BRAIN 3M – A NEW APPROACH TO LEARNING ABOUT BRAIN, BEHAVIOR, AND COGNITION

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ABSTRACT

By combining emerging technologies with cognitive and education theories, we are capitalizing on recent findings from adaptive exploration and embodied learning research to address significant gaps in the education of brain sciences for school children and college level students. Through the development of virtual learning tools in combination with innovative education techniques, we are testing novel ways to train students of all ages about the function, anatomy, and evolutionary history of brains. The approach we are taking focuses on key brain regions that are typically taught in college-level introductory courses, as well as a comparative component that introduces features and specializations of other vertebrate brains. By adopting methods grounded in cognitive and learning science theories, we are studying how technology-rich platforms promote better learning and knowledge about the brain. The first phase of the project is aimed at transforming learning by allowing school students to digitally manipulate brain structures, identify real brain images, and 3D print and assemble brain models of different animals. Our aim is to determine how learning in this technology-rich context compares with traditional classroom learning. To test this, we will use behavioral studies that assess the learner's knowledge and the efficacy of knowledge integration into long-term memory. Understanding the brain is a highly interdisciplinary endeavor that bridges neuroscience, psychology, education, biological and medical sciences. We call this approach Brain3M, because it is a combination of (1) virtual brain interfaces in the form of **M**obile device apps (e.g., on smartphones and tablets) and web-based tools for learning; (2) **M**agnetic resonance images (MRI) that connect with mobile and web interfaces, and (3) 3D printing **M**odels and puzzles of vertebrate brains. The goal is to devise technological tools for learning about brains, as well as understanding the mind through investigating learner experiences with the technology. The research represents a significant step in bringing together technology, learning, and the brain.

KEYWORDS

Embodied cognition, adaptive exploratory learning, 3D printing, 3D brain models, virtual brain interface

1. INTRODUCTION

In a typical neuroanatomy class, the learner can become overwhelmed by large numbers of terms and definitions. Brain structures vary in size, shape, and location; remembering the myriad of terms along with their functional and behavioral associations can be challenging for many students. Often, exams are passed after short-term intensive work, but the obtained knowledge does not become integrated into long-term memory. Our cyberlearning and technology-based methods are designed to create learner experiences that result in long-term and highly integrated knowledge representations, making neuroscience more accessible. Ultimately, we plan to capture the outcomes of learning in cognitive representation through both behavioral and neuroimaging methods.

It is now known that self-directed, explorative learning with guidance from well-designed, flexible programs can result in successful learning outcomes. In particular, tools that provide learners with flexibility in navigating and examining the contents of a particular domain (adaptive exploration) are very effective (Chariker et al., 2011; Pani et al., 2013; Naaz et al., 2014). These tools can simultaneously present information, test comprehension, and identify learner-specific interests and difficulties. For example, when learning about brain structures, Pani and colleagues showed that computer-based interactive learning, where the learner explores animated computer graphical models of the brain, yield significant gains with better long-term retention and positive transfer to other related domains of knowledge.

Adaptive self-exploration promotes the learner's discovery and organization of the various anatomical structures and their shape, location, and configuration in the brain. Our Brain3M approach delivers a structured representation of brain parts and functions, providing a more embodied and effective learning experience as compared to current textbook-based teaching methods. In the textbook-based method, concept learning is a symbolic formalization (i.e., "amodal" representations) stripped away from the perceptual and tactile details. Our Brain3M provides an alternative "multimodal" platform for students to learn in a technology-rich context. This may provide a comparable experience to real brain dissection, albeit in a virtual environment with more learner-driven activities and exploration interactions. We argue that Brain3M enables the learner to establish "embodied representations", through the learner's integration of visual, auditory, kinesthetic, and other sensorimotor aspects of the learning target (Barsalou, 2008; Glenberg & Kaschak, 2002; Kemmerer, 2015). Thus, Brain3M allows one to integrate the obtained knowledge in interconnected conceptual representations, which is achieved through an individual's experiences of bodily sensation, perception, and action in the learning environment (in this case, the technology-rich context).

Embodied cognition theory proposes that cognition arises directly from somatosensory interactions with the real world, dependent on specific modalities (including auditory, visual, motoric, olfactory, tactile, and verbal experiences) that integrate within the system of knowledge representation. Adaptive exploration and embodied learning can significantly enhance learning outcomes, especially with regard to long-term memory representation (e.g., Pani et al., 2013) Additionally, Johnson-Glenberg et al. (2014) found that embodied learning environments, involving kinesthetic, collaborative, and multimodal /sensorimotor engagement, produce superior student learning given the same time period, teacher, and educational content. There is further evidence from cognitive neuroscience that the brain's sensorimotor regions are responsive to multimodal information as a result of embodied representation (Aziz-Zadeh & Damasio, 2008; Borghi, Glenberg, & Kaschak, 2004; Hauk et al., 2004), which is different from the abstract amodal representation housed in the anterior temporal lobe (see Figure 1; Lambon Ralph, 2014).

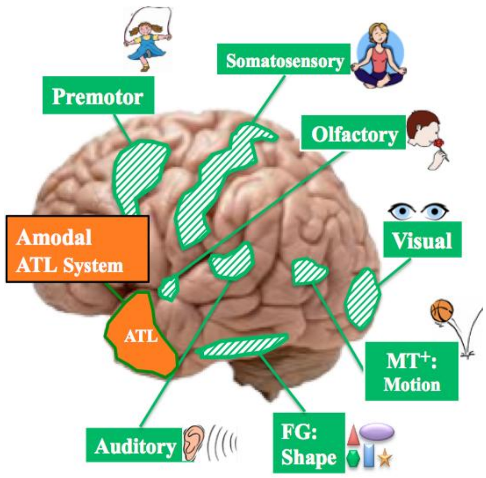

Figure 1. Multimodal, multisensory effects of embodied cognition (green) vs. amodal representation in the anterior temporal lobe (ATL; orange)

Our project, builds on embodied cognition theories, to examine how adaptive and embodied approaches aid learning about brain anatomy and function. Brain3M targets embodied cognition in multiple sensory modalities reaching auditory, visual, and kinesthetic learners. By targeting all types of learners, our model helps to provide all participants with an improved capacity for long-term memory and retention.

2. APPROACH AND METHOD

We use a comparative approach with human and fish brains, to introduce an important evolutionary component to help the learner understand how neural specializations are linked to an organism's environment, or behavioral needs. While the human brain is more familiar to most students, the simpler fish brain is less so. A comparison between them highlights evolutionarily conserved areas, as well as regions specialized for aquatic life or processing alternative kinds of sensory information. The project focuses on specific brain areas (limbic system, cortical and subcortical regions) and their structure and function. For instance, within the limbic system the hippocampus is a highly developed structure in humans, and present, but less well defined in fish. The hippocampus is important for learning and memory and supports other aspects of cognition and behavior. A Brain3M teaching module is being developed to teach middle school students about the function, anatomy, and evolutionary context of the hippocampus (see Figure 2).

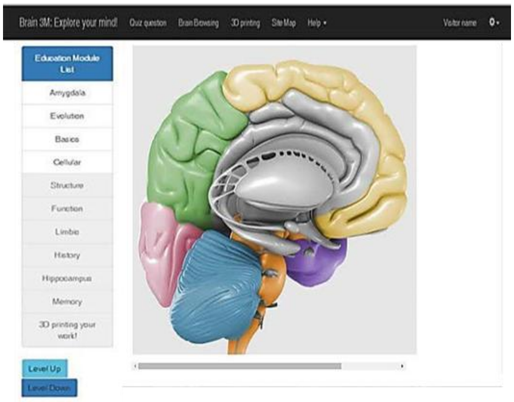

Figure 2. Brain 3M interactive model website. Regions of interest can be manipulated independently or in combination with each other. Clicking a region accesses information about its function, anatomy & connections

The module uses interactive quiz games that can run on tablets and iPads (e.g., www.neurogames.co.uk), and direct instruction, scientific demonstrations and 3D printed materials (e.g., brain puzzles). Knowledge gained through this module is compared to that of students exposed to traditional textbook methods. 20 key facts and ideas about the hippocampus are learned. Half of the material is taught with a traditional method, using Powerpoint and printed text, and half using self-directed methods with the Brain3M approach.

A 'waitlist control' within-subject design is used to conduct the traditional instruction vs. technology-based learning, and different groups experience both conditions with the order counterbalanced (see Figure 3). Midway through the teaching module, the two learner groups switch methods; learners using the traditional methods now learn 10 new facts and ideas through the technology-based method, whereas the Brain3M learners switch to traditional methods. Johnson-Glenberg et al. (2014) and Tolentino et al. (2009) have successfully used this study design. All participants receive learning evaluations at two time points: Pre-test and Post-test. We ensure that the information learned by the two groups is as equivalent as possible.

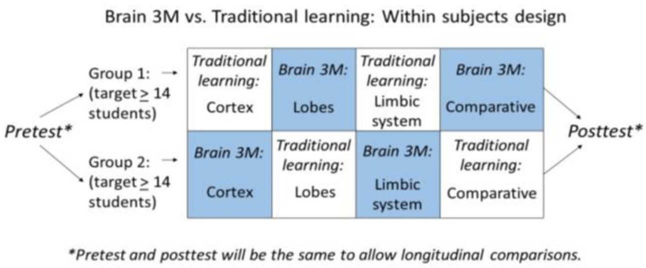

Figure 3. Study design

2.1 Assessment of Learning

Learning is assessed using semantic priming timed response quizzes, allowing us to tap into the learner's knowledge representation structure. Semantic priming is an established cognitive paradigm that tests the relatedness of concepts in mental representation (Neely, 1991). Semantic priming is the backbone of structured conceptual representation according to prominent cognitive theories (e.g., Collins & Loftus, 1975). The learner responds to a 'target' (e.g., parahippocampus) after they have seen a 'prime' word or phrase (e.g., false memory). The dependent measure that reflects the 'priming effect' (from the prime to the target) is the speed of response for identifying correct related pairs, such as "parahippocampus – false memory" compared to unrelated words such as "amygdala – false memory". The faster the response, the more automatic the connection between the prime and the target, as is the case in an integrated knowledge representation system such as our mental dictionary about related words (e.g., honeycomb automatically primes bee). The semantic priming experiment will be programmed using the software E-Prime (Schneider et al., 2002).

This research has implications for student learning, because it caters for individually tailored learning needs (e.g., those with below average spatial ability). In the future, neuroimaging experiments will help identify the neural basis of learning under technology-rich contexts vs. traditional classrooms.

3. CONCLUSION

Our research aims to (a) enable adaptive exploration and embodied learning through multimodal visual and tactile interaction with virtual and plastic models of the brain, and (b) designing behavioral and neurocognitive experiments to understand processes within the learner as they interact with technology.

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