Augmented Cognition

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With the advent of new wearables, novel sensing modalities, and portable neuroimaging technologies, we're presented with new opportunities to enhance human cognition. New systems in a range of form factors can help us direct and optimise our natural function, expand the capacity or velocity of that function, and extend their capabilities. In this special issue, the three featured articles illustrate how pervasive technologies are being applied to cognition, from critical thinking to affect recognition to use of music for theraputic and wellbeing purposes.

How can sensors extend humans' ability to perceive our environments? Can computers help us to sustain and direct our attention to important stimuli? What happens in our brains when we make a memory, and can digital data storage play a role?

Visions of cognitive augmentation predate the mobile and ubiquitous technologies that make such systems feasible (e.g., J. C. R. Licklider's Man-Computer Symbiosis[1]). With the advent of new wearables, novel sensing modalities and portable neuroimaging technologies, we see incredible opportunities to extend our perception, direct and enhance attention, boost working and long-term memory capacity, and support higher order thinking (e.g., critical reflection, risk assessment, decision making). This emerging area will have a profound impact on how we learn, interact, behave, and live as social beings. Despite diversity in the cognitive processes themselves, one might subdivide intelligence augmentation into systems that direct existing capability (e.g., through use of biofeedback[2]) and those that extend it (see Figure 1). Furthermore, when we talk about extending cognition, this could be by extending the reach of innate capabilities (e.g., visual perception of nonvisible portions of the electromagnetic spectrum[3]), or by extending our capacity when innate resources are limited (e.g., cognitive offloading for human memory augmentation[4]). The articles in this special issue provide examples both of augmentation systems that direct and those that extend.

Our first article[A1] reports outputs from a Dagstuhl seminar and two workshops at academic conferences that explore the approaches to overcome cognitive biases and critical thinking in a contemporary society where the volume and veracity of information pose significant challenge. Building on the rich insights that emerged from these events, Nattapat Boonprakong, Benjamin Tag, and Tilman Dingler identify a research agenda that seeks both to better equip individuals with the skills to respond to the morass of misinformation, and to design affordances that promote critical thinking.

The face provides some of the richest information that can be conveyed to others about our emotional state, or affect. Yet affect, and specifically the valence of affect, is notoriously difficult to capture automatically in daily life settings, largely due to limitations with conventional sensor systems (e.g., obtrusive skin-attached electrodes, or on-face cameras). Our second article[A2] introduces a wearable tool designed to help solve this problem through the use of unobtrusive, on-face multimodal sensors. In this paper, James Arthur, Ifigeneia Mavridou, Simon Stankoski, M. John Broulidakis, Andrew Cleal, and Charles Nduka at Emteq Labs present the technical details of their OCO sense product alongside a preliminary evaluation of its capabilities in recognizing facial expressions.

Our final article[A3] reviews the state of the art in our understanding on the use and effects of music as a tool for therapy. Authors Nicole Lai-Tan, Marios G. Philiastides, Fahim Kawsar, and Fani Deligianni survey a range of works that explore the close interactions between the auditory and motor cortex and how these connections might be utilized for therapy. The article provides a useful summary on the influence of music and rhythm upon a range of neurological and mood disorders, and highlights some opportunities for studying the impact of music on healthy participants in their everyday lives.

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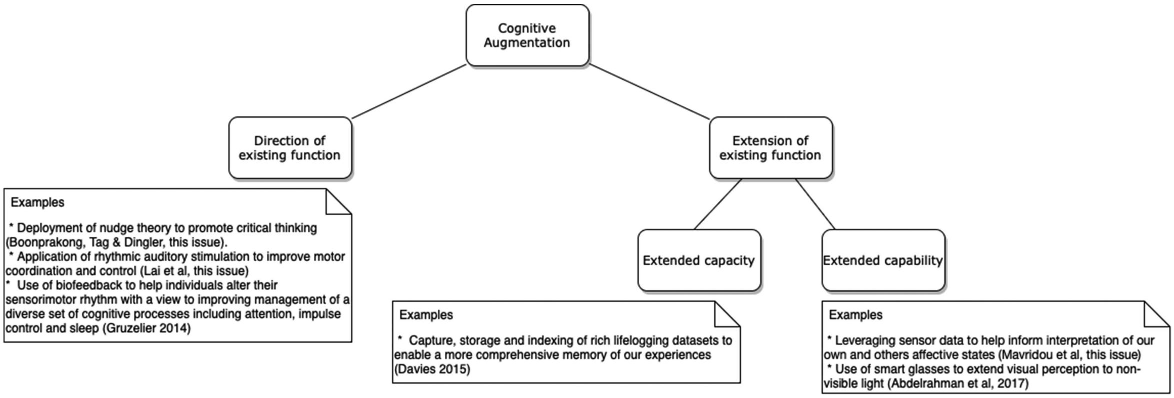

FIGURE 1. Taxonomy of cognitive augmentation systems.

Our three articles are diverse, and highlight the importance of interdisciplinary collaboration in this field. Across the articles, authors identify a need for understanding of the underlying cognitive processes (psychology), specialized hardware (mobile computing), novel user interfaces, and experiences (design, HCI), and informed policy/legislation (law). As an inherently human-centered problem space, individual, societal, political, and ethical issues will be key sculptors and drivers for the technical.

Although the vision is largely optimistic, there is also an element of wariness. Tooling and machinery has allowed many of us to become more sedentary and reduced physical prowess. Both popular culture, and research, speculate about whether intelligence augmentations have similar impacts on our innate cognitive abilities, and whether such changes are inherently problematic. Identifying and balancing these tradeoffs will be critical to future adoption.

APPENDIX: RELATED ARTICLES

A1. N. Boonprakong, B. Tag, and T. Dingler, "Designing technologies to support critical thinking in an age of misinformation," *IEEE Pervasive Comput.*, vol. 22, no. 3, pp. 8–17, Jul.-Sep. 2023.

A2. J. Archer et al., "OCOsense smart glasses for analyzing facial expressions using optomyographic sensors," *IEEE Pervasive Comput.*, vol. 22, no. 3, pp. 18–26, Jul.-Sep. 2023.

A3. N. Lai-Tan et al., "Toward personalized music-therapy: A neurocomputational modeling perspective," *IEEE Pervasive Comput.*, vol. 22, no. 3, pp. 27–37, Jul.-Sep. 2023.

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2. J. H. Gruzelier, "EEG-neurofeedback for optimising performance. I: A review of cognitive and affective outcome in healthy participants," *Neurosci. Biobehav. Rev.*, vol. 44, pp. 124–141, Jul. 2014, doi: 10.1016/j.neubiorev.2013.09.015.
3. Y. Abdelrahman, P. Knierim, P. W. Wozniak, N. Henze, and A. Schmidt, "See through the fire: Evaluating the augmentation of visual perception of firefighters using depth and thermal cameras," *Proc. Ubicomp*, Sep. 2017, pp. 693–696, doi: 10.1145/3123024.3129269.
4. N. Davies, A. Friday, S. Clinch, C. Sas, M. Langheinrich, G. Ward, and A. Schmidt, "Security and privacy implications of pervasive memory augmentation," *IEEE Pervasive Comput.*, vol. 14, no. 1, pp. 44–53, Jan. 2015, doi: 10.1109/MPRV.2015.13.

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