Is Homework Good for You?

When looking at a pile of homework, do you ever wonder, why bother?

Even if you enjoy the challenge of learning new things, have you ever thought about what might be going on in your brain when you read, work on math problems, or study other subjects?

Source: http://www.libcoop.net/warren/

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In this lesson, you will have the opportunity to examine the results of some experiments and decide for yourself what might be happening in your brain as you learn.

Before you look at the experiments, you need to understand the relationship between learning and memory.

Recent studies in neuroscience provide some insight into what might be going on in your brain as you learn new information.

Sources: http://www.med.harvard.edu/publications/On_The_Brain/Volume4/Number2/SP95In.html; http://www.vision.caltech.edu/feifeili/101_ObjectCategories/brain/
Learning is how we acquire new information. Memory is the process that results in storage of learned information. Learning and memory are fundamentally related:

Many researchers believe that short-term memory lasts for less than 30 seconds, just long enough to perform a simple task, like dialing a phone number you just looked up in the phone book.
How good is your short-term memory?

Try these two on-line tests...

- http://faculty.washington.edu/chudler/puzmatch.html
- http://faculty.washington.edu/chudler/stm0.html
Here's another test of your short-term memory.

Read the following sequence silently, pausing at each dash:

MT-VVC-RC-IAU-SAB-MW

Look away from the computer and write down any letters from this sequence that you can remember.
Now, read the following sequence silently, again pausing at each dash:

MTV-VCR-CIA-USA-BMW

Look away from the computer and write down any letters from this sequence that you can remember.
Take another look at the two sequences:

MT-VVC-RC-IAU-SAB-MW

MTV-VCR-CIA-USA-BMW

Notice anything?

The letters are the same in each sequence.

Yet, you most likely found it a lot easier to remember the second sequence. Why?
Most people can hold about 7 meaningful pieces of information in their short-term memory. Meaningful pieces of information could be numbers, words, faces, objects, or any other “chunks” of information.

While short-term memory is important, it is long-term memory that really matters when it comes to learning.

How does short-term memory become long-term memory?

Practice (also called rehearsal) of information is required to convert short-term memory into long-term memory. Without practice, short-term memory is forgotten.
Practice? That sounds an awful lot like studying.

What kind of practice? How much practice is necessary to develop long-term memory? It depends on what you want to learn.

London taxi drivers study for about two years to learn how to navigate between thousands of places—a unique education generally called “The Knowledge.”

The drivers must then pass difficult tests to obtain a license to operate a taxi.

Given the intense mental workout required to learn The Knowledge, taxi drivers seemed like the perfect subjects for scientists at University College London who wanted to study what, if any, changes occur in the brain as people learn.

What happens in the brain when taxi drivers recall routes around London?

In one study, 11 licensed male London taxi drivers performed different mental tasks while their brain activity was recorded using positron emission tomography (PET) scans and functional magnetic resonance imaging (fMRI).

The researchers' hypothesized that different brain regions in the taxi drivers would be activated during performance of these varied mental tasks.
Thinking about *experimental design*

The researchers studied only male taxi drivers who were right-handed, had worked as drivers for at least 3 years, and had no history of psychiatric or neurological illness. *Why?*

Well, for example, men and women’s brains generally show differences in size and certain features. Brain imaging studies demonstrate that men and women process some information differently. The PET scans at right show high activity (in red) in different brain regions while men and women watched an emotional film.

*How to interpret brain scan images*

Do you think other variables like handedness and mental illness could have affected the results of this experiment? *Why or why not?*
How to interpret brain scan images

PET and MRI can be used to create brain images in three different planes:

Axial (horizontal)  Coronal  Saggital

Repetitive measurements are taken and analyzed by computer to create images like the MRI shown below (left). Colors can be superimposed onto the images to clearly indicate regions of higher brain activity. Typically, multiple images at slightly different locations are analyzed (center). These images can be used to create a 3-dimensional model of the brain (right).

Source: http://www-psych.stanford.edu/~kalina/BB/Lecture02/index.html
Source: http://www.fmrib.ox.ac.uk/fmri_intro/brief.html
Positron Emission Tomography (PET) is a common way to visualize brain activity while the patient is conscious and alert.

PET creates images of the brain using positrons, tiny particles emitted from a radioactive substance administered to the patient. Commonly, this radioactive substance is attached to glucose. Where glucose is metabolized to produce energy, more radioactive particles will be emitted. Thus, areas of the brain that are more active during certain mental tasks can be identified.

http://www.radiologyinfo.org/content/petomography.htm
**Functional Magnetic Resonance Imaging (fMRI)**

is a common way to visualize brain activity while the patient is conscious and alert.

fMRI creates images of the brain using radio waves and a strong magnetic field. fMRI can be used to identify regions of rapid metabolism. Images produced by fMRI locate where blood vessels are expanding, extra oxygen is being used, or chemical changes are occurring. As with PET, areas of the brain that are more active during certain mental tasks can be identified using fMRI.

[http://www.radiologyinfo.org/content/functional_mr.htm](http://www.radiologyinfo.org/content/functional_mr.htm)
The brain is organized into different regions based on shape and function. Past studies of people with brain injuries and laboratory animals suggest that certain regions of the brain are required for different types of memory. Damage to these regions results in memory loss.

The figure below identifies several regions of the brain associated with memory.

Source: http://www.colorado.edu/epob/epob3730rlynch/image/figure17-7.jpg
The taxi driver experiment

Researchers used the PET scans and fMRI to observe activity in taxi drivers’ brains as they

• Repeated two four-digit numbers

• Described the shortest legal route between two locations in London

• Described the appearance of individual world-famous landmarks

• Described the plots of famous films between certain points in the film

• Described individual frames from famous films

Why do you think the researchers chose to compare these five different tasks?
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Thinking about experimental design

The researchers were interested in finding out what regions of the brain were active while taxi drivers recalled the shortest legal distance between two London locations. The researchers did not want to know what regions of the brain were involved in speaking. However, the drivers had to talk during the PET scan so that researchers knew the routes that drivers remembered.

Recording brain activity while drivers repeated two four-digit sequences allowed researchers to establish what regions of the brain were involved in speaking (shown at left.) Activity observed in these regions was used as a baseline (or control) to determine change in activity as drivers remembered routes, landmarks, film sequences, and film scenes.

http://www.siu.edu/departments/cola/ling01/fronttext.html
An example of the shortest legal route described by a taxi driver during a PET scan (drawn on London map)

"Grosvenor square, I’d leave that by Upper Grosvenor Street and turn left into Park Lane. I would eh enter Hyde Park Corner, a one-way system and turn second left into Constitution Hill. I’d enter Queen Victoria Memorial one-way system and eh leave by the Mall. Turn right Birdcage Walk, sorry right Horse Guards Parade, left Birdcage Walk, left forward Great George Street, forward into Parliament Square, forward Bridge Street. I would then go left into the eh the Victoria Embankment, forward the Victoria Embankment under the Blackfriars underpass and turn immediate left into Puddledock, right into Queen Victoria Street, left into Friday Street, right into Queen Victoria Street eh and drop the passenger at the Bank where I would then leave the Bank by Lombard Street, forward King William Street eh and forward London Bridge. I would cross the River Thames and London Bridge and go forward into Borough High Street. I would go down Borough High Street into Newington Causeway and then I would reach the Elephant and Castle where I would go around the one-way system... . "
(Maguire et al., 1997, http://www.jneurosci.org/cgi/content/full/17/18/7103)
In recalling routes, it was believed that taxi drivers would remember landmarks and the spatial relationship between landmarks (sequence). The researchers designed an experiment primarily to **test two things:**

- Are the same regions of the brain activated when drivers remember **landmarks in sequence** (routes) compared to **landmarks in no sequence**?

- Are the same regions of the brain activated when drivers remember **landmarks in sequence** (routes) compared to **story elements in sequence** (film plots)?
Results

The graph (below right) shows levels of blood flow in the region highlighted by the black arrow in the fMRI image (above right).

**How to interpret brain scan images**

Which mental task resulted in the most blood flow in that region?

How does blood flow relate to brain activity?

How to interpret brain scan images

PET and MRI can be used to create brain images in three different planes:

- Axial (horizontal)
- Coronal
- Saggital

Repeated measurements are taken and analyzed by computer to create images like the MRI shown below (left). Colors can be superimposed onto the images to clearly indicate regions of higher brain activity. Typically, multiple images at slightly different locations are analyzed (center). These images can be used to create a 3-dimensional model of the brain (right).

Source: http://www-psych.stanford.edu/~kalina/BB/Lecture02/index.html

Source: http://www.fmrib.ox.ac.uk/fmri_intro/brief.html
Results

One area of the brain showed a high level of activity ONLY when drivers recalled routes.

The PET scan at left shows the increased level of activity in this region, a part of the hippocampus.

These results suggested that the hippocampus is critical for recalling routes and perhaps other spatial sequences.

Where is the hippocampus located in the brain?

Source: Maguire et al. 1997, http://www.jneurosci.org/cgi/content/full/17/18/7103
PET and fMRI show changes in brain activity and structure: Examples

Activity during mental arithmetic (images at right)

Increased activity while dancers watched other dancers (images at left)

Locations of structural differences between musicians and non-musicians (images above)

Source: http://www.hfi.unimelb.edu.au/content/research/projects/hm_mentala.html
Source: http://www.pbs.org/wgbh/nova/sciencenow/3204/01-audiocap.html
Source: http://www.jneurosci.org/cgi/content/full/23/27/9240
Do taxi drivers’ brains change as they learn?

In a follow-up study, the brains of 16 licensed male London taxi drivers were analyzed using structural magnetic resonance imagining (MRI). While technically similar to fMRI, this type of MRI visualizes brain structures but does not identify regions of brain activity.

Images of the brains of taxi drivers were compared to images of the brains of 50 healthy males who were not taxi drivers.

The researchers hypothesized that, due to the mental challenge of The Knowledge, the brains of taxi drivers would be different in structure in comparison to the brains of the control group.

Thinking about experimental design

The researchers studied only male taxi drivers who were right-handed, had worked as drivers for at least 3 years, and had no history of psychiatric or neurological illness. Why?

Well, for example, men and women’s brains generally show differences in size and certain features. Brain imaging studies demonstrate that men and women process some information differently. The PET scans at left show high activity (in red) in different brain regions while men and women watched an emotional film.

Do you think other variables like handedness and mental illness could have affected the results of this experiment? Why or why not?

Functional Magnetic Resonance Imaging (fMRI) is a common way to visualize brain activity while the patient is conscious and alert.

fMRI creates images of the brain using radio waves and a strong magnetic field. fMRI can be used to identify regions of rapid metabolism. Images produced by fMRI locate where blood vessels are expanding, extra oxygen is being used, or chemical changes are occurring. As with PET, areas of the brain that are more active during certain mental tasks can be identified using fMRI.

http://www.radiologyinfo.org/content/functional_mr.htm
Thinking about experimental design

Based on earlier studies, including the results you have already analyzed, researchers expected that they would see changes in the size of the hippocampus.

To avoid missing unexpected changes in other regions besides the hippocampus, the researchers used an automated computerized procedure to check for structural differences in all brain regions.

Explore evidence from other species that spatial memory involves the hippocampus.

Studies of other animals suggest the hippocampus plays a role in spatial memory

For example, many seed storing birds have been found to have large hippocampuses. In black-capped chickadees, this brain region expands during fall and winter as the birds store and later recover seeds from food caches.

Female brown headed cowbirds lay their eggs in other birds’ nests. Females of this species identify 10-20 possible locations to lay eggs the following day. Unlike male cowbirds and females of related species that do not lay eggs in other birds’ nests, female cowbirds show enlargement of the hippocampus.

Results

Sagittal cross-sections (right) highlight in yellow those areas in the left hippocampus (LH) and right hippocampus (RH) that were larger in taxi drivers compared to the brains of men who did not drive taxis.

A coronal cross-section (right) highlights in yellow those areas in the hippocampus that were larger in taxi drivers when compared to men who did not drive taxis.

What can we conclude about the brains of the taxi-drivers based on these images?

Sources: Maguire et al., 2000
http://www.pnas.org/cgi/content/full/97/8/4398;
http://www-psych.stanford.edu/~kalina/BB/Lecture02/index.html
Results

Examine the graph below. VBM is a measure of density in the brain. Higher values of VBM mean the brain contains more nerve tissue in a particular region.

What changes appear to be related to the amount of time each man has been a licensed taxi driver?

What can we learn from London taxi drivers?

Besides helping us find our way around London, these taxi drivers teach us some important things about the human brain.

The researchers concluded that the connections between neurons in the hippocampus had been rearranged so that drivers could store a “mental map” of London in the posterior hippocampus.

Sources:
Maguire et al. 1997, http://www.jneurosci.org/cgi/content/full/17/18/7103
Results of taxi driver studies show that the adult brain can change due to mental activity

The results you have analyzed suggest that the brain grows in response to experience. In this case, taxi drivers showed structural changes in the part of their brain where they stored their “mental map” of London. Other regions of the brain remained unchanged.

Other studies show that different regions of the brain are active during different activities.

See some results of other studies of brain activity and structure

How might these activities affect growth in the brain?
Is homework good for you?

When you do homework, you are giving your brain a workout. This workout gives your brain the opportunity to practice, or convert short-term memory into long-term memory. Does this practice change your brain?

What do you think?