Risk taking and the dopamine receptor gene DRD4

Anna Dreber Almenberg
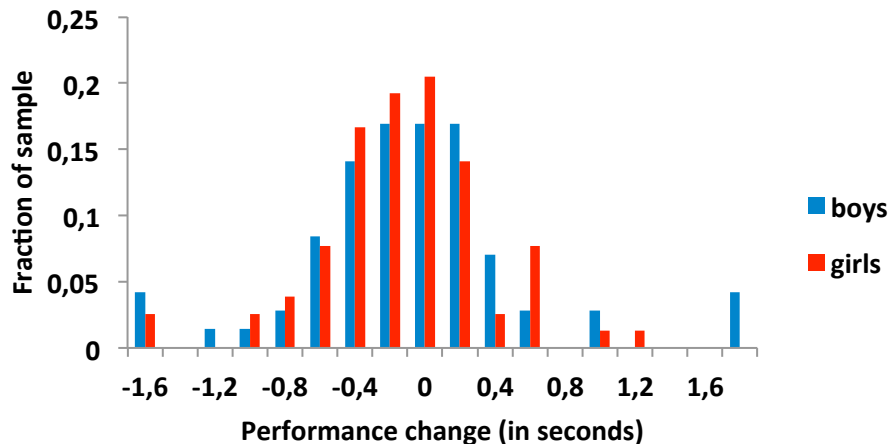
Stockholm School of Economics

Why biology in economics?

- Individuals differ in preferences/economic behavior

  – Cultural variables clearly important: cooperation, trust, competitiveness, risk taking, etc
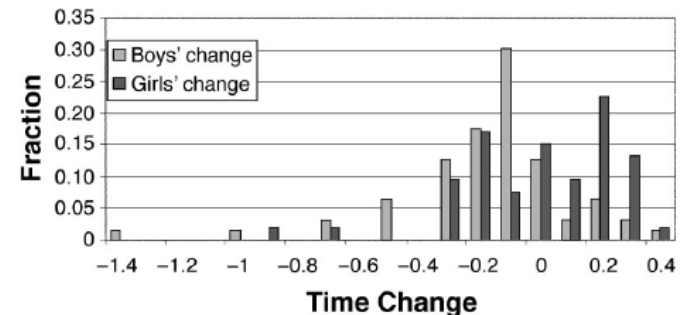
Sweden   *Israel*

FIGURE 3. DISTRIBUTION OF CHANGE IN RUNNING TIMES
(TIME IN ROUND 2 MINUS TIME IN ROUND 1)
IN THE COMPETITION TREATMENT

Gneezy and Rustichini 2004, Dreber, von Essen and Ranehill 2011

- Biological variables might also help us explain and understand some of this individual variation
  - Hormones
  - Genetics

Outline

- Genetic factors
- DRD4
  - Risk preferences
- Other genes
  - Risk preferences
- New work
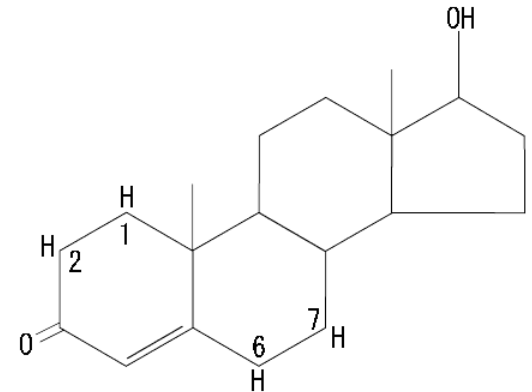
Genetic factors – Twin studies

- Compare correlation in behavior between genetically identical twins (monozygotic) with fraternal (dizygotic) twins brought up together
  - Higher correlation in behavior in identical than fraternal – evidence of behavior having genetic component

- Risk preferences are partly genetic
  - Risk preferences measured from lab and field data

Calvet and Sodini 2009, Cesarini et al. 2009, Zhong et al. 2009, Barnea et al. 2010, Cesarini et al. 2010

Twin studies say nothing about specific genes…

- Molecular genetics / studies on specific genes give us insight into what is driving the risk-related behavior
  - What happens when receptors are affected by e.g., Ritalin, cocaine or L-DOPA

Basic genetics terminology

- What is a gene?
  - A gene is a piece of DNA. Each gene codes for a protein, and the proteins are the functional units of the cells of the body
- What is a neurotransmitter?
  - A protein used for signalling between neurons in the brain
    - E.g., dopamine and serotonin
- Basic idea of the brain: neurons passing information back and forth to each other
  - Neurotransmitters and their receptors modulate how that information is passed on
- Affecting neurotransmitters or receptors can dramatically alter behavior
  - E.g., prozac, heroin, cocaine

Dopamine receptor gene *DRD4*

- Many genes have different versions ("alleles")
  - Explains some individual differences (e.g., eye colour)
- *DRD4* alleles come in 2-11 repeats
- 2 classes of the gene: 4R and 7R
  - 4R is the common version
  - 7R is less common and evolutionary novel
    - 40k old: 5-10-fold younger than 4R
    - Recent increase – more than expected by random drift
      - Favored by natural selection
      - Frequency dependent?

Ding et al. 2002, Wang et al. 2004

7R

- Activation of dopaminergic pathways make you feel good
  - Dopamine system is reward system
- 7R associated with decreased sensitivity to dopamine
  - Binds less dopamine molecules than 4R class
- Blunted response to dopamine molecules make the neurons using the 7R receptor need increased amount of dopamine in order to function "normally"/activate dopaminergic pathways

So…

- Polymorphisms in *DRD4* may contribute to individual differences in personality and behavioral traits that are associated with the production of dopamine

Behaviors positively related to 7R

- ADHD
  - Most robust association
- Substance abuse
- Novelty seeking
- Migration
  - Out of Africa and contemporary
    - Populations who migrated farther in the past 30k-1k years ago have higher frequency of 7R class
- Pathological gambling
- Impulsivity

Chen et al. 1999, Eisenberg et al. 2007, Laucht et al. 2007, Li et al. 2006, Munafo et al. 2008

Our first study

- 98 young men aged 18-23
- Risk task
- DNA sample
  - We classify individuals as 7R+ if they have at least one 7R
- Competitiveness task
- Salivary testosterone
- Photos of faces – testosterone exposure in puberty
- 2D:4D – testosterone exposure in utero (?)
- Anthropometric data
- Questionnaire

Dreber, Apicella, Eisenberg, Garcia, Zamore, Lum & Campbell 2009

Risk task

- Adapted from Gneezy and Potters (1997)/Charness and Gneezy (2010)
- You "get" $250 on your balance
- Choose **X** 0-250 to invest in a risky investment
- Remainder $250-X is kept on balance
- A coin flip determines the outcome of the risky investment
  - probability of success is 0.5
- If failure: X lost, you have $250-X
- If successful: X is given back and multiplied by 2.5, you have $250+1.5X
  - In the end, one participant actually gets what remains on balance after choice and outcome of investment
- X is our measure of risk-taking

# 7R men take more risk than other men
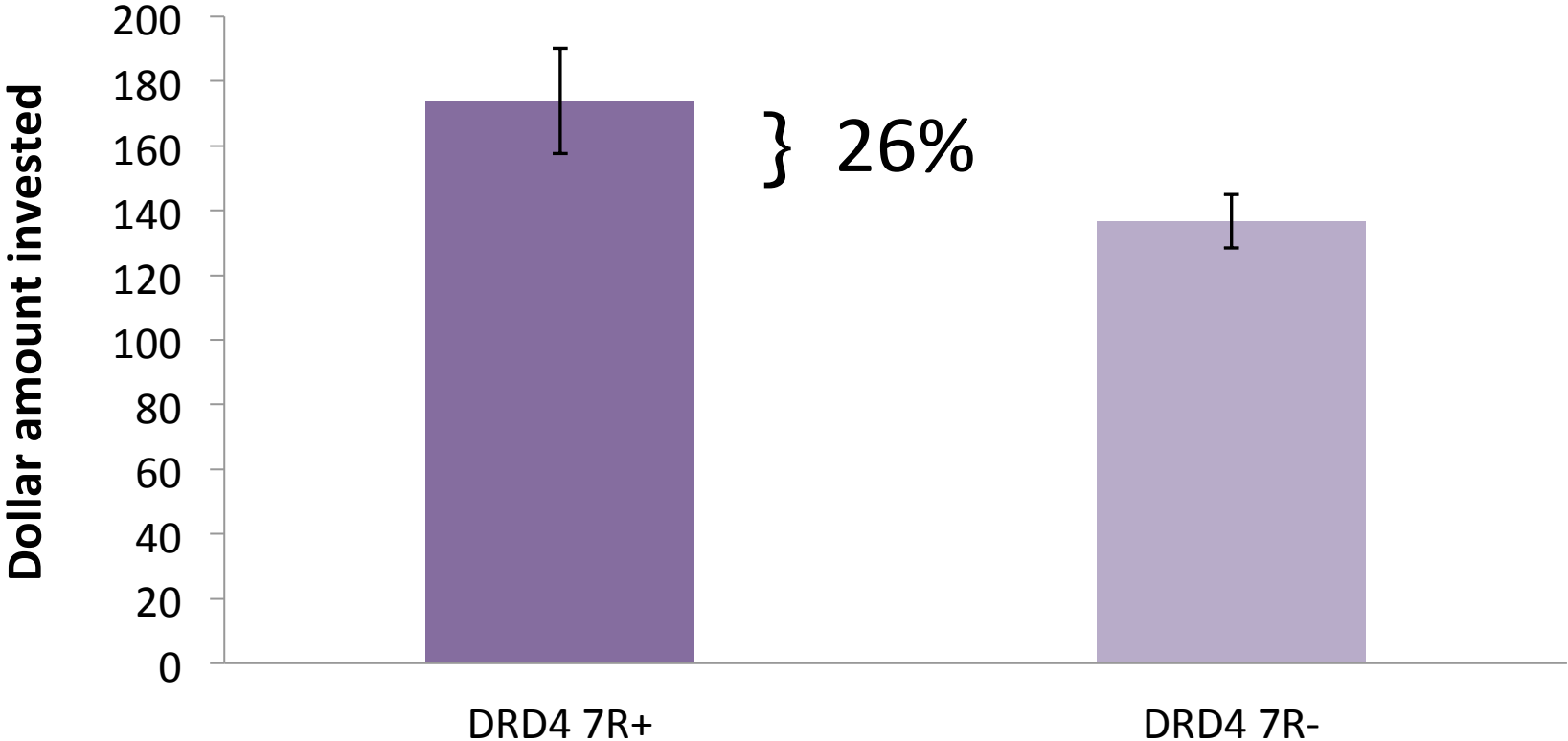
Controlling for testosterone (T)

- In Apicella et al. (2008) we find a positive relationship between T and risk taking
- So we also want to control for T in the analysis
  - We have 3 (?) measures of T exposure

Apicella, Dreber, Campbell, Gray, Hoffman & Little 2008

Circulating testosterone

- Current level of testosterone
- Measure T from saliva sample
  - Taken when participants enter the lab, in order to get the baseline level
    - We use passive drooling
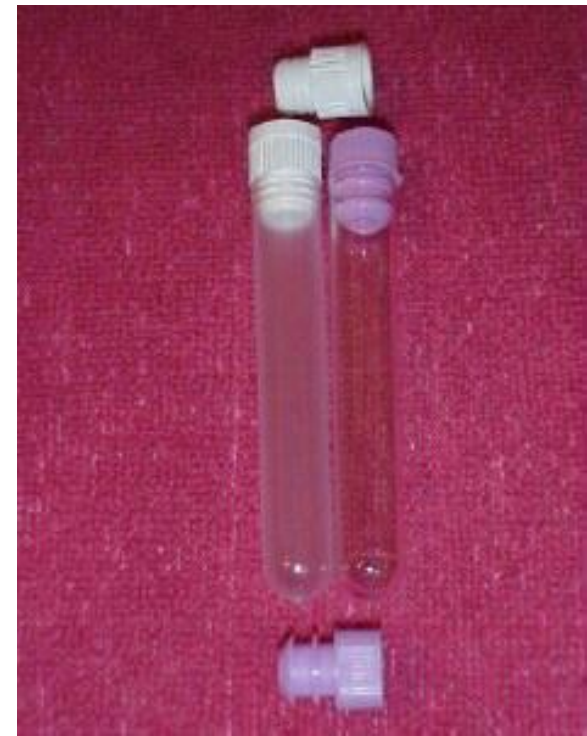
Facial masculinity

- Testosterone during puberty affects cranofacial bone growth

- 4 measurements are typically taken from sexually dimorphic points in the face

- Taken from photos, measured with software

Linked to pubertal testosterone exposure – organizational effects on the brain?

Johnston et al. 2001, Little et al. 2008, Penton-Voak et al. 2001

2D:4D (finger lengths)

2D:4D is the ratio between the length of the 2nd (index) finger/ digit and the 4th (ring) finger/digit – you simply measure the fingers

Lower ratio = more prenatal T exposure(?)

Men have lower 2D:4D
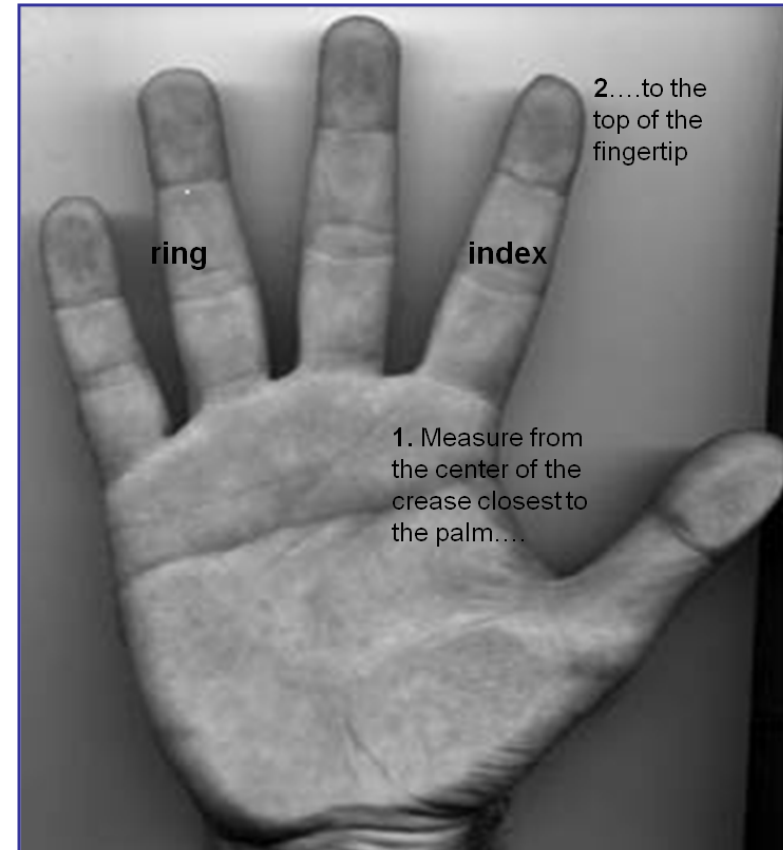
Thought to be a proxy of prenatal T exposure (???)

Manning et al. 1998

Regression table 7R

	(1)	(2)	(3)
	risk		
7R	39.087	42.258	38.840
	(2.23)*	(2.57)*	(2.53)*
Sexual orientation		-79.923	-93.065
		(4.51)**	(4.53)**
Testosterone			0.464
			(2.39)*
Facial masculinity			9.216
			(2.83)**
Constant	135.814	142.850	99.895
	(16.21)**	(16.54)**	(4.61)**
Observations	94	92	90
R-squared	0.05	0.14	0.26
Robust t statistics in parentheses			
* significant at 5%; ** significant at 1%			

A young man with…

- a T level one std deviation > mean invested 12% more than a man with average T levels

- masculinized facial features one std deviation > mean invested 6% more than a man with average masculinity features

- 7R invested 26% more than a man without 7R

- Nothing on 2D:4D

Explaining 7R and economic risk

- 7R needs higher levels of dopamine for it to produce a response of similar magnitude as that of 4R version
  - This leads to behaviors that increase dopamine levels
  - Economic risk taking might be one of them

Our second study on DRD4

- Fall 2008 North American Bridge Championship in Boston, MA

- 237 participants
  - Men and women

- DNA sample for DRD4
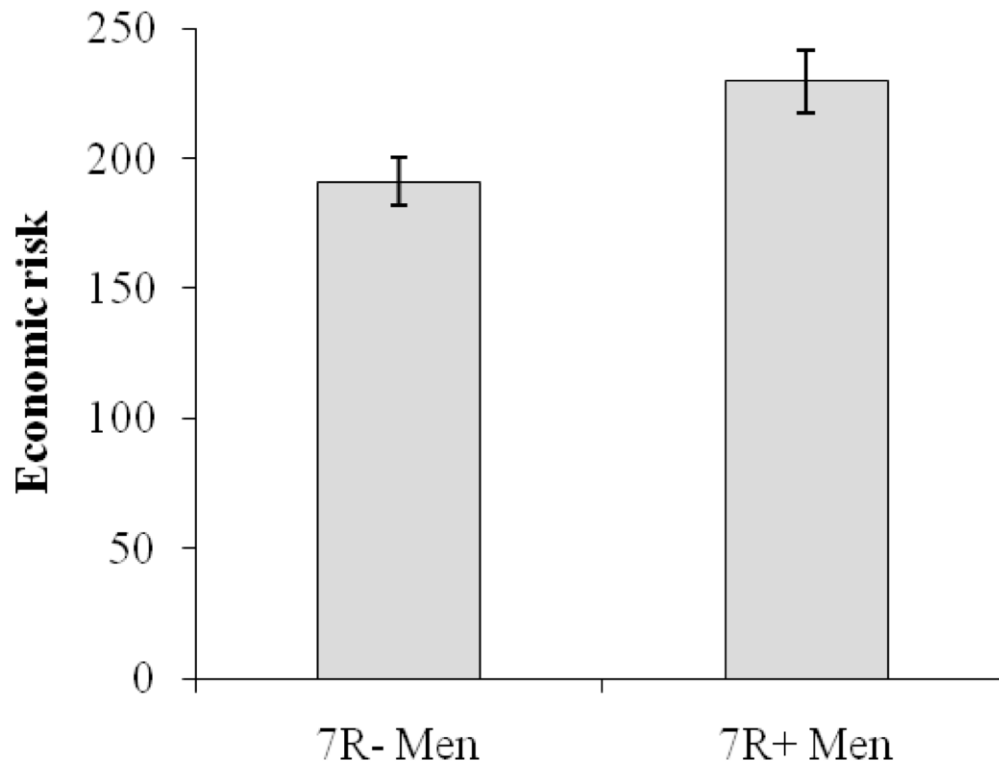 - DNA extracted for 175 men and women

Dreber, Rand, Wernerfelt, Garcia, Vilar, Lum & Zeckhauser 2011

Background info

- Subjects aged 30 to >90
- 98 men, 16 with 7R (16.3%)
- 77 women, only 6 with 7R (7.8%)
  - Frequencies significantly different

Economic risk and 7R+

- Only effect in men, no effect in women
  - Why no effect in women?

Our third study on DRD4

- 135 OPM students at HBS
  - Mainly men
- Same economic risk measure as before
- Social risk taking: Trust game
  - Player 1 and 2
- DNA sample

Dreber, Rand, Wernerfelt, Montgomery and Malhotra 2011

3 genes

- DRD4
- Arginine vasopressin 1a receptor gene (AVPR1a)
- Monoamine Oxidase A gene (MAOA)

Arginine vasopressin 1a receptor (AVPR1a)

- Neurotransmitter vasopressin linked to social behavior in several species
  - Vole example: Two closely related vole species where one species is asocial, promiscuous, and does not form close pair bonds and other species is the opposite. Males differ in their neuroanatomical distributions of vasopressin 1a receptors.

  - Humans:
    - Long repeat version assosicated with increased socability (e.g. higher donations in DG), strength of pair-bonding

Bielsky et al. 2004, Donaldson and Young 2008, Knafo et al. 2008

Monoamine Oxidase A Gene (MAOA)

- Low vs. high activity (MAOA-L vs. MAOA-H)
- L-genotype associated with more aggressive behavior
- Risk taking:
  - H-genotype positively associated with longshot risk taking
    - Ranking a 1% chance of receiving Y200 and 0 otherwise over a 10% chance of receiving Y20 and 0 otherwise over 2 for sure
  - L-genotype positively associated with advantageous risk taking
  - L-genotype positively related to credit card debt

Zhong et al. 2009, De Neve and Fowler 2010, Frydman et al. 2010

Tests

- 3 outcome variables: risk, trust p1, trust p2
- 3 genes
- Need for Bonferroni correction for multiple testing

Priors

- 7R+ individuals more economically risk taking, perhaps more socially risk taking

- Long repeat AVPR1a individuals send more in TG as P1 and P2

- MAOA-L individuals more economically risk taking, send less in TG as P1 and P2

Results

- Nothing on economic risk taking!
- Only one significant result after Bonferroni correction:
- 7R+ men send *less* as P1 in trust game
  - Nothing on MAOA or AVPR1

Total of 7 papers on *DRD4* and economic risk taking now

- 3 studies find similar result
- Opposite in 1
  - But also looks at ambiguity and loss aversion and finds that 7R individuals are more risk taking in these domains
- No result in 3
  - But one study finds an effect of L-DOPA only on 7R+ men
- More studies needed!
  - With similar measures?

Dreber et al. 2009, Kuhnen & Chiao 2009, Eisenegger et al. 2010, Frydman et al. 2010, Carpenter et al. 2011, Dreber et al. 2011a, Dreber et al. 2011b

In sum

- Twin studies suggest genetic component of risk taking
- Identifying genes is tricky
- Replication studies, GWAS studies – more studies needed

- Gene-environment interactions, epigenetics

Genomic imprinting

- Not only the case of having a gene or not – it can also matter from which parent you got the gene
  - Number of diseases that differ whether you got gene from mother or father (e.g. Angelman syndrome & Prader-Willi syndrome)
- Father's X always shows up in daughter
  - Traits that are adaptive for women should be on the father's X

Turner's syndrome

- Women that lack an X chromosome
  - Can be mother's or father's
- Happens in 1/3000 girls
- Women with X from father have been found to be more social
- Our study:
- Compare risk aversion, competitiveness and altruism between two groups of Turner women
  - Econ behaviors with most robust gender diff
  - We can genotype mother and daughter

THANKS!