



## ICE - Linear Functions

### Without proper brain exercise, London cabbies would be lost

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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.



Figure 1: Classic black London taxi cab.

***If you have ever visited London (or even watched a movie set in London) you will be familiar with the black taxi cabs (see Figure 1<sup>1</sup>). According to reports in the popular press<sup>2</sup> and the scientific literature<sup>3</sup>, the posterior hippocampi (see Figure 2<sup>4</sup>) of experienced taxi drivers are significantly larger than the posterior hippocampi of the population at large.***

<sup>1</sup> Image source: <http://www.taxiknowledge.co.uk/>

<sup>2</sup> "Without proper brain exercise, London cabbies would be lost." by Emma Ross, Associated Press, March 15, 2000.

<sup>3</sup> Maguire, E.A., Gadian, D.G., Johnsrude, I.S., Good, C.D., Ashburner, J. Frackowiak, R.S.J. and Frith, C.D. (2000) "Navigation-related structural changes in the hippocampi of taxi drivers." *Proceedings of the National Academy of Science*, **97**(8): 4398-4403.

<sup>4</sup> Image source: Scientific American.

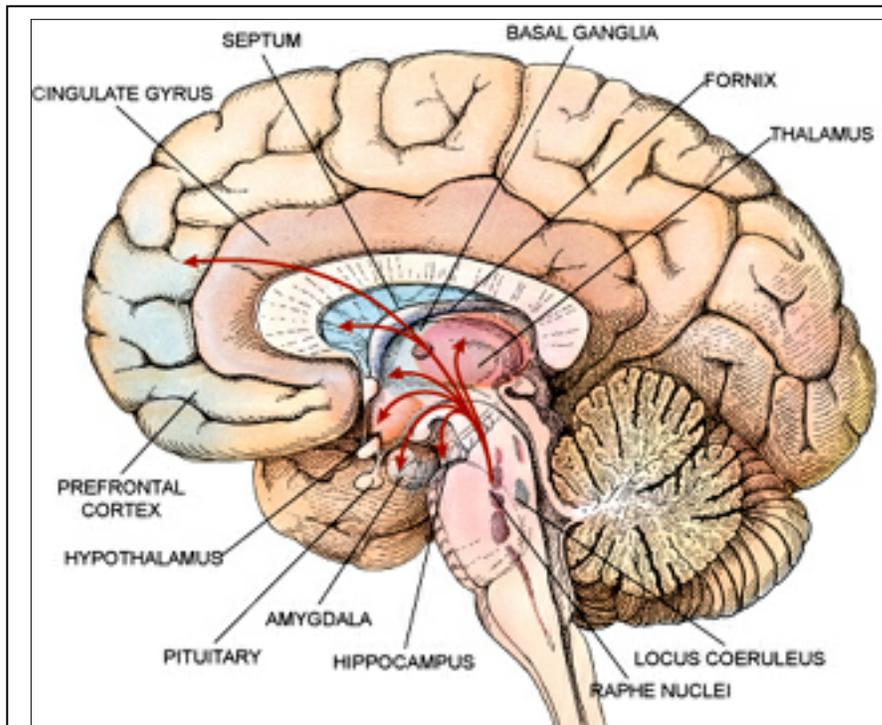


Figure 2: Anatomy of the human brain. (Note the hippocampus near the base of the brain.)

**Increased hippocampal size (relative to brain and body size) has been related to spatial memory behaviors in animals (such as squirrels and some kinds of birds) that store and later retrieve food<sup>5</sup>. Studies of brain damaged humans<sup>6</sup> has also suggested that the hippocampus**

**is involved in tasks involving spatial memory and navigation.**

**In the study of Maguire et al. (2000), the researchers made MRI scans of 16 London taxi drivers with between 1.5 and 42 years of taxi driving experience (see Figure 3<sup>8</sup>) and scans of an equivalent control group who were not taxi drivers. The size of the hippocampus was measured from the MRI. (The specific analytical technique used was "voxel based morphometry" or VBM<sup>9</sup>)**

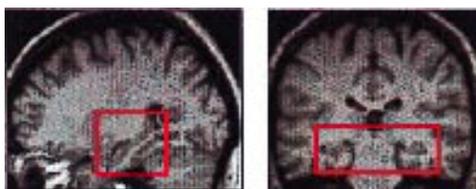


Figure 3(a): MRI images of a taxi driver's brain.



Figure 3(b): Close-up of hippocampus in MRI image of a taxi driver's brain.

<sup>5</sup> Hampton, R., Sherry, D. Shettleworth, S. Khurgel, M. and Ivy, G. (1995) "Hippocampal volume and food-storing behavior are related in *Parids*." *Brain, Behavior and Evolution*, **45**: 54-61.

<sup>6</sup> Maguire, E.A., Burgess, N. and O'Keefe, J. (1999) *Current Opinions in Neurobiology*, **9**: 171-177.

<sup>7</sup> Magnetic Resonance Imaging.

<sup>8</sup> Image source: Maguire et al., 2000.

<sup>9</sup> For a description of the VBM technique see: I.C. Wright, P.K. McGuire, J.-B. Poline, J.M. Travers, R.M. Murray, C.D. Frith, R.S.J. Frackowiak and K.J. Friston. (1995) "A voxel-based method for the statistical analysis of gray and white matter density applied to schizophrenia." *NeuroImage*, **2**(4): 244-252.

- ***In the abstract of their study, Maguire and her collaborators state:***

“... 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)

***What representation of the data would reveal such a pattern? If the researchers are correct, what appearance would you expect the representation of the data to have?***

***Some of the data collected in the Maguire study are shown in Figure 4 below<sup>10</sup>.***

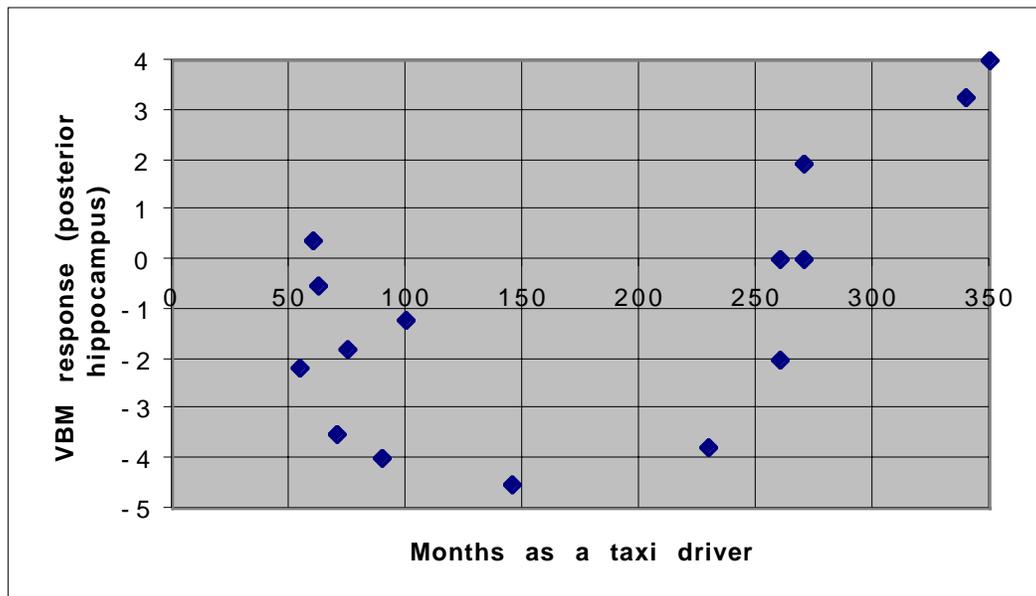


Figure 4: VBM response versus number of months as a taxi driver (after Maguire et al., 2000).

- ***Does the data support the researcher’s conclusions? What about the claims of the newspaper report that claims that the cabbies are “...working their brains so hard they become enlarged in the zone associated with navigation...” ?***

<sup>10</sup> VBM stands for “Voxel-based morphometry.” This is a technique for comparing MRI scans from different individuals that takes things like different head sizes into account when the comparison is made.

• *In their article, Maguire et. al. used a linear function to summarize the trend in the data shown in Figure 4. Is it possible to find a linear function that precisely models the data shown in Figure 4? Why or why not?*

• *Use Figure 4 to sketch a linear function that shows the overall trend in the data. Find an equation for this linear function.*

• *One of the most famous London taxi drivers was Mr. Herbert Smith (1859-1950) who drove cabs in London for 48 years, beginning in 1883<sup>11</sup>. What VBM response would you predict if Mr. Smith underwent an MRI at the end of his career?*

• *What VBM response would you predict for a person with no experience as a taxi driver?*

• *How much experience (as a taxi driver) does a person need in order to give a VBM response of zero?*

• *According to English law<sup>12</sup> a person must be at least 21 years of age to drive a taxi cab. The average life expectancy of people in England is currently about 76 years<sup>13</sup>. From these facts, what is the "problem domain" of the linear function that you have found?*

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<sup>11</sup> Source: The London Vintage Taxi Association, <http://www.osfn.org/britishcabs/>

<sup>12</sup> "Private Hire Vehicles (London) Bill 1997/98" *Research Paper 98/14*, House of Commons Library, London, England.

<sup>13</sup> Source: South West Public Health Authority, King Square House, King Square, Bristol BS2 8EE, England.