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Editorial

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# Using fMRI to Assess the Effectiveness of New Learning and Development for Remediation

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## Editorial

Since the early 1990s, functional Magnetic Resonance Imaging (fMRI) has served as a noninvasive safe imaging technique that allows researchers to investigate which areas in the brain are active for a given cognitive event (Figure 1) [1]. In recent years, educational scientists have shown a great interest in the development of a cognitive neuroscience approach to study the learning and teaching of science using fMRI [2-5].

All learning enters the brain through the senses. It has been shown that specific areas of the brain are activated upon different types of sensory information, such as that visual cortex and fusiform gyrus are activated during the processing of visual information [6], the auditory cortex is activated during the recollection of acoustic stimuli and language [7], and regions within the pre-frontal cortex are activated during conceptual processing [8,9]. The responses of these neural markers may be used as a measure of the effectiveness of new learning. For instance, researchers can assess brain activations to compare different forms of educational input on new learning, to investigate the individual differences in learning, and to explore a best way to customize input to a learner. In particular, it has now become possible to use real-time fMRI to watch ones' own brain activation 'live'.

Accordingly, a student can directly monitor his/her own brain and potentially modulate his/her thoughts to aid efficient learning [10]. As another example, fMRI technique has been used to investigate the relation between emotion and learning. Erk et al. [1] showed that learning is most effective when a person feels good (Figure 2), and successful learning under a positive emotional context causes an unique activation pattern in the brain (positive emotion activates right parahippocampus gyrus; but negative and neutral emotions are corresponding to right amygdala and left inferior frontal cortex, respectively (Figure 1). Therefore to construct and strengthen memory patterns, classroom fear or stress should be largely reduced, otherwise, efficient learning would not take place [11]. These neuroimaging findings are particularly constructive as at school students' greatest fear is making a mistake in front of the whole class, yet learning increases with mistakes [12]. It could also be noted that the immediate corrective feedback should be provided during the learning process [13].

fMRI can provide insights into the development of new training programs, and the development of specific instructional methodologies. Yet caution must be exercised as any claim or application based on imaging findings requires attention to the research design and interpretation. Simply speaking, researchers need firstly identify or explore brain regions associated with particular cognitive functions or deficits [14,15]. Before researchers are able to link the results of brain imaging studies and pedagogy, testing the exact brain–behavioral relation is critical [16,17]. As

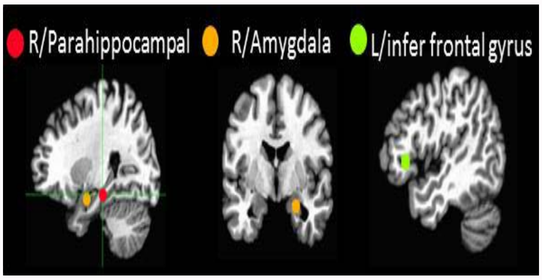


**Figure 1:** fMRI results by Erk et al. [10] illustrating the fact that the initial emotional context modulates subsequent memory effect (Figure reproduced).

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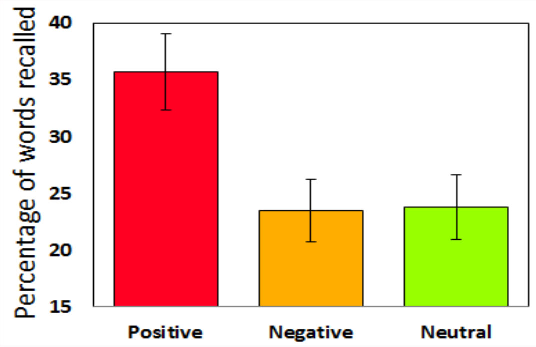


**Figure 2:** Percentage of words subsequently recalled for each emotional condition (Figure reproduced) [1].

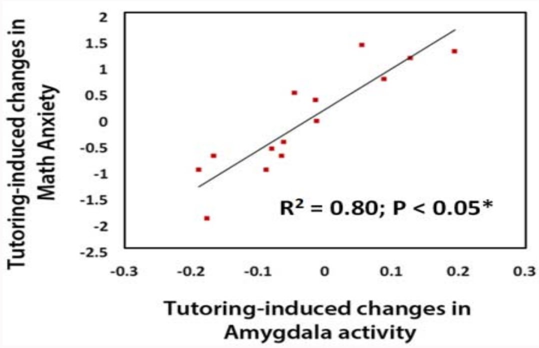


**Figure 3:** Remediation of aberrant amygdala reactivity predicts tutoring-induced reductions in math anxiety (Figure reproduced) [16].

an example, Supekar et al. [16] investigated whether an intensive cognitive tutoring program designed to improve mathematical skills reduces math anxiety in elementary school children. They found that 8 weeks of intensive one-to-one math tutoring not only reduces negative emotional response to math, but also normalizes atypical functional responses and connectivity in emotion-related circuits anchored in the amygdala. This study is particularly encouraging as it shows that greater tutoring-induced decreases in amygdala reactivity had larger reductions in math anxiety (Figure 3). During the latter stage researchers usually propel further questions, such as "why good learners can do that, whereas poor learns cannot perform?", "how and why is a training program effective?", and "could the observed effect be generalized to other tasks or problems?" Finally, the findings have to be extensively evaluated via a pedagogical approach.

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