Cross-disciplinary synthesis of ecological and neuroimaging methods

Neuroimaging epidemiologists: We're in your department, eating your cake and using your analytical tool set

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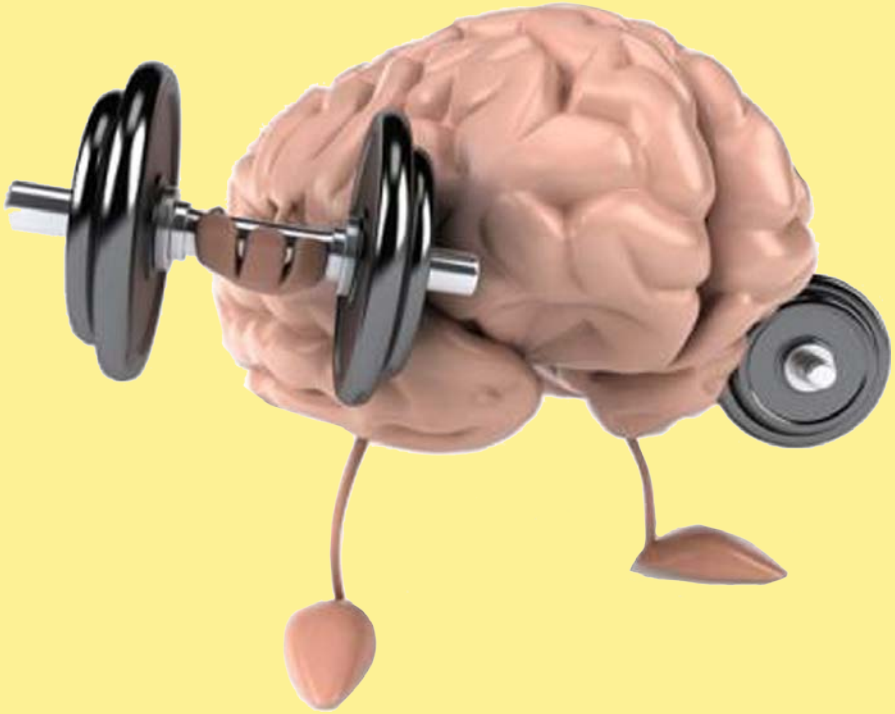
Brain ageing

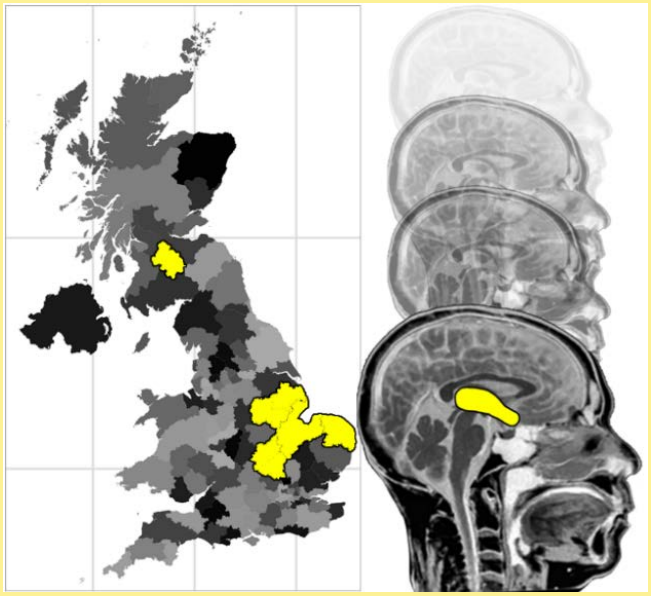


- There are lots of ageing brains
  - In 2017, 15% (3,794,800) of the population were aged over 65[(1)] (>25% by 2096[(2)])
- Some aspects of brain ageing are typical
  - Between ages 60-80, ~10% total brain volume loss[(3)]
- Some aspects of brain ageing aren't typical, and this is a problem
  - e.g. Dementia is the second leading cause of death in Australia[(4)]
- No treatment, so prevention of pathological decline is vital
- Looking at brain volume/atrophy is a good start

Source: https://cheba.unsw.edu.au/blog/positive-ageing

Brain ageing in geospatial context

- We know physical location can impact brain ageing
  - Lower dementia incidence in wealthier urban than poorer rural settings[5]
- We know correlates of unhealthy brain ageing have a spatial distribution
  - Stroke belt in the US [7]
  - Dementia incidence hotspots[6]
- What about brain volumes?



Sources: Wikimedia commons, http://s2.quickmeme.com/img/ea/ead1ca67d16171c250c442d51ad1b0e3c579e55898465cba6d403b67b8fef953.jpg

Mountain goats in British Columbia

- Use resources
  - e.g. tasty grasses
- Resources may be correlated or mutually exclusive
  - e.g. climate and grass distribution
- Resources may be fixed or seasonal
  - e.g. habitat elevation vs day length
- Resource use is *selective*; resources are used disproportionately to availability
  - E.g. tastiest grasses are preferentially eaten
- Location can be used as a proxy of resource use
  - disproportionate time spent in habitat (given habitat availability) indicates selective use of resources
- **Resource use can be thought of in terms of a maximum likelihood relative probability function.**

Human brains in the United Kingdom

- Exposed to risk/protective factors
  - e.g. type 2 diabetes
- These factors may be correlated or mutually exclusive
  - e.g. depression and diet quality
- These may be fixed or seasonal
  - e.g. genetics vs pollution exposure
- Exposure to these factors is *selective*; risks are distributed disproportionately in the population
  - e.g. genetic predisposition
- Location can be used as a proxy of factor exposure
  - disproportionate amount of pollution near residence indicates selective exposure to air pollution.
- **Risk/protective factors can be thought of in terms of a maximum likelihood relative probability function… Probably?**

Mountain goats in British Columbia

Conceptually

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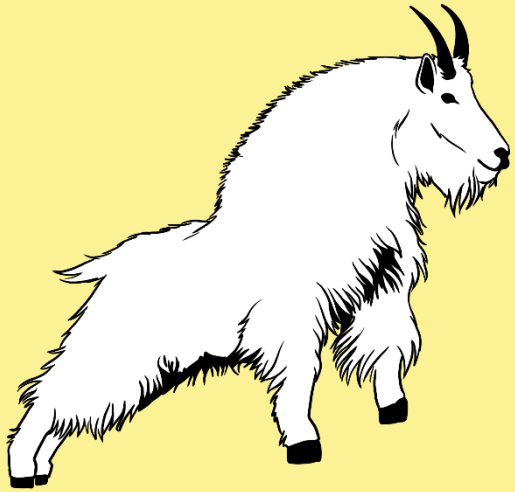
Human brains in the UK



Think of resource distribution in terms of risk/protective factor distribution

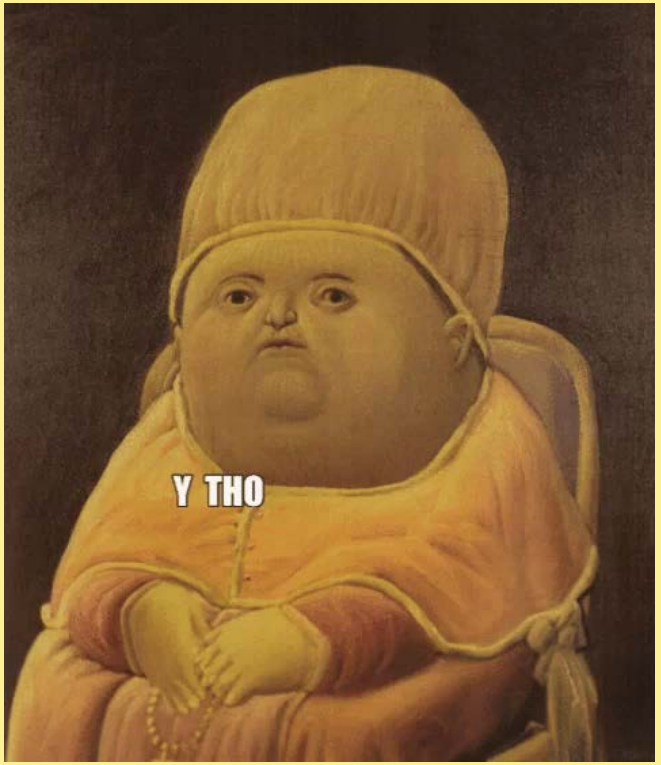
But… Why?

Existing methods in spatial epidemiology…

- Physical overlap of range e.g. Sørensen–Dice index
- Hotspot analysis, e.g. Getis-Ord statistic G_i^*
- Gradient analysis

Cope poorly when factors are:

- Too numerous
- Correlated or mutually exclusive
- Four-dimensional (especially a mix of fixed and seasonal)
- Distributed disproportionately in the population (except G_i^*)



Source: http://knowyourmeme.com/memes/y-tho

Mountain goats in British Columbia

Conceptually

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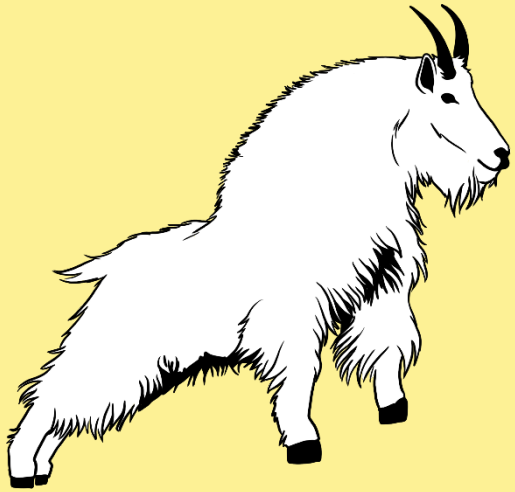
Human brains in the UK



Think of resource distribution in terms of risk/protective factor distribution

Statistically

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?

$$P(Y = 1 \mid \mathbf{X} = \mathbf{x}) = \pi(x, \beta)$$

Mountain goats in British Columbia

Conceptually

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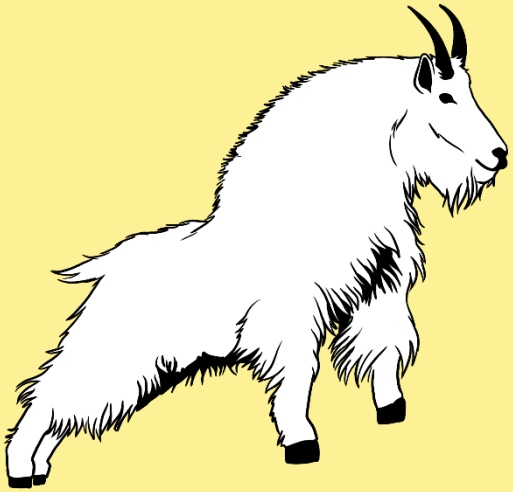
Human brains in the UK



Statistically

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?

$$P(Y = 1 \mid \mathbf{X} = \mathbf{x}) = \pi(x, \beta)$$

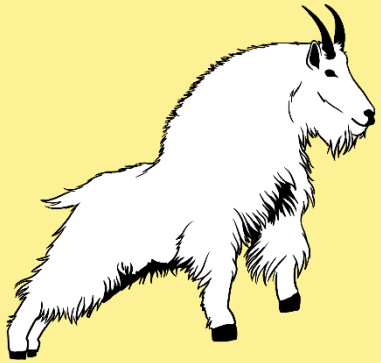
A constellation of resources/factors at a particular location ($\mathbf{X}=X_1,X_2\ldots X_p$) have a corresponding value Y_i ($Y_i=1$, $Y_i=0$)

β can be interpreted as the slope of the association

As long as $\mathbf{X}_i$ is a random sample from a multivariate distribution $f^A(\mathbf{x})$

β is embedded in a weighted distribution $f^U(X = x|Y = 1; \beta) = \frac{\pi(x,\beta) f^A(x)}{P(\beta)}$

Mountain goats in British Columbia



Conceptually

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Think of resource distribution in terms of risk/protective factor distribution

Statistically

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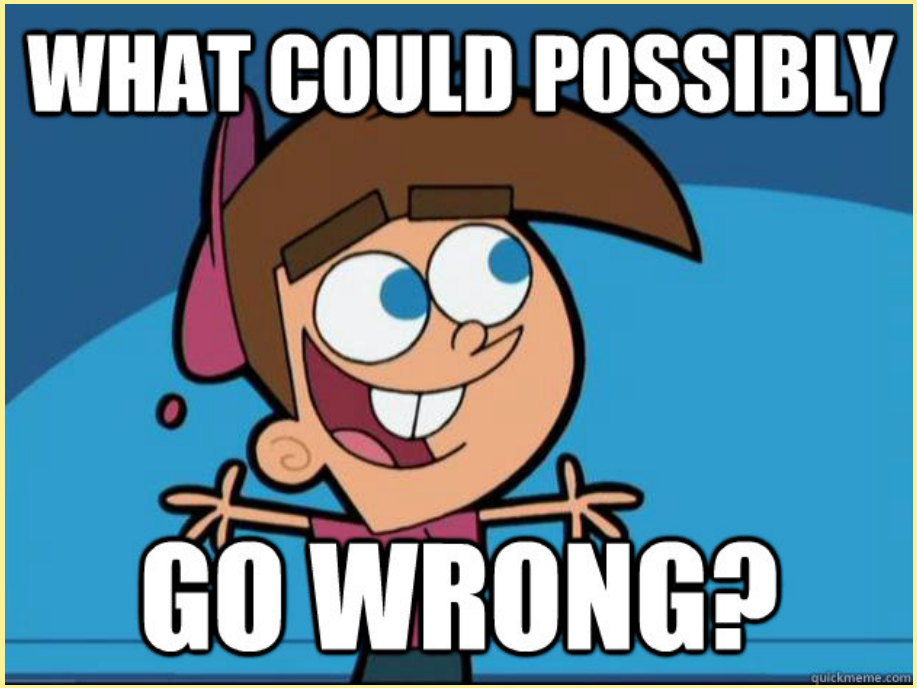
$$f^U(X = x|Y = 1; \beta) = \frac{\pi(x, \beta) f^A(x)}{P(\beta)}$$

Human brains in the UK

β shouldn't care if it's for goats and grasses vs brain volumes and risk/protective factors.

(seriously, I'm after your input!)



Source: http://i0.kym-cdn.com/photos/images/original/000/930/538/7cc.jpg

Thanks to:

- **Brain people:** A/Prof Nic Cherbuin and the rest of the NeuroImaging Brain Lab (CRAHW in RSPH)
- **Geospatial people:** Dr. Nasser Bagheri, Department of Health Services Research and Policy (RSPH)
- **Biology people:** Prof Scott Keogh et al (E&E).

References: 1. Australian Bureau of Statistics.3101.0 - Australian Demographic Statistics, Jun 2017.2017. | 2. Booth H, Tickle L.The future aged. Journal on Ageing.2003;22(4):196-202. | 3. Resnick SM, Pham DL, Kraut MA, Zonderman AB, Davatzikos C. Longitudinal magnetic resonance imaging studies of older adults. The Journal of Neuroscience.2003;23(8):3295-301. | 4. Brown L, Hansnata E, La H. Economic cost of dementia in Australia 2016-2056.Alzheimer's Australia Canberra, University of Canberra.2017 | 5. Ferri CP et al.Global prevalence of dementia. The lancet.2005;366(9503) | 6. Bagheri N, Wangdi K, Cherbuin N, Anstey KJ.General Practice Clinical Data Help Identify Dementia Hotspots: A Novel Geospatial Analysis Approach. Journal of Alzheimer's Disease.2018:1-10. | 7. Sergeev AV.Racial and rural-urban disparities in stroke mortality outside the Stroke Belt. Ethnicity and Disease.2011;21(3):307. | 8. Lele, S. R., & Keim, J. L. (2006). Weighted distributions and estimation of resource selection probability functions. Ecology, 87(12), 3021-3028.

THE FUN PARTS (thank you for asking):

- Physical overlap of range
  - e.g. Sørensen–Dice index
- Hotspot analysis, e.g. Getis-Ord statistic G_i^*
    - *n* are the number of observations
    - *x* is the characteristic of interest
    - *j* is a value for *x*
  - $G_i^* = \frac{\sum_{j=i}^{n} w_{i,j}x_j - \bar{X}\ \sum_{j=1}^{n} w_{i,j}}{\sqrt{\frac{n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2}{n-1}}}$
  - x_i value is high compared to $\bar{X}$.
- Gradient analysis, e.g. change in value (*z*) over a distance (*d*)
  - Expressed as the partial derivative of the x and y location *T*=*T*(*x,y*),
  - And the vector $\nabla T = \left(\frac{\partial T}{\partial x}, \frac{\partial T}{\partial y}, \frac{\partial T}{\partial t}\right)$
- Resource selection function
    - $X=X_1,X_2\ldots$ resources/factors at a particular location, X_i is a random sample from a multivariate distribution $f^A_{(x)}$
    - Y_i corresponding value to X_i ($Y_i=1$, $Y_i=0$)
    - β is the slope
  - $f^U(X = x|Y = 1; \beta) = \frac{\pi(x,\beta) f^A(x)}{P(\beta)}$