT. There is a long precedent in the developmental psychology literature for triangulating the relationship and interaction between cognitive processes and the processes of social interaction (Musatti, 1993), taking into account what Vygotsky (1960) referred to as the cultural structure of the environment and that it is "instrumentally created" when systems of meanings become apparent to the child and they become practiced at identifying and interacting with relevant information from their environment (Wertsch and Rupert, 1993). Precedent for observing this now comes from emerging studies examining neural systems that monitor one's perception of themselves in space (Macaluso and Maravita, 2010) and in a virtual world (Baumgartner et al., 2008). fMRI, on a physical level, is a socially isolating experience. Drawing from this, ELICIT creates its own contingencies that define the goal and establishes the cultural structure around the interaction, decreasing the degrees of freedom one has to account for in characterizing the acquisition and role of knowledge and the variation of a dynamic.

Reasoning

Another useful analogy to draw from Hutchins' chapter on ship navigation (1996) is that of the 'fix cycle' relating to the maintenance functions of a ship (p.43). He makes the point that this cycle can run at a more leisurely pace of 30-minute intervals or it can be accelerated to run at one-minute intervals when the ship is in restricted waters. It is the same with the brain. The brain reasons on many levels. We typically equate reasoning with decisions and choices made under conditions where we have all the information needed to make a choice but not a lot of time (Kalbfleisch et al., 2006, 2007) or, all the time we need but struggle to gain all the relevant information and have to approximate and take a risk. Again, ELICIT's parameters maneuver along those axes as evidenced by the explicit behavioral measures and the landscape laid out for its participants in either hierarchical or edge configurations. The beauty of the brain is that it has multiple systems to draw from that enable us to reason (Goel and Dolan, 2003, Hynes et al., 2006, van den Bos et al., 2007), some that are affiliated with the feeling of making a distinct choice and others that provide a perceptual assist when variables of a decision become perceptually or explicitly complex (Christoff et al., 2002; Kroger et al., 2002; Wright et al., 2008, Stoneham et al., 2008; Roberts et al., 2009; Halavi et al., in submission). Knowing this, it approaches the realm of possibility that there are additional subtleties of higher-level cognition instantiated in neural tissue that we haven't seen yet.

Functional magnetic resonance imaging (fMRI) paradigms in cognitive neuroscience have historically documented basic building blocks of human cognition (visual perception, attention, memory) apart from decision-making. More recently, the field has jumped to naturalistic paradigms (social affective phenomenon, neuroeconomics, theory of mind), some of which lack the experimental controls that permit an accurate interpretation and contextual understanding of their studied phenomenon (Kriegeskorte et al., 2009), and others that require such complex signal processing outside of standardized image analysis protocols, that assessing the validity of the result becomes quite difficult. To that end, a layperson trying to understand basic principles and guideposts would benefit from knowing that some have compiled neuroprimers to assist in the application and interpretation of neuroimaging work in cognitive and social paradigms (Cacioppo et al., 2003; Kalbfleisch, 2008). Some fMRI paradigms appear more to fit the "brain to the game" rather than the other way around. In particular, investigations of the relationship between emotion and cognition report findings in dichotomies that suggest that emotion and cognition happen aside each other (Pessoa, 2008). This draws particular concern for our understanding of reasoning, the most summative functional cognitive outcome.

The current state of the discussion about implicit priming of cognition, one way to characterize how emotion and environmental context shape cognition, is defined by experiments that have taken a classical conditioning approach to demonstrate modulation on activity in primary visual cortex when pairing emotion-laden images with a shock (Padmala and Pessoa, 2008) or a masked priming approach that demonstrates modulation for responses to financial reward and punishment (Pessiglione et al., 2008). While these are valuable contributions to our knowledge of how cognition is modulated by sensation, emotion and incentive, an encompassing strategy is still needed to characterize a prescriptive understanding of how environmental context modulates performance under a wider array of conditions and incentives than has been previously documented.

In the face of emerging data that the brain calculates its own moves under conditions of uncertainty (Kalbfleisch et al., 2006, 2007) and much earlier than the moment of the behavioral response (Eichele et al., 2008), that we believe we can assess one's action intention (Kaplan & Iacoboni, 2006), and still characterize what we would say is volitional action (Kalbfleisch, 2004, Haggard, 2008), it is even more important to understand how neural systems of reasoning are executed differently in varying emotional contexts. Thus, the capability to document ELICIT is built on an understanding of the influences outlined here and an ability to use this information as a tool for experimental design.

ELICIT and the Neuroscience of Gaming

Investigations of the neural underpinnings of gaming have focused on the neural systems of executing the game and significant improvements in those systems or changes in performance (Green & Bavelier, 2003; Thorell et al., 2009). No studies have been able to directly correlate structural change with meaningful functional change in brain activity (Haier et al., 2009). Many of these studies are called into question because of weaknesses in experimental design such as players logging into a site to play for a certain amount of time, not enough time spent on task, or difficulty in enforcing participation compliance.

Some papers report findings related to the state(s) of awareness of the players, but the main focus is still what is going on in the game context and the impact that distractors have on keeping a game player in flow (Wentura et al., 2009) or using the game to suppress other mental activity (Holmes et al., 2009). The closest comparison to addressing a state effect we could find outside of documentation of studies of augmented cognition for military use (Kalbfleisch and Forsythe, in press) is one study which demonstrated that visual images of the game Tetris persisted while they were trying to fall asleep and that those images may assist or, more neutrally, are present during the re-organization and consolidation of the procedural skills tied to playing the game (Stickgold et al., 2000).

While the branches of behaviorist, cognitive, humanist, and social psychology, are all fields, they are also all discrete aspects of a larger network of ways that learning occurs. Behaviorism marks the beginning of the sense-making process when the environment or ideas being encountered are unfamiliar to the learner. It helps build access to an association that will have the potential to be meaningfully integrated as the participant makes sense of new information. We can, in part, recognize this integration in someone's "natural", appropriate, effective behavior that can be likened to tacit knowledge. This is the basis of the approach to examine ELICIT processes during neuroimaging. The surface assumption is that we will document the moment of trust and, henceforth, refer to trust as if it is a crystallized object. When, in reality, trust is a process and a state, a noun and a verb. Thus, taking the ELICIT platform into virtual and physiological experimental paradigms provides the opportunity for examining any number of "nouns" and "verbs" important to our understanding of social cognition and context-dependent decision-making. In this paper, we have attempted to outline the layers of knowledge and understanding that will permit an optimal look.

With the knowledge that well-controlled experimental design offers insight about the internal workings of the Edge organization with high levels of reliability and internal validity in the ELICIT multiplayer counterterrorism intelligence game (Leweling & Nissen, 2007), we can take this game into a neurophysiological experimental design. Knowing that Edge organizations outperform Hierarchy organizations in certain tasks, environmental contexts, and performance measures and that participants' tacit knowledge and contextual influence on their reasoning may strongly affect such results offers behavioral data significant enough to be explored during neuroimaging. Understanding people's tacit knowledge and contextual influences on their reasoning at the physiological level during ELICIT—and linking such understanding to individual and team performance—will reveal novel insight into how to organize, lead and perform in high-capability organizations (Kalbfleisch et al., 2006, 2007, Roberts et al., 2009; Kalbfleisch, in press).

References

Alberts, D.S. and Hayes, R.E. (2003). *Power to the Edge*. Washington, DC: CCRP.

Baumgartner, T., Speck, D., Wettstein, D., Masnari, O., Beeli, G., Jancke, L. (2008). Feeling present in arousing virtual reality worlds: prefrontal brain regions differentially orchestrate presence experience in adults and children. *Frontiers in Human Neuroscience 2* (8): 1-12.

Cacioppo, J.T., Bernston, G.G., Lorig, T.S., Norris, C.J., Rickett, E., Nusbaum, H. (2003). Just because you're imaging your brain doesn't mean you can stop using your head: a primer and set of first principles. *Journal of Personality and Social Psychology, 85* (4): 650-661.

Cameron O.G., Minoshima S. (2002). Regional brain activation due to pharmacologically induced adrenergic interoceptive stimulation in humans. *Psychosomatic Medicine 64*: 851-861.

Christoff, K., Prabhakaran, V., Dorfman, J., Zhao, Z., Kroger, J.K., Holyoak, K.J., Gabrieli, J.D. (2001). Rostrolateral prefrontal cortex involvement in relational integration during reasoning. *NeuroImage 14* (5), 1136–1149.

Craig, A.D. (2003). Interoception: the sense of the physiological condition of the body. *Current Opinion in Neurobiology 13*: 500-505.

Critchley, H.D., Melmed, R.N., Featherstone, E., Mathias, C.J., Dolan, R.J. (2002). Volitional control of autonomic arousal: a functional magnetic resonance study. *NeuroImage 16*: 909-919.

Dietrich, A. (2004). Neurocognitive mechanisms underlying the experience of flow. *Consciousness and Cognition, 13*: 746-761.

Eichele, T., Debener, S., Calhoun, V.D., Specht, K., Engel, A.K., Hugdahl, K., von Cramon, D.Y., Ullsperger M. (2008). Prediction of human errors by maladaptive changes in event-related brain networks. *Proceedings of the National Academy of Sciences, 105* (15), 6173-6178.

Gateau, J. B., Leweling, T. A., Looney, J. P., & Nissen, M. E. (2007). Hypothesis testing of edge organizations: Modeling the C2 organization design space. *Proceedings International Command & Control Research & Technology Symposium*, Newport, RI.

Ghacibeh, G.A., Shenker, J.I., Shenal, B., Uthman, B.M., Heilman, K.M. (2006). Effect of vagus nerve stimulation on creativity and cognitive flexibility. *Epilepsy Behavior, 8* (4): 720-725.

Goel, V., Dolan, R.J. (2003). Reciprocal neural response within lateral and ventral medial prefrontal cortex during hot and cold reasoning. *NeuroImage 20* (4): 2314-2321.

Green, C.S., Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*: 534-537.

Haier, R.J., Karama,S., Leyba, L., Jung, R.E. (2009). MRI assessment of cortical thickness and functional activity changes in adolescent girls following three months of practice on a visual-spatial task. *BMC Research Notes, 2*: 174-181.

Haggard, P. (2008). Human volition: towards a neuroscience of will. *Nature Reviews Neuroscience, 9*, 934-946.

Halavi, M., de Bettencourt, M.T., Kopperman, R., Roberts, J.L., Kalbfleisch, M.L. (in submission). Environmental influences on relational complexity.

Heilman, K.M., Nadeau, S.E., Beversdorf, D.O. (2003). Creative innovation: possible brain mechanisms. *Neurocase 9* (5): 369-379.

Hoeksma, J.B., Oosterlaan, J., Schipper, E.M. (2004) Emotion regulation and the dynamics of feelings: a conceptual and methodological framework. *Child Development 75* (2): 354-360.

Holmes, E.A., James, E.L., Coode-Bate, T., Deeprose, C. (2009). Can playing the computer game “Tetris” reduce the build-up of flashbacks for trauma? A proposal from cognitive science. *PLoS One, 4*(1): e4153.

Hutchins, E. (1996). Learning to navigate. In S. Chaiklin and J. Lave (Eds.) *Understanding Practice: Perspectives on Activity and Context*. New York, NY: Cambridge University Press. (pp. 35-63).

Hynes, C.A., Baird, A.A., Grafton, S.T. (2006). Differential role of the orbital frontal lob in emotion versus cognitive perspective taking. *Neuropsychologia 44* (3): 374-383.

Kalbfleisch, M.L, Forsythe, C. (in press). Instantiating the progress of neurotechnology for applications in national defense intelligence. *National Defense and Intelligence Journal.*

Kalbfleisch, M.L. (in-press). Potential constructs and cognitive components in design creativity: Paradigms from educational psychology and neuroscience. In J.Gero (Ed.) *Studying Design Creativity*. New York, NY: Springer.

Kalbfleisch, M.L. (2009). The neural plasticity of giftedness. In L. Shavinina (Ed.) *International Handbook on Giftedness*. New York, NY: Springer. (pp. 275-293).

Kalbfleisch, M.L. (2008). Getting to the heart of the brain: using cognitive neuroscience to explore the nature of human ability and performance. In L.Kalbfleisch (ed.) *Special Issue on the Cognitive Neuroscience of Giftedess, Roeper Review, 30* (3): 162-170.

Kalbfleisch, M.L., Van Meter, J.W., Zeffiro, T.A. (online 2006, print 2007). The influences of task difficulty and response correctness on neural systems supporting fluid reasoning. *Cognitive Neurodynamics 1* (1): 71-84.

Kaplan, J.T., Iacoboni, M. (2006). Getting a grip on other minds: mirror neurons, intention understanding, and cognitive empathy. *Social Neuroscience, 1* (3-4): 175-183.

Kriegeskorte, N., Simmons, W.K., Bellgowan, P.S.F., Baker, C.I. (2009). Circular analysis in systems neuroscience. *Nature Neuroscience, 12* (5): 535-540.

Kroger, J.K., Sabb, F.W., Fales, C.L., Bookheimer, S.Y., Cohen, M.S., Holyoak, K.J. (2002). Recruitment of Anterior Dorsolateral Prefrontal Cortex in human reasoning: a parametric study of Relational Complexity. *Cerebral Cortex 12*: 477–485.

Leweling, T.A., Nissen, M. (2007). *Proceedings International Command & Control Research & Technology Symposium*, Newport, RI.

Longo, M.R., Azanon, E., Haggard, P. (2010). More than skin deep: Body representation beyond primary somatosensory cortex. *Neuropsychologia 48*: 655-668.

Macaluso, E., Maravita, A. (2010). The representation of space near the body through touch and vision. *Neuropsychologia 48*: 782-795.

Musatti, T. (1993). Meaning between peers: The meaning of peer. *Cognition and Instruction 11* (3), 241-250.

Owen, A.M., Hampshire, A., Grahn, J.A., Stenton, R., Dajani, S., Burns, A.S., Howard, R.J., Ballard, C.G. (2010). Putting brain training to the test. *Nature, 464* (1111): online doi:10.1038/4641111a.

Padmala, S., Pessoa, L. (2008). Affective learning enhances visual detection and responses in primary visual cortex. *The Journal of Neuroscience, 28* (24): 6202-6210.

Parvizi J., Van Hoesen, G.W.V., Buckwalter, J., Damasio A. (2006) Neural connections of the posteromedial cortex in the macaque. *Proceedings of the National Academy of Sciences 103* (5): 1563-1568.

Pessiglione, M., Petrovic, R., Daunizeau, J., Palminteri, S., Dolan, R.J., Frith, C.D. (2008). Subliminal instrumental conditioning demonstrated in the human brain. *Neuron, 59*: 561-567.

Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature Reviews Neuroscience, 9* (2): 148-158.

Rainville, P., Bechara, A., Naqvi, N., Damasio, A.R. (2006). Basic emotions are associated with distinct patterns of cardiorespiratory activity. *International Journal of Psychophysiology 60*: 5-18.

Roberts, J.M., Stoneham, E.T., Halavi, M., Serpati, L.A., deBettencourt, M.T., Donohue, M.E., Loughan, A.R., Zhang, D.X., Kalbfleisch, M.L. (2009). *Differential neural systems of state-dependent reasoning*. (Nanosymposium Presentation). Society for Neuroscience, Chicago, IL.

Stickgold, R., Malia, A., Maguire, D., Roddenberry, D., O'Connor, M. (2000). Replaying the game: hypnogogic images in normals and amnesics. *Science, 290* (5490): 350-353.

Stoneham, E., Debettencourt, M., Halavi, M., Shaw, A., Donohue, M., Kopperman, R., Sandford, C., Serpati, L., Roberts, J., Kalbfleisch, M.L. (November, 2008). *Neural Systems of Color Relational Complexity*. (Presentation). Society for Neuroscience, Washington, D.C.

Thorell, L.B., Lindquist, S., Nutley, S.B., Bohlin, G., Klingberg, T. (2009). Training and transfer effects of executive function in preschool children. *Developmental Science, 12*: 106-113.

Vygotsky, L.S. (1981). The genesis of higher mental functions. In J.V. Wertsch (Ed. and Trans.), *The concept of activity in Soviet psychology* (pp.144-188). Armonk, NY: M.E. Sharpe. (Reprinted from *Razvitie vysshikh psikhiches-kikj funktsii*, 1960, pp.182-223).

Van den Bos, W., McClure, S.M., Harris, L.T., Fiske, S.T., Cohen, J.D. (2007). Dissociating affective evaluation and social cognitive perspective taking in the ventral medial frontal cortex. *Cognitive Affective Behavioral Neuroscience, 7* (4): 337-46.

Wentura, D., Voss, A., Rothermund, K. (2009). Playing Tetris for science counter-regulatory affective processing in a motivationally “hot” context. *Acta Psychologia, 131* (3): 171-177.

Wright, S.B., Matlen, B.J., Baym, C.L., Ferrer, E., Bunge, S.A. (2008). Neural correlates of fluid reasoning in children and adults. *Frontiers in Neuroscience 1* (8): 1-8.