Using pooled data to estimate genetic parameters for social interaction traits

Katrijn Peeters, Esther Ellen and Piter Bijma

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Pooling phenotypic data

Collecting individual data
in group housing systems

Expensive *Difficult*

Pooling data

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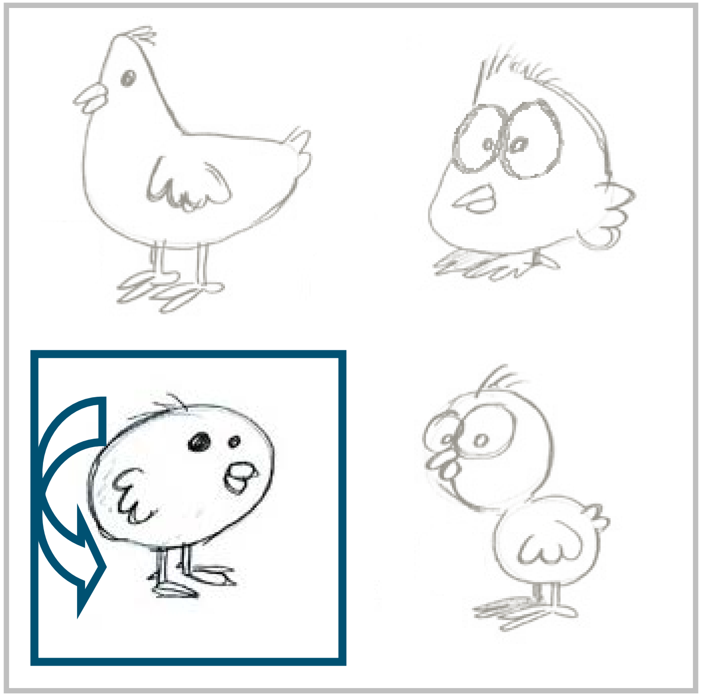
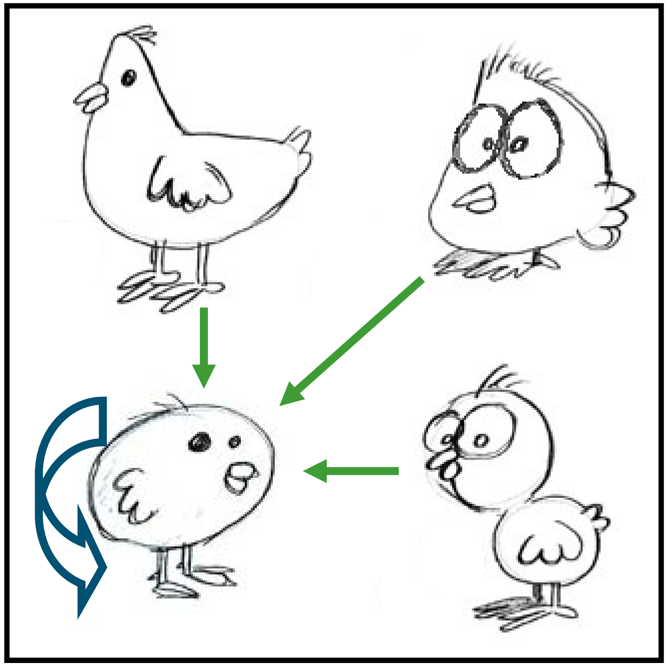
Social interaction theory



Direct

$$P_i = A_{D_i} + E_{D_i}$$

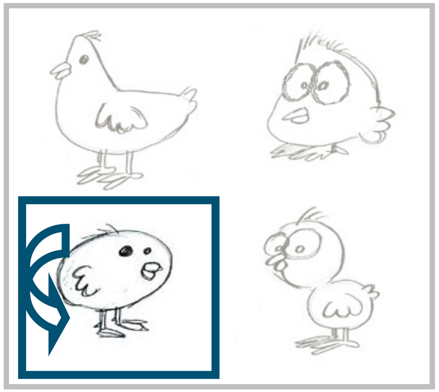
Social interactions theory



Direct | **Social**

$$P_i = A_{D_i} + E_{D_i} + \sum_{i \neq j}^{n-1} A_{S_j} + \sum_{i \neq j}^{n-1} E_{S_j}$$

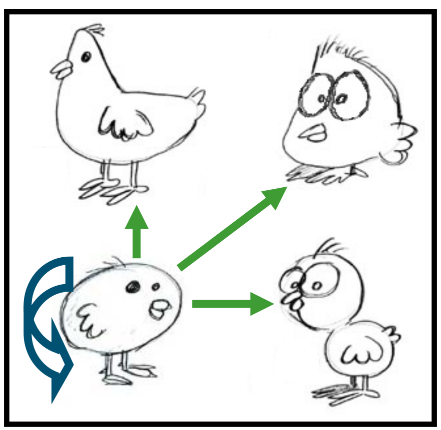
Direct model ⇔ Direct-Social model



Direct

$$A_D$$

$$\sigma^2_{A_D}$$

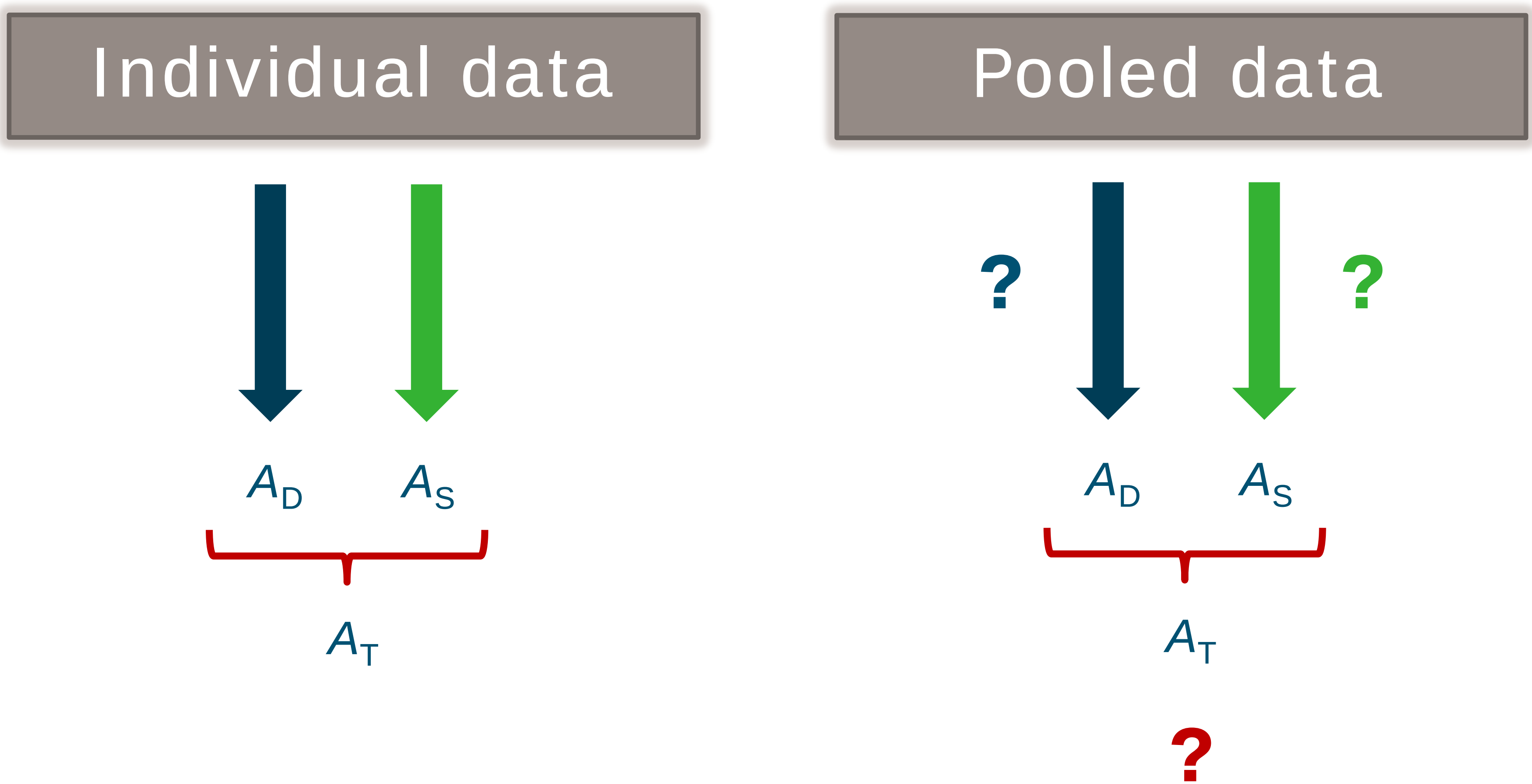


Direct-indirect

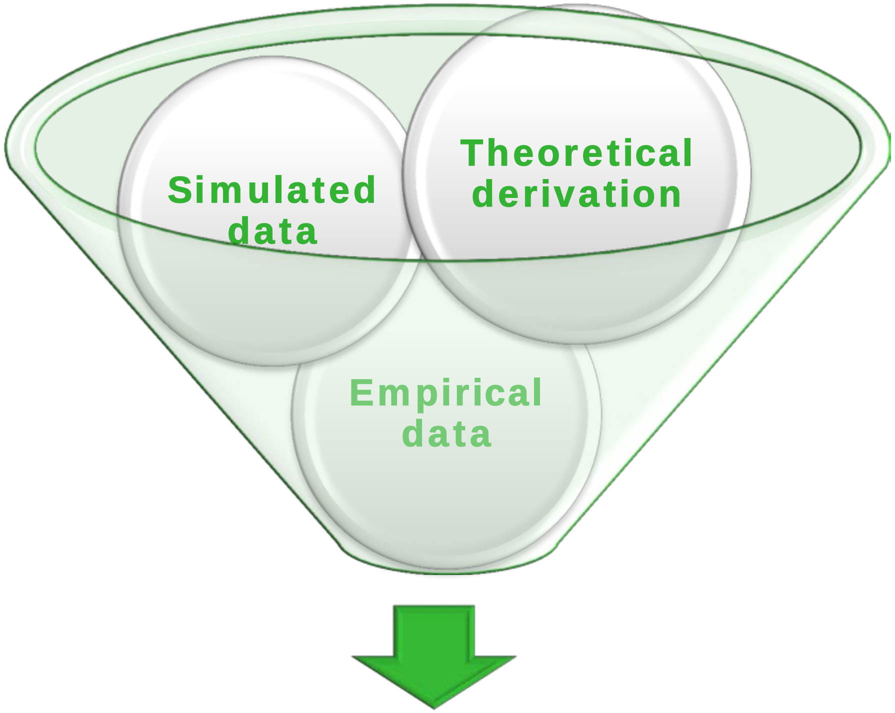
$$A_T = A_D + 3A_S$$

$$\sigma^2_{A_T} = \sigma^2_{A_D} + 6\sigma_{A_{DS}} + 9\sigma^2_{A_S}$$

Aim: what can we estimate?



Three Methods

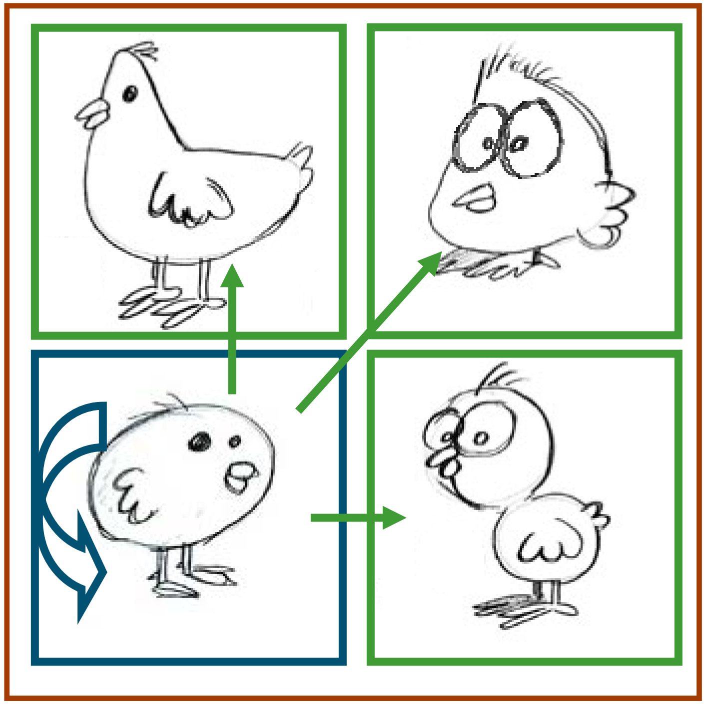


Can we estimate

direct and social genetic parameters

from pooled data?

1. Theoretical derivation: Individual data



$$P_1 = \mathbf{A_{D1}} + A_{S2} + A_{S3} + A_{S4} + E$$

$$P_2 = A_{D2} + \mathbf{A_{S1}} + A_{S3} + A_{S4} + E$$

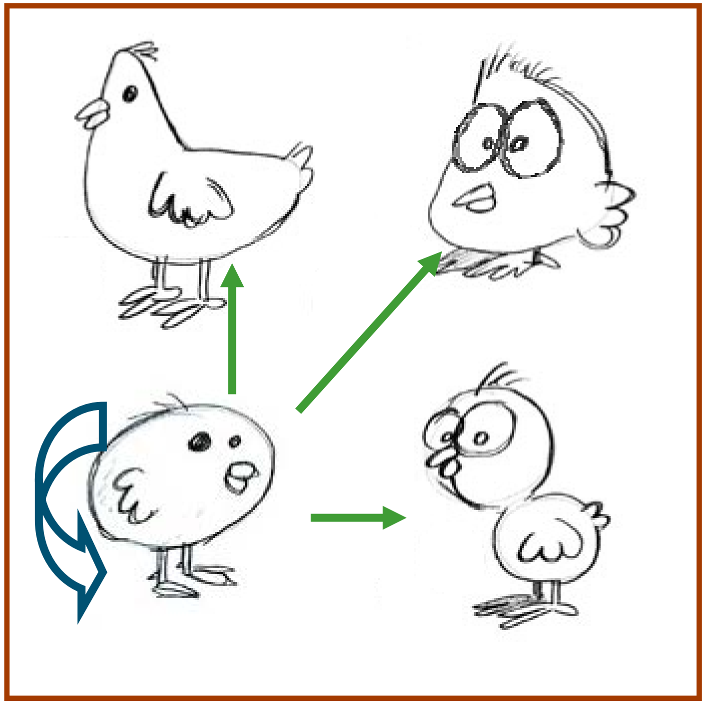
$$P_3 = A_{D3} + \mathbf{A_{S1}} + A_{S2} + A_{S4} + E$$

$$P_4 = A_{D4} + \mathbf{A_{S1}} + A_{S2} + A_{S3} + E$$

Information on A_D and A_S is obtained from different phenotypes ($P_1 \neq P_{2/3/4}$)

Both A_D and A_S are estimable

1. Theoretical derivation: Pooled data (P*)



$$P^* = \boldsymbol{A_{D1}} + A_{D2} + A_{D3} + A_{D4} + 3(\boldsymbol{A_{S1}} + A_{S2} + A_{S3} + A_{S4}) + E$$

An individual's A_D and its full A_S is always lumped into a single record (P^*)

➔ A_D and A_S are fully confounded

$$P^* = \boldsymbol{A_{T1}} + A_{T2} + A_{T3} + A_{T4} + E$$

➔ A_T can be estimated

➔ **y** = **Xb** + Σ**Za** + **e** will estimate A_T

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2. Simulated data

- 500 Sires, 500 Dams, 12 offspring per mating
- 12,000 individuals
- Direct and Social effects
- 3,000 groups of 4 individuals each
- Record = pooled phenotype per group

2. Simulated data

- Input

$\sigma^2_{A_D} = 1;\ \sigma^2_{A_S} = 1;\ \sigma_{A_{DS}} = 0.5$
$\sigma^2_{E_D} = 2;\ \sigma^2_{E_S} = 2;\ \sigma_{E_{DS}} = 0$

- Pooled data model (ASReml)

$\mathbf{y} = \mathbf{Xb} + \Sigma\mathbf{Za} + \mathbf{e}$

$\mathrm{y} \sim \mathrm{mu}\ \ \mathrm{FIXED}\ \ !\mathrm{r}\ \ A_1\ \mathrm{and}(A_2)\ \mathrm{and}(A_3)\ \mathrm{and}(A_4)$

- Expected values ⇔ obtained values (100 replicates)

$\sigma^2_{A_T} = \sigma^2_{A_D} + 6\,\sigma_{A_{DS}} + 9\,\sigma^2_{A_S} = 13 \quad \Leftrightarrow \quad \hat{\sigma}^2_A = 13.05\ (\pm 2.12)$
$\sigma^2_{E^*} = 4\left(\sigma^2_{E_D} + 6\,\sigma_{E_{DS}} + 9\,\sigma^2_{E_S}\right) = 80 \quad \Leftrightarrow \quad \hat{\sigma}^2_E = 80.32\ (\pm 7.30)$

Note: $\hat{\sigma}^2_A \neq \hat{\sigma}^2_{A_D}$ but $\hat{\sigma}^2_A = \hat{\sigma}^2_{A_T}$

3. Empirical data: cannibalistic laying hens

- 12,944 Laying hens → 6,092 W1 / 6,852 WB

- Individual survival time:

$$y \sim mu \;\; FIXED \;\; !r \;\; A_{D1} \;\; A_{I2} \; and(A_{I3}) \; and(A_{I4}) \;\; Cage$$

- Group survival time (pooled per cage):

$$y \sim mu \;\; FIXED \;\; !r \;\; A_{T1} \; and(A_{T2}) \; and(A_{T3}) \; and(A_{T4})$$

3. Empirical data

Individual data

Pooled data

	W1	WB
$\sigma^2_{A_D}$	705 (±171)	1,404 (±301)
$\sigma_{A_{DS}}$	59 (±61)	-162 (±105)
$\sigma^2_{A_S}$	104 (±41)	292 (±72)
σ^2_{Cage}	799 (±166)	1,191 (±238)
σ^2_{E}	7,980 (±210)	12,675 (±365)

$$\sigma^2_{A_D} + 6\,\sigma_{A_{DS}} + 9\,\sigma^2_{A_S} = \sigma^2_{A_T}$$

$$16\,\sigma^2_{Cage} + 4\sigma^2_E = \sigma^2_{E^*}$$

3. Empirical data

Individual data		
	W1	**WB**
$\sigma^2_{A_T}$	1,996 (±640)	2,521 (±842)
$\sigma^2_{E^*}$	44,700 (±2,526)	69,752 (±3,513)

Pooled data		
	W1	**WB**
$\sigma^2_{A_T}$	1,979 (±643)	2,521 (±845)
$\sigma^2_{E^*}$	44,750 (±2,538)	69,750 (±3,519)

Indeed: analysis of pooled records yields $\hat{\sigma}^2_{A_T}$ rather than $\hat{\sigma}^2_{A_D}$

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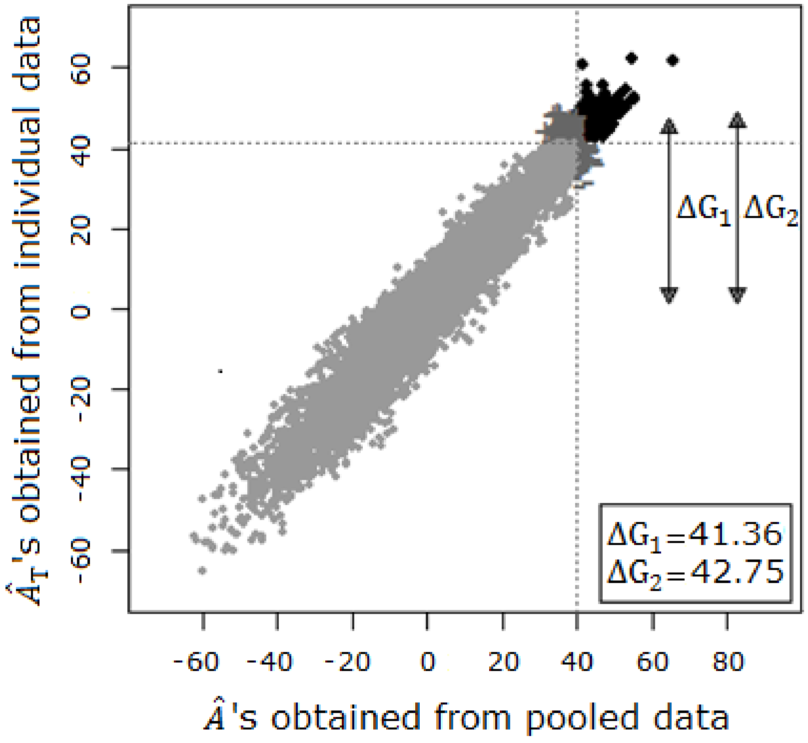
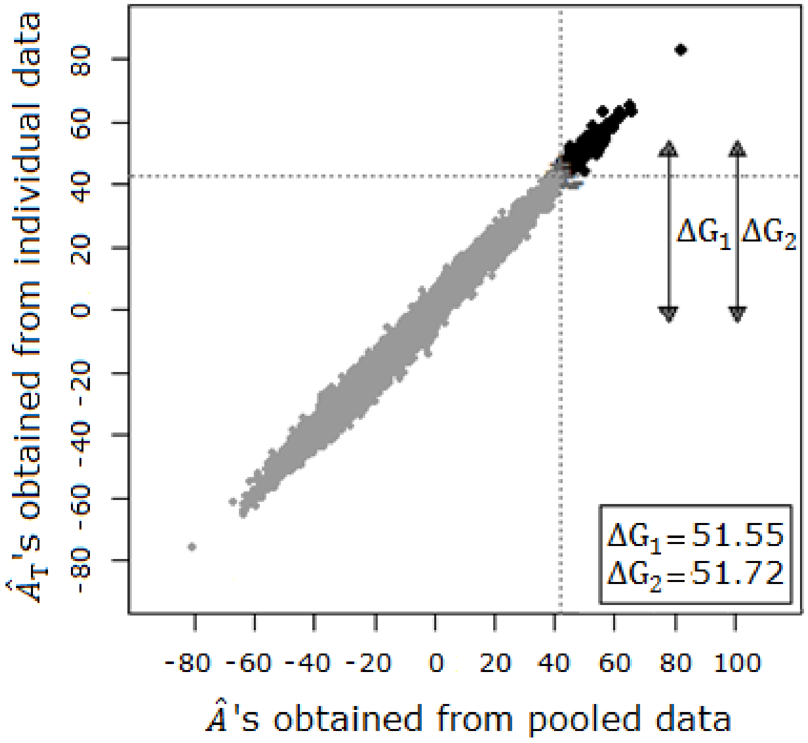
3. Empirical data: The cost of pooling

W1

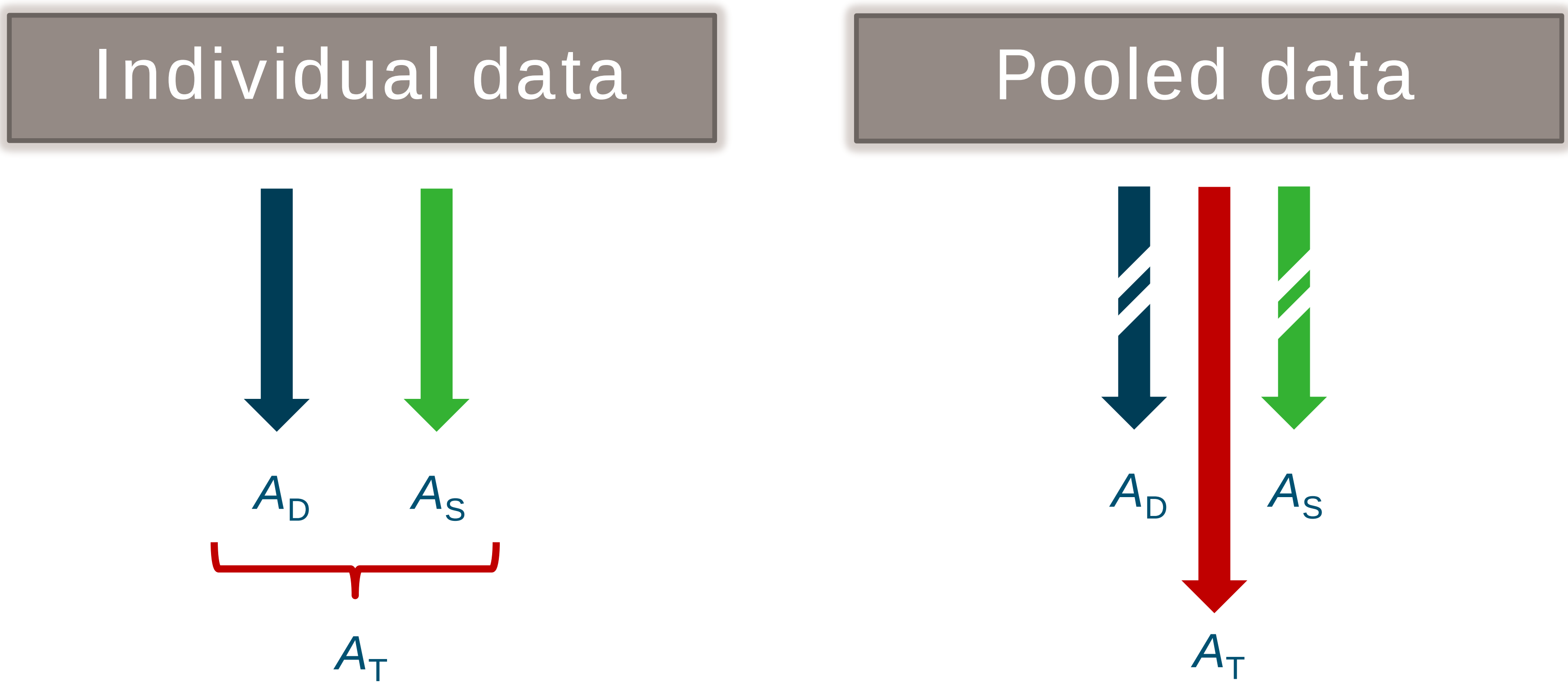


WB



Pooling causes surprisingly little reduction in response to selection for socially-affected traits.

Conclusion



With social interactions,

estimated Var(A) from pooled data will differ from ordinary Var(A).

$$\mathrm{Var}(A)_{pooled} = \mathrm{Var}(A_T)$$

Social interactions

Peeters *et al.*, Genetics Selection Evolution **45**:27

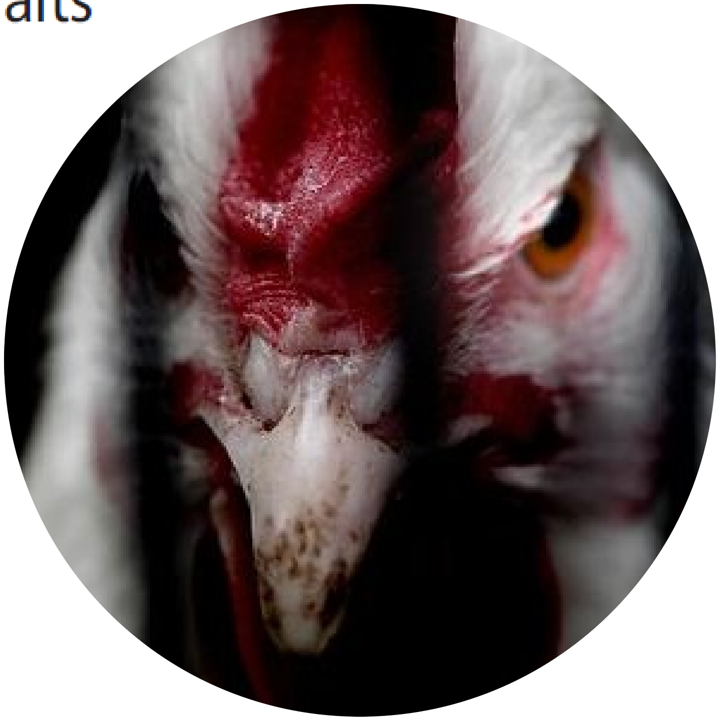
katrijn.peeters@wur.nl

Genetics Selection Evolution

RESEARCH Open Access

Using pooled data to estimate variance components and breeding values for traits affected by social interactions

Katrijn Peeters*, Esther Dorien Ellen and Piter Bijma



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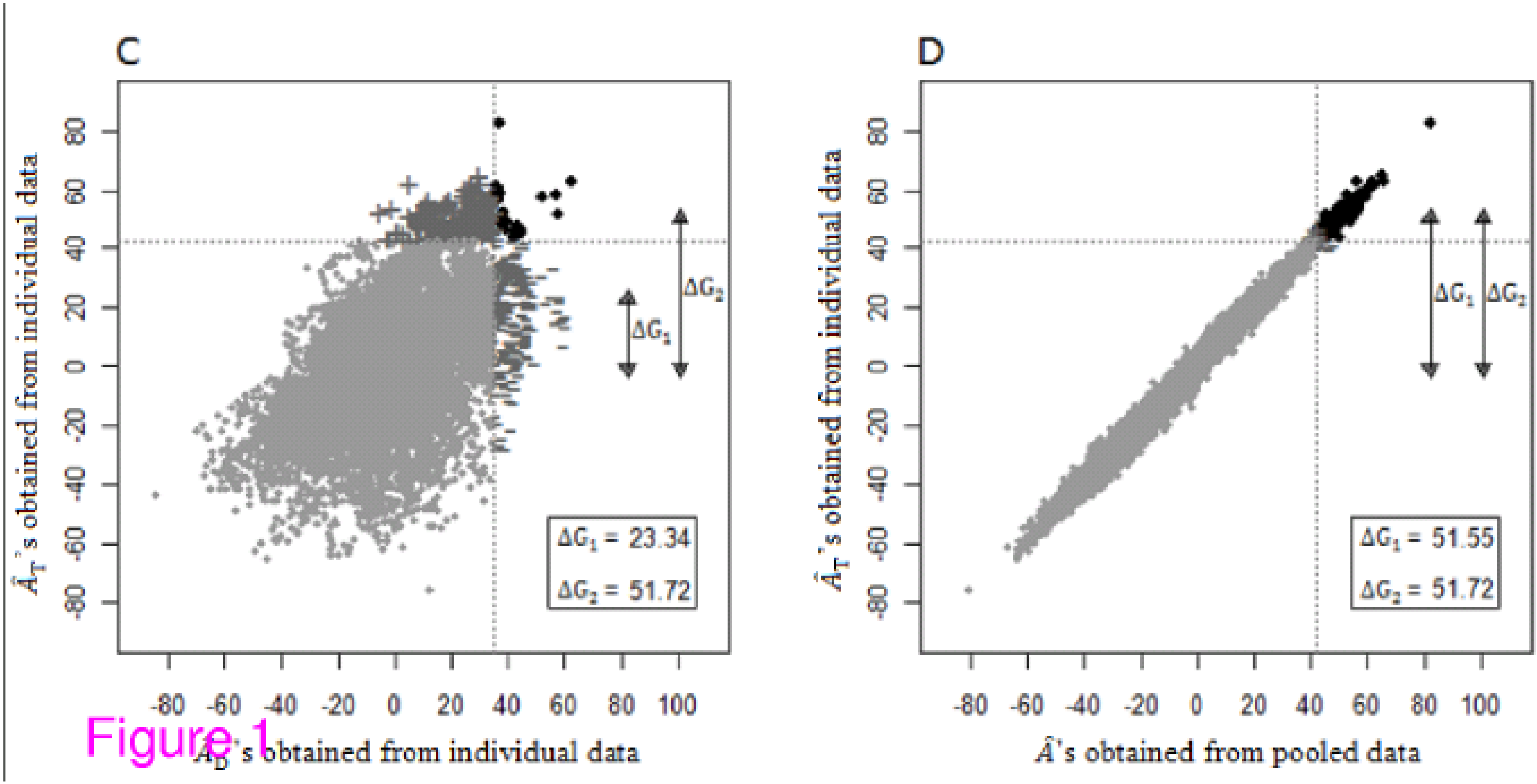
C
D
Â_T's obtained from individual data
Â_D's obtained from individual data
Â's obtained from pooled data
ΔG1
ΔG2
ΔG1 = 23.34
ΔG2 = 51.72
ΔG1 = 51.55
ΔG2 = 51.72

Figure 1