Cognitive Technologies: Research Agenda

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This article is a list of questions about various technologies that send information into or out of a brain, or change the way the brain processes information. By defining these questions, I hope to develop a better understanding of the large possibility space in modern brain technology.

Background Motivation

One potential way to increase human effectiveness would be to improve the functioning of the certain parts of the human brain.[1] We could examine the *input, processing,* and *output* stages of the information flow, and look for ways to *understand, improve,* and *extend* each of those stages. Eventually, we may be able to create tools that improve the parts of the brain that make good decisions, solve tough problems, invent new ideas, conduct moral reasoning, or experience empathy. If human brains became better at such mental abilities, I believe it would have positive ripple effects into many other areas of human activity.

Breadth-First Approach

This article examines many possible pathways to that target. The initial approach is take an even survey of the potential tools to add to our toolbox. Our investigation will hold off on getting attached to specific solutions, or discarding broad classes of solutions for lack of known specifics. It's organized in rough order of levels of information: perception, language, motion, physiology, cellular biology; then macro- and micro- circuit systems in the brain. Finally, there is an initial list of items to be understood in ethics and strategy.

Giving shape to a possibility space

A larger goal in this document is to provide a starting framework for researching technologies at multiple levels. I think that answers to these questions will help us start to navigate and define the possibility space in brain technology. The questions and categories in this post don't form a complete survey- they're the the ones that are fruitful for conversation, conservative enough to post on the internet, and known to me at the time of writing this.[2]

Over time, I may return to this post and continue to add more specific questions or categories. Enjoy!

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[1] My working hypothesis is that *strategic implementation* of technologies that improve brain function would make humans more effective *at the activities that matter* (and would otherwise have a net positive effect), but this is not guaranteed. The second section on "Ethics and Strategy" offers some initial reasons this might *not* be true.

[2] Disclaimer: I will acknowledge some potential reasons not to publish a blog post like this one. A detailed discussion about creating certain brain technologies could pose an information hazard (specifically, idea or attention hazards). Another potential pitfall is that it might distract myself or other people from more important activities that we could be doing otherwise (opportunity cost). Because these topics are already relatively well-known, these disclaimers don't concern me for now, but they may be revisited in the future.

Technology Development

MEDIA

Information- Software [Input + Output]	
Leveraging group intelligence	What are core design principles for software that harnesses group intelligence? ● Prediction Markets ● Large-scale citizen science i.e. Eyewire, Foldit ● Wikis/Forums
Perception [Input]	
"Immersive Media" = Virtual Reality + Gesture Tracking + Haptic Feedback	Are there good examples (prototypes, concept sketches, or from science fiction) of using Virtual Reality or Augmented Reality for the following: ● Medical operations ● Clinical psychology ● Rationality training / real world cognitive bias or puzzle solving exercises ● Formal research experiments in social psychology or perception
Technology Integration	Are there efforts to combine avatar control with natural language processing and generation, to create a platform for artificially intelligent character avatars? This could be a service/engine for building many kinds of games / applications.
Hardware timelines	What are the timelines for contact lenses, optical projection?
Natural Language Understanding and Generation [Input + Output]	
Timelines for NLP	● Given a long piece of text, ability to generate a natural-sounding summary of most important ideas of the text.

	● Given a psychographic profile, ability to generate a simple story from the perspective of the character. ● Upcoming milestones.
Motion Sensors [Output]	
Gesture Tracking	Kinect, Leap, etc.
Worn on body	Myo
Motion Actuators [Input]	
Questions about motion actuators	● After refining/solving the vision problem (Rift C1?) Haptic feedback will be the bottleneck to immersive VR. ○ Alternative/creative attempts to to glove or suit? Air compression, Sound waves, Nanomaterials? ● Have there been studies on using haptic feedback for mood regulation, neuroplastic training in healthy adults to develop extra senses, or just information “data sensualization”?

BODY - EXTERNAL

External Bio Sensors [Output]	
Types of external biosensors	● ECG (Heart Rate Variability), Respiration, Galvanic Skin Response
Questions: Usefulness of external biosensors?	● Is it the case that (1) combinations of today's external sensors (EEG, ECG...) along with Virtual Reality/ haptics can be used in radically different ways? Or is it the case that (2) their applications are confined to 'meditation / neurofeedback / focus training', and more advanced types of applications must wait for smaller BioMEMS or implantables? ● Right now, (2) seems more likely given the amount of people exploring vs. amount of actually new potential applications.
Questions: Parasympathetic Nervous System Regulation	● What studies show the benefits of moderating physiology on cognition (as can be done with current biosensors)? Can this actually help people focus better? ● What is the largest recorded increase in concentration, creativity problem solving or related metrics in healthy adults, using biofeedback?

BODY - INTERNAL

Bio-MEMS [Input + Output]	
Questions: BioMEMS ability	• Can BioMEMS also act as actuators/controllers/builders (or are they mostly sensors?)
Bioengineering [Input, Processing, Output]	
Questions: Genetic engineering	• What types of genes / how many genes are addressable with modern gene therapy? • What kinds of neural tissues have had success with stem cell therapy? • Exploratory engineering: the hippocampus continuously generates new cells (neurogenesis). Could an increase in the rate of hippocampal neurogenesis influence its higher-level performance (say, spatial learning)? An initial study shows the brain is resilient to decreased neurogenesis, but the door remains open to experiments that increase neurogenesis.
Synthetic Bio [Input + Output]	
Questions: Future developments in synthetic biology	• What tools might we inherit from nano/molecular bio? (See Autodesk's Bio/Nano/Programmable matter group). • Given a psychographic profile, ability to generate a simple story from the perspective of the character. • Upcoming milestones.

BRAIN

Chemicals [Processing]	
Questions: integration of chemicals with other technologies	● Are there studies on the combination of chemical stimulants with macro-scale stimulation ie tMS? ● What about with immersive media, virtual reality, video games, group therapy circles, CBT, or other high-level psychological interventions? ● (There are a number of chemicals that affect mood and mental state, more and less common. I do not necessarily believe they should be used, but find it useful to understand the principles behind their effects.)
The following sections are organized according to the general types of neuroengineering technologies in Ed Boyden's MIT class.	
Brain - Macro Circuit Reading [Output]	
Tools for noninvasive mapping and measurement	PET, photoacoustic, MEG, EEG, fMRI, infrared imaging, x-rays.
Brain - Macro Circuit Stimulation [Input, Processing]	
Tools for macrocircuit control	● Magnetic, electrical, ultrasonic, chemical, pharmacological/pharmacogenetic, thermal. ● Upcoming milestones.
Brain - Micro Circuit Reading [Output]	
Tools for invasive mapping and measurement	● Electrodes ● nanoprobes, nanoparticles ● optical imaging and optical microscopy ● endoscopy, ● multiphoton microscopy, electron microscopy, light scattering, ● bioluminscence,

Brain - Micro Circuit Stimulation [Input, Processing]	
Tools for microcircuit control	● DBS, infrared optical stimulation, optogenetics, ● nanoparticle-mediated control, uncaging ● signaling control.

Ethics and Strategy

- **What is an appropriate target demographic for different levels of brain technology?**
    - For discussions specific to cognitive enhancement, this book (Cognitive Enhancement, Hildt and Franke, 2013) offers an excellent, detailed discussion on the ethics of cognitive enhancement from multiple views. The introductory chapter offers an overview discussion.

- **Examine the relationship between neuroscience, intelligence amplification, and artificial intelligence safety.**
    - Likelihood of neuro research to contribute to neuromorphic AI (seems likely).
    - Likelihood of various fields in neuroscience to lead to amplification of various forms of intelligence.
        - Opportunities to bolster moral reasoning / empathy in parallel with or before other forms of intelligence. (This would become very important as the strength of the intelligence amplification (IA) technology increases).
        - Amount of overlap between research contributing to intelligence amplification and research contributing to neuromorphic AI (some research areas may be completely separate and safer to pursue).
    - Likelihood of intelligence amplification to lead to improvements in AI safety (seems unlikely by itself, better chance when combined with improved moral reasoning / rationality).
    - Are there feasible ways to make IA tools available only available to select research scientists (such as those advancing technology safety).
        - Advancing activity in all fields in science and technology equally could have a neutral or negative effect, because of the high risks from some emerging technologies.
    - Overall benefits or costs of IA neuro research.
    - See also: Luke Muehlhauser on Intelligence Amplification and Friendly AI

- **Estimating the actual value of technological development, and the replaceability of a particular project.**

- If one desires to make a large social impact, they must take into account expected value of making particular technologies, when (1) very similar things could be made by others a few years down the road, and/or (2) their functionality may eventually be replaced by more advanced technologies. (Example: creating wearables now vs. personally working on biomems now vs waiting for biomems to arrive while doing something else.)
    - Consideration: The value of the project is the value of having the information or use of the tool sooner than we would have otherwise. [3]
        - However, counterfactuals (and relative impact) are hard or impossible to compute well.
        - There may be some arguments for why this is not a well-founded concern, or even if it is well-founded, that it may not be practical to give it a lot of weight. For now, I believe this consideration *does* matter when determining what to prioritize.

[3] This view is described the first few pages of Chapter 15 in Nick Bostrom's "Superintelligence."