Research Program in Applied Neuroscience

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The Research Program in Applied Neuroscience (RPAN) aims to establish and maintain a decisive information and technology advantage for the nation and our allies in the area of neural interfaces and brain–computer communications (NI/BCC).

The need for investment in this domain is motivated by the increasing number of applications of NI/BCC in the military and consumer markets and the potential for NI/BCC to revolutionize the way that analysts interact with computer systems (Fig. 1).

The scope of our effort will include identifying short-, medium-, and long-term opportunities for NI/BCC, developing novel NI/BCC devices, and ensuring that we preserve our credibility, expertise, and leadership in the field of NI/BCC by conducting enabling research.

RPAN research and development activities will be organized into five "Thrust Areas," the first four of which will focus on different applications of NI/BCC while the fifth will provide supporting technology. The working titles of the RPAN Thrust Areas are as follows:

- Cognitive computer interfaces
- Computer-assisted cortical processing
- Performance optimization, monitoring, and assessment
- Neurosecurity
- Neurotechnology

In collaboration with a multi-disciplinary group of JHU faculty, we are currently conducting pilot studies in all of these areas.

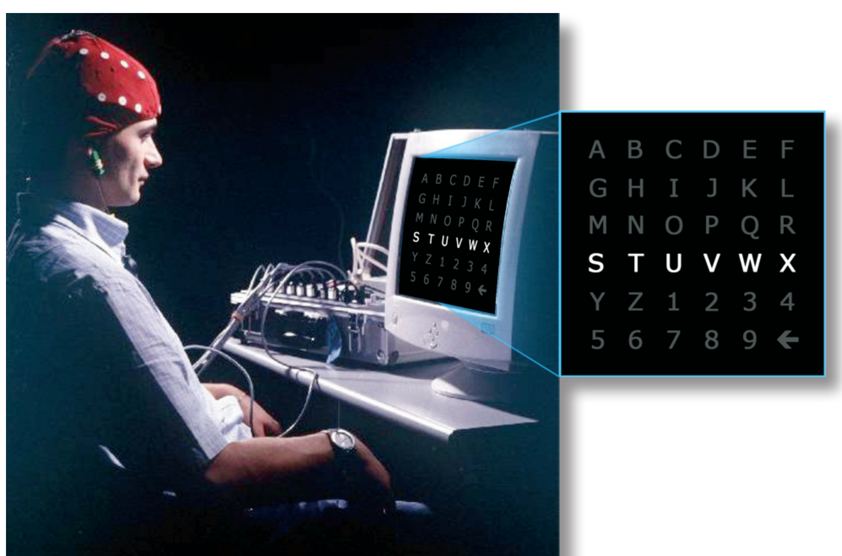

Figure 1. RPAN will facilitate groundbreaking research in the area of NI/BCC.

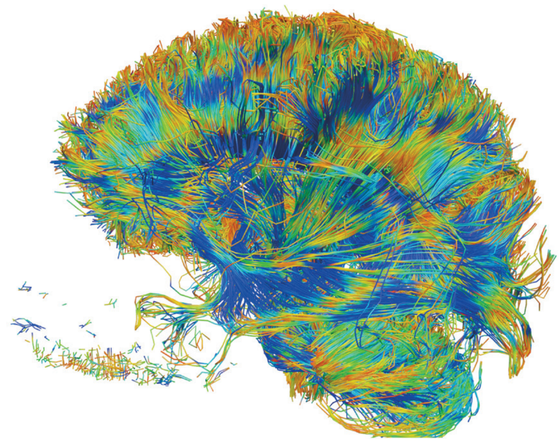

Figure 2. Characterization of the brain's network structure, as well as mathematical tools to compare structures from different brains, will be key to developing aptitude assessment tools.

Figure 3. Advances in the RPAN Thrust Areas may revolutionize the way humans interact with computer systems.

PILOT STUDY NO. 1: NEUROCOGNITIVE GRAPH THEORY

Goal: Develop aptitude assessment tools based on neurocognitive graph theory, which relates a person's "connectome" to specific cognitive functions.

Scientific Basis: If brains can be fully characterized by network structure (Fig. 2), cognitive aptitude must be encoded in brain structure; groups with similar aptitudes should have brains with similar (sub)structure. In neurocognitive graph theory, the brain is treated as a large directed and weighted graph (the connectome) with neurons as nodes and synapses as edges. This work requires experimental tools to identify the brain's network structure (e.g., diffusion tensor imaging) and mathematical tools to measure (dis)similarity between graphs.

PILOT STUDY NO. 2: EXTERNALIZING MENTAL IMAGERY

Goal: Develop a technology to facilitate externalizing mental imagery, so that, eventually, a user could visualize a particular person, place, or object and the computer would render it (Fig. 3).

Scientific Basis: Visual perceptual experience can be reconstructed from non-invasive neural interfaces such as functional magnetic resonance imaging (fMRI). We interpret the voxel patterns in the lateral occipital region of the visual cortex (LOC) as observed by fMRI by employing a model of neural activity in LOC.

Assumptions: The brain decomposes objects into constituent pieces ("shape fragments"). Some neurons within the LOC are tuned to specific features of shape fragments (orientation, curvature, location, etc.). Tuning is apparent at the level of individual voxels or groups of voxels. A particular voxel pattern observed during visual perception of an image or visual imagery will correspond to a particular combination of shape fragments present in that image.

ACCOMPLISHMENTS AND FUTURE PLANS

RPAN has encouraged many new collaborations and interactions between APL and the academic divisions of JHU. These collaborations are facilitated by the new Laboratory for Cross-disciplinary Research in Applied Neuroscience and Neural Engineering (AnnEX), operated by APL staff and located on the JHU Homewood campus. As RPAN grows in funding and scope, this cross-disciplinary laboratory will become a hub of collaborative activity between APL staff and JHU faculty and students.

In the next year, the RPAN team will present preliminary results and technology prototypes from the pilot research studies and development efforts. We also will expand the number of parallel activities across all research and development Thrust Areas as we bring in additional funding and make new connections, both inside and outside the Hopkins community, and look for additional synergistic programs and opportunities for collaboration that can advance the state of the art in applied neuroscience and neural engineering.

For further information on the work reported here, contact jacob.vogelstein@jhuapl.edu.