Trauma-like multisystem stress-physiology signatures in young adults with a history of adolescent peer victimization

(Heumann et al. 2025)

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JH, 2025-08-27

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- … resembling diagnostic criteria of post-traumatic stress disorder (PTSD)
- *Is PV a significant social adversity with clinical and societal consequences?*

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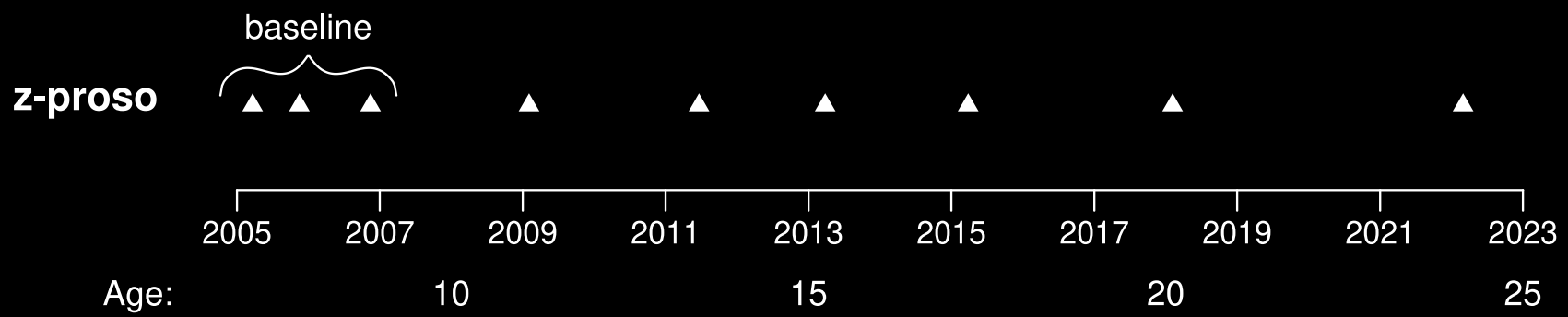

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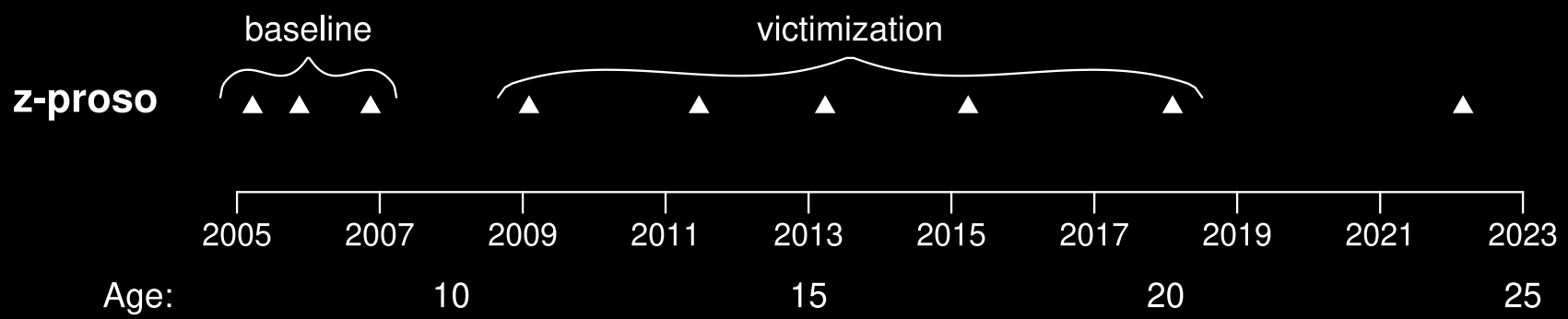

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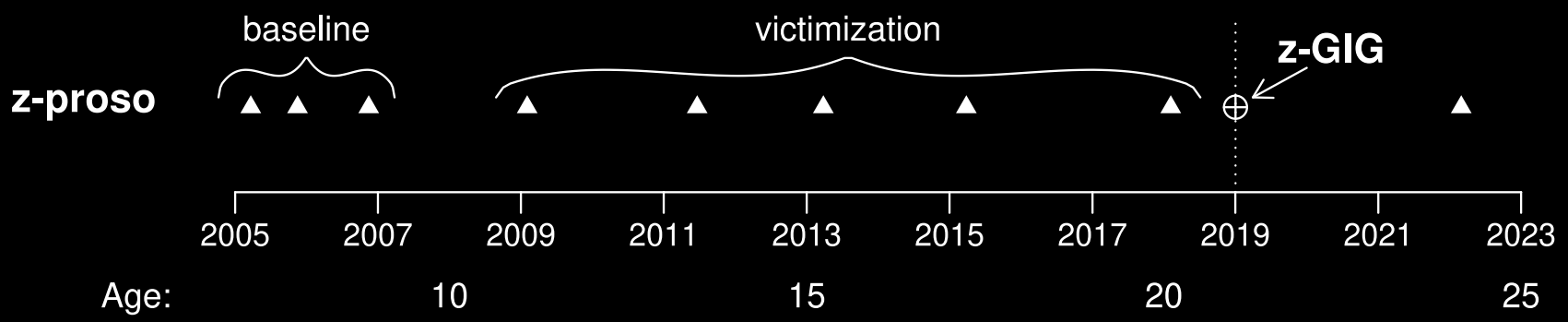

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1.2 Data: z-GIG Outcomes

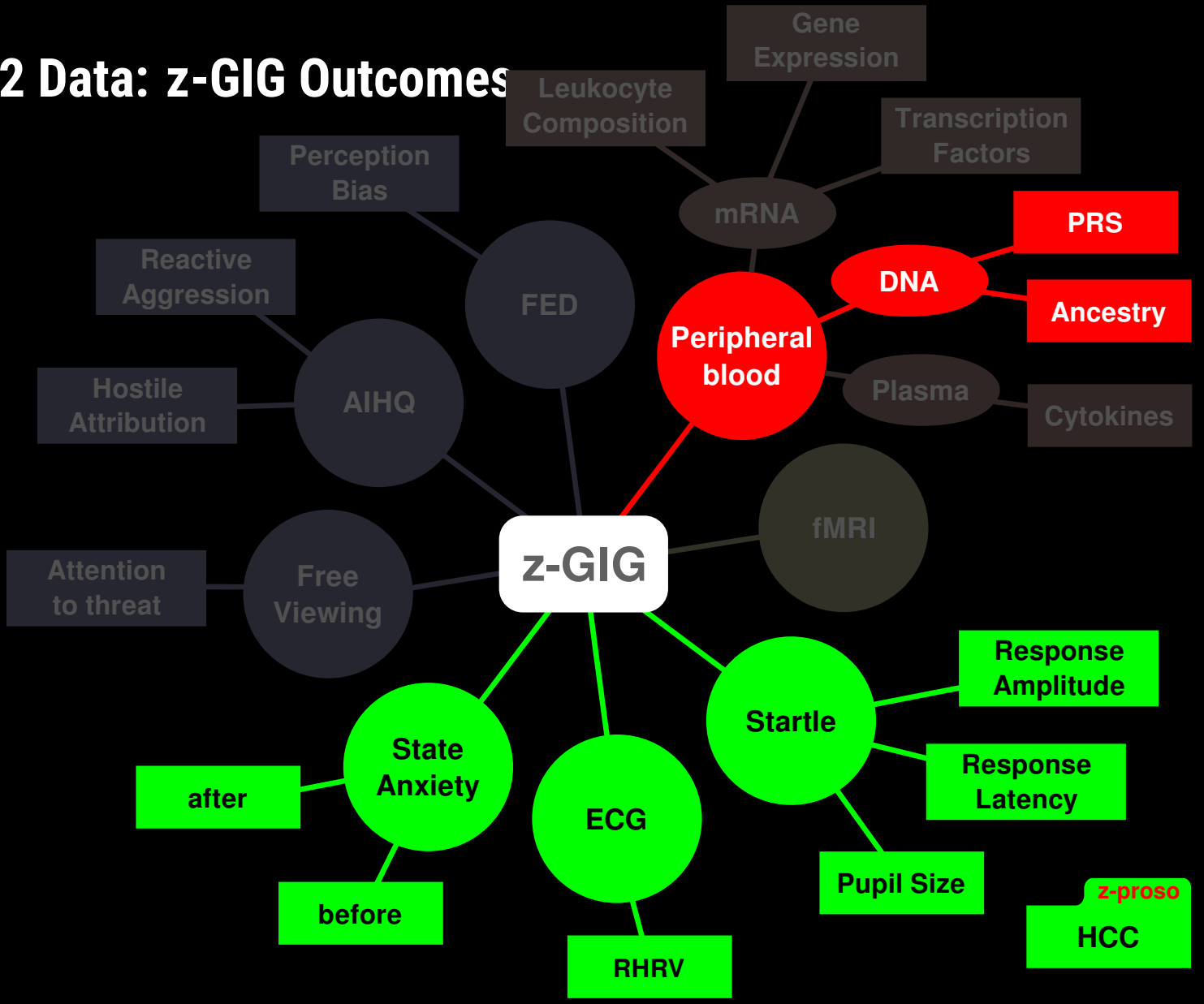

Fig 2. z-GIG outcomes. red=immune, green=neuroendocrine, (blue=cognitive–affective, yellow=neural functional activity). ECG, electrocardiography; HCC, hair cortisol concentration; PRS, polygenic risk scores; RHRV, resting heart rate variability

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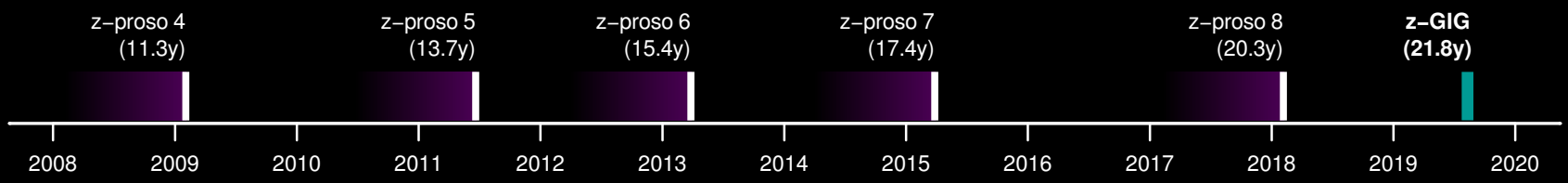

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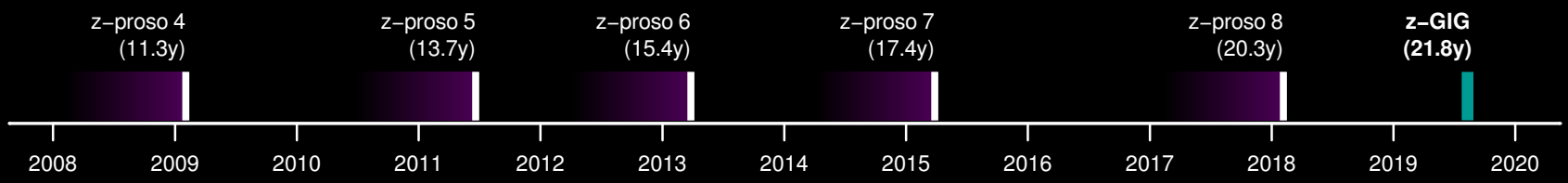

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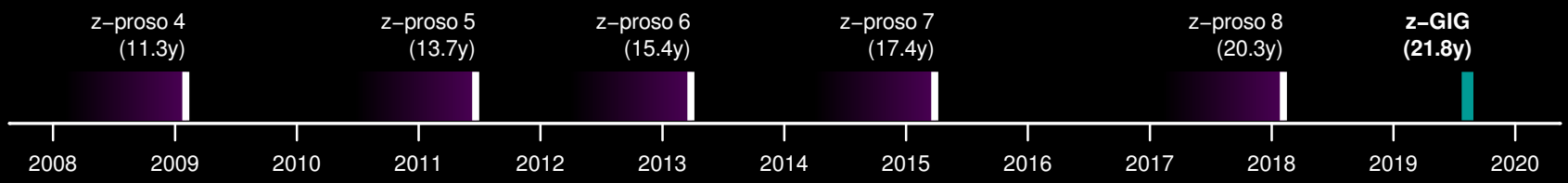

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- Binary variable: 21 PV-victims ($11.5\%;\ n_1 = 21;\ n_0 = 182$)

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- Mixed effects models w/ random effects for subjects and trials

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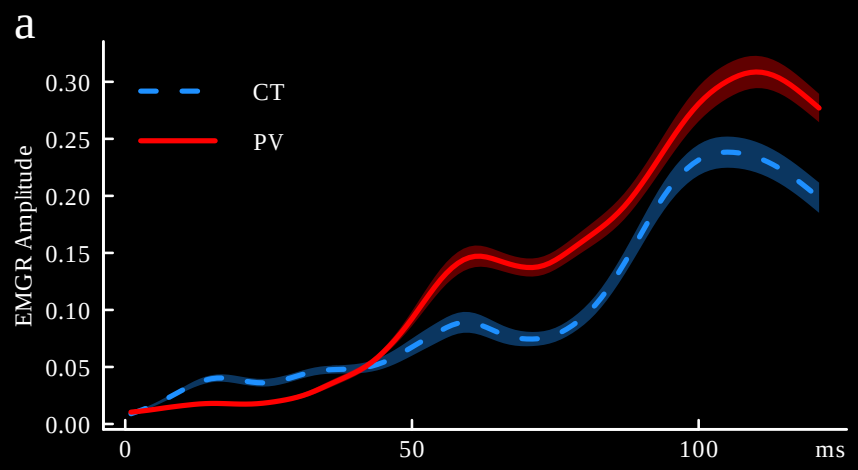

Fig 4. Startle-related physiological responses. ANG, angry facial stimulus; AU, arbitrary units; CT, controls; EMGR, electromyographic response (startle); LATE, later trial block; NEU, neutral facial stimulus; PV, peer victimization. Bands show SEM. Mixed-effects models were used in b–j;***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

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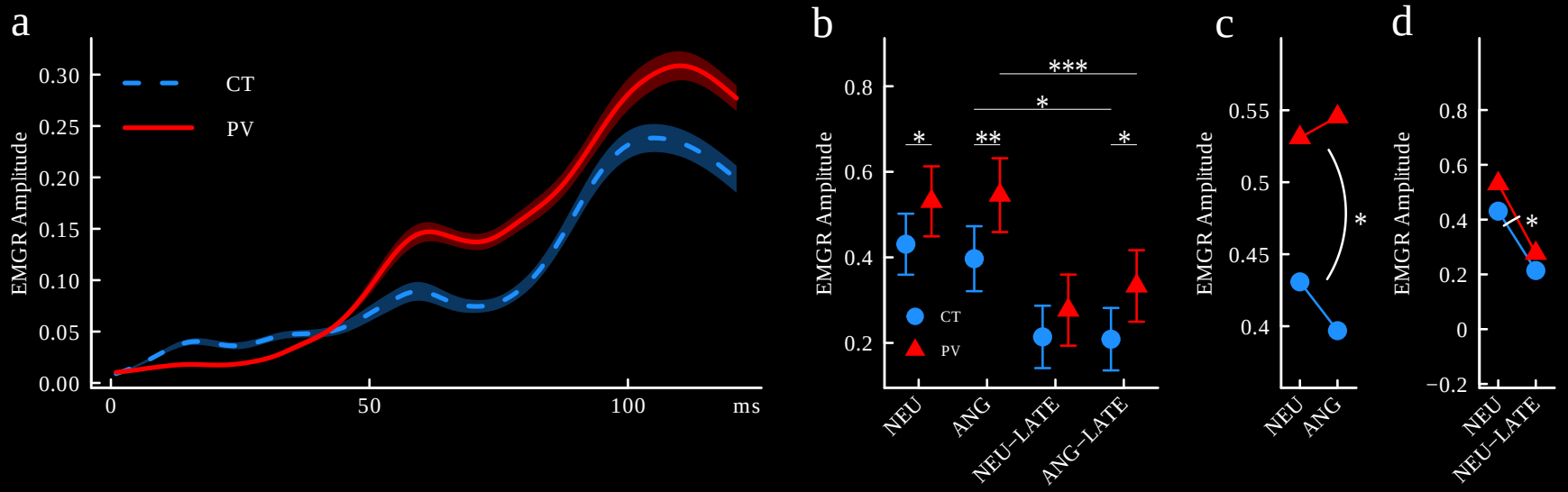

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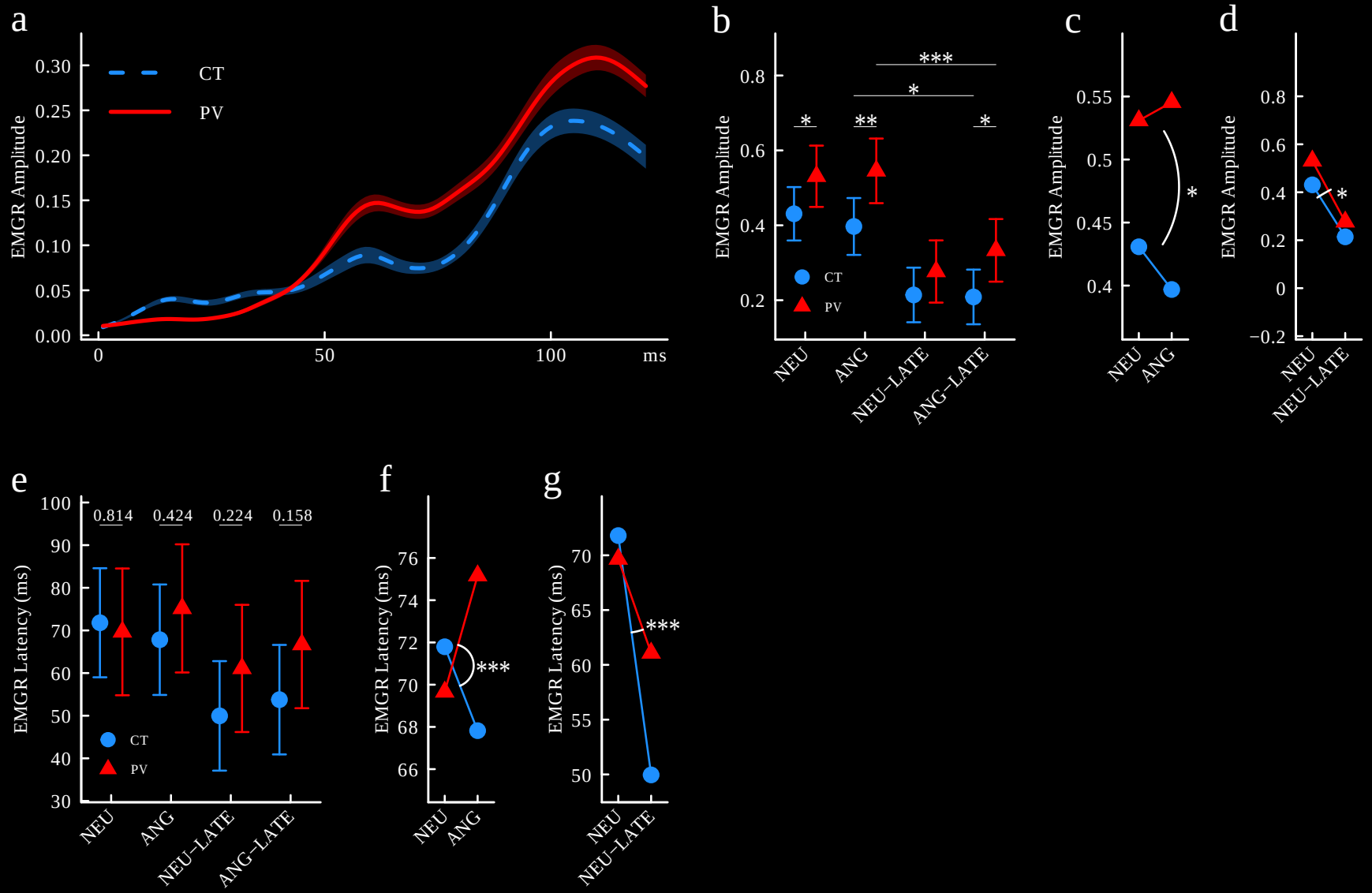

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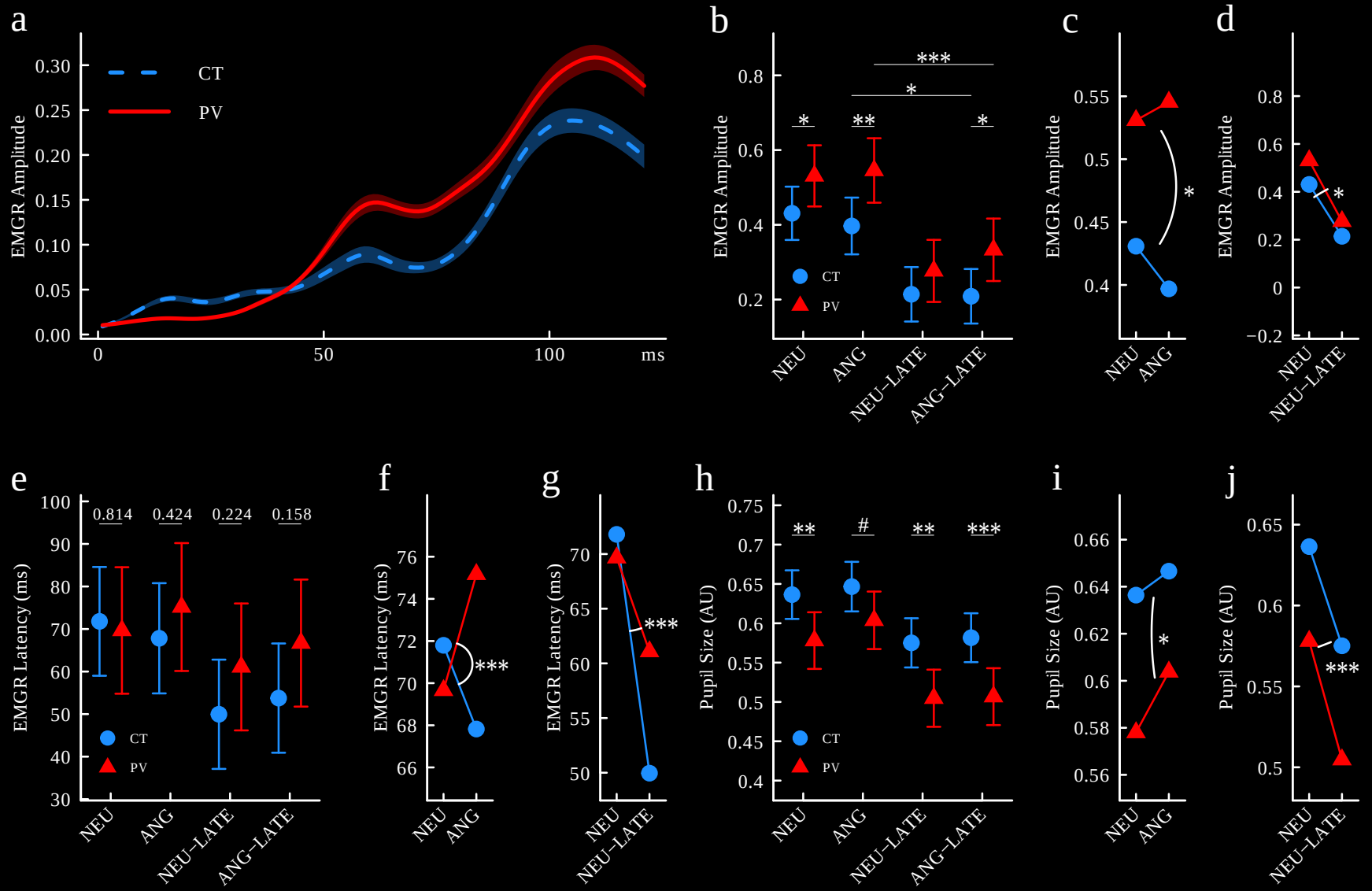

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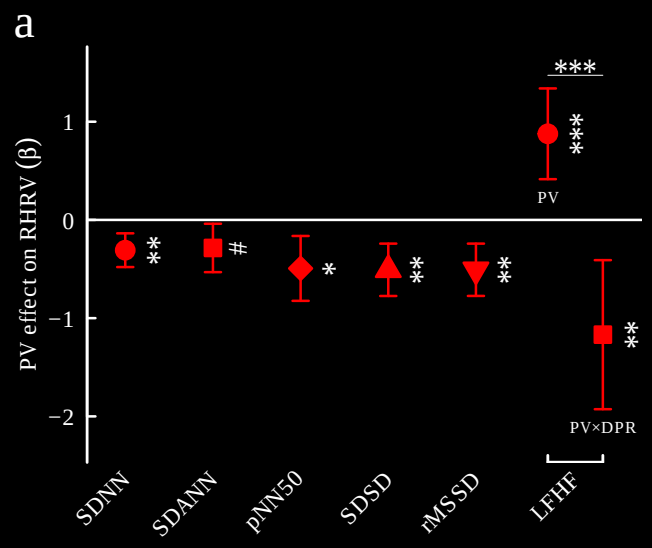

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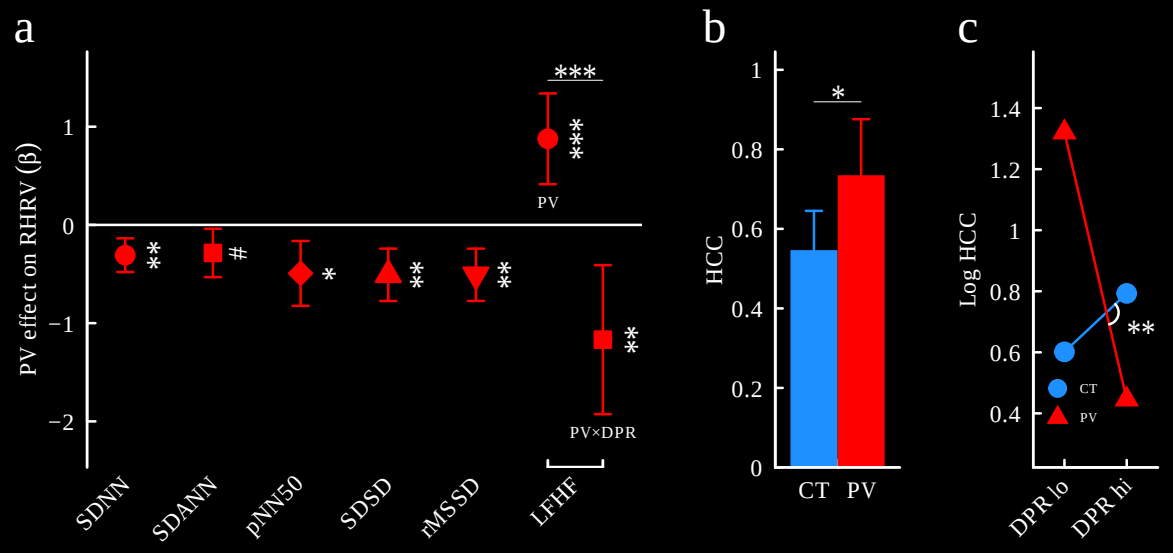

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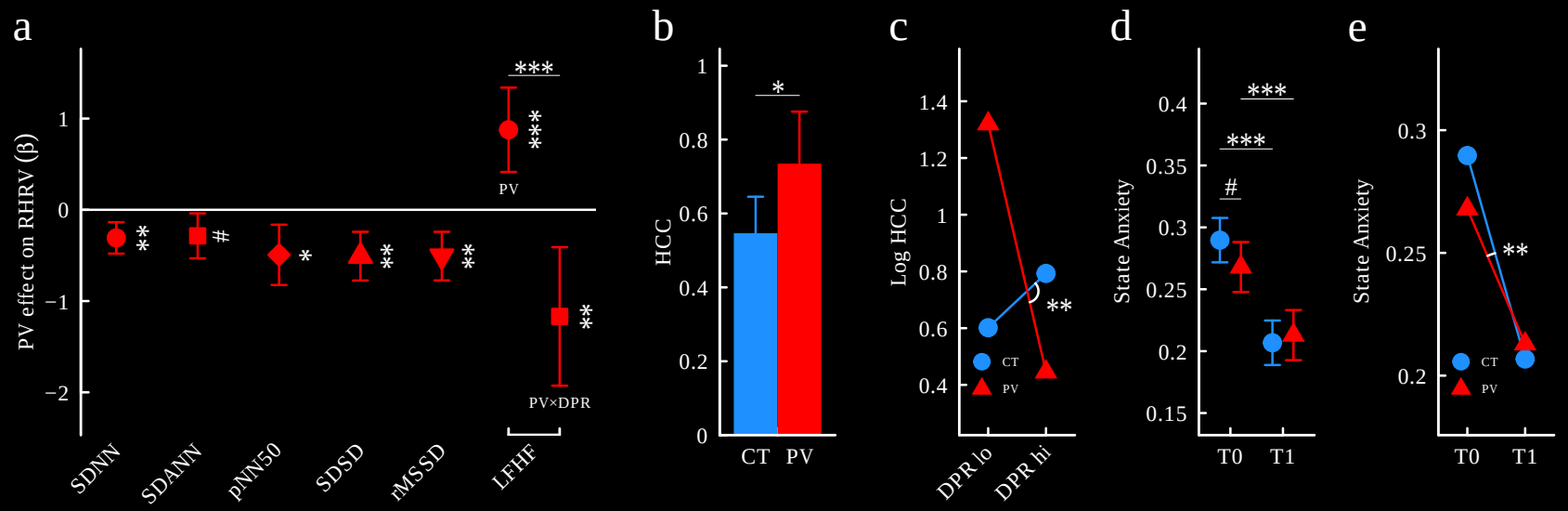

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- **Convergence: PTSD-like multisystem profile** (↑ reactivity, ↓ adaptation; endocrine imbalance)

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- No early/late or chronic/acute PV distinction $\rightarrow$ larger samples needed

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- Pattern resembles trauma-related profiles (PTSD-like)
- PV = clinically important social adversity
- Prevention & timely intervention may reduce risks for psychopathology and societal costs

References

Biswas, T., J. G. Scott, K. Munir, H. J. Thomas, M. M. Huda, M. M. Hasan, T. David De Vries, J. Baxter, and A. A. Mamun (2020). "Global variation in the prevalence of bullying victimisation amongst adolescents: Role of peer and parental supports". *EClinicalMedicine*. 15.1 20, p. 100276. DOI: 10.1016/j.eclinm.2020.100276.

Heumann, J., B. B. Quednow, J. Chumbley, M. Eisner, D. Ribeaud, L. Shanahan, and M. J. Shanahan (2025). "Adolescent Peer Victimization Through a Trauma Lens: Heightened Startle Response, Increased Pupil Dilation, Elevated Cortisol, and Reduced Heart Rate Variability in Young Adulthood". DOI: 10.1101/2025.05.11.652731.

Ribeaud, D., A. Murray, L. Shanahan, M. J. Shanahan, and M. Eisner (2022). "Cohort Profile: The Zurich Project on the Social Development from Childhood to Adulthood (z-proso)". *Journal of Developmental and Life-Course Criminology*. 2.36 8.1, pp. 151–171. DOI: 10.1007/s40865-022-00195-x.

Sapolsky, R. M. (2004). "Social Status and Health in Humans and Other Animals". *Annual Review of Anthropology*. 4.7 33.1, pp. 393–418. DOI: 10.1146/annurev.anthro.33.070203.144000.

Thank you!

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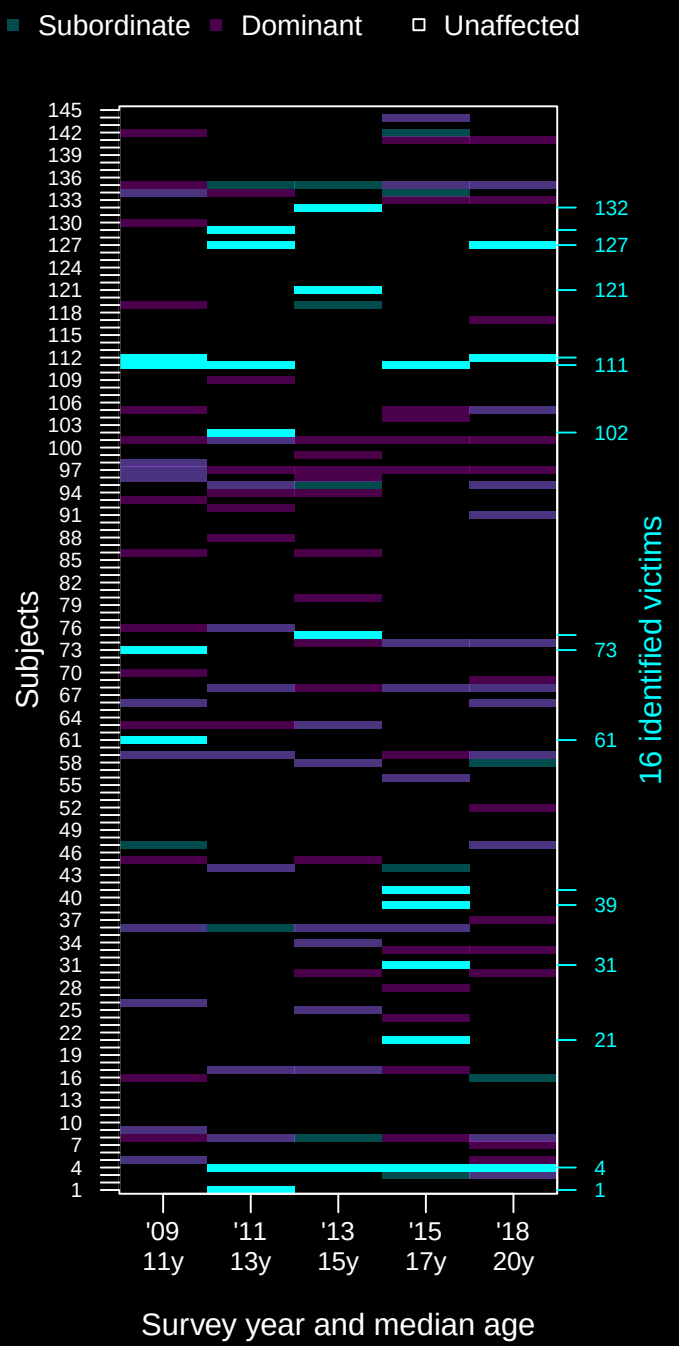
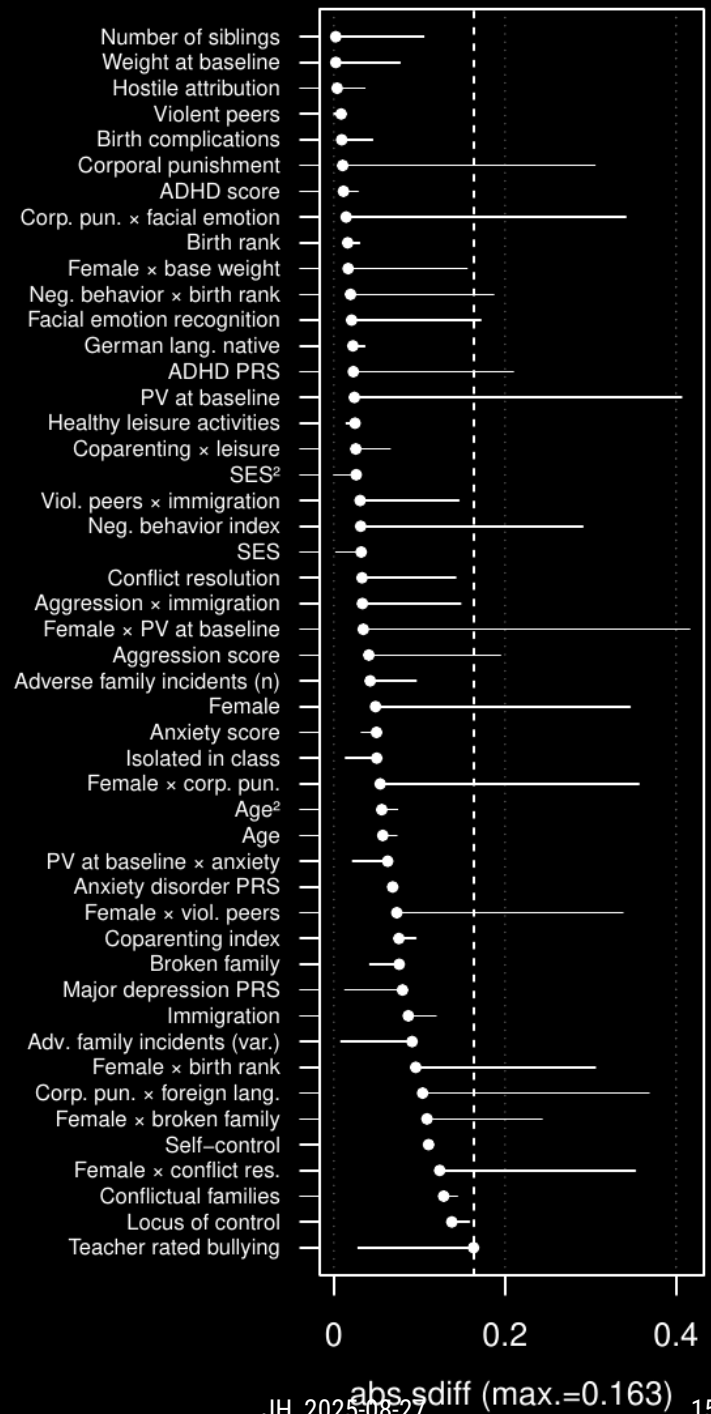
Appendix A1

Fig. A1: Peer victimization. Prevalence of social peer adversity. The figure shows subordinate experiences and dominant behavior above 90% quantiles for each survey year. As the highest deciles, subjects above these thresholds are considered to be severely affected from the respective phenomenon. 16 individuals (7 male and 9 female) subjected to only subordinate experiences are identified as peer-victimized at the time of our study at around age 22.



Appendix A2

Fig. A2: Balancing after IPW. The lollipop plot shows absolute standardized differences between treated (PV) and control after IPW.



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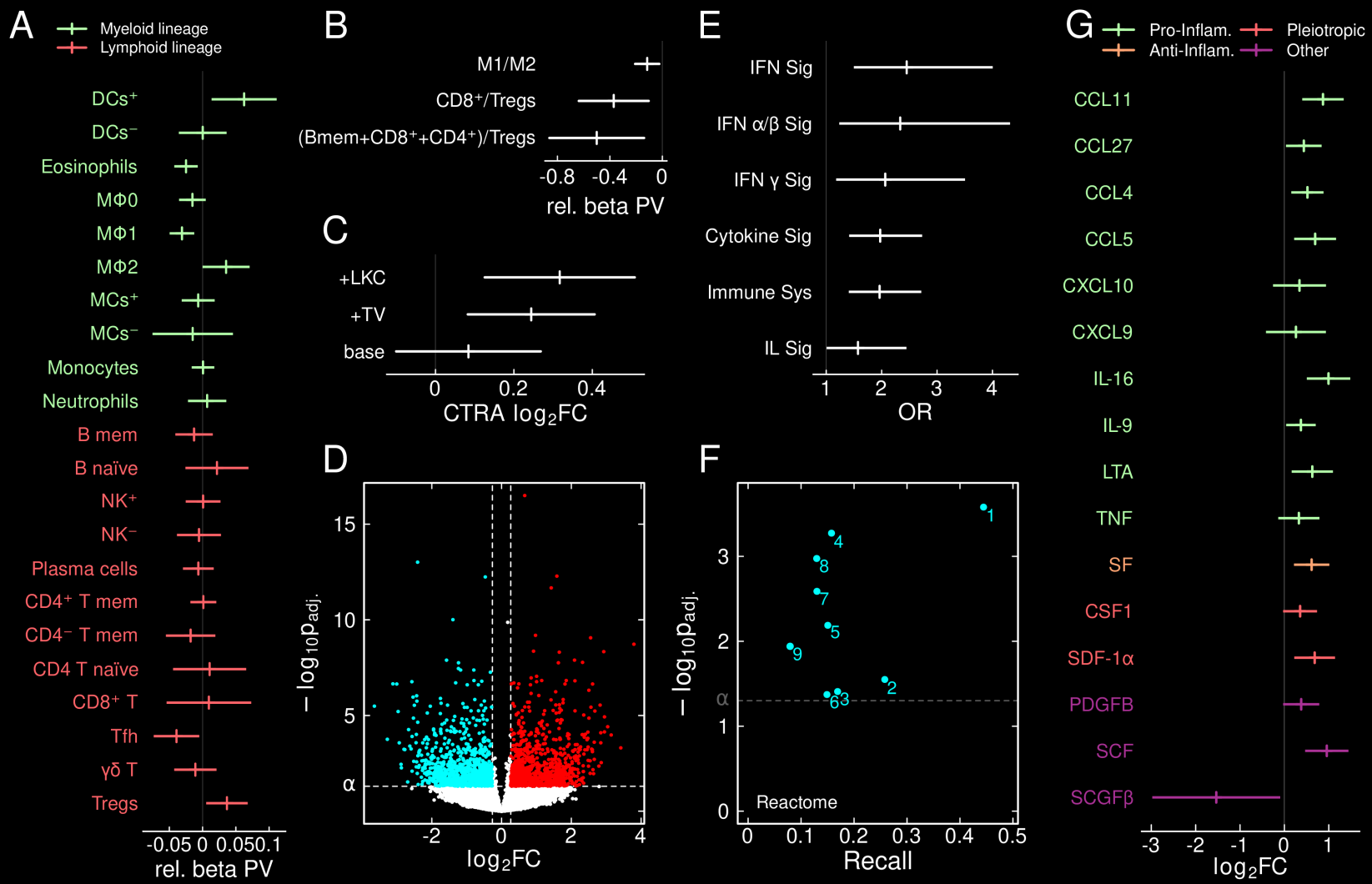
A
Myeloid lineage
Lymphoid lineage
DCs+
DCs−
Eosinophils
MΦ0
MΦ1
MΦ2
MCs+
MCs−
Monocytes
Neutrophils
B mem
B naïve
NK+
NK−
Plasma cells
CD4+ T mem
CD4− T mem
CD4 T naïve
CD8+ T
Tfh
γδ T
Tregs
-0.05 0 0.050.1
rel. beta PV
B
M1/M2
CD8+/Tregs
(Bmem+CD8++CD4+)/Tregs
-0.8 -0.4 0
rel. beta PV
C
+LKC
+TV
base
0 0.2 0.4
CTRA log2FC
D
15
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-2 0 2 4
log2FC
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IFN α/β Sig
IFN γ Sig
Cytokine Sig
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Reactome
0 0.1 0.2 0.3 0.4 0.5
Recall
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Pro-Inflam.
Anti-Inflam.
Pleiotropic
Other
CCL11
CCL27
CCL4
CCL5
CXCL10
CXCL9
IL-16
IL-9
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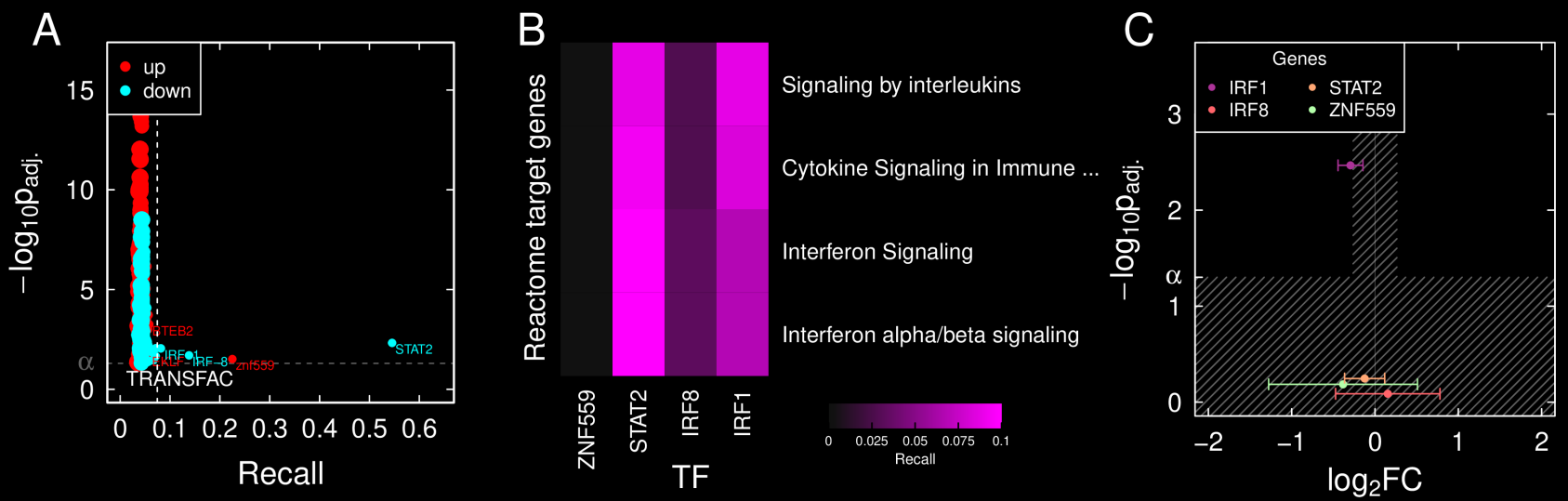
Appendix B2


A
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down
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0.2
0.3
0.4
0.5
0.6
Recall
STAT2
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B
Reactome target genes
Signaling by interleukins
Cytokine Signaling in Immune ...
Interferon Signaling
Interferon alpha/beta signaling
ZNF559
STAT2
IRF8
IRF1
TF
0
0.025
0.05
0.075
0.1
Recall
C
Genes
IRF1
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STAT2
ZNF559
3
2
α
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−2
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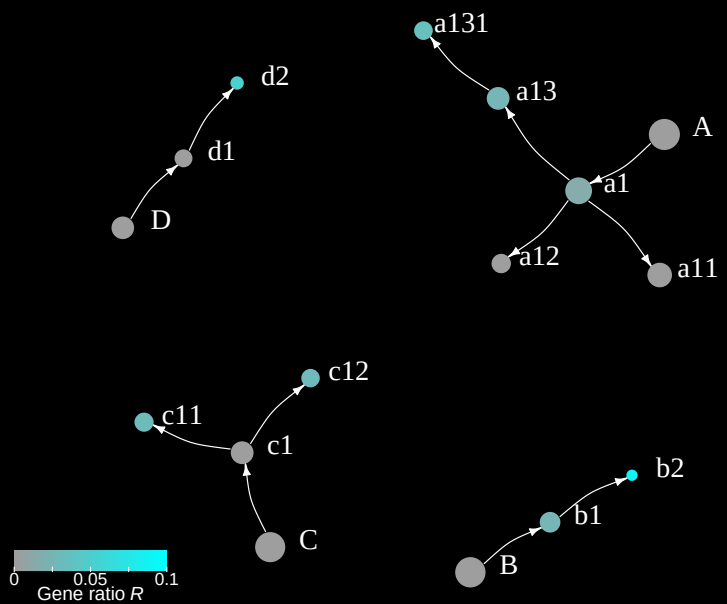
0
1
2
$\log_2FC$

Appendix B3

Fig. A3: Hierarchy of queried Reactome pathways. The figure displays the hierarchical organization of pathways from the Reactome query with overrepresentation in downregulated genes (the query did not show any upregulation), as also visualized in the Reactome pathway browser. Node sizes represent relative term sizes, colors the gene ratio R. A=Immune system, a1=Cytokine Signaling in Immune system, a11=Signaling by Interleukins, a12=TNFR2 non-canonical NF-κB pathway, a13=Interferon signaling, a131=Interferon alpha/beta signaling, B=Metabolism, b1=The citric acid (TCA) cycle and respiratory electron transport, b2=Formation of ATP by chemiosmotic coupling, C=Metabolism of proteins, c1=Translation, c11=SRP-dependent cotranslational protein targeting to membrane, c12=Eukaryotic Translation Termination, D=Organelle biogenesis and maintenance, d1=Mitochondrial biogenesis, d2=Cristae formation. The Gene ratio indicates the proportion of DE genes within a specific pathway that are present in the query set.



Appendix C1

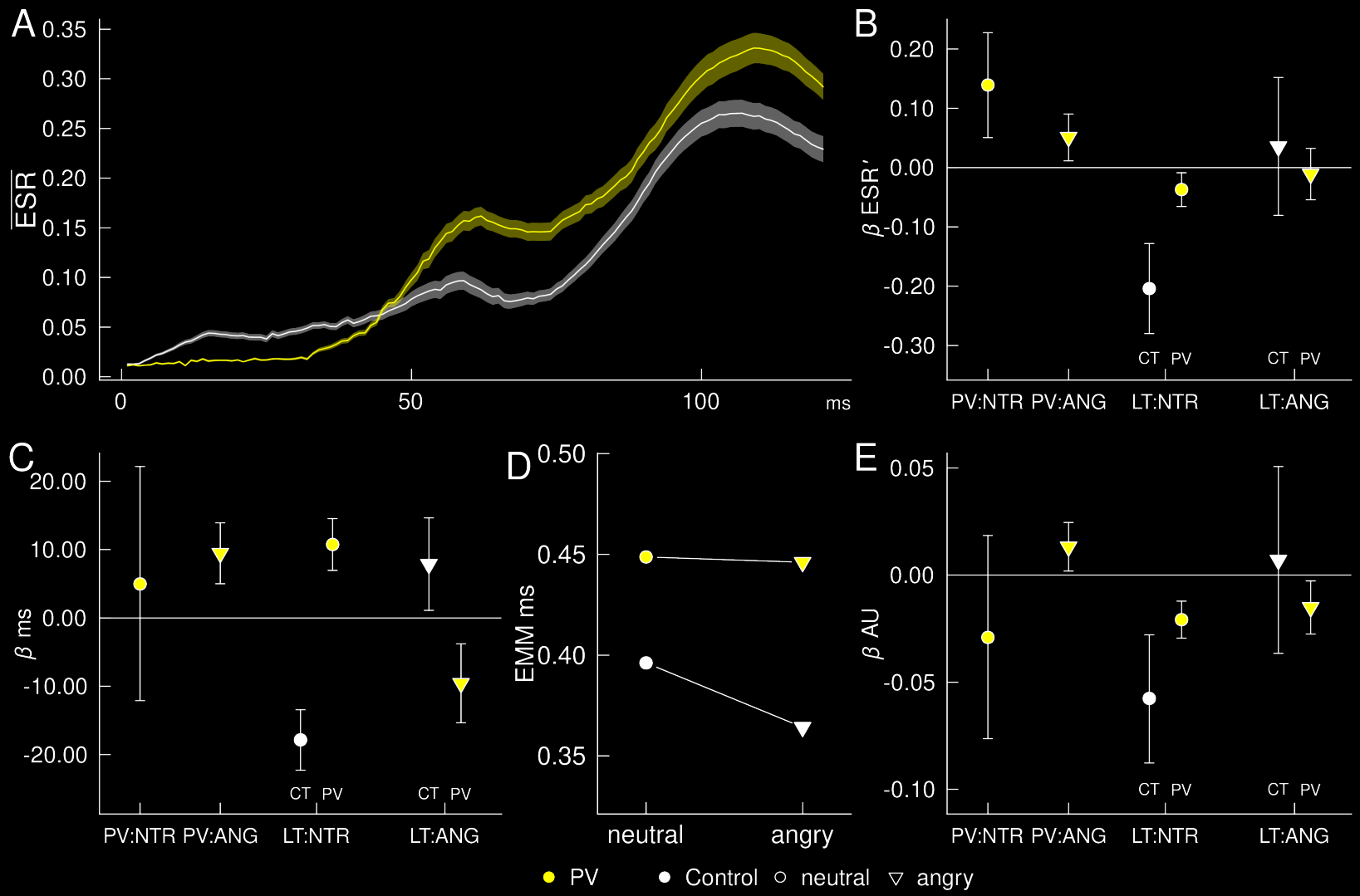


Fig. B1: Eyeblink startle response (ESR). Eyeblink startle response (ESR). **(A)** ESR functional forms by group. **(B)** Maximum ESR. β coefficients of maximum normalized ESR amplitude with 95% CIs. PV=victims, CT=controls, NTR=neutral, ANG=angry, LT=later trials. **(C)** ESR reaction times. ms=milliseconds. **(D)** Estimated marginal means (EMM) of reaction times (ms). **(E)** Beta coefficients for pupil size (PS) in arbitrary units (AU) with 95% CIs.

Appendix C2

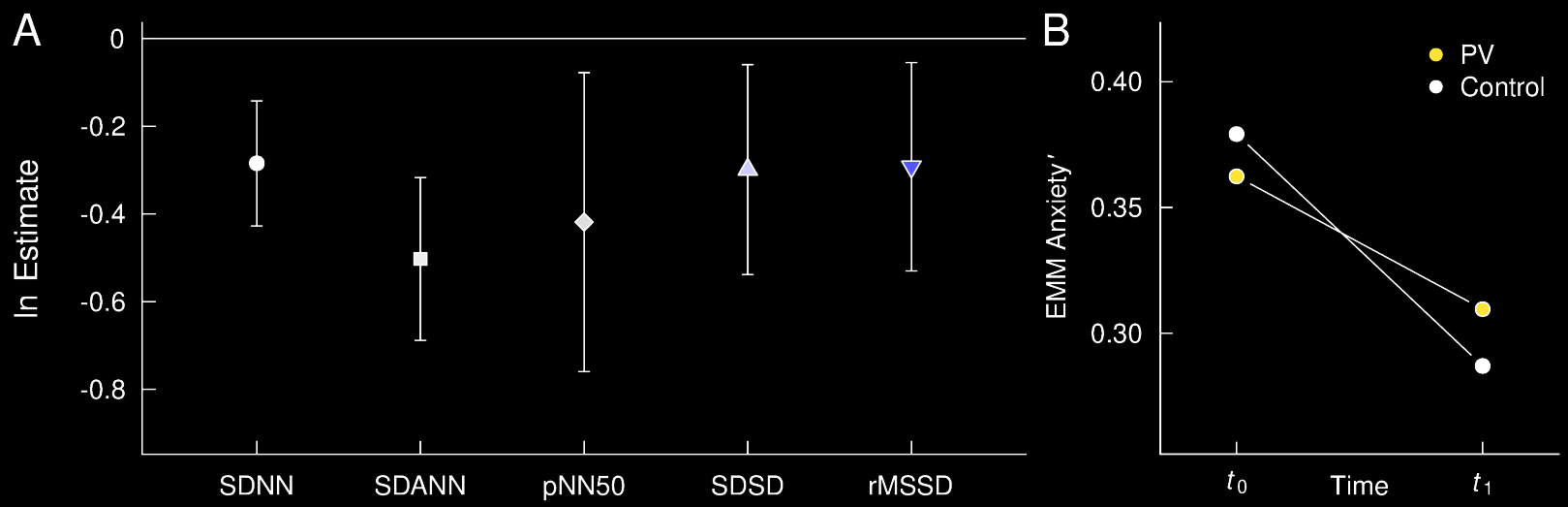


Fig. B2: (A) Heart rate variability (HRV) metrics. ln-transformed β coefficients with 95% CIs. **(B)** Perceived anxiety changes over time. Estimated marginal means (EMM) show perceived anxiety levels at baseline (t_0) and post-treatment ($t1$).