The use of real-time fMRI can be combined with educational psychology to create a system which helps students learn efficiently.

There is an abundance of theoretical models and empirical data which present efficient methods for learning. However, currently this information can only be used by the teacher to shape the pedagogical methodology, and by the student to attempt to monitor and direct his own thoughts accordingly. No system exists which allows real-time feedback such that the student can modulate his thoughts to aid efficient learning. I propose that with the technology of real-time fMRI, a system can be devised to monitor the student’s brain activity and provide appropriate feedback, such that the student will modify his thinking and learn more efficiently. This paper will first present methods determined to enhance learning, and show the possibility of their detection using existing fMRI technology. Then, efficient methods of practicing learned material will be described. Finally, I will show how a system could be built to use these techniques in order to aid a student to efficiently learn certain material.

The basic process of learning involves observation and recording of environmental data, such that a mental representation is created which can later evoke an appropriate behavioral response. In more complex situations, learning not only causes the organism to record and replay behavior, but may also require understanding of relationships between concepts, discrimination between different types of data, and inference of new information. Learning can occur over variety of subjects and involve different types of mental processes. However, educational psychology has found that a set of common processes can be applied to aid learning in general; since these processes are fMRI observable, direct real-time feedback can be given to help the student learn more efficiently.

During the learning process, the amount of practice accorded to specific concepts is a major contributor to the accuracy of recall of these items – studies show that the more times an item is practiced, the better it is recalled [4]. MRI studies show specific areas of the brain are activated upon different types of stimulus processing, and this can be used to keep track of how long the student processes an item. For example, when visual information is processed, areas such as the visual cortex and fusiform gyrus [1] are activated; acoustic and language recollection activates auditory cortex [2]; conceptual processing activates the pre-frontal cortex at different points depending on the concept's level of abstraction [3]. Therefore the system could monitor the brain activation of the student during a specific learning task, and suggest more relevant activity if the student is found concentrating on other tasks. Another important factor in learning is the depth of processing of a stimulus. If a stimulus is accorded a large amount of attention and cognitive processing, such as when the student relates this to other concepts or previous experiences, then the stimulus will be better learned [10]. To determine the depth of processing, the system can monitor activity in the pre-frontal cortex which is thought to orchestrate processing of conscious information and also create abstract relations between concepts [5, 3], and the
the medial temporal lobe which deals with memory representations [6]. Concurrent activity in visual, auditory, olfactory and tactile centers could also signal further multimodal processing of the same information, which also improves the learning effects [10]. The amount of semantic organization of learned information is directly related to the efficiency of learning – the more attention is awarded to categorization of information, the better its recall [11], since items are more easily discriminated. This type of processing can also be detected, by monitoring the medial temporal lobe as shown in [6].

Finally, learning is enhanced through distributed practice - this requires that the learner study in short repeated sessions rather than a long continuous study period. This type of learning is preferred since it increases the variability in learning environments (and thus creates diverse access paths to the same information [10]), it allows information to be consolidated into memory [10], and most importantly it avoids loss of attention through habituation. Habituation causes the brain to process a repeated task in a shallow manner [10]; this is commonly observed after a long period of reading, as a lack of attention to detail. It can be observed through fMRI as a decrease in brain activity, specifically in areas dealing with control of cognitive mechanisms [7]; when this occurs, the system can notify the user that learning efficiency has decreased and he should take a break. These procedures can be applied while the subject is studying the theory behind a subject, or while the subject is practicing.

There are several methods of practicing learned information, which improve the learning process and can be directed by the real-time fMRI system during a following practice session. The simplest method is to review materials studied; the machine could detect this by monitoring re-activation of brain areas which fired during learning – if the system feels an important area has been missed, it could direct the student to think about what aspects of the learned material require that sort of processing. A more efficient practice is to think about the implications and applications of the studied material. This approach is similar to the depth of processing during learning, and would probably invite abstract thinking and orchestration to happen in the pre-frontal cortex. A related method is to practice old (or previously failed-to-be-solved) problems and try to find novel solutions. This helps the student because it causes learned information to be revisited and observed from new perspectives. Interestingly, a study [8] has found a fMRI observable neural correlate in the hipocampus, which corresponds to the process of finding novel and “insightful” solutions to problems. Thus, the real-time system could also greatly benefit the student during practice of studied information.

It is important to keep in mind that although current fMRI data can detect types of processing in specific brain areas, it cannot yet discern high resolution details, such as determining that a person is accessing a specific conceptual item. Because of this, the system cannot infer the specific problem which the subject is engaging in, unless a-priori information is provided. Problems on different topics will require different mental activation – for example, mathematics, physics, and other concrete scientific problems will require the subject to focus on calculations (areas described by [9]), handling of concrete rather than abstract thoughts (pre-frontal cortex), and possibly information visualization (visual cortex); humanities problems will involve more abstract thinking and emotions (amygdala and
lymbic system); while music/theater tasks may involve visuo-spatial and auditory processing. Thus the system will need to account for the task at hand. In light of these facts, the hypothetical system could currently operate in the following manner. A set of tasks would need to be predefined, along with correlations to general brain activity experienced by subjects while learning these tasks. A student interested in the subject matter would come for a ‘power learning’ session, during which the system monitors the student’s learning activity and employs the above techniques for optimizing the learning. This causes the student to understand the subject matter better than if he had no feedback while learning, and possibly also teaches the student how to control his thinking, in order to learn better independently the future.

In summary, techniques of educational psychology for improved learning, such as repetitive practice, deep processing and organization of information, can be employed by a real-time fMRI system in order to improve a student’s learning experience on a variety of topics.

References:
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