Sex beyond the genitalia: The human brain mosaic

Presented by Ștefan

Little Story

- “The Nothing Box”
- Female brain
- Male brain

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"Your spouse may irritate you until the day you die.....but the good news is, you die."

~ Mark Gungor

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- Hormone Equations

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Women's Hormone Equations

$$\frac{dx_i}{dt} = x_i\{K - D(X - M_1x_i)(X - M_2x_i)\}, \quad i = 1, \ldots, N, \quad \frac{1}{M_1} + \frac{1}{M_2} < 1, \quad X = \sum_{j=1}^{N} x_j.$$

Men's Hormone Equations

$$\lambda(t) = H_{1,2}\left(\oint_{(t-l_{1,1})\vee 0}^{(t-l_{1,1})\vee 0} X_{Te}(r)\,dr, \oint_{(t-l_{2,2})\vee 0}^{(t-l_{2,1})\vee 0} X_G(r)\,dr\right), \quad \oint_{s-l_2}^{s-l_1} X_A(r)\,dr \stackrel{\text{def}}{=} \begin{cases} \dfrac{1}{l_2-l_1}\displaystyle\int_{s-l_2}^{s-l_1} X_A(r)\,dr, & \text{if } l_2 > l_1 \\ X_A(s-l_1), & \text{if } l_2 = l_1 \end{cases},$$

$$p(s \mid T_G^{k-1}, \lambda(\cdot)) = \gamma \times \lambda(s)\left(\int_{T_G^{k-1}}^{s} \lambda(r)\,dr\right)^{\gamma-1} \exp^{-\left(\int_{T_G^{k-1}}^{s}\lambda(r)\,dr\right)^{\gamma}}, \quad T_L^k = \left[\min_j\left\{T_G^j \mid T_G^j \geq T_L^{k-1} + r_L\right\}\right] + \tau_L\,,$$

$$N_G(t) = \sum_{j=1}^{\infty} 1_{\{T_G^j \leq t\}}\,, \quad N_L(t) = \sum_{j=1}^{\infty} 1_{\{T_L^j \leq t\}}\,, \quad S_G(t) = H_3\left(\oint_{(t-l_{3,2})\vee 0}^{(t-l_{3,1})\vee 0} X_{Te}(s)\,ds\right) + \xi_G(t)\,, \quad S_{Te}(t) = H_4\left(\mu(t) \times \oint_{(t-l_{4,2})\vee 0}^{(t-l_{4,1})\vee 0} X_L(s)\,ds\right) + \xi_{Te}(t)\,,$$

$$S_L(t) = H_{5,6}\left(\sum_{j=0}^{N_L(t)} \int_{(T_L^j - l_{5,2})\vee 0}^{(T_L^j - l_{5,1})\vee 0} X_G(s)\,ds \times \Gamma(t - T_L^j), \oint_{(t-l_{6,2})\vee 0}^{(t-l_{6,1})\vee 0} X_{Te}(s)\,ds\right) + \xi_L(t)\,,$$

$$d\xi_i(t) = -\delta_i \xi_i(t) + \tau_i(S_i(t))\,dB_i(t)\,, \quad \xi_i(0) = 0, \quad \delta_i > 0, \quad i = Te, G, L,$$

$$A_G^j = \int_{T_G^{j-1}}^{T_G^j} S_G(t)\,dt\,, \quad A_L^j = \int_{T_L^{j-1}}^{T_j^i} (1 - e^{-\eta(t - T_L^{j-1})}) S_L(t)\,dt\,, \quad M_i^j = \Psi_i(T_i^{j-1}, T_i^j) \times M_i^{j-1} + A_i^j\,, \quad i = G, L,$$

$$Z_G(t)\,dt = [\beta_G + M_G^{N_G(t)} \psi_G(t - T_G^{N_G(t)})]\,dt\,, \quad dX_G(t) = \{-\alpha_G(X_G(t))X_G(t) + Z_G(t)\}\,dt + \sigma_G(X_G(t))\,dW_G(t)\,,$$

$$Z_L(t)\,dt = [\beta_L + M_L^{N_L(t)} \psi_L(t - T_L^{N_L(t)}) + e^{-\eta(t - T_L^{N_L(t)})} + S_L(t)]\,dt\,, \quad dX_L(t) = \{-\alpha_L(X_L(t))X_L(t) + Z_L(t)\}\,dt + \sigma_L(X_L(t))\,dW_L(t)\,,$$

$$Z_{Te}\,dt = [\beta_{Te} + S_{Te}(t)]\,dt\,, \quad dX_{Te}(t) = \{-\alpha_{Te}(X_{Te}(t))X_{Te}(t) + Z_{Te}(t)\}\,dt + \sigma_{Te}(X_{Te}(t))\,dW_{Te}(t)\,.$$

It’s ok to be different

- Racial difference
- Jews
- “Gender equality Paradox”
- Norway
- “The Agenda” argue

Differences between males and females

- In the womb
- Babies and faces
- Puberty
- Hippocampus
- Daphne Joel

Male	Female
- Big brain	- Small brain
- Thin cortex	- Thick cortex
- High proportion white matter	- High proportion grey matter
- Big amygdala	- Small amygdala
- Small hippocampus	- Big hippocampus
...	...
Male brain	Female brain

Motivation

- Social differences
- Stress effects
- Education

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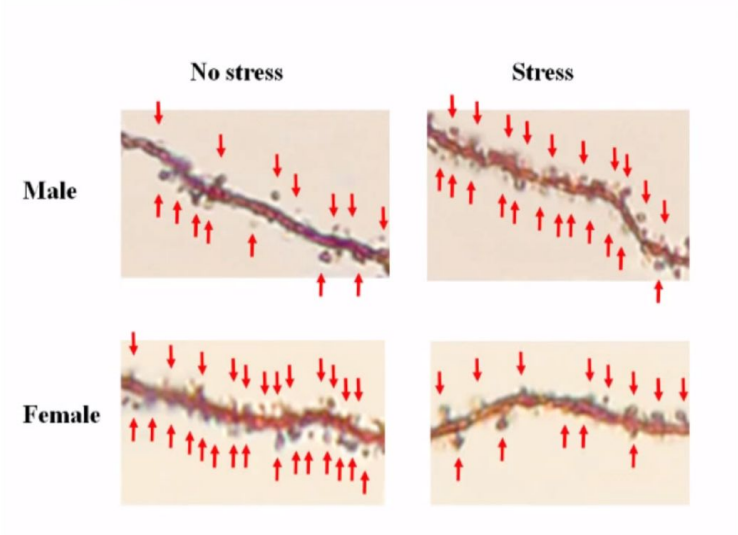

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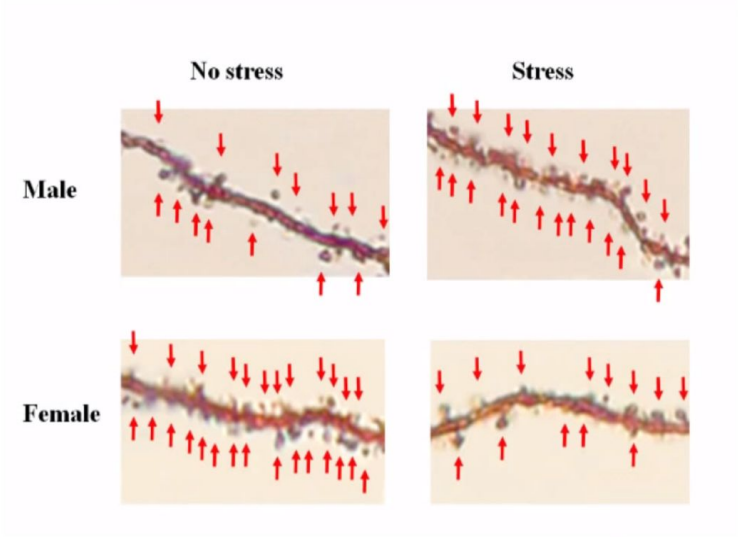
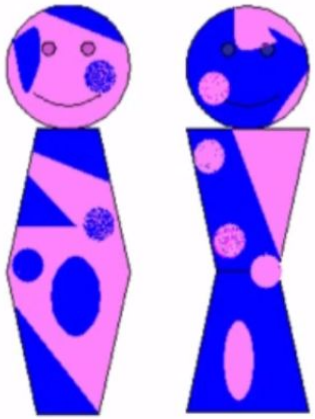
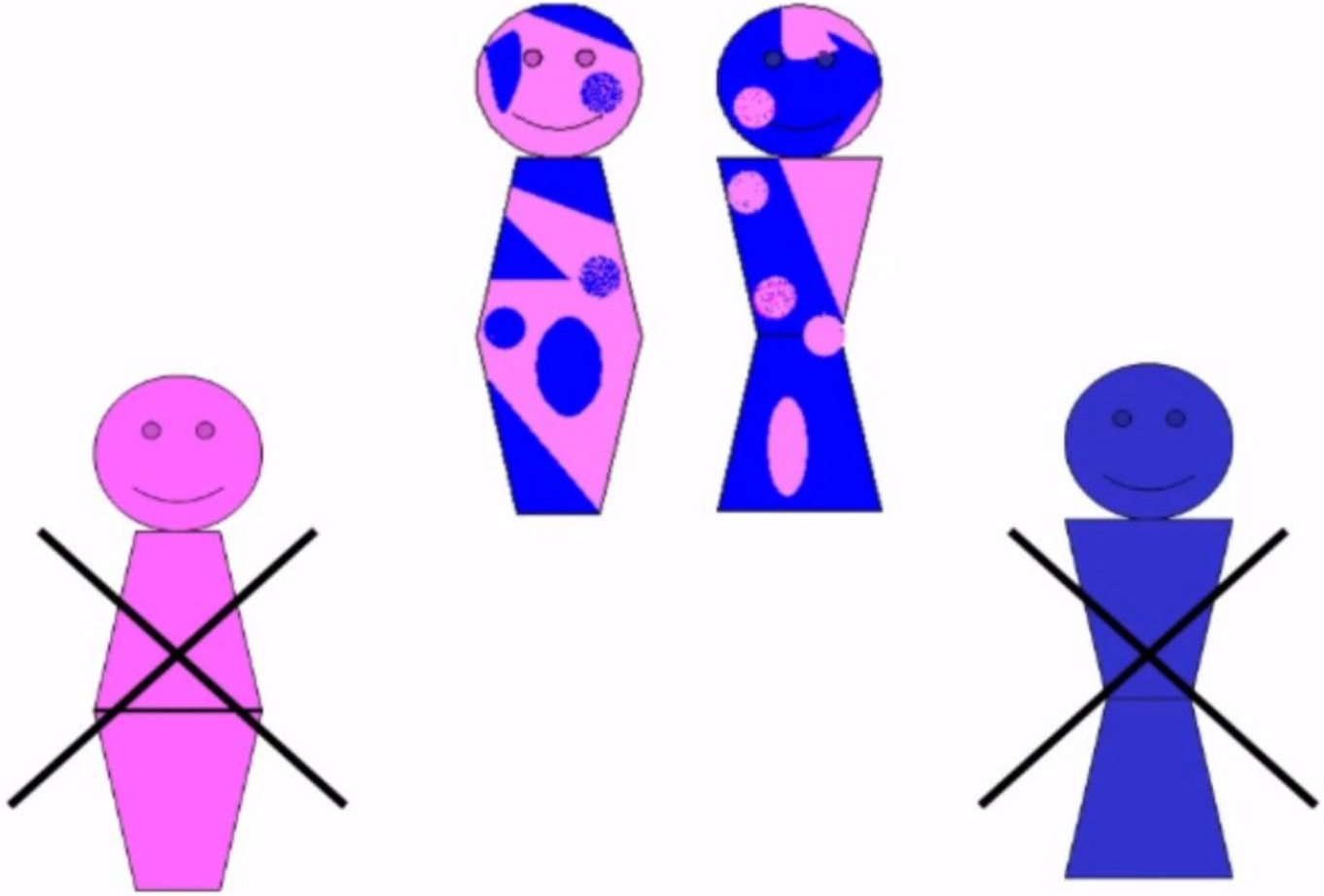




Main Results

- Internal consistency
- Brain Mosaic
- Psychological characteristics
- The gender is not enough
- Impossible to distinguish sex only by MRI brain analysis

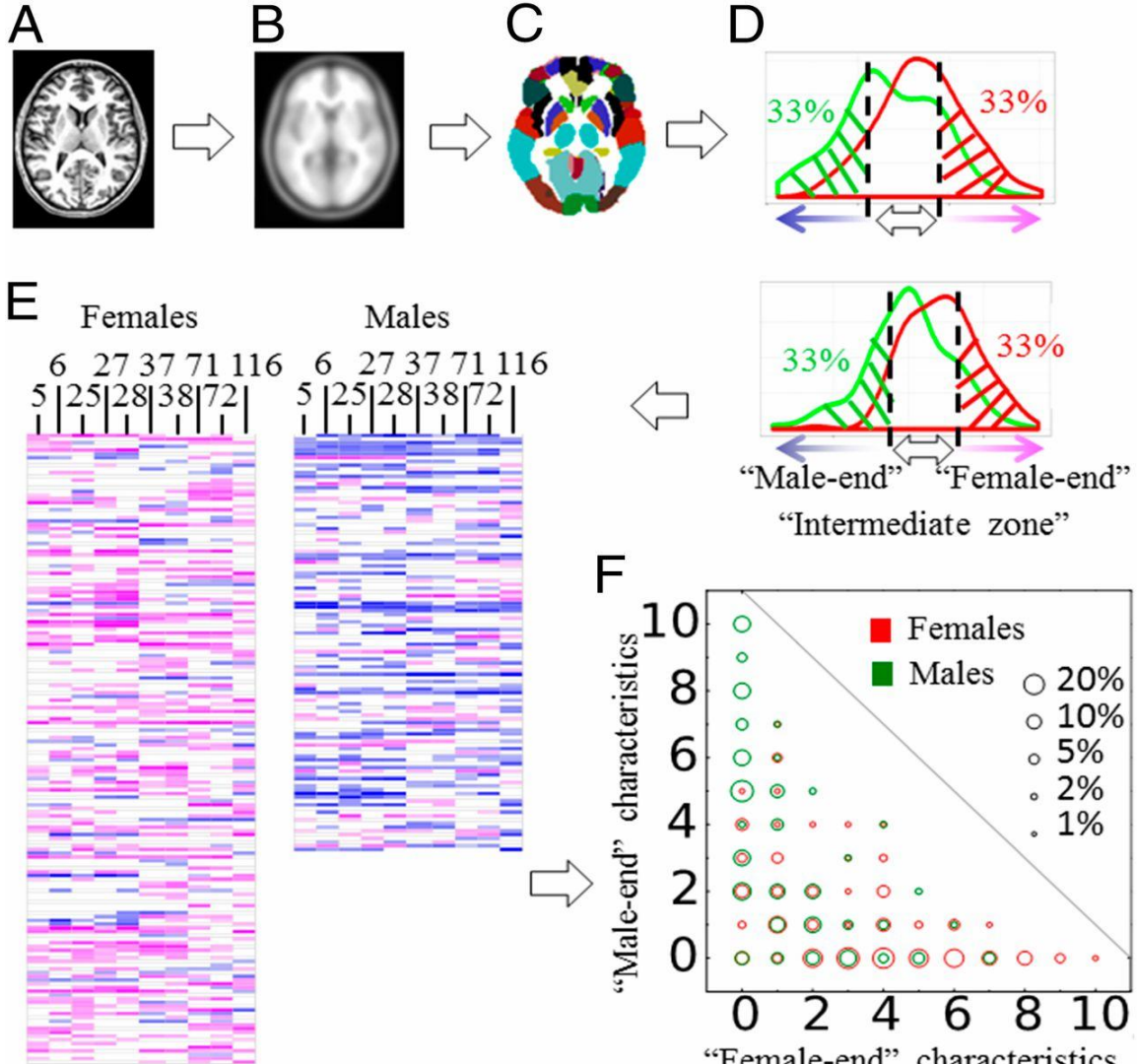


Measured

- White matter
- Grey matter
- Connections assessed
- Cortical thickness
- Corroborated with similar personality study

Table 1. Internal consistency and substantial variability in human brain and behavior

Dataset	Age: range, mean (SD)	Number of characteristics in analysis of internal consistency (number of characteristics assessed for sex/gender differences)	Percent of brains/individuals with substantial variability: both male-end and female-end features	Percent of brains/individuals with internal consistency: only female-end (F), only intermediate (I), or only male-end (M) (all, ♂, ♀)	Average (SD) percent of features at the female-end (F) and male-end (M) zones (♂, ♀) and Cohen's *d* of the sex/gender difference
First sample, VBM	♂: 18–79, 31.5 (12.0) ♀: 18–75 28.9 (10.4)	10 (116) $0.70 < \|d\| \leq 0.84$ all $P < 0.0001$	All: 35% ♂: 35% ♀: 34%	F: 0.4, 0.0, 0.6% I: 3.6, 3.6, 3.6% M: 2.0, 5.0, 0%	F: 13 (17), 33 (25) $d = 0.95$* M: 33 (30), 10 (15) $d = -0.96$*
1000,† VBM	♂: 18–74, 28.8 (14.3) ♀: 18–78, 26.8 (10.4)	10 (116) $0.51 < \|d\| \leq 0.69$ all $P < 0.0001$	All: 39% ♂: 37% ♀: 40%	F: 0.1, 0.0, 0.2% I: 2.3, 3.3, 1.6% M: 2.9, 5.3, 1.2%	F: 15 (19), 33 (25) $d = 0.83$* M: 33 (31), 17 (23) $d = -0.61$*
1000,† VBM 18–26 subsample	♂: 18–26, 21.5 (1.9) ♀: 18–26, 21.5 (2)	9‡ (116) $0.46 < \|d\| \leq 0.60$ all $P < 0.0001$	All: 53% ♂: 47% ♀: 55%	F: 0.3, 0.4, 0.2% I: 1.3, 0.8, 1.6% M: 0.8, 1.2, 0.5%	F: 16 (19), 33 (24) $d = 0.79$* M: 33 (25), 19 (20) $d = -0.62$*
NKI, SBA, cortical thickness	♂: 13–83, 41.0 (20.3) ♀: 12–85, 48.7 (17.4)	7 (68) $0.41 < \|d\| \leq 0.56$ all $P < 0.002$	All: 24% ♂: 21% ♀: 26%	F: 4.5, 2.0, 5.9% I: 2.2, 2.0, 2.4% M: 3.7, 8.0, 1.2%	F: 21 (27), 33 (29) $d = 0.42$* M: 33 (34), 15 (22) $d = -0.64$*
NKI, SBA, volume		12 (168) $0.94 < \|d\| \leq 1.04$ all $P < 0.0001$	All: 23% ♂: 25% ♀: 21%	F: 1.5, 0.0, 2.3% I: 3.3, 2.9, 3.6% M: 0.7, 1.9, 0.0%	F: 9 (16), 33 (27) $d = 1.05$* M: 33 (27), 16 (15) $d = -1.13$*
DTI fractional anisotropy	♂: 17–43, 24.8 (4.6) ♀: 18–57, 26.3 (7.0)	11 (116) $0.73 < \|d\| \leq 1.05$ all $P < 0.0001$	All: 25% ♂: 29% ♀: 20%	F: 2.2, 0.0, 4.3% I: 2.9, 2.9, 2.9% M: 0.7, 1.4, 0.0%	F: 9 (15), 33 (33) $d = 0.93$* M: 33 (29), 12 (20) $d = -0.83$*
DTI connectivity		7 (4,005) $0.66 < \|d\| \leq 0.96$ all $P < 0.00017$§	All: 48% ♂: 52% ♀: 43%	F: 0.0, 0.0, 0.0% I: 0.7, 0.0, 1.4% M: 0.0, 0.0, 0.0%	F: 14 (16), 33 (18) $d = 1.15$* M: 33 (20), 9 (11) $d = -1.53$*
MADICS	♂: 20–23, 21.6 (0.7) ♀: 20–23, 21.3 (0.6)	7 (31) $0.43 < \|d\| \leq 0.77$ all $P < 0.0001$	All: 59% ♂: 64% ♀: 56%	F: 0.0, 0.0, 0.0% I: 1.8, 1.1, 2.1% M: 0.0, 0.0, 0.0%	F: 17 (15), 32 (18) $d = 0.92$* M: 32 (17), 13 (14) $d = -1.23$*
ADD Health	♂: 18–28, 22.4 (1.9) ♀: 18–28, 22.1 (1.9)	8 (26) $0.41 < \|d\| \leq 0.57$ all $P < 0.0001$	All: 70% ♂: 81% ♀: 62%	F: 0.0, 0.0, 0.0% I: 0.1, 0.2, 0.03% M: 0.0, 0.0, 0.0%	F: 27 (16), 45¶ (19) $d = 1.04$* M: 29¶ (17), 13 (13) $d = -1.01$*
Carothers & Reis' data	21.15 (7.68)	10 (10) $1.0 < \|d\| \leq 2.02$ all $P < 0.0001$	All: 55% ♂: 65% ♀: 48%	F: 0.4, 0.0, 0.6% I: 0.4, 0.9, 0.0% M: 0.4, 0.9, 0.0%	F: 11 (11), 48¶ (20) $d = 2.27$* M: 41¶ (17), 8 (10) $d = -2.42$*



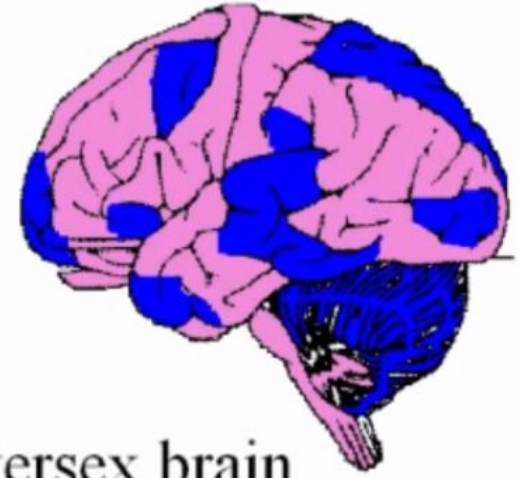
- Left hippocampus
- Left caudate
- 55% of subjects presented variability
- 1.2% showed consistency
- Similar distributions for 8 other regions

Female brain

Male brain

Female brain

Male brain



Intersex brain

Conclusions

- Females can do male jobs
- Medication
- Social categories
- Public debates
- Education

The end!

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