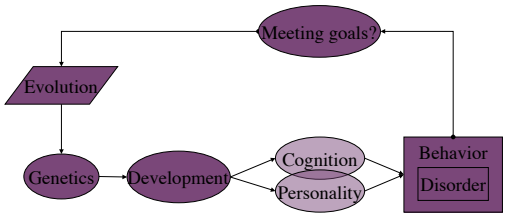
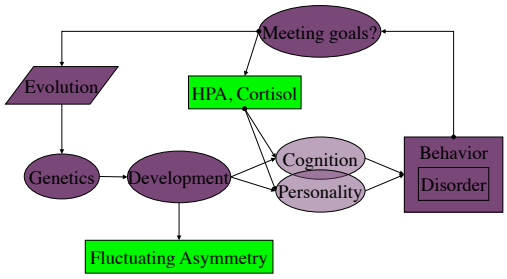
Fluctuating Asymmetry, and precision

Timothy C. Bates
Macquarie Centre for Cognitive Science
Sydney Australia
tim@maccs.mq.edu.au

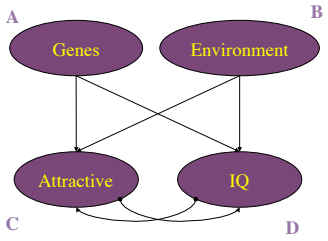
A Model for Behavior



Behavior & Strain

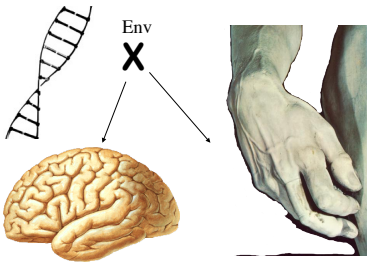


Zebrowitz et al. (2002)

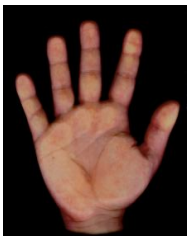


Asymmetry as developmental instability

- Gangestad, Yeo, Möller and others



FA



Heritable traits in man

- Intelligence predicts success in many activities, yet, surprisingly…
- *g* is among the most heritable of human traits: h^2 peaks at 0.8 in adults
  - Bartels, Rietveld, Van Baal, & Boomsma (2002).

Survival selection and polygenes

- Survival selection acts to canalize traits: to reduce the number of genes on which they depend uniquely, via redundancy and modifier genes

Polygenic bases

- The basis for genetic variability in IQ appears to lie in many, rather than a few genes.
- Genome-wide searches for genes for intelligence indicate that the maximum variance accounted for any single gene affecting normal intelligence is less than 1-2%
  - Bouchard & McGue, 2003)
- While intelligence is strongly biologically determined, it reflects allelic fitness in a large array of variable genes.

Forces underlying sexual-selection (Andersson, 1994)

1. Arbitrary choice followed by Fisherian runaway
   Darwin (1871) *Fisher* (1930)
2. Sensory bias
   Jones (1996)
3. Direct benefits
4. Good-genes
   Wallace, Williams, Trivers, Hamilton
   *Honest display (*Handicap theory; *Zahavi,* 1975)

Canalization & Developmental Instability

- Unstable expression of the developmental design, with instability being
  "noisiness in development"
  (Waddington, 1957).
- If variance in intelligence is largely an outcome of fitness-related variation across the genome then IQ should correlate with arbitrary indicators of DI.

Testing the theory

- A readily accessible measure of DI is fluctuating asymmetry (FA)
  - *Subtle, random, departures from symmetry in normally symmetrical bilateral traits*
    - Ludwig, 1932; Palmer & Strobeck, 1986; Van Valen, 1962.
- Deviations from symmetry indicate developmental imprecision or noise.

Previous work

- Furlow et al. (1997) assessed FA
  - Foot breadth, ankle breadth, finger lengths for the third, fourth and fifth fingers wrist breadth, elbow breadth, ear breadth and ear length
  - Independent samples of 111 and 123 students
  - Cattell's Culture Fair test of intelligence *r* .2 & .27
- Prokosch (2004).4 correlation with Ravens

Experiment 1: Replicate Furlow et al

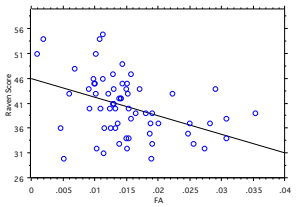
- Subjects
  - Sixty-seven subjects participated (43 female (mean age 36 years, SD 14.7) and 34 male (mean age 33 years SD 9.8).
  - Subjects were recruited from the community by word of mouth.
  - Participants were asked if they had suffered a significant injury to any of the measured body parts. Injured body parts were excluded for that subject.
  - No other exclusion criteria were used.

Measures

- Intelligence
  - Raven Standard Progressive Matrices (Raven, 1992) un-timed computerized.
- Fluctuating asymmetry:
  - Width of the palm, length of each of the four fingers excluding the thumb, ear height and width, and the widths of the ankle and elbow.
  - All measures were made using digital calipers accurate to 0.1 mm.
  - Each body part was measured twice and averaged.
  - FA = Sum(|(left–right)/(left+right)|)

Results

- A regression of FA on Raven gave a significant R2 of .171 ($F(1,63)=13.04$, $p<.0006$)



Effects of covariates

- Age was not significant,
- Significant main effect of sex
  - Females showed less FA than males
- Interaction of sex and FA was significant
  - Separate regressions for sex showed an R^2 of 0.34 in males and only .07 in females.

Discussion

- Magnitude of the correlation of Raven and FA reported here is very similar to that found by Prokosch et al. (2004)
  - *r*= .39 vs. 0.414 in the present study
- Larger than the *r* of -0.21 reported by Furlow et al. (1997) using the Cattell Culture Fair measure of IQ).
- Significant interaction with sex

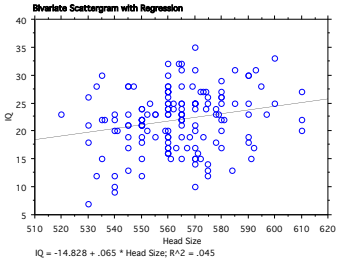
Experiment II: Replicate expt 1 and extend

- Is the sex interaction replicable?
- IQ also correlates with height, health, longevity, and a range of other physical traits including head size
- IQ correlates .4 with brain volume and around . 2 with head size
- If FA is driving these correlations, then they should reduce or minimise when FA is covaried.

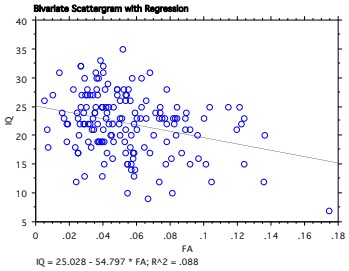
Subjects

- One hundred & sixty-four reagents
  - 124 female (mean age 21.6 years, SD 7.34) and 40 male (mean age 21 years SD 7.47)
  - Course credit or payment of $10.

Results: head size



Results … FA & IQ



Results…

- ANCOVA accounting for sex and age, FA was significant ($F(2,154)=12$, $p<.05$). The effect of sex was not significant, nor was there any sex*FA interaction.
- Head size, significant, but not after FA.

Discussion

- FA—IQ correlation replicated
- Lower *r* in females not replicated
- FA mediates the head-size-IQ correlation

Symmetry and Aging

Developmental Patterns in Cognitive Aging

- Two important findings which must be accounted for by any model of cognitive aging are:
- "Brain and Cognitive Reserve"
  - The finding that some people appear more resistant to pathology than others (Katzman et al., 1988, Richards & Deary, 2005)
- The "Common Cause"
  - The finding of high levels of synchronization across diverse cognitive faculties and physiological systems (Lindenberger & Baltes, 1994).
  - A person declining in one of these areas—or holding up— tends to decline or holding up in the others, including sensory acuity
  - General physiological integrity of the aging brain, and perhaps the body more generally (Lindenberger & Ghisletta, 2009).

Why does cognition decline?

- Understanding the causes of cognitive development and cognitive aging is of great importance – not only for specific diseases such as Alzheimer's but also for understanding normal development.
- While some progress has been made as exemplified by the link of *APOE-* ε 4 status to late onset Alzheimer's disease (Schmechel *et al.*, 1993), the causes of people's differences in normal cognitive decline remain largely unknown (Deary *et al.*, 2009).

Early Causes (Marmot 2010)

- *"The foundations for virtually every aspect of human development – physical, intellectual and emotional– are laid in early childhood. What happens during these early years (starting in the womb) has lifelong effects on many aspects of health and well-being–from obesity, heart disease and mental health, to educational achievement and economic status"*
- (p16 Marmot, 2010).

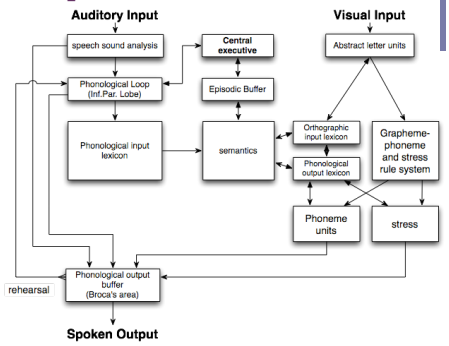
Barker

- Many negative outcomes such as coronary heart disease are predictable from birth: Decades before they result in deficit and mortality.
- Barker (1995, 2007) hypothesized that fetal programming is the cause of these early differences.
- The basis of these effects or the nature of the program, already present at birth, is however unclear.

Markers of early developmental programming

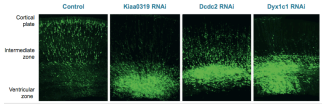
- Typically, only crude measures such as birth weight are used to indicate developmental success or problems.
- Here we test whether cognitive development reflects, in part, early developmental precision.
- Defined as a programmed highly precise physical alignment of developing organs and organelles

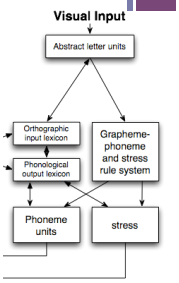
Lots of parts…



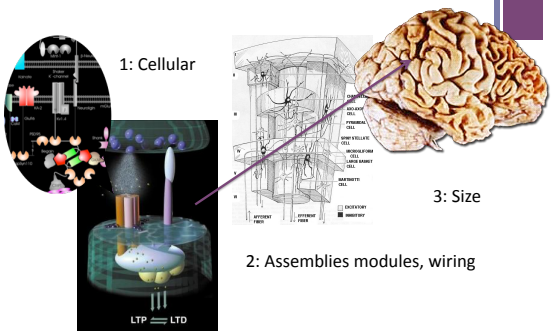
Have to get them (and all their trillion pieces) in the right place

- Molecular research has been considerably more successful for dyslexia than language impairment
- Cortical migration
  - ***KIAA0319*** (Cope, et al., 2005; Luciano, et al., 2007)
  - ***DCDC2*** (Lind, et al., 2009; Meng, et al., 2005)
  - ***DYX1C1*** (Bates, et al., 2009 Mol Psychiat.)

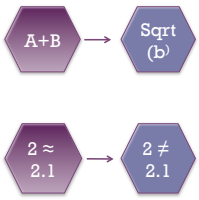


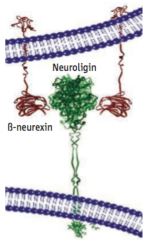


What changed? Several Levels



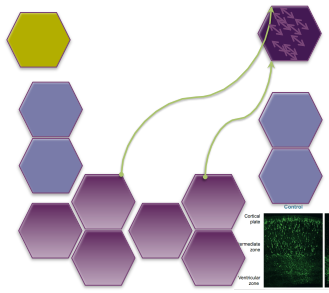
Different computations or New demands on precision (Autism)



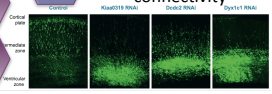


Critical connection. Neurexins and neuroligins coming together in the synapse. Alterations in these proteins could change how neurons communicate and lead to autism.

Different connections (Dyslexia)



Paradoxically, increased brain size decreases absolute neuronal connectivity



Assessing Precision

- We assess this construct using fluctuating asymmetry (FA: the sum of departures from bilateral symmetry in body parts, Van Valen, 1962).
- We suggest that FA may in part reflect genetic differences coding for a higher-precision developmental plan; analogous to a blueprint specifying construction in a higher resolution, leading to higher symmetry as a side effect.
- If developmental precision underlies significant elements of cognitive aging it should be associated with intelligence not only contemporaneously but also across many decades.

Testing the precision hypothesis

- Clearly difficult to test: few studies have lifespan data and FA.
- We examined, for the first time, whether bodily precision as measured in old age is related to intelligence and specific cognitive domains over a 76-year period.
- What would this mean?
  - Links cognitive ability in old age to lasting markers of early development
  - Suggests that a key determinant of aging can be studied and (perhaps) modified in young populations.

Participants

- All subjects were born in 1921, and participated in 1932 in the national Scottish Mental Survey, involving administration of the Moray House Test of intelligence (MHT) at age 11.
- They were traced and given both follow-up general ability tests as well as a number of additional measures of cognitive and non-cognitive function (Deary *et al.*, 2004).
- At initial recruitment at age 79 (wave 1) all subjects lived independently in the community. Subjects were recalled at a mean age of 83 (wave 2). Subjects were aged 87 with a very narrow range at the time of testing for the present study (wave 3), and 173 subjects (80 male and 93 female) completed the FA measures and cognitive testing this age.
- At age 87, 10 subjects had MMSE (Folstein *et al.*, 1975) scores < 24 (a typical indicator of mild cognitive impairment), and MMSE was controlled in all analyses.

Method and Procedures

- FA was assessed during clinic visits at age 87.
  - High-resolution images of the hands were made using a digital flatbed scanner, and finger lengths and widths, and the length of the palm were measured digitally on computer screen.
  - Where necessary due to a lack of full extension, finger lengths were measured as the sum of the length of each finger joint segment, ensuring that finger length was not inappropriately shortened as a result of failing to take account of curvature.
  - Ear height and width, wrist, elbow and ankle diameter were measured three times for each for the left and right side of the body using digital calipers with .1 mm accuracy.
  - All measures were combined using the standard formula for FA based on left (L) and right (R) differences of $\sum \text{abs}((L-R)/(L+R)/2)$ to produce a combined FA variable scaled in percent. The combined value was then log transformed to normality.
- Cognitive battery was administered in a predetermined order in a quiet room either in the clinic or, in a small number of cases at the age 87 assessments, at the patient's home by a trained researcher.
  - The Moray House Test (Deary et al., 2004, Scottish Council for Research in Education, 1933) of verbal, numerical, spatial, and abstract reasoning was administered with a 45-minute time limit.
  - Subjects completed this test three times; Once on June 1, 1932, at age 11 years (Deary et al., 2000, Scottish Council for Research in Education, 1933), and again at mean ages of 79 and 87.
  - After statistically controlling for age in days, it was converted, separately for both measurement points, to an IQ-type score (MHT IQ; M=100; S.D.=15).

Testing

- At mean ages 79, 83 and 87, (Deary *et al.*, 2004, Gow *et al.*, 2008) subjects were administered
  - 60-item Raven's Progressive Matrices (Raven *et al.*, 1998), scored as number of items completed correctly within 20 minutes.
  - National Adult Reading Test (NART :Nelson & Willison, 1991) administered as a measure of irregular word pronunciation, used to estimate of pre-morbid IQ and lexical storage
  - Mini-Mental State Examination (MMSE) (Folstein *et al.*, 1975), a widely used screening test for dementia.
- At ages 83 and 87 subjects completed
  - Letter–Number Sequencing subtest of the Wechsler Adult Intelligence Scale–III (Wechsler, 1998) test of working memory.
  - It involves listening to jumbled sequences of letters and numbers and recounting them with the numbers first in numerical order, followed by the letters in alphabetical order

Bodily FA: An archaeological marker of IQ from age 11 to 87

	FA effect-size (β) and p-value (in brackets) at each age			
	11 years	79 years	83 Years	87 Years
Moray House IQ	**-0.17** (.035)	**-.18** (.018)	--	**-0.17** (.015)
Raven's Matrices	--	--	**-.15** (.033)	**-0.18** (.016)
LNS	--	--	**-.22** (.003)	**-0.23** (.002)
NART	--	**-0.18** (.019)	**-.22** (.004)	**-0.19** (.019)

FA unrelated to specific cognitive abilities

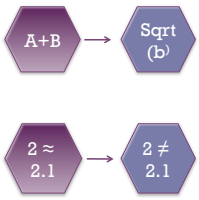
Specific Abilities		
Verbal Fluency	.057 (.429)	
Logical Memory (immediate)	.031 (.635)	
Logical Memory (delayed)	.004 (.892)	
MMSE 87	.043 (.579)	

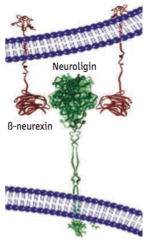
- beta (p)

(non-)Effects of Deprivation/ Resources

	Fluctuating Asymmetry effect-size (β) (and p-value)	
	Age 87	**Age 11**
General Ability Measures		
Moray House IQ	**-.127** (.05)	**-.167** (.04)
Controlling for paternal education	**-.170** (.01)	**-.200** (.02)
Controlling for height	**-.164** (.02)	**-.202** (.02)

Perhaps the computations of IQ are (uniquely) demanding of (mechanical) precision





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Background Research

- FA may be related to cognition, brain and body: measures of developmental precision have already been linked to candidate markers of cognitive reserve such as brain volume (Bates, 2007, Furlow *et al.*, 1997), and FA explicitly relates bodily integrity to cognitive integrity via providing a theoretical basis for the observed "*common cause*" pattern. FA is also associated with a wide range of biological and social factors, including fertility (Jasienska *et al.*, 2006), health (Thornhill & Gangestad, 2006, Thornhill & Moller, 1997), as well as intelligence (Bates, 2007, Furlow *et al.*, 1997, Luxen & Buunk, 2006, Prokosch *et al.*, 2005, Rahman *et al.*, 2004, Thoma *et al.*, 2006, Thoma *et al.*, 2005). The association of FA to this constellation of reproductive, health, and cognitive traits is of particular interest because each of them in turn predicts longevity (Deary, 2008).
- FA, then, is a potentially valuable tool for understanding otherwise difficult-to-assess characteristics that are predictive of important outcomes such as successful aging. Bodily FA has not, however, previously been reported in the realm of aging. Here we extend the concept to life-span development and successful cognitive aging. We focus on FA as a measure of the precision of development in early life, and next derive a series of predictions form this model, to be tested here.

Hypotheses

- If FA measured late in life is as strongly associated with intelligence in childhood as it is with contemporaneous cognitive ability, this would suggest that successful cognitive aging is in part due to to success in early life, in particular the precision with which early development is accomplished by adolescence.
- This in turn would suggest importantly that significant improvements in aging would be dependent on improved early development (Barker, 2007, Marmot, 2010).
- Alternative hypotheses
- Aging is largely a product of
  - Stochastic insults accumulated across the life-span (Seeman *et al.*, 2010)
  - Effects such as *APOE- ε* 4 which are much more apparent in old age (Deary *et al.*, 2002, Kirkwood & Holliday, 1979, Schmechel *et al.*, 1993)
  - Prediction: FA measured in late life associated with late-life cognition, but not age 11 cognition.
- Finally, if bodily state bears either no relationship to cognition, then FA should be unrelated to cognition at any age.