HealthPaths Dynamics II: Using Functional Health Trajectories to Quantify Impacts on Health-Adjusted Life Expectancy (HALE) in Canada

- core concepts – life course trajectories, functional health
- estimating multiple co-evolving dynamic relationships
- drawing out implications using microsimulation

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REVES: Austin, May 2013

General Plan of Analysis

- use one major longitudinal data set – Statistics Canada's National Population Health Survey
- characterize statistically multiple co-evolving individual health and health-related characteristics
- incorporate all estimated statistical relationships into a computerized microsimulation model
- simulate health-adjusted life expectancy (HALE)
- attribute ΔHALE to selected health determinants via comparative simulations
- today: progress towards HealthPaths II

Statistics Canada’s National Population Health Survey (NPHS)

- developed and fielded by Canada’s national statistical bureau
- started in 1994; interviews every 2 years; includes institutionalized; includes mortality follow-up
- n = ~20,000 individuals initially; now ~14,000
- all responses self-report
- mostly conventional health survey content, e.g. socio-demographics, chronic disease check list, major risk factors, health care utilization
- some content more exploratory, e.g. Antonovsky’s Sense of Coherence, McMaster Health Utilities Index (HUI)

Focus of Analysis – Functional Health

- using NPHS Health Utility Index (HUI): a generic index of functional health status.

1	$\Rightarrow$	full health
0	$\Rightarrow$	as good as dead
< 0	$\Rightarrow$	worse than dead

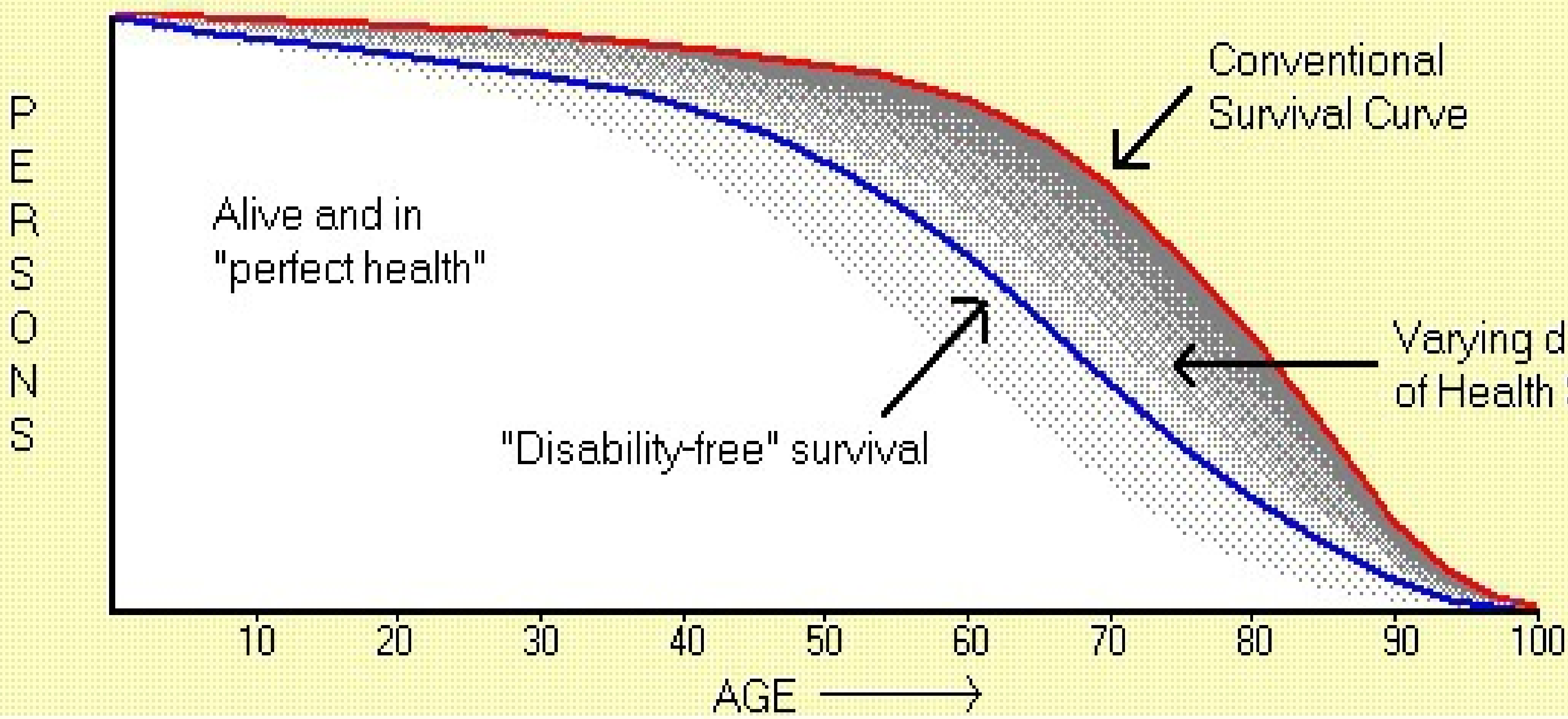
- based on eight separately assessed attributes: vision, hearing, speech, mobility, dexterity, cognition, emotion, and pain
- aggregated into a summary numerical index based on an empirical “weighting function”

Focus of Analysis: Health-Adjusted Life Expectancy

- extension of widely used concept of life expectancy (LE)
- combine length of life with “healthiness” of life, or “capacity to function” while alive, using HUI
- original approach – Sullivan method
- but here – complete lifecycle trajectories, using microsimulation

Basic Definitions

- LE = area under survival curve
- HALE = “weighted” area under survival curve
  - where “weights” are levels of individual health status, ranging between zero (dead) and one (fully healthy)



Risk factors & events included

Ordinal Variables

- **Vision**
- **Hearing**
- **Speech**
- **Mobility**
- **Dexterity**
- **Emotion**
- **Cognition**
- **Pain**

Functional Health summarized via HUI

- Income Deciles
- Leisure Activity
- Daily Activity
- **Smoking Status**

Binary Variables

- Employed this Year
- Family Member
- Institutional Resident
- **High School Graduation**
- **Community College**
- **University Graduation**
- **Mortality**

Quantitative Variables

- **Body Mass Index**
- Sense of Mastery
- **Sense of Coherence**
- **Years of Daily Smoking**

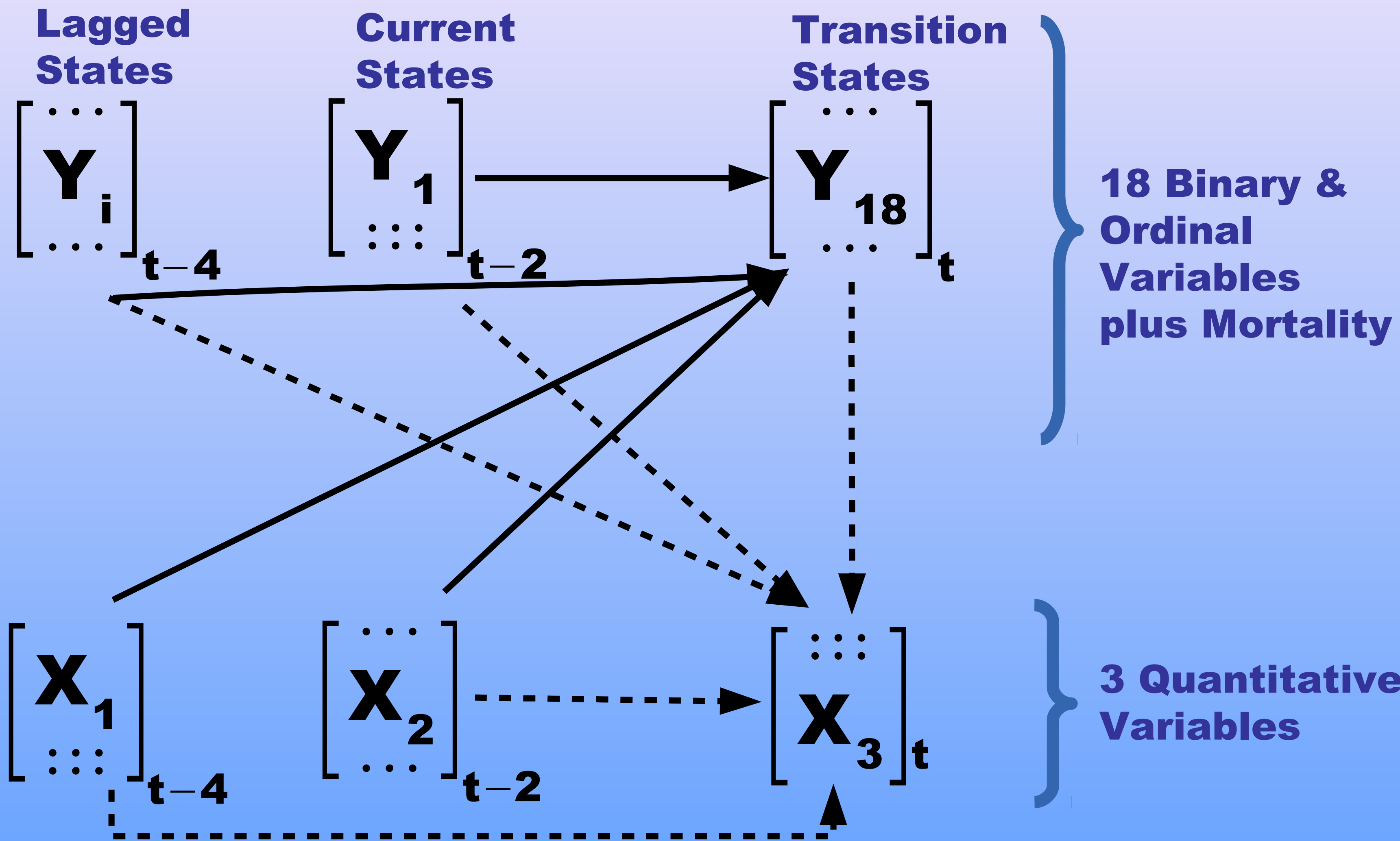
Modeling Health & Risk Factor transitions

Transitions from the '***current***' level of a health variable or risk factor to a higher or a lower level.

Separate binary or ordinal logistic regressions for each row of each transition matrix.

Each health variable or risk factor plays both the role of dependent <u>and</u> of independent variable (everything effects everything over time).

Dynamic Structure of Equations



Covariates in Binary/Ordinal equations

Covariate	Logistic Equation Terms	df
Immigrant Status	Immigrant & Non-European Immigrant	2
Institutional Status	Non-Institutional, Institutionalized	2
Vision	5 levels of health deficit	10
Hearing	5 levels of health deficit	10
Speech	4 levels of health deficit	8
Mobility	5 levels of health deficit	10
Dexterity	5 levels of health deficit	10
Emotion	4 levels of health deficit	8
Cognition	5 levels of health deficit	10
Pain	4 levels of health deficit	8
Education	Secondary School, College, & University	6
Leisure Activity	Moderate & Active	4
Daily Activity	Walking, Light Work, & Heavy Work	6
Smoking Status	Occasional, Former Daily, & Daily	6
Years of Smoking	linear slope & spline coefficient	4
Employment	Employed in the past 12 months	2
Family Membership	Family Member/Non-Member	2
Household Income	Household Income Deciles	18
Body Mass Index	linear slope & spline coefficient	4
Sense of Mastery	28 increments	56
Sense of Coherence	linear slope & spline coefficient	4
Time Interval	slope (log(ΔTime)) = 1	0
	Total	190

Age-varying estimates

Parameters are estimated using separate local weights for each target age from 20 to 100.

If respondent age = target age:

local weight = survey weight

If respondent age ≠ target age:

local weight = survey weight X f((age-target)^2)

Local weights shrink relative to survey weights. After age 75, the rate of shrinkage increases to compensate for sparse data.

Estimating large/complex equations

Model selection using penalized logistic regression:

elastic net **-** a compromise between

ridge regression and the ***lasso*** minimizing:

$$-2 \text{ loglikelihood} / N + \lambda \Sigma [\alpha |\beta| + (1- \alpha) \beta^2]$$

λ is chosen by cross-validation with **α** = 0.5

Zhou & Hastie(2005), Friedman, et.al. (2010)

R package ***glmnet***

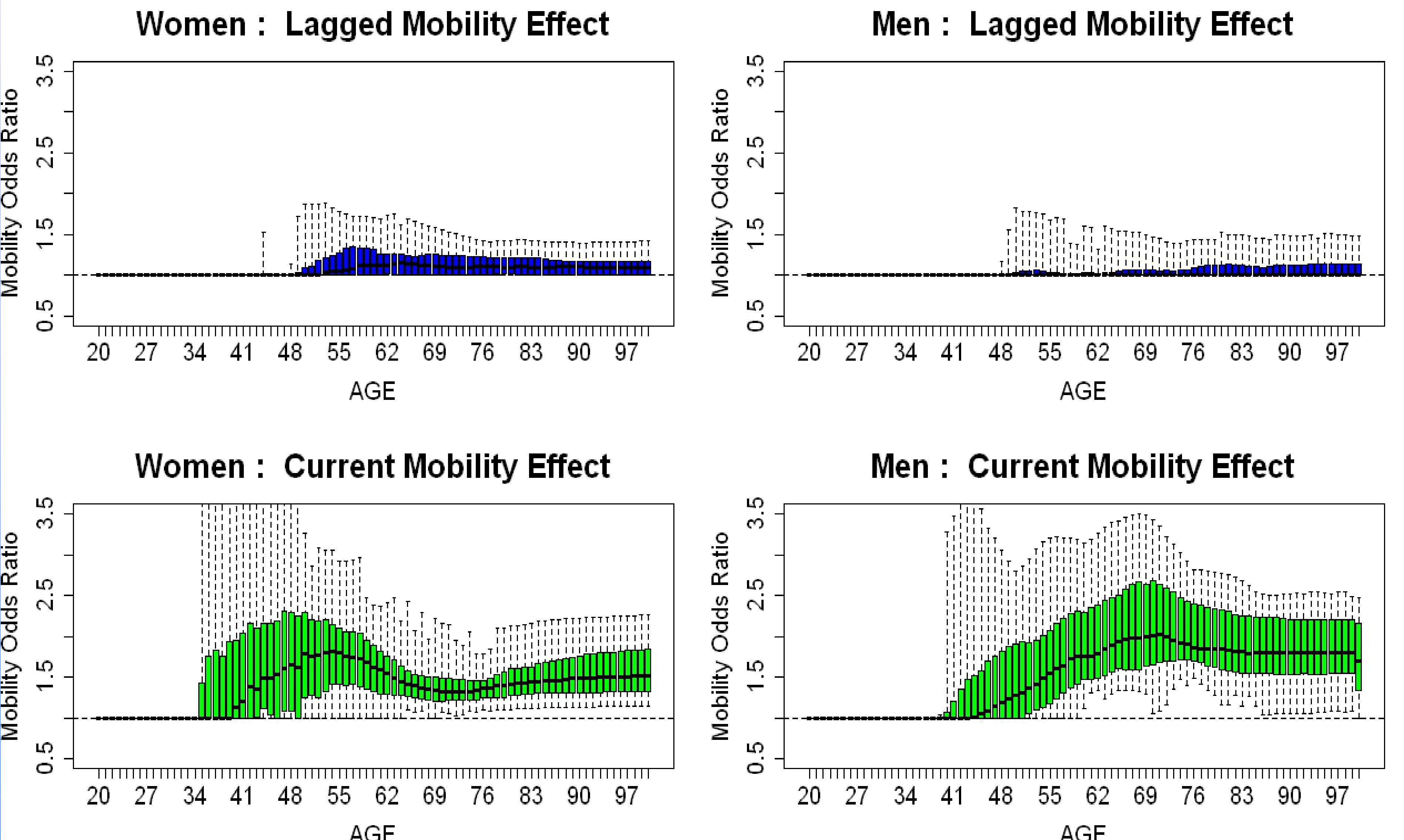
HealthPaths II:
a detailed model => a large model

2	Sexes
81	Ages
40	Bootstrap samples
190+	Coefficients per equation
22	Binary/ordinal dependent variables
2+	Transition matrix rows

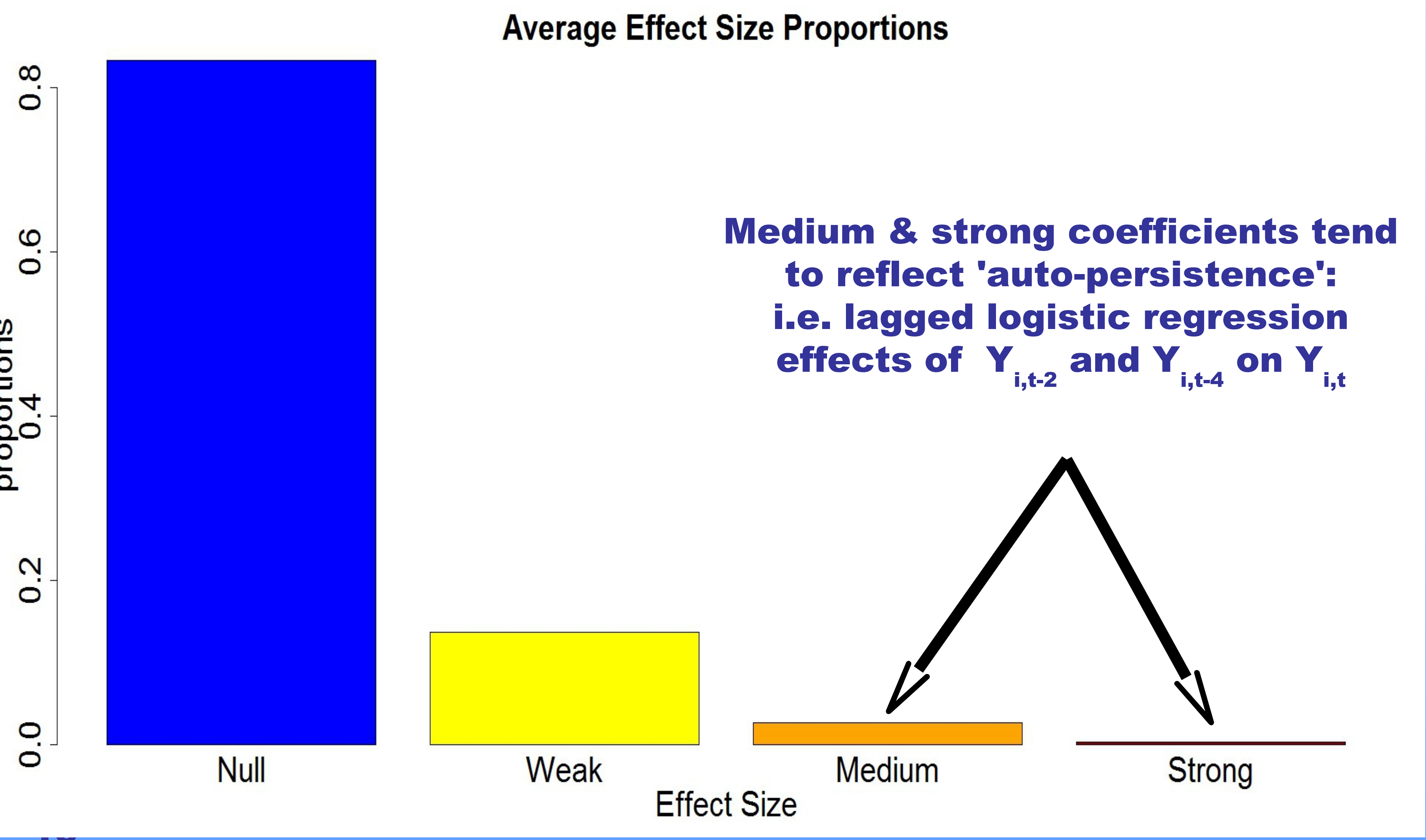
=> more than 46 million coefficient estimates, or

about 7,000 age-sex profiles of odds ratios like the “Age-specific Mobility effects on Mortality“

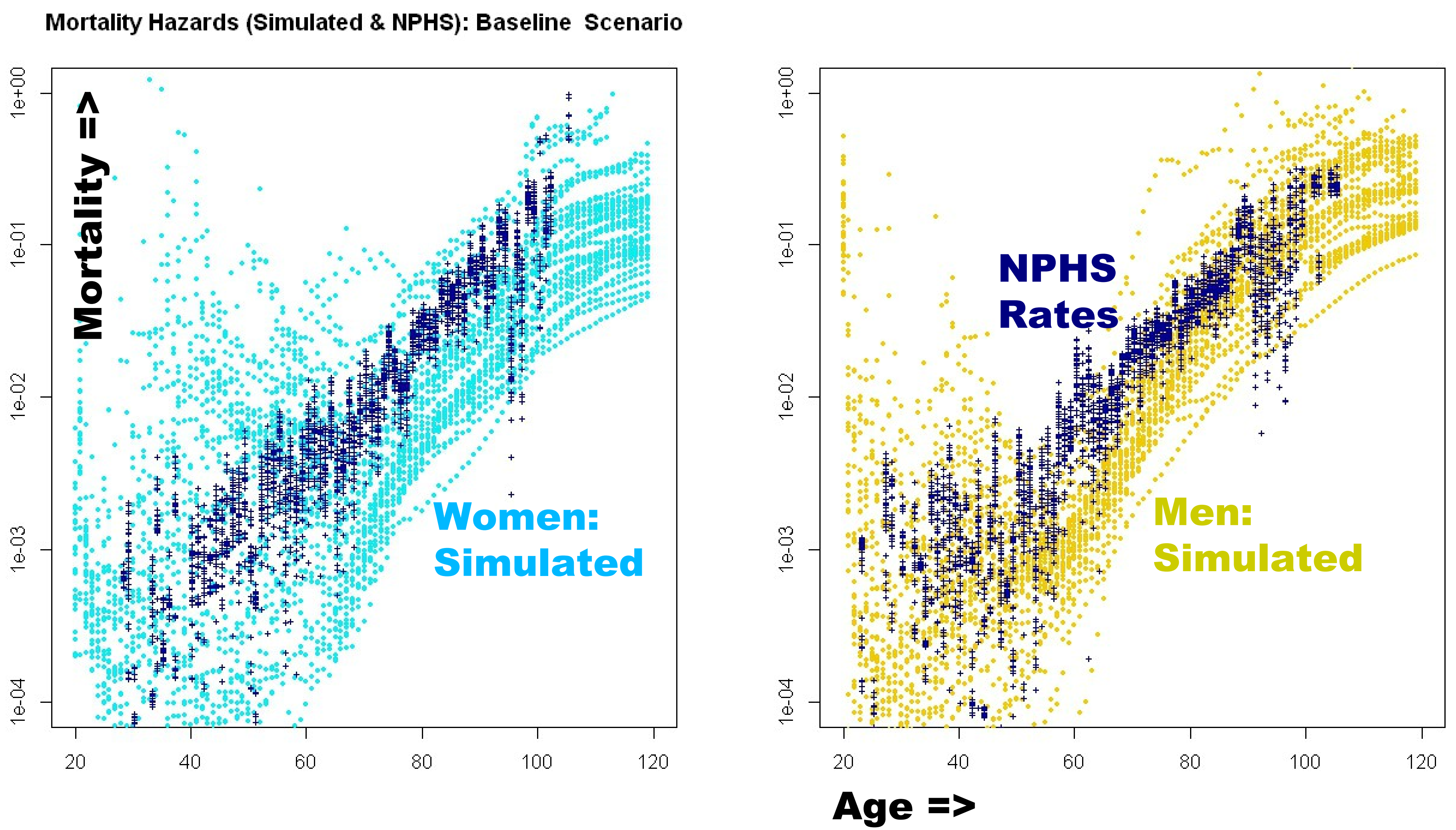
Age-specific Mobility effect on Mortality



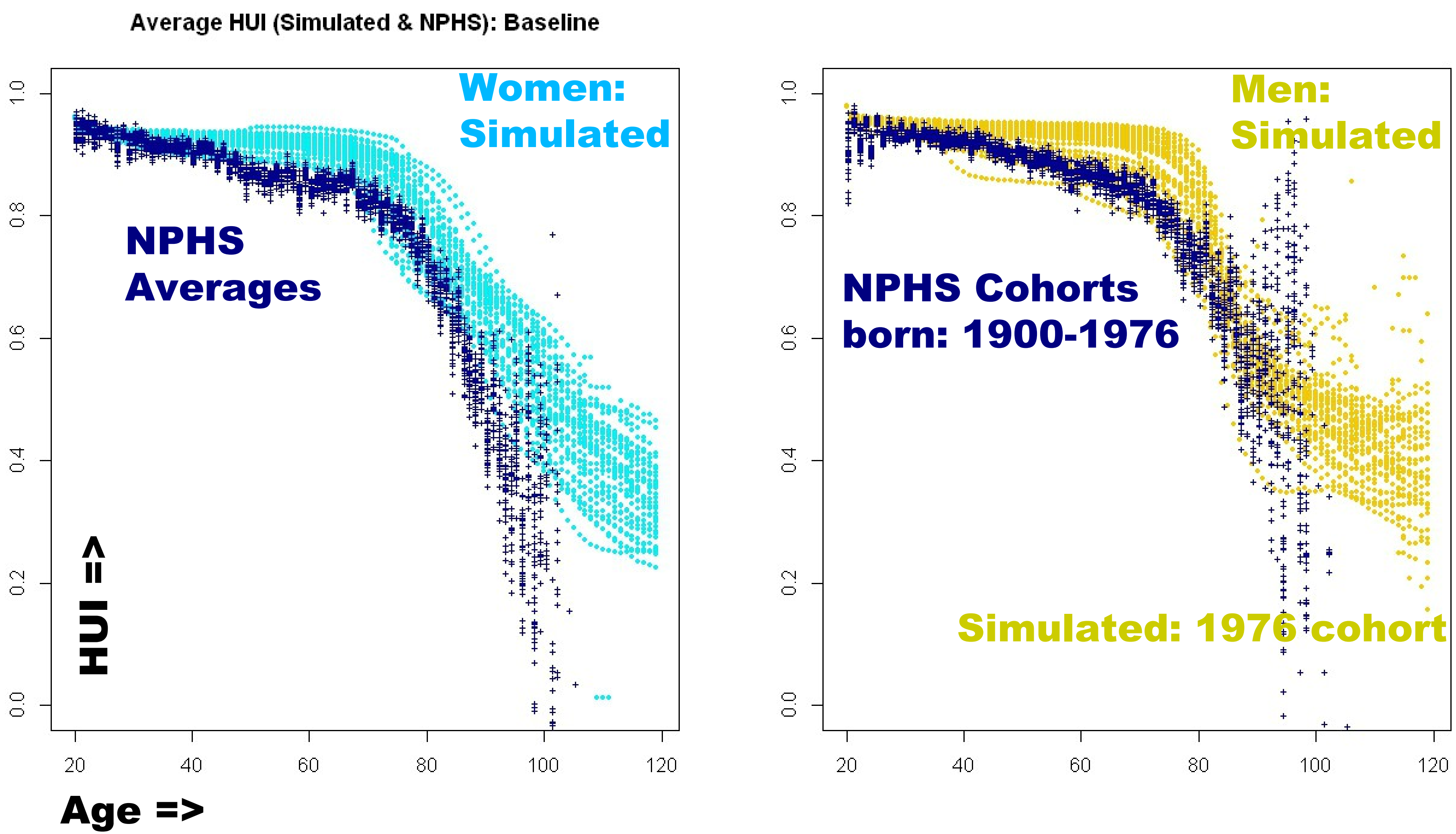
Average coefficient effect sizes: strong effects are rare



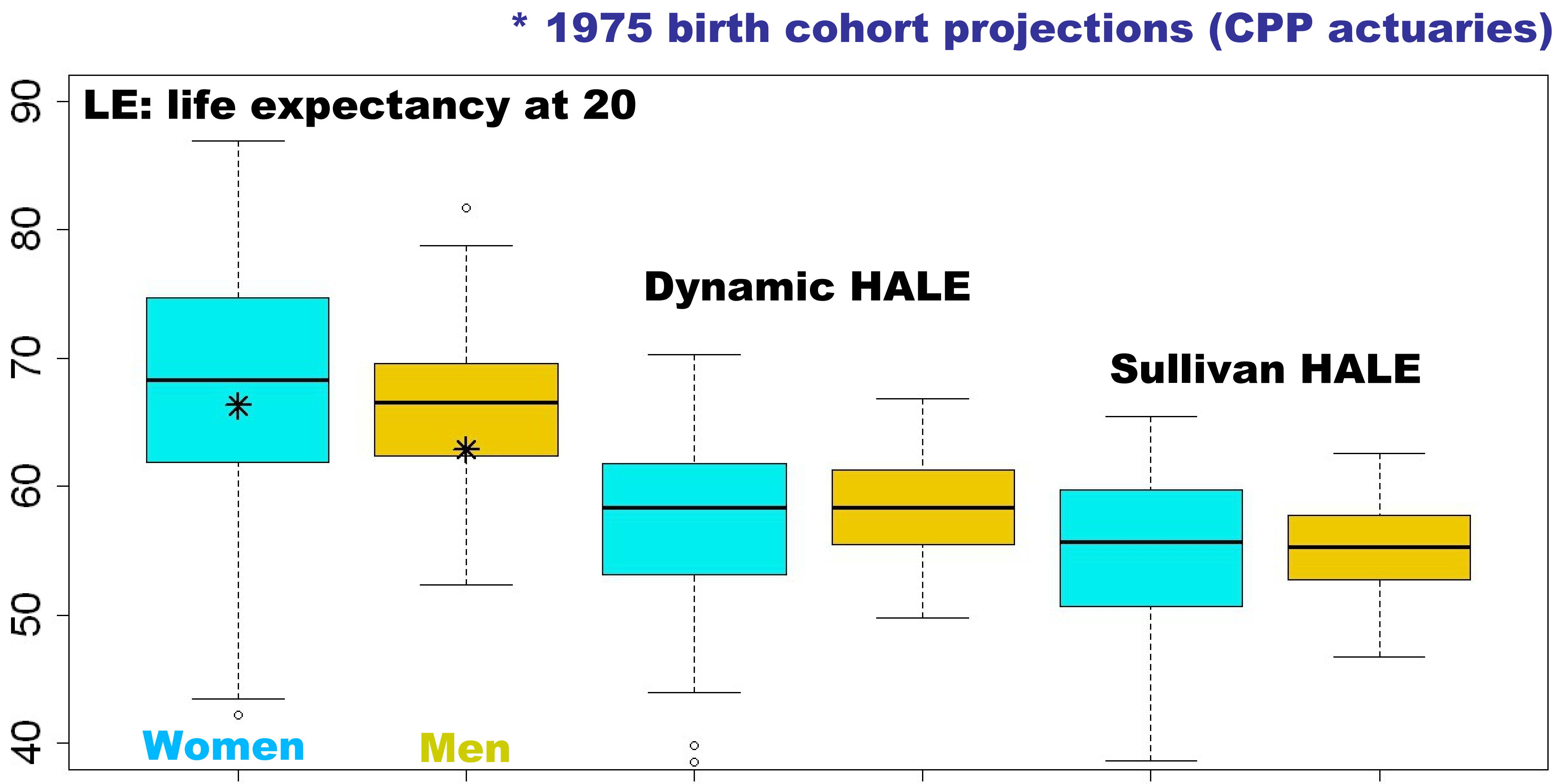
Validation: Mortality Hazards NPHS Rates & Simulated



Validation: Average HUI NPHS & Simulated

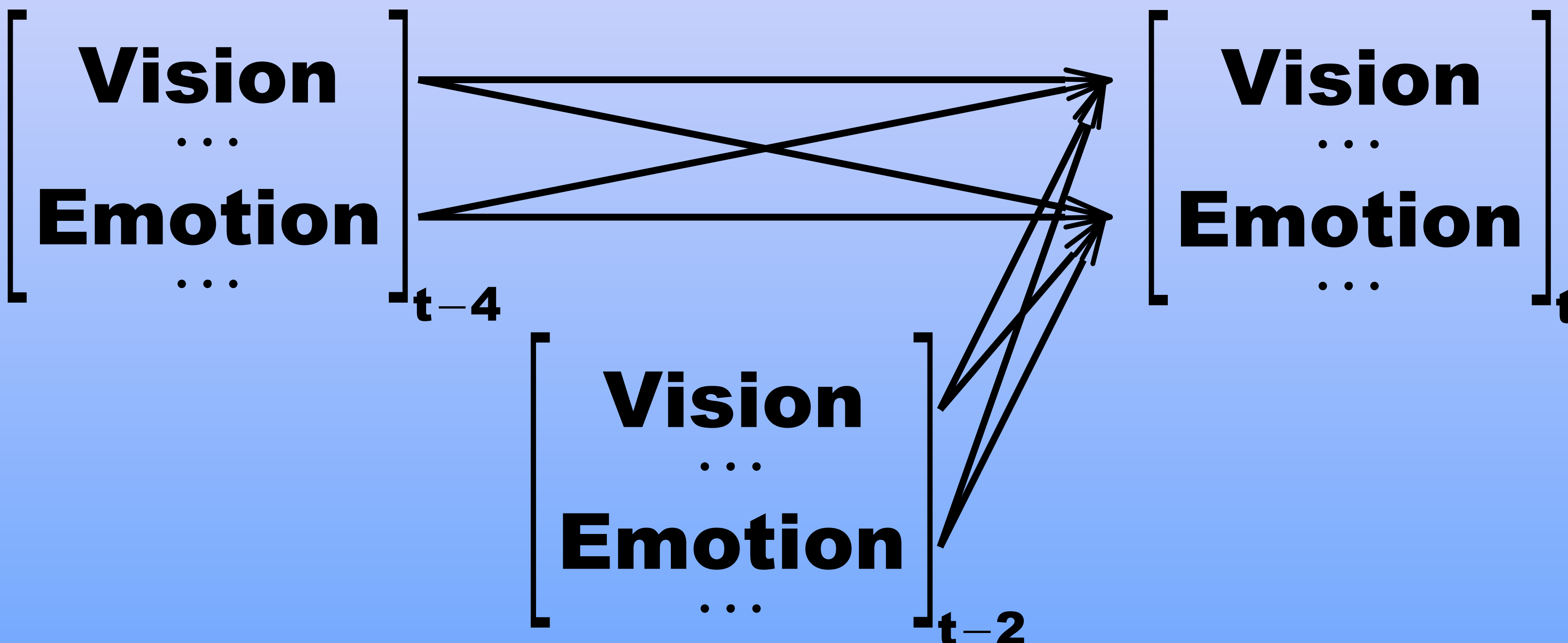


Baseline LEs and Dynamic & Sullivan HALEs



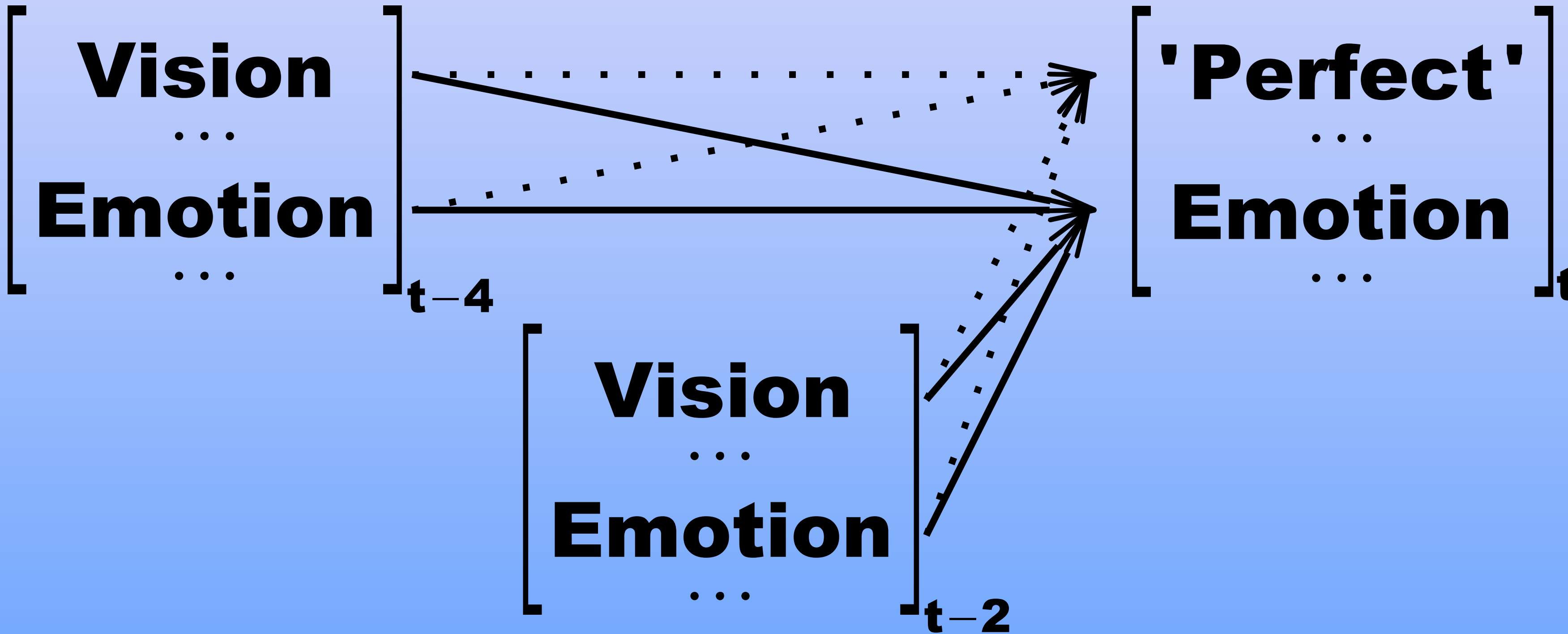
Constructing “what-if” scenarios

Baseline: everything influences everything else



Cutting pathways to selected variables

Perfect Vision Scenario: over-ride transitions, and assign a 'Perfect' score at each step



Assessing effect size

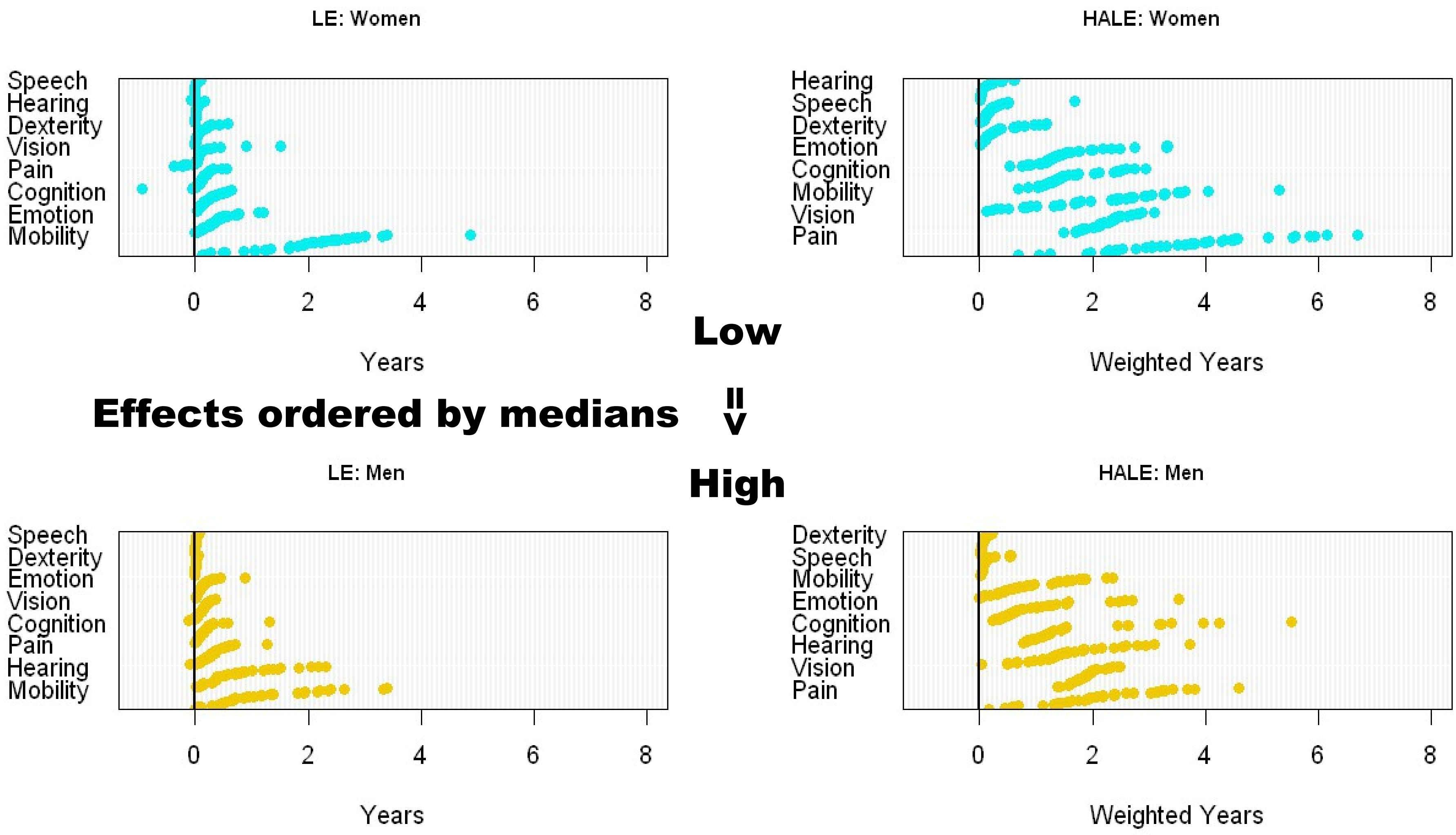
$\mathrm{HALE}_{\text{perfect vision}}$ minus $\mathrm{HALE}_{\text{baseline}}$

≈ healthy years lost due to imperfect vision

Sensitive to:

- Initial states (at age 20)
- Subsequent frequency of transitions

Functional Health Effect Sizes: scenario minus baseline at age 20



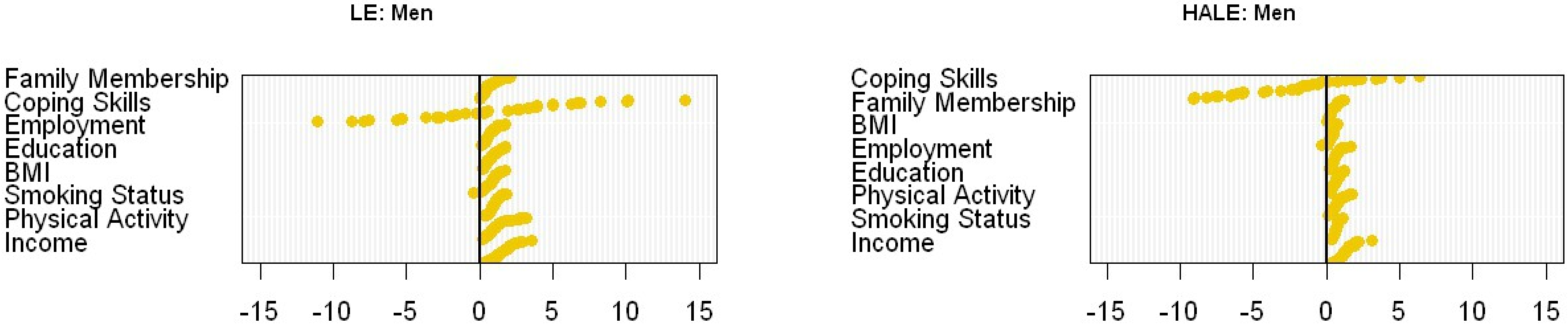
Composite Risk Factors I

- **Socio-Economic Status** = Education + Income
- **Physical Activity** = Leisure + Daily Non-leisure
- **Coping Skills** = Sense of Coherence +
  Sense of Mastery

Composite scenarios fix a set of variables at 'optimal' scores (eg. everyone is a university graduate with income in the top decile)

Risk Factor Effect Sizes: scenario minus baseline at age 20

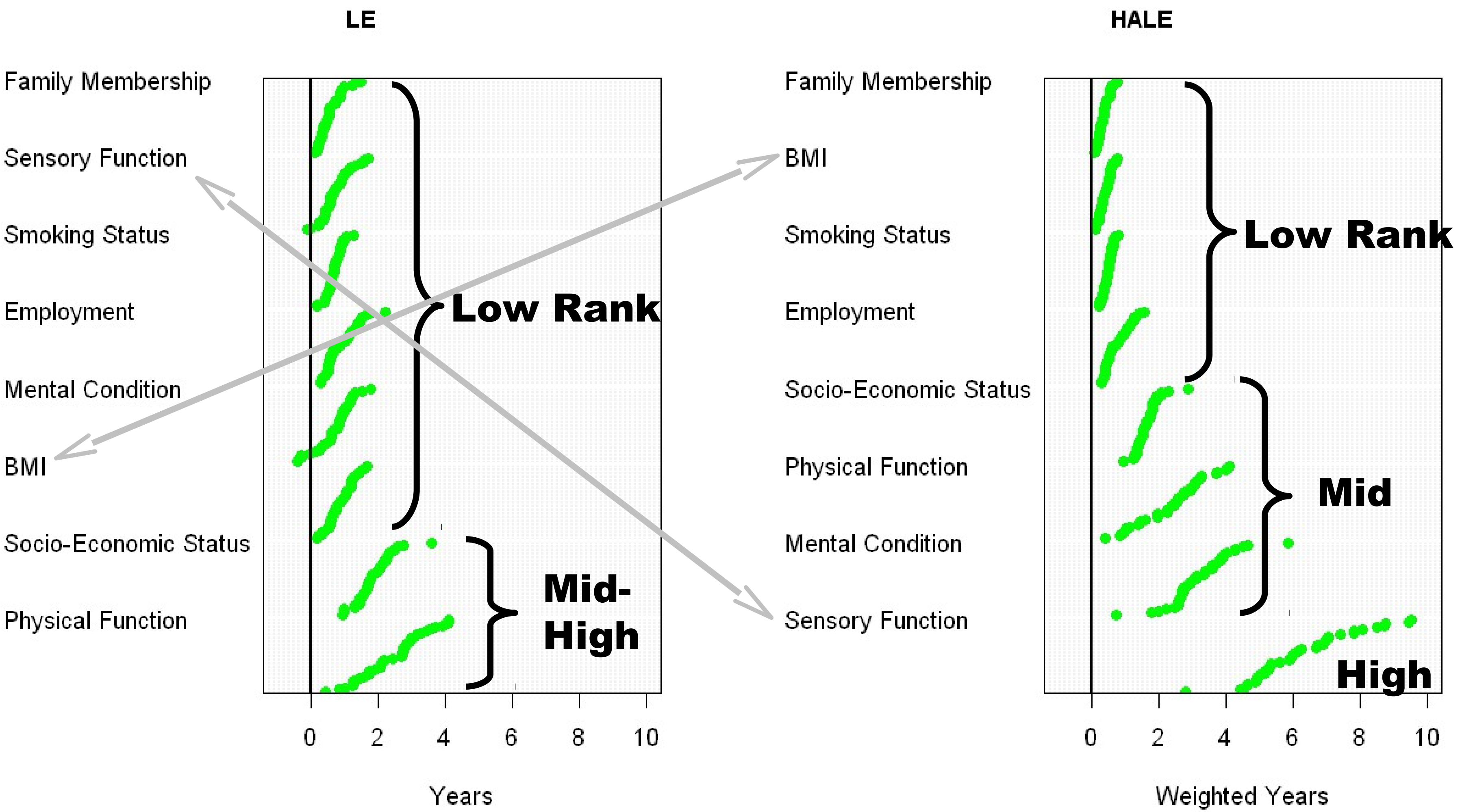
Coping Skills: high median & high missing value imputation variance



Composite Risk Factors II

- **Physical Function** = Physical Activity + Mobility + Dexterity
- **Mental Condition** = Coping Skills + Emotion + Cognition
- **Sensory Function** = Vision + Hearing + Speech + Pain

Grouped Risk Factor Effect Sizes: both sexes, ranked sets



Concluding Comments

<u>Effect Sizes</u>: many changes/improvements in HealthPaths II

- HALE rankings markedly different from LE rankings
- **Sensory Function** tops the list for HALE
- **Smoking** effect weak in this cohort because there are many life-long non-smokers (the war is won!)
- **BMI** & **Hearing** effects point to need for more complex counterfactuals: healthy ageing can include change

<u>Effect Variance</u>

Multiple sources of variability: sampling, non-response (missing value imputation), response error, variable choice, equation specification, coefficient estimation, ...

Unambiguous ranking of risk factor impacts on HALE is not yet possible given the limitations of data as it is generally available.