SAND2011-1617C

Cultural Neuroscience and Individual Differences: Implications for Augmented Cognition

Laura E. Matzen

Sandia National Laboratories
PO Box 5800, MS 1188,
Albuquerque, NM, USA 87185
lematze@sandia.gov

Abstract. Technologies that augment human cognition have the potential to enhance human performance in a wide variety of domains. However, there are a number of individual differences in brain activity that must be taken into account during the development, validation, and application of augmented cognition tools. A growing body of research in cultural neuroscience has shown that there are substantial differences in how people from different cultural backgrounds approach various cognitive tasks. In addition, there are many other types of individual differences and even changes in a single individual over time that have implications for augmented cognition research and development. The aim of this session is to highlight a few of those differences and to discuss how they might impact augmented cognition technologies.

Keywords: Cultural neuroscience, individual differences

1 Introduction

Augmented cognition technologies use physiological measures recorded from humans to direct human-systems interactions and improve human performance [1]. A major challenge in developing augmented cognition systems stems from the variability of physiological measures across individuals. Differences in age, fitness, cultural background, use of cognitive strategies, and numerous other factors can affect the performance of augmented cognition systems. A tool that works for one group of people may not work for another group. A technology that improves one person's performance may hinder another's performance. Even a tool designed for a single individual may become less effective as he or she changes over time. In order to develop effective augmented cognition tools, researchers and designers must take cultural and individual differences into account. Although these differences can be problematic, research on cultural and individual differences also provides information that designers could leverage to improve their systems.

2 Cultural Neuroscience

A growing body of research shows that a person's cultural background influences his or her cognitive processes in fundamental and pervasive ways. Researchers have argued that several common behavioral findings thought to be universal may not generalize to groups other than the narrow demographic from which they were collected [2]. For example, people from different cultural backgrounds are differentially sensitive to simple visual illusions such as the Müller-Lyer illusion [2,3]. Neuroimaging research faces the same problems; patterns of brain activity observed for one group of participants may be very different from the patterns observed for participants from a different culture [4].

Researchers studying cultural neuroscience have already found many differences in neural processing between groups of people from different cultures. Gutchess and colleagues describe culture as a lens through which people attend to and process their environment [5]. This lens can have a profound effect on how people perceive the world [6].

A framework for understanding cultural differences in brain activity and behavior comes from the work of Nisbett and colleagues [7,8]. They propose that values and beliefs that are central to different cultures bias the ways in which people process their environment. Western cultures value individualism, biasing Westerners to focus on central objects and categorical relationships. East Asian cultures value collectivism, biasing East Asians to use more holistic processing and to focus more on relationships than on categories [8].

A great deal of experimental evidence supports this framework. Westerners and East Asians often have different patterns of eye movement when viewing scenes [9, 10] and faces [11]. Cultural background also influences emotional processing and responses to social information [12,13]. Westerners and East Asians have different patterns of brain activity that correspond with these processing biases [12,13,14,15]. Perhaps because of these fundamental differences in perceptual processing, Westerners and East Asians also tend to categorize information differently [16,17]. This leads the two groups to use different memory strategies [18] and also makes them susceptible to different types of memory errors [5].

Cultural differences may also be reflected in the physical structure of the brain. Functional magnetic resonance imaging (fMRI) studies have found that certain brain regions related to language processing are larger for Chinese speakers than for English speakers [19,20]. Other studies have found differences in cortical thickness between Westerners and East Asians [21].

The numerous differences in neural processing between people of different cultural backgrounds could impact augmented cognition technologies in a variety of ways. For example, a visual display that is optimized for Western users may be less effective for East Asian users. If a system is designed to support memory performance, the characteristics of that system may need to be customized for different groups. A system intended to help users avoid errors might use different types of error detection for people of different cultural backgrounds. Although cultural differences might be problematic in some cases, designers can also take advantage of the growing literature on cultural neuroscience to make augmented cognition systems as effective as possible.

3 Individual Differences

There are also important individual differences between people of the same cultural group. Fitness levels can play a major role in brain activity and cognitive function, differentiating people within the same cultural and age groups. Erickson and colleagues have found that an exercise intervention can effectively reverse age-related losses in brain volume [22]. In one study, older adults with higher levels of aerobic fitness were found to have better spatial memory performance and greater hippocampus volume. In a second study, older adults were assigned to participate in aerobic or non-aerobic exercise three times per week for a year. The participants in the aerobic exercise group benefited from a 2% increase in hippocampus volume. These studies indicate that factors related to lifestyle can have a substantial impact on individuals' brain volume and cognitive function. Human cognitive performance can be augmented simply by a change in lifestyle, such as beginning a moderate exercise regimen. In addition, this research indicates that human brains retain some plasticity throughout the lifespan. Neurogenesis can occur even for older adults.

Brain plasticity can also affect an individual's neural responses over very short time frames, such as the duration of a single experiment. Weisend and colleagues have conducted experiments to measure the variability in individuals' responses to stimuli over the course of an experimental session. Using magnetoencephalography (MEG) recordings of an oddball paradigm, they have found that participants' responses to the stimuli become less variable over time. This stabilization may to be related to synaptic plasticity. As participants gain experience with the experimental paradigm, changes may occur in the timing, phase, or frequency of the neural response [23]. These results indicate that a person's expertise with a system or a set of stimuli may be an important factor in augmented cognition technologies. As an individual interacts with an augmented cognition system, that system may need to adapt to the user's changing neural response as he or she gains expertise.

Like cultural differences, differences in personality and previous experience can also influence individuals' strategy choices and their corresponding brain activity. Forsythe and colleagues have shown that differences in working memory capacity and processing speed, as assessed by standard cognitive tests, correlate with individuals' strategy choices and their willingness to change strategies [24]. These correlations have been observed for extremely simple tasks such as drawing a figure eight under time or accuracy pressure. The individual differences that correlate with performance are fundamental aspects of cognitive processing. These differences are likely to affect how people approach any type of task, from the very simple to the very complex. It may prove useful to adapt augmented cognition systems to particular users by assessing each user's abilities with a battery of individual difference measures. While ignoring such differences could hinder the usability of a system, taking them into account and leveraging them could optimize the system's ability to improve human performance.

References

1. Schmorrow, D., Stanney, K.M., Wilson, G., Young, P.: Augmented cognition in human system interaction. In: Salvendy, G. (ed.) Handbook of human factors and ergonomics, 3rd edn., John Wiley, New York (2005)
2. Henrich, J., Heine, S.J., Norenzayan, A.: The weirdest people in the world? Behavioral and Brain Sciences, 33, 61-135 (2010)
3. Segall, M.H., Campbell, D.T., Herskovits, M.J.: The influence of culture on visual perception. Bobbs-Merrill, Indianapolis (1966)
4. Chiao, J.Y., Cheon, B.K.: The weirdest brains in the world. Behavioral and Brain Sciences, 33, 88-90 (2010)
5. Gutchess, A.H., Schwartz, A.J., Boduroğlu, A. The influence of culture on memory. This volume.
6. Park, D.C., Huang, C-M. Culture wires the brain: A cognitive neuroscience perspective. Perspectives on Psychological Science, 5, 391-400 (2010)
7. Nisbett, R.E., Masuda, T. Culture and point of view. Proceedings of the National Academy of Sciences, USA, 100, 11163-11170 (2003)
8. Nisbett, R.E., Peng, K., Choi, I., Norenzayan, A. Culture and systems of thought: Holistic versus analytic cognition. Psychological Review, 108, 291-310 (2001)
9. Chua, H.F., Boland, J.E., Nisbett, R.E. Cultural variation in eye movements during scene perception. Proceedings of the National Academy of Sciences, USA, 102, 12629-12633 (2005)
10. Goh, J.O., Tan, J.C., Park, D.C. Culture modulates eye-movements to visual novelty. PLoS One, 4, e8238 (2009)
11. Blais, C., Jack, R.E., Scheepers, C., Fiset, D., Caldara, R. Culture shapes how we look at faces. PLoS One, 3, e3022 (2008)
12. Chiao, J.Y., Harada, T., Komeda, H., Li, Z., Mano, Y., Saito, D., et al.: Neural basis of individual and collectivistic views of self. Human Brain Mapping, 30, 2813-2820 (2009)
13. Chiao, J.Y., Iidaka, T., Gordon, H.L., Nogawa, J., Bar, M., Aminoff, E., et al.: Cultural specificity in amygdale response to fear faces. Journal of Cognitive Neuroscience, 20, 2167-2174 (2008)
14. Gutchess, A.H., Welsh, R.C., Boduroğlu, A, Park, D.C. Cultural differences in neural function associated with object processing. Cognitive, Affective, & Behavioral Neuroscience, 6, 102-109 (2006)
15. Goh, J.O., Park, D.C. Culture sculpts the perceptual brain. Progress in Brain Research, 178, 95-111.
16. Chiu, L.H..: A cross-cultural comparison of cognitive styles in Chinese and American children. International Journal of Psychology, 7, 235-242 (1972)
17. Ji, L.J., Zhang, Z., Nisbett, R.E.: Is it culture or is it language? Examination of language effects in cross-cultural research on categorization. Journal of Personality and Social Psychology, 87, 57-65 (2004)
18. Gutchess, A.H., Yoon, C., Lou, T., Feinberg, F., Hedden, T., Jing, Q., Nisbett, R.E., Park, D.C.: Categorical organization in free recall across culture and age. Gerontology, 52, 314-323 (2006)
19. Green, D.W., Crinion, J., Price, C.J.: Exploring cross-linguistic vocabulary effects on brain structures using voxel-based morphometry. Bilingualism: Language and Cognition, 10, 189-199 (2007)
20. Kochunov, P., Lancaster, J., Tan, L.H., Amunts, K., Zilles, K., et al.: Localized morphological brain differences between English-speaking Caucasians and Chinese-speaking Asians: New evidence of anatomical plasticity. NeuroReport, 14, 961-964 (2003)

21. Chee, M.W., Zheng, H., Goh, J.O., Park, D.C.: Brain structure in young and old East Asians and Westerners: Comparisons of structural volume and cortical thickness. Journal of Cognitive Neuroscience, 23, 1065-1079 (2010)
22. Erickson, K.: Augmenting brain and cognition by aerobic exercise. This volume.
23. Weisend, M.P.: Inter and intrasubject variability in time-frequency analyses of responses to complex audiovisual stimuli. This volume.
24. Trumbo, M., Stevens-Adams, S., Hendrickson, S. M. L., Abbott, R., Haass, M., Forsythe, C.: Individual differences and the science of human performance. This volume.