

As it appears in *Behavioral and Brain Sciences*, as a peer commentary on:
Anderson, M. (2010, in press) Neural re-use as a fundamental organizational principle of the brain.

NEURAL RE-USE IN THE SOCIAL AND EMOTIONAL BRAIN

Mary Helen Immordino-Yang¹, Joan Y. Chiao² and Alan P. Fiske³

Brain and Creativity Institute and Rossier School of Education, University of Southern California¹; Psychology Department, Northwestern University²; Anthropology Department, University of California Los Angeles³

Corresponding Author: Mary Helen Immordino-Yang
3641 Watt Way Suite B17
Los Angeles, CA 90089-2520

Email: mhimmordino-yang@post.harvard.edu

URL:

http://rossier.usc.edu/faculty/mary_helen_immordinoyang.html

Telephone: (213) 821-2969

Fax: 213-821-3099

Co-corresponding Author: Joan Y. Chiao
2029 Sheridan Rd.
Evanston, IL 60208

Email: jchiao@northwestern.edu

URL: <http://culturalneuro.psych.northwestern.edu>

Telephone: 847- 1467-0481

Fax: (847) 491-7859

WORD COUNTS:

Abstract: 60; Main Text without citations: 974; References: 294; Total (Entire): 1464

ABSTRACT

Presenting evidence from the social brain, we argue that neural re-use is a dynamic, socially organized process that is influenced ontogenetically and evolutionarily by the cultural transmission of mental techniques, values, and modes of thought. Anderson's theory should be broadened to accommodate cultural effects on the functioning of architecturally similar neural systems, and the implications of these differences for re-use.

Re-use of tissues, organs and systems is a key adaptive strategy in all phyla across evolution and through development (Gould & Vrba, 1982; Andrews, Gangestad & Matthews, 2002). Neural systems are reused in the evolution and development of complex human behaviors, including social emotion and the representation of social status. Research shows (1) evolutionary and developmental reciprocal re-use between social and non-social neural systems; (2) the importance of cultural transmission as a mode for learning evolutionarily and ontogenetically new uses and combinations of neural systems; (3) the possibility that socially mediated re-use may affect the original, primitive function of a neural system, either developmentally or evolutionarily. In short, although Anderson's approach maps distinct cognitive functions to unique networks, neural re-use within and between networks is a dynamic process involving culture and sociality.

Compassion and admiration: neural re-use between a social and a somatosensory system

A growing body of evidence points to developmental and evolutionary re-use between a social and a somatosensory system in the feeling of social emotions. Brain systems involved in the direct sensation of physical pain in the gut and viscera (e.g., during stomach ache), are also involved in the feeling of one's own social or psychological pain (Decety & Chaminade, 2003; Eisenberger & Lieberman, 2004; Panksepp, 2005). These systems are also involved in the feeling of late-developing social emotions about another person's psychologically or physically painful, or admirable, circumstances (Immordino-Yang, McColl, Damasio & Damasio, 2009). These systems most notably involve the anterior insula, anterior middle cingulate and ascending somatosensory systems in the dorsal midbrain, most directly associated with regulation of arousal and homeostasis.

Comparative social status: neural re-use between a social and a cognitive system

The intraparietal sulcus (IPS) is important to representing comparative numerosity, quantity, magnitude, extent, and intensity (Dehaene, 2003; Cohen Kadosh, Lammertyn, & Izard, 2008); it is also involved in representing social status hierarchy (Chiao et al., 2009). Particularly when comparisons are close, neural activations observed within the IPS for numerical and social status comparisons parallel behavioral distance effects in reaction time and error rates, and are thought

to reflect a domain-independent spatial representation of magnitude, including the ‘magnitude’ of social rank.

All animals are responsive to magnitudes, distances, temporal intervals, and intensities (Gallistel, 1993). The neurocognitive systems that support this seem to have been reused in evolution to represent the linear dominance hierarchies that are ubiquitous in both vertebrates and invertebrates. Social dominance hierarchies existed long before the invention of symbols to mediate mathematical calculation, so it is likely that the neural systems modern humans use for analog processing of numerical symbols reflect this phylogenetic history.

The social chicken or the useful egg?: learning cognitive skills through cultural transmission

In addition to demonstrating neural re-use in the social brain, the juxtaposition of these examples demonstrates the importance of considering the social sources and functions of the complex skills underlain by neural re-use. Many of modern humans’ complex mental functions, both social and non-social, are learned through cultural transmission of practices and cognitive techniques, and are further shaped by social values, emotional relevance, and cultural modes of thought. For example, the use of numeral symbols to represent, remember, and communicate magnitude depends on the cultural invention and transmission of such symbols. Learning to use a number board or abacus allows the reuse of systems in the motor and visual cortices to calculate and remember quantities. Similarly, the cultural invention and transmission of calendars and later digital PDAs entails the reuse of perceptual object recognition and spatial relations systems, in conjunction with fine motor control skills, for temporal mnemonics. Similar processes operate in neurochemistry. For example, oxytocin, whose original functions were to mediate birth and lactation, was evolutionarily reused to bond infants and mothers, then further reused in a small proportion of mammals for parental pair-bonding (Lee et al., 2009). Subsequently, oxytocin systems were culturally reused in diverse social bonding rituals, and recently exploited in recreational ingestion of MDMA (ecstasy).

The function of culture in shaping the use of neural systems is demonstrated by cultural variation in the neural correlates of visual attention (Lin, Lin & Han, 2008) and self-representation (Chiao et al., 2009), including differential activation patterns within the same neural systems, which can

be manipulated by cultural priming in bi-cultural individuals (Chiao et al., 2010). Together, these findings suggest that Anderson's assertion that "putting together the same parts in the same way [will lead to] the same functional outcomes" (p. XX) may not adequately account for the dynamic effects of socialization on neural re-use.

Conversely, the re-use of a neural system for a more complex, culturally organized task apparently can affect its recruitment for a phylogenetically or ontogenetically earlier use. Cross-cultural psychiatric research shows that various Asian populations tend to manifest psychosocial distress somatically, in medically unexplained bodily symptoms, while Westerners tend to express depression psychologically (Parker, Cheah, Roy, 2001). Cross-cultural work in progress by Immordino-Yang and colleagues suggests that such tendencies may be associated with cultural differences in the recruitment of neural systems for somatosensation in the cortex and brain stem during social processing, extending even into midbrain nuclei that regulate basic bodily functions.

From use to re-use and back: toward a dynamic, socio-cultural theory of re-use

Anderson's theory proposes that neural re-use is mainly a process of organizing low-level circuits with relatively fixed functions into interconnected networks, and that functional differences between cognitive domains correspond to differences in the architecture or organization of these networks. Here we argue that Anderson's model should be expanded to account for the possibilities that social learning produces distinct culturally-informed operations within architecturally similar complex networks, and that the re-use of a low-level neural circuit may in turn influence its original, primary function. Future research should investigate how socioculturally shaped ontogenetic processes interact with the constraints and potentials of neural subsystems, connectivity, and chemistry. Are there (as Anderson assumes) fundamental components of neurocognition that are not decomposable — or how modifiable are the functions of such basic components? What biologically and culturally transmitted processes, and what social and nonsocial experiences at what stages of development, determine how neurocognitive components are combined? In humans, neural re-use involves dynamic interplay among social and nonsocial (re)uses over developmental, cultural-historical, and evolutionary timescales.

References

- Andrews, P. W., Gangestad, S. W., & Matthews, D. (2002). Adaptationism - how to carry out an exaptationist program. *Behavioral and Brain Sciences*, 25(04), 489-504.
- Chiao, J.Y., Harada, T., Komeda, H., Li, Z., Mano, Y., Saito, D.N., Parrish, T.B., Sadato, N., Iidaka, T. (2010). Dynamic cultural influences on neural representations of the self. *Journal of Cognitive Neuroscience*, 22(1), 1-11.
- Chiao, J.Y., Harada, T., Komeda, H., Li, Z., Mano, Y., Saito, D.N., Parrish, T.B., Sadato, N., Iidaka, T. (2009). Neural basis of individualistic and collectivistic views of self. *Human Brain Mapping*, 30(9), 2813-20.
- Chiao, J.Y., Harada, T., Oby, E.R., Li, Z., Parrish, T., Bridge, D.J. (2009). Neural representations of social status hierarchy in human inferior parietal cortex. *Neuropsychologia*, 47(2), 354-63.
- Cohen Kadosh, Lammertyn, Izard. (2008). Are numbers special? An overview of chronometric, neuroimaging, developmental and comparative studies of magnitude representation. *Progress in Neurobiology*, 84(2), 132-147.
- Decety, J., & Chaminade, T. (2003). Neural correlates of feeling sympathy. *Neuropsychologia*, 41(2), 127-138.
- Dehaene, S., Piazza, M., Pinel, P., Cohen, L. (2003). Three parietal circuits for number processing. *Cognitive Neuropsychology*, 20(3), 487-506.
- Eisenberger, N. I., & Lieberman, M. D. (2004). Why rejection hurts: A common neural alarm system for physical and social pain. *Trends in Cognitive Sciences*, 8(7), 294-300.
- Gallistel, C. R. (1993). *The Organization of Learning*. Cambridge: MIT Press.
- Gould, S. J., & Vrba, E. S. (1982). Exaptation- A Missing Term in the Science of Form. *Paleobiology*, 8(1), 4-15.
- Immordino-Yang, M.H., McColl, A., Damasio, H., Damasio, A. (2009). Neural correlates of admiration and compassion. *Proceedings of the National Academy of Science*, 106(19), 8021-8026.
- Lee, H., Macbeth, A.H., Pagani, J.H., & Young, W.S., III. (2009). Oxytocin: The great facilitator of life. *Progress In Neurobiology* 88:127-151.
- Lin, Z., Lin, Y., Han, S. (2008). Self-construal priming modulates visual activity underlying global/local perception. *Biological Psychology*. 77(1), 93-97.
- Panksepp, J. (2005). Why does separation distress hurt? Comment on MacDonald and Leary (2005). *Psychological Bulletin*, 131(2), 224-230.
- Parker, G., Cheah, Y.C., Roy, K. (2001). Do the Chinese somatize depression?: A cross-cultural study. *Social Psychiatry and Psychiatric Epidemiology*, 36, 287-293.