ICE - Positive and Negative "Area"

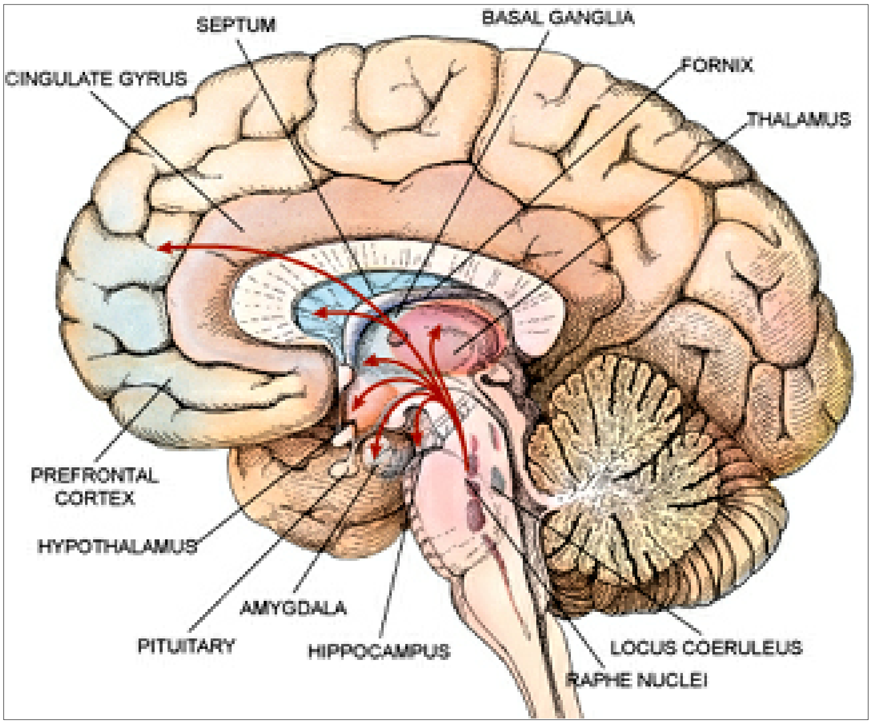

Figure 1: Anatomy of the human brain. (Note the hippocampus near the base of the brain.)

In Math Xa, you may have completed a learning activity on the neurological development of London taxi cab drivers[1]. Some neurobiologists have suggested that the area of the brain known as the hippocampus may be important to spatial tasks such as navigating and remembering where hidden objects are located[2]. In humans, the hippocampus is located near the base of the brain (see Figure 1[3]).

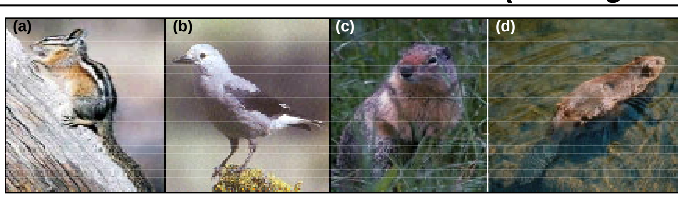

Figure 2: Examples of animals that exhibit food-caching behavior. (a) Townsend's Chipmunk (*Tamias townsendii*). (b) Clark's nutcracker (*Nucifraga columbiana*). (c) Columbian ground squirrel (*Spermophilus columbiansus*). (d) Common beaver (*Castor canadensis*).

In recent years, biologists have undertaken several studies to try to clarify the role of the hippocampus in animals that appear to depend on navigational skills and

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[1] See the appendix at the end of this ICE for a description of that learning activity.

[2] For example, see: J. O'Keefe and L. Nadel. *The Hippocampus as a Cognitive Map*. Oxford, England: The Clarendon Press, 1978. or more recently: L. Nadel. "The psychobiology of spatial behavior: The hippocampal formation and spatial mapping." in E. Alleva, H.-P. Lipp, L. Nadel, A. Fasolo and L. Ricceri (eds.) *Behavioral Brain Research in Naturalistic and Semi-naturalistic Settings: Possibilities and Perspectives.* Dordrecht, The Netherlands: Kluwer Academic Press, 1995. or even more recently: R. Hampton, D. Sherry, S. Sheetleworth, M. Khurgel and G. Ivy. (1995) "Hippocampal volume and food-storing behavior are related in *Parids*." *Brain, Behavior and Evolution*, **45**: 54-61.

[3] Image source: Scientific American.

spatial memory. Figure 2[4] shows a number of animals that create hidden food "hordes" or "caches" in times when food is plentiful, and retrieve the stored food (sometimes months later) when food is scarce. Neurological theorists have speculated that animals who show this "food storing" behavior may also exhibit seasonal fluctuations in either the size or level of activity in the hippocampus to reflect the greater use that the animals might make of spatial memory when establishing food caches or when locating food caches in hard times.

Figure 3: The black-capped chickadee (*Poecile atricapillus*).

In this ICE, you will use data collected by researchers on the black-capped chickadee[5] (Poecile atricapillus). The black-capped chickadee is a small bird (see Figure 3[6]) that establishes caches of seeds during the spring and later retrieves food from these caches during the winter. In particular, you will review experimental data to determine whether or not the speculations of the theoretical neurobiologists correspond to the reality of animal neurobiology or not.

Table 1 and Figure 4 give information[7] regarding the rate at which the number of cells in a chickadee's hippocampus changed throughout the year. (January is month 1 and December is month 12.)

Month	0	2	4	6	8	10
Rate of change of number of neurons in hippocampus (hundreds of thousands of neurons per month)	–14.74	–7.61	–2.56	0.42	1.32	0.148

Table 1: Rate of change of number of neurons in chickadee hippocampus.

[4] Image sources: (a) http://www.washington.edu/burkemuseum/ (b) http://www.scsc.k12.ar.us/ (c) http://www.washington.edu/burkemuseum/ (d) http://www.pnl.gov/ecology/

[5] Source: T.V. Smulders, M.W. Shiflett, A.J. Sperling and T.J. DeVoogd. (2000) "Seasonal changes in neuron numbers in the hippocampal formation of a food-hoarding bird: The black-capped chickadee." *Journal of Neurobiology*, **44**(4): 414-422.

[6] Image source: http://www.cevl.msu.edu/

[7] Source: T.V. Smulders, M.W. Shiflett, A.J. Sperling and T.J. DeVoogd. (2000) "Seasonal changes in neuron numbers in the hippocampal formation of a food-hoarding bird: The black-capped chickadee." *Journal of Neurobiology*, **44**(4): 414-422.

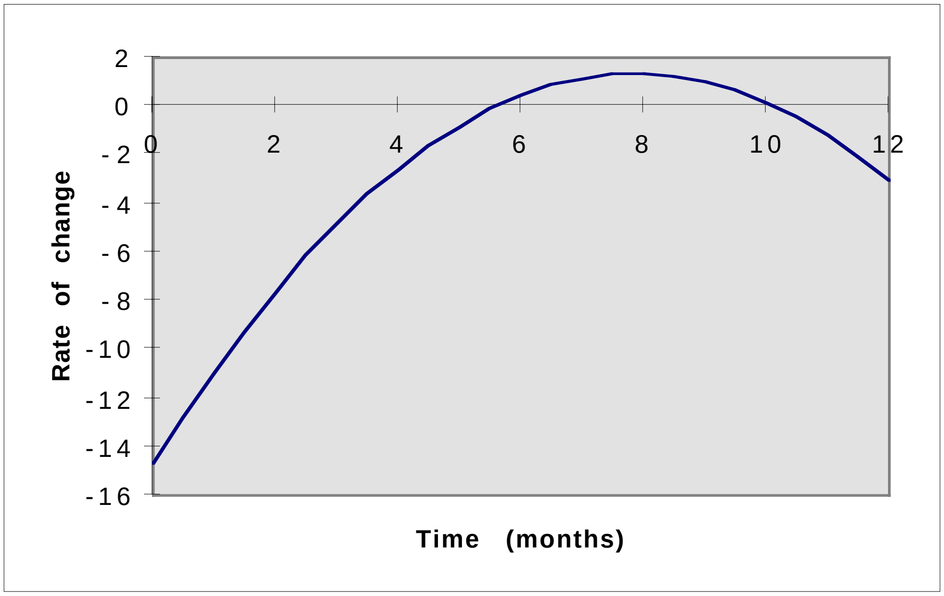
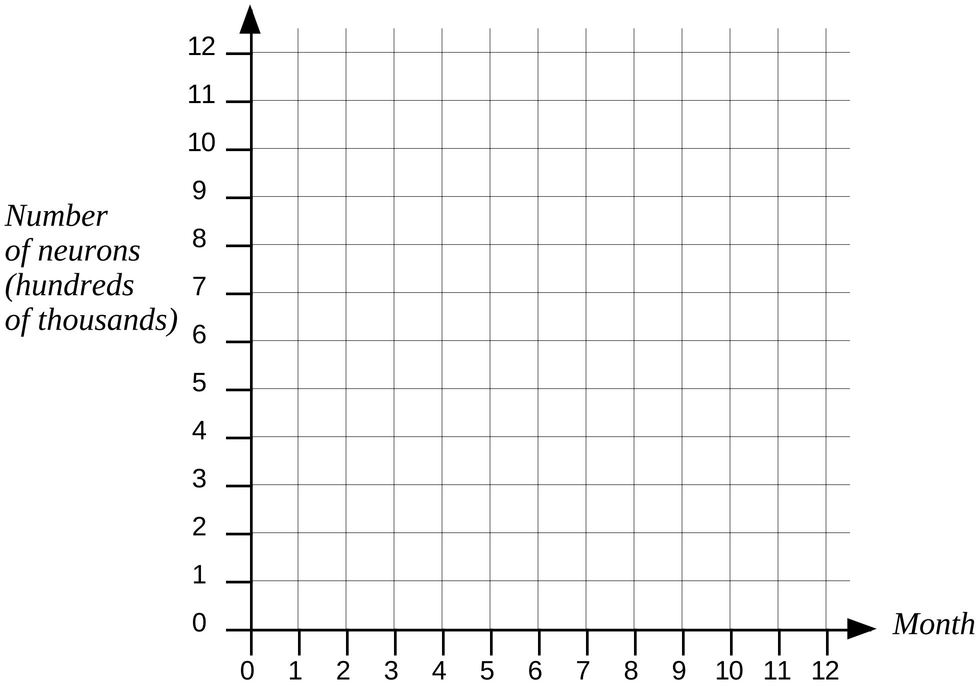


Figure 4: Rate of change of number of neurons in chickadee hippocampus.

- ***Based on Figure 4, what kind of function would do a reasonable job of representing the rate of change of hippocampal neurons? Use your calculator and the information in Table 1 to find an equation for this rate of change.***

- ***Over which periods of time would you expect the original function to be increasing? Over which periods of time would you expect the original function to decrease?***

• ***In April (i.e. month 4) the researchers measured the number of neurons in the chickadee's hippocampus. They determined that there were about 920,000 neurons in the hippocampus at that time. Use this information together with the data in Table 1 and Figure 4 to sketch a plausible graph of the number of neurons in the chickadee's hippocampus as a function of time.***



In the next part of the ICE, you will use your graphing calculator to determine the area beneath the rate of change curve (Figure 4) over different time intervals. Figure 5 (below) shows the steps involved in using a TI-83 to approximate the area under the graph of:

$$g(x) = 1 + 0.1 \cdot x^2$$

between $x = 3$ ***and*** $x = 5$ ***using 8 rectangles.***

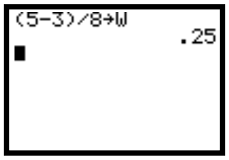


Figure 5(a): Store the width of the rectangles in W.

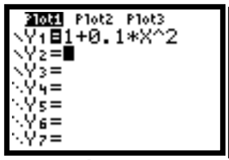


Figure 5(b): Enter the equation of the function into Y1.

Figure 5(c): After returning to the main screen, use the LIST menu to obtain the sum(command.

Figure 5(d): The main screen of your calculator should now look something like this.

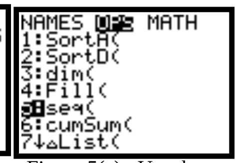


Figure 5(e): Use the list menu to obtain the seq(command.

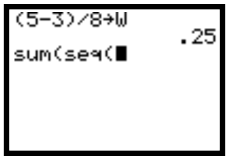


Figure 5(f): The main screen of your calculator should now look something like this.

Figure 5(g): Press the VARS button and select the Y-VARS menu. Press ENTER to select the “Function” option.

Figure 5(h): Press ENTER to choose Y1.

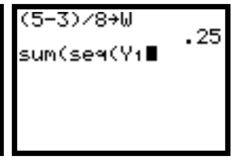


Figure 5(i): The main screen of your calculator should now look something like this.

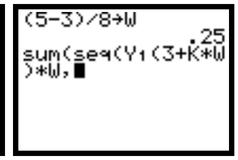


Figure 5(j): Enter the appropriate symbols into your calculator so that the calculator will sum:

$f(3+k*\Delta x)*\Delta x$

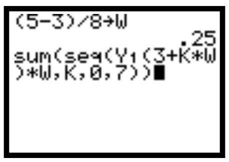


Figure 5(k): Enter the appropriate limits of summation (here they are 0 and 19) for the number of rectangles added.

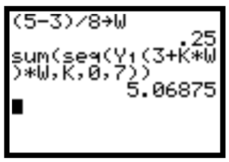


Figure 5(l): Press ENTER and the calculator will work out the total area of all of the rectangles.

- ***Adapt the instructions shown in Figure 5 and use the function that you found for hippocampal rate of change to complete the table shown below. In each case, use 100 rectangles to approximate the area under the curve.***

Time interval	Width of rectangles	Area Under Curve (using 100 rectangles)
T=5 to T=10		
T=0 to T=5		
T=0 to T=10		

At the beginning of the lesson, we made an argument to suggest that:

The area under the curve $y = f'(x)$ between $x = a$ and $x = b$ is equal to the change in the original function, $y = f(x)$, between $x = a$ and $x = b$. That is, $f(b) - f(a)$.

- ***How can you use this understanding of the area under a derivative graph to explain why the area between*** $T = 0$ ***and*** $T = 5$ ***is negative?***

Appendix: Hippocampal Development of London Taxi Cab Drivers

Without proper brain exercise, London cabbies would be lost

Wednesday March 15, 2000

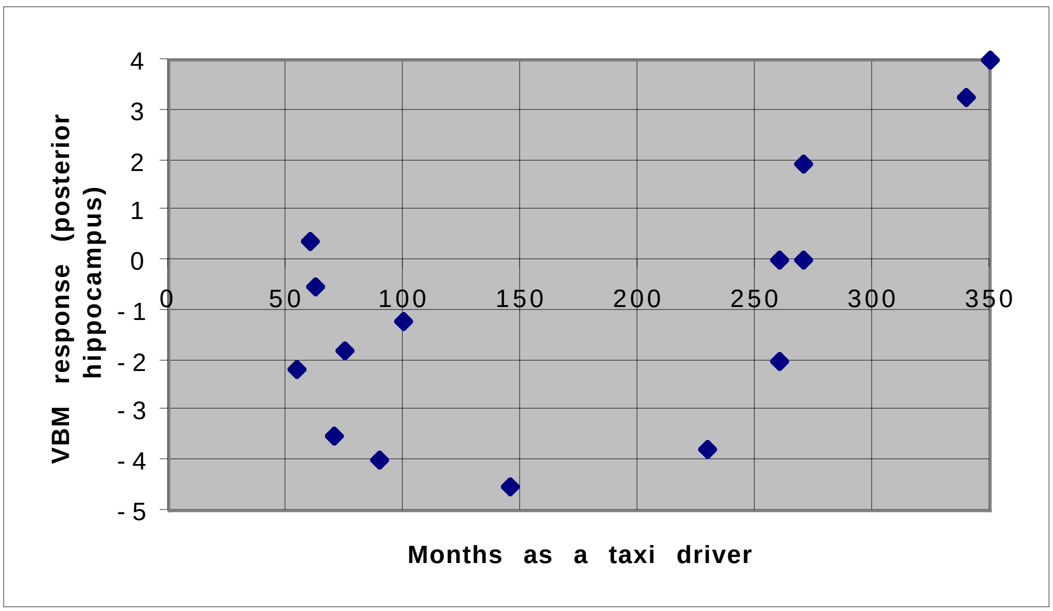
by EMMA ROSS
THE ASSOCIATED PRESS

LONDON -- Anyone who's ever taken a taxi in London must have wondered how the city's cabbies know how to reach even the most obscure destination without a street map or even a hint from their passengers.

A new study indicates cabbies are working their brains so hard they become enlarged in the zone associated with navigation -- the rear hippocampus.

Evidence that the brain is physically able to change according to the way it is used could have important implications for people with brain damage or brain diseases such as Alzheimer's, experts say.

In the study published in 2000, researchers[8] made MRI[9] scans of 16 London taxi drivers with between 1.5 and 42 years of taxi driving experience and scans of an equivalent control group who were not taxi drivers. The size of the hippocampus was measured from the MRIs. Some of the data is given in the graph shown below.



VBM response versus number of months as a taxi driver (after Maguire et al., 2000).

In the abstract of their study, the researchers concluded:

> "... data are in accordance with the idea that the posterior hippocampus stores a spatial representation of the environment and can expand regionally to accommodate elaboration of this representation in people with a high dependence on navigational skills." (p. 4398)

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[8] E.A. Maguire, D.G. Gadian, I.S. Johnsrude, C.D. Good, J. Ashburner, R.S.J. Frackowiak and C.D. Frith. (2000) "Navigation-related structural changes in the hippocampi of taxi drivers." *Proceedings of the National Academy of Science*, **97**(8): 4398-4403.

[9] Magnetic Resonance Imaging. The specific technique that the researchers used is called Voxel-Based Morphometry (VBM).