Supplementary Materials

A Lifespan Normative Reference for Spectral Signatures of Brain Activity

Supplementary Table S1: Dataset Characteristics

Overview of all datasets included in the sqEEGNorms framework, ordered by age range. For each dataset, the table reports the total number of unique participants (N), the allocation to normative training, held-out reference, and clinical cohorts, demographic characteristics (age range, mean age with standard deviation, percentage female), EEG acquisition parameters (system, channel count, sampling frequency, power line frequency), resting-state conditions (EC = eyes closed; EO = eyes open), data access repository, and the diagnostic groups represented with per-group sample sizes. All datasets were sourced from OpenNeuro. Ch. = number of EEG channels; SF = sampling frequency; PL = power line frequency; ADHD = attention-deficit/hyperactivity disorder; ASD = autism spectrum disorder; PTSD = post-traumatic stress disorder; FTD = frontotemporal dementia; MDD = major depressive disorder; SLD = specific learning disorder.

Site	Dataset ID	Institution	EEG System	N	Train	Held-out	Clinical	Age Range	Age (M ± SD)	% F	Ch.	SF (Hz)	PL (Hz)	Eyes	DOI	Diagnostic Groups (n)
A	ds004577	Univ. Nac. Autónoma de México	Neuronic Medicid 3-E	103	93	10	0	1	1.0 ± 0.0	40	19–24	200	60	EC, EO	10.18112/openneuro.ds004577	Control (103)
B	ds004186	Univ. of California, San Diego	EGI	2755	475	288	1992	5–22	10.3 ± 3.5	64	129	500	60	EC, EO	10.18112/openneuro.ds004186	Control (233), No diagnosis (530), ADHD (1034), ASD (174), Anxiety (272), PTSD (35), Depression (90), SLD (167), Other (220)
C	ds003944	Univ. of Pittsburgh	Elekta Neuromag Vectorview	82	29	3	50	13–36	22.1 ± 4.6	34	61	1000	60	EC, EO	10.18112/openneuro.ds003944	Control (32)

Site	Dataset ID	Institution	EEG System	N	Train	Held-out	Clinical	Age Range	Age (M ± SD)	% F	Ch.	SF (Hz)	PL (Hz)	Eyes	DOI	Diagnostic Groups (n)
C	ds003947	Univ. of Pittsburgh	Elekta Neuromag Vectorview	61	27	3	31	14–38	23.8 ± 4.9	38	61	1000	60	EC, EO	10.18112/openneuro.ds003947	Control (30)
D	ds003775	Univ. of Oslo	BioSemi	111	100	11	0	17–71	37.6 ± 14.0	62	64	1024	50	EC	10.18112/openneuro.ds003775	Control (111)
E	ds003478	Univ. of Arizona	Neuroscan Synamps2	120	79	9	32	18–24	18.9 ± 1.2	62	64	500	60	EC, EO	10.18112/openneuro.ds003478	Control (88)
F	ds004148	Southwest University	Brain Products actiCHamp	60	54	6	0	18–28	20.0 ± 1.9	53	60–64	500	50	EC	10.18112/openneuro.ds004148	Control (60)
G	ds003838	Ural Federal University	Brain Products actiCHamp	53	48	5	0	18–37	20.0 ± 2.8	92	64	1000	50	EC	10.18112/openneuro.ds003838	Control (53)
H	ds005385	Leibniz Research Centre for Working Environment and Human Factors	Brain Products	528	475	53	0	20–70	43.7 ± 14.5	62	64	1000	50	EC	10.18112/openneuro.ds005385	Control (528)
I	ds003602	Washington Univ. School of Medicine	Neuroscan 4.5	115	103	12	0	33–43	37.2 ± 2.6	100	35	1000	60	EC, EO	10.18112/openneuro.ds003602	Control (115)
L	ds004504	Univ. of Ioannina	EEG 2100	86	25	3	58	44–79	66.2 ± 7.4	51	19	500	50	EC	10.18112/openneuro.ds004504	Control (28), Alzheimer (36), FTD (22)
—	ds003490	Univ. of New Mexico	Brain Vision ActiChamp	49	22	2	25	48–84	69.2 ± 9.0	37	64	500	60	EC, EO	10.18112/openneuro.ds003490	Control (24)
	Pre-QC Total			**4123**	**1530**	**405**	**2188**									

Note: ds003944 and ds003947 originate from the same institution (University of Pittsburgh) using the same acquisition system, although independent studies with non-overlapping participants. ds004186 contains the largest and most diagnostically diverse cohort, contributing the majority of clinical participants. The “Other” category for ds004186 includes communication disorder, disruptive/impulse-control disorders, intellectual disability, obsessive-compulsive disorders, motor disorders, elimination disorders, bipolar disorder, schizophrenia, eating disorders, neurocognitive disorders, and other conditions. Datasets with 0 clinical participants contributed exclusively to the normative reference (training and held-out cohorts). The Pre-QC Total row reflects participant counts at the dataset-allocation stage, before subject-level quality control. Final post-QC counts used for analysis (1,891 training recordings from 1,427 individuals; 678 held-out recordings from 400 individuals) are reported in Supplementary Table S2a. ds003490 (University of New Mexico) was excluded during quality control before training and contributed no participants to the analyses reported in the main text or in Tables S2–S13.

Supplementary Note S1: Diagnostic criteria across contributing datasets

Diagnostic labels listed in Table S1 were taken directly from each study's participants.tsv file. The original procedures used to assign those labels are summarised below for transparency. As described in the Table S1 note, only participants explicitly flagged as healthy / control / no-diagnosis (or whose participants.tsv entry indicated that no diagnostic assessment was performed) contributed to the normative reference; all other participants were assigned to the Clinical column. Of the diagnostic labels below, only those from ds004186 (HBN) and ds004504 (Ioannina) were carried forward into the diagnostic analyses reported in the main text.

ds004186 (Healthy Brain Network, Child Mind Institute; UCSD acquisition site). All participants were administered the computerised Schedule for Affective Disorders and Schizophrenia for School-Age Children (KSADS-COMP), a semi-structured DSM-5-based psychiatric interview administered by a licensed clinician through parent and child interviews. Clinically synthesised consensus DSM-5 diagnoses were generated by the clinical team after review of the interview output and supplemental targeted assessments where indicated (e.g., the Autism Diagnostic Observation Schedule [ADOS] for suspected autism, the Clinical Evaluation of Language Fundamentals [CELF] for suspected language disorder). The HBN clinician-consensus diagnosis ("Diagnosis_ClinicianConsensus" field) was the basis for the ADHD, ASD, anxiety, PTSD, depression, SLD, and "Other" labels reported in Table S1; participants with "No Diagnosis Given" were assigned to the no-diagnosis reference.

ds004504 (University of Ioannina; AHEPA General University Hospital, Thessaloniki). Diagnoses of Alzheimer's disease and frontotemporal dementia were established by experienced neurologists. Per the data descriptor (Miltiadous et al., 2023), diagnoses were made according to the DSM-IIIR / DSM-IV and ICD-10 criteria, with Alzheimer's disease additionally assessed against the NINCDS–ADRDA criteria. Cognitive status was characterised using the Mini-Mental State Examination (MMSE; mean 17.75 ± 4.5 for AD; 22.17 ± 8.22 for FTD; 30 for controls). No dementia-related comorbidities were reported.

ds003478 (University of Arizona). Per the source data descriptor (Cavanagh, 2021), college-age participants were stratified using the Beck Depression Inventory (BDI). The participants.tsv labels distinguish controls (stable BDI < 7, no Axis I symptoms) from depressed participants (BDI ≥ 13 with corroborating clinical features). Only participants flagged as controls in participants.tsv were used in the normative reference; depressed participants are counted in the Clinical column of Table S1 but were not analysed as a separate diagnostic cohort in the main text.

ds003944 / ds003947 (University of Pittsburgh). In the source datasets (Salisbury, Seebold & Coffman, 2022), the clinical cohort comprised first-episode psychosis (FEP) participants, with the participants.tsv file separating FEP from healthy controls. Only participants flagged as controls in participants.tsv were used in the normative reference; FEP participants are counted in the Clinical column but were not analysed as a separate diagnostic cohort in the main text.

ds003490 (University of New Mexico). Per the source data descriptor (Cavanagh, Singh & Narayanan, 2021), the cohort comprised Parkinson's disease patients (recorded ON and OFF dopaminergic medication, with accelerometry of the most-affected hand) and matched controls. This dataset was excluded in its entirety during quality control prior to model training; neither controls nor PD participants contributed to any reported analysis.

Supplementary Table S2: Dataset Split and Diagnostic Cohort Demographics

Supplementary Table S2a. Recordings are defined as unique subject × resting-state condition (eyes-closed or eyes-open) combinations, restricted to the first run of the first session of each study and retained after preprocessing and quality control (see Methods).

Cohort	Recordings	Individuals	Age Range	% Female
Training (reference)	1891	1427	1–82	64%
Held-out (reference)	678	400	1–70	64%
Testing (multi-diagnostic)	3033	2146	5–79	63%
Total	5602	3973	1–82	63%

Supplementary Table S2b. Diagnostic cohorts in the testing set (six cohorts analyzed in the main text).

Diagnosis	N individuals	N recordings	Age Range	Age (M ± SD)	% Female	EC / EO	Site
ADHD	1034	2032	5–22	10.4 ± 3.5	65.4%	1028 / 1004	UCSD (EGI)
Anxiety	272	530	5–22	10.3 ± 3.4	59.9%	269 / 261	UCSD (EGI)
ASD	174	343	5–22	10.8 ± 3.8	63.2%	174 / 169	UCSD (EGI)
Alzheimer's disease	36	36	49–79	66.4 ± 7.9	66.7%	36 / 0	Ioannina (EEG 2100)
PTSD	35	70	5–21	10.8 ± 3.9	77.1%	35 / 35	UCSD (EGI)
FTD	22	22	44–78	63.7 ± 8.4	40.9%	22 / 0	Ioannina (EEG 2100)

Supplementary Table S3: Model Validation Metrics

Supplementary Table S3. Aggregate model performance across 231 feature-region models. Values summarize distributions across models. Training set: n = 1,427 subjects (1,891 recordings); held-out test set: n = 400 subjects (678 recordings). Per-feature training row counts ranged from 1,762 to 1,891 due to regional electrode coverage variation across acquisition montages.

Metric	Train Mean	Train Median	Test Mean	Test Median	|Gap| Mean	Gap IQR
Z-score Mean	0.002	-0.001	0.006	0.019	0.052	0.104
Z-score SD	1.002	1.001	1.042	1.047	0.052	0.060
Skewness	-0.001	-0.003	0.023	0.036	0.146	0.236
Kurtosis	-0.025	-0.020	0.394	0.404	0.465	0.540
R^2	0.341	0.374	0.281	0.309	0.095	0.192
RMSE	0.957	0.650	0.937	0.613	0.084	0.723
MSE	1.933	0.423	1.888	0.376	0.325	0.822

Supplementary Table S4: ICA vs. Non-ICA Pipeline Comparison

Supplementary Table S4. Comparison of model performance between base and ICA-augmented preprocessing. Cohen's d and practical significance alongside FDR-corrected p-values. Only R^2 showed significance ($d = 0.54$, $q < 0.001$); ICA improved explained variance but had negligible effect on all other metrics including z-score calibration.

Metric	No-ICA Mean	ICA Mean	Δ Mean	Cohen's d	Effect	q (FDR)	Sig.
MSE	1.8879	1.7910	-0.0969	-0.0290	Negligible	0.8962	False
Mean_Error	0.0440	0.0395	-0.0045	-0.0397	Negligible	0.8962	False
RMSE	0.9371	0.9129	-0.0241	-0.0243	Negligible	0.8962	False
R_Squared	0.2811	0.3656	0.0845	0.5399	Medium	0.0000	True
Z_Scores_Mean	0.0059	0.0037	-0.0022	-0.0363	Negligible	0.8962	False
Z_Scores_SD	1.0424	1.0412	-0.0012	-0.0267	Negligible	0.8962	False
Kurtosis	0.3944	0.3077	-0.0867	-0.2337	Small	0.1195	False
Normality_Test_Statistic	0.9947	0.9950	0.0003	0.0944	Negligible	0.8962	False
Skewness	0.0232	0.0213	-0.0019	-0.0110	Negligible	0.9088	False
AIC	2104.3432	2012.1484	-92.1948	-0.0175	Negligible	0.8962	False
BIC	2299.6512	2208.4558	-91.1954	-0.0173	Negligible	0.8962	False
Logarithmic_Score	-0.5429	-0.5338	0.0091	0.0061	Negligible	0.9088	False

Supplementary Table S5: Trajectory Comparison Summary

Supplementary Table S5. Summary of trajectory-level statistical comparisons. Circular-shift permutation testing (2,000 permutations) on the absolute-area statistic, FDR-corrected.

Analysis	N significant	N total	% significant	Min q	Mean q
Sex q50 shape	0	143	0.0%	0.55	0.98
Sex q50 level	33	143	23.1%	0.003	0.59
Sex σ shape	0	143	0.0%	0.58	0.96
Lateralization q50	0	104	0.0%	1.0	0.94

Full per-feature results are provided as supplementary CSV files: sex_effects_table.csv, lateralization_table.csv, topology_table.csv.

Supplementary Table S5b: Regional Normative Trajectory Summaries

Supplementary Tables S5b.1–S5b.5. Qualitative summary of normative spectral trajectories per cortical region. For each frequency band, the table reports sex differences in relative power spectral density (f/m ΔPSD), trajectory shape similarity between sexes (f/m trend), variance characteristics across the lifespan, and the general trend direction. Regions: LF = Left Frontal, MF = Median Frontal, RF = Right Frontal, LT = Left Temporal, RT = Right Temporal, LP = Left Parietal, MP = Median Parietal, RP = Right Parietal, LO = Left Occipital, RO = Right Occipital, MO = Median Occipital. "=" indicates the pattern is equivalent to the reference region listed.

S5b – δ band: Delta (δ) rPSD normative trends

Region	f/m ΔrPSD	f/m trend	general variance	general trend
LF	No	=	Constant	Decrease. Constant from 20-25
MF	No	=	= LF	= LF
RF	No	=	= LF	= LF
LT	No	=	Constant	Decrease. Plateau 25-50. Decrease >50
RT	No	=	= LT	= LT
LP	No	=	= LT	Decrease. Constant from 20-25

MP	No	=	= LP	= LP
RP	No	=	= LP	= LP
LO	No	=	Constant	Decrease. Constant from 20-25
RO	No	=	= LO	= LO
MO	No	=	= LO	= LO

S5b – θ band: Theta (θ) rPSD normative trends

Region	f/m ΔrPSD	f/m trend	general variance	general trend
LF	No	=	Constant	Decrease
MF	No	=	= LF	= LF
RF	No	=	= LF	= LF
LT	No	=	Constant	Decrease
RT	No	=	Constant	= LT
LP	No	=	Decrease. Constant from 15-20	Decrease. Plateau 20-40. Decrease >40
MP	No	=	= LP	= LP
RP	No	=	= LP	= LP
LO	No	=	Decrease. Constant from 15-20	Decrease. Constant from 15-20
RO	No	=	= LO	= LO
MO	No	=	= LO	= LO

S5b – α + PAF band: Alpha (α) rPSD and PAF normative trends

Region	f/m ΔrPSD	f/m trend	general variance	general trend	PAF trend	PAF variance
LF	No	=	Increase. Constant from 30	Increase. Peak + plateaus at 20-40. Slow decrease from 40	Increase. Peak at 20-30. Slow decrease	Constant
MF	No	=	= LF	= LF	= LF	= LF
RF	No	=	= LF	= LF	= LF	= LF
LT	No	=	Increase. Constant from 30	Increase. Peak + plateaus at 20-40. Slow decrease from 40	Increase. Peak at 20-30. Slow decrease	Constant
RT	No	=	= LT	= LT	= LT	= LT
LP	No	=	Increase. Constant from 30	Increase. Peak + plateaus at 20-40. Slow decrease from 40	Increase. Peak at 20-30. Slow decrease	Constant
MP	No	=	= LP	= LP	= LP	= LP
RP	No	=	= LP	= LP	= LP	= LP
LO	No	=	Increase. Constant from 30	Increase. Peak + plateaus at 20-40. Slow decrease from 40	Increase. Peak at 20-30. Slow decrease	Constant
RO	No	=	= LO	= LO	= LO	= LO
MO	No	=	= LO	= LO	= LO	= LO

S5b – β band: Beta (β) rPSD normative trends

Region	f/m ΔrPSD	f/m trend	general variance	general trend
LF	No	=	Increase	Increase (slower 20-30)
MF	No	=	= LF	Increase

RF	No	=	= LF	= LF
LT	No	=	Increase	Increase (slower from 20)
RT	No	=	= LT	= LT
LP	No	=	Increase	Increase (slower from 20)
MP	No	=	= LP	= LP
RP	No	=	= LP	= LP
LO	No	=	Increase (slower from 20)	Increase (slower from 20)
RO	No	=	= LO	= LO
MO	No	=	= LO	= LO

S5b – γ band: Gamma (γ) rPSD normative trends

Region	**f/m ΔrPSD**	**f/m trend**	**general variance**	**general trend**
LF	No	=	Increase. Plateau 20-50	Increase
MF	No	=	Increase (slower from 20)	= LF
RF	No	=	Monotonic increase	= LF
LT	No	=	Increase (1-5). Constant (5-15). Increase (15-20). Constant >20	Increase
RT	No	=	= LT	= LT
LP	No	=	Increase	Increase
MP	No	=	Increase. Plateau 5-15	Increase. Plateau 20-30
RP	No	=	= LP	= LP
LO	No	=	Increase. Plateau 20-30	Increase. Plateau 20-30
RO	No	=	= LO	= LO
MO	No	=	= LO	= LO

Supplementary Table S6: Full Univariate Deviation Results

Supplementary Table S6a. Diagnosis vs. reference comparisons. Mann-Whitney U with rank-biserial r; BH-FDR corrected.

Diagnosis	Feature	N diag	N ref	r	q (FDR)	Sig.
ADHD	1/f int.	1034	400	0.123	0.001	**
ADHD	1/f slope	1034	400	-0.014	0.763	n.s.
ADHD	F/S	1034	400	0.149	6.00e-05	***
ADHD	PAF	1034	400	-0.021	0.638	n.s.
ADHD	α [dB]	1034	400	0.176	1.66e-06	***
ADHD	β [dB]	1034	400	0.071	0.066	n.s.
ADHD	γ [dB]	1034	400	0.031	0.459	n.s.
ADHD	δ [dB]	1034	400	-0.147	7.43e-05	***
ADHD	θ [dB]	1034	400	0.138	1.98e-04	***
ADHD	θ/α	1034	400	-0.120	0.001	**
ADHD	θ/β	1034	400	0.033	0.445	n.s.
ASD	1/f int.	174	400	0.072	0.248	n.s.
ASD	1/f slope	174	400	-0.076	0.227	n.s.
ASD	F/S	174	400	0.153	0.009	**
ASD	PAF	174	400	-0.090	0.152	n.s.
ASD	α [dB]	174	400	0.155	0.008	**
ASD	β [dB]	174	400	0.115	0.056	n.s.
ASD	γ [dB]	174	400	0.135	0.022	*
ASD	δ [dB]	174	400	-0.168	0.004	**
ASD	θ [dB]	174	400	0.209	2.41e-04	***
ASD	θ/α	174	400	-0.074	0.235	n.s.
ASD	θ/β	174	400	0.026	0.706	n.s.
Alzheimer	1/f int.	36	400	0.574	1.07e-07	***
Alzheimer	1/f slope	36	400	0.348	0.002	**
Alzheimer	F/S	36	400	-0.686	3.10e-10	***
Alzheimer	PAF	36	400	-0.284	0.011	*
Alzheimer	α [dB]	36	400	-0.664	7.87e-10	***
Alzheimer	β [dB]	36	400	-0.597	3.24e-08	***
Alzheimer	γ [dB]	36	400	0.219	0.057	n.s.
Alzheimer	δ [dB]	36	400	0.442	5.98e-05	***
Alzheimer	θ [dB]	36	400	0.650	1.39e-09	***
Alzheimer	θ/α	36	400	0.787	3.39e-13	***
Alzheimer	θ/β	36	400	0.662	7.87e-10	***
Anxiety	1/f int.	272	400	0.145	0.004	**
Anxiety	1/f slope	272	400	0.004	0.961	n.s.
Anxiety	F/S	272	400	0.106	0.041	*
Anxiety	PAF	272	400	-0.033	0.571	n.s.
Anxiety	α [dB]	272	400	0.122	0.017	*
Anxiety	β [dB]	272	400	0.045	0.434	n.s.
Anxiety	γ [dB]	272	400	0.025	0.683	n.s.
Anxiety	δ [dB]	272	400	-0.074	0.175	n.s.
Anxiety	θ [dB]	272	400	0.059	0.279	n.s.
Anxiety	θ/α	272	400	-0.096	0.064	n.s.
Anxiety	θ/β	272	400	0.014	0.813	n.s.
FTD	1/f int.	22	400	0.413	0.003	**
FTD	1/f slope	22	400	0.143	0.362	n.s.
FTD	F/S	22	400	-0.588	2.07e-05	***
FTD	PAF	22	400	0.050	0.763	n.s.

FTD	α [dB]	22	400	-0.518	1.86e-04	***
FTD	β [dB]	22	400	-0.378	0.007	**
FTD	γ [dB]	22	400	0.095	0.568	n.s.
FTD	δ [dB]	22	400	0.331	0.020	*
FTD	θ [dB]	22	400	0.603	1.24e-05	***
FTD	θ/α	22	400	0.718	1.16e-07	***
FTD	θ/β	22	400	0.513	1.98e-04	***
PTSD	1/f int.	35	400	0.159	0.190	n.s.
PTSD	1/f slope	35	400	-0.015	0.938	n.s.
PTSD	F/S	35	400	0.054	0.690	n.s.
PTSD	PAF	35	400	-0.214	0.066	n.s.
PTSD	α [dB]	35	400	0.076	0.568	n.s.
PTSD	β [dB]	35	400	-0.013	0.944	n.s.
PTSD	γ [dB]	35	400	-0.001	0.990	n.s.
PTSD	δ [dB]	35	400	-0.103	0.430	n.s.
PTSD	θ [dB]	35	400	0.157	0.194	n.s.
PTSD	θ/α	35	400	0.007	0.961	n.s.
PTSD	θ/β	35	400	0.160	0.190	n.s.

Supplementary Table S6b. Within-category pairwise comparisons.

Group 1	Group 2	Feature	N_1	N_2	r	q (FDR)	Sig.
ADHD	ASD	1/f int.	1034	174	0.060	0.490	n.s.
ADHD	ASD	1/f slope	1034	174	0.075	0.366	n.s.
ADHD	ASD	F/S	1034	174	-0.019	0.867	n.s.
ADHD	ASD	PAF	1034	174	0.077	0.366	n.s.
ADHD	ASD	α [dB]	1034	174	0.013	0.869	n.s.
ADHD	ASD	β [dB]	1034	174	-0.066	0.417	n.s.
ADHD	ASD	γ [dB]	1034	174	-0.124	0.294	n.s.
ADHD	ASD	δ [dB]	1034	174	0.035	0.732	n.s.
ADHD	ASD	θ [dB]	1034	174	-0.103	0.366	n.s.
ADHD	ASD	θ/α	1034	174	-0.048	0.550	n.s.
ADHD	ASD	θ/β	1034	174	0.006	0.924	n.s.
Alzheimer	FTD	1/f int.	36	22	0.098	0.789	n.s.
Alzheimer	FTD	1/f slope	36	22	0.159	0.550	n.s.
Alzheimer	FTD	F/S	36	22	-0.265	0.366	n.s.
Alzheimer	FTD	PAF	36	22	-0.275	0.366	n.s.
Alzheimer	FTD	α [dB]	36	22	-0.260	0.366	n.s.
Alzheimer	FTD	β [dB]	36	22	-0.189	0.512	n.s.
Alzheimer	FTD	γ [dB]	36	22	0.086	0.813	n.s.
Alzheimer	FTD	δ [dB]	36	22	0.172	0.550	n.s.
Alzheimer	FTD	θ [dB]	36	22	0.245	0.366	n.s.
Alzheimer	FTD	θ/α	36	22	0.321	0.366	n.s.
Alzheimer	FTD	θ/β	36	22	0.268	0.366	n.s.
Anxiety	PTSD	1/f int.	272	35	-0.004	0.972	n.s.
Anxiety	PTSD	1/f slope	272	35	0.023	0.878	n.s.
Anxiety	PTSD	F/S	272	35	0.049	0.838	n.s.
Anxiety	PTSD	PAF	272	35	0.173	0.366	n.s.
Anxiety	PTSD	α [dB]	272	35	0.039	0.867	n.s.
Anxiety	PTSD	β [dB]	272	35	0.062	0.789	n.s.
Anxiety	PTSD	γ [dB]	272	35	0.029	0.869	n.s.
Anxiety	PTSD	δ [dB]	272	35	0.030	0.869	n.s.

Anxiety	PTSD	θ [dB]	272	35	-0.110	0.550	n.s.
Anxiety	PTSD	θ/α	272	35	-0.097	0.577	n.s.
Anxiety	PTSD	θ/β	272	35	-0.151	0.399	n.s.

Supplementary Table S7: Mahalanobis Distances

Supplementary Table S7a. Diagnosis vs. reference (K=11 features).

Diagnosis	D^2 Mean	D^2 SD	N	K
ADHD	2.300	0.725	1034	11
ASD	2.822	0.931	174	11
Alzheimer	9.183	3.204	36	11
FTD	7.413	3.874	22	11
Anxiety	2.772	1.029	272	11
PTSD	3.169	1.019	35	11

Supplementary Table S7b. Within-category symmetric distances.

Comparison	D^2sym	D^2(A→B)	D^2(B→A)	N_1	N_2
ADHD vs ASD	3.288	2.671	3.905	1034	174
Alzheimer vs FTD	4.741	5.611	3.871	36	22
Anxiety vs PTSD	3.586	3.565	3.607	272	35

Supplementary Table S8: Covariate Effects (Figure 4)

Diagnosis	Comparison	r	q (FDR)	Sig.	Significant
ADHD	vs_reference	-0.457	2.00e-70	***	True
ASD	vs_reference	-0.094	0.017	*	True
Alzheimer	vs_reference	0.941	4.88e-21	***	True
FTD	vs_reference	0.690	7.04e-08	***	True
Anxiety	vs_reference	-0.180	1.19e-07	***	True
PTSD	vs_reference	0.116	0.111	ns	False
Reference	sex_Male_vs_Female	0.007	0.907	ns	False
ADHD	sex_Male_vs_Female	0.070	0.444	ns	False
ASD	sex_Male_vs_Female	-0.036	0.907	ns	False
Alzheimer	sex_Male_vs_Female	-0.319	0.444	ns	False
FTD	sex_Male_vs_Female	0.214	0.796	ns	False
Anxiety	sex_Male_vs_Female	0.054	0.796	ns	False
PTSD	sex_Male_vs_Female	0.056	0.907	ns	False
Reference	eyes_EC_vs_EO	0.034	0.757	ns	False
ADHD	eyes_EC_vs_EO	0.063	0.036	*	True
ASD	eyes_EC_vs_EO	0.031	0.771	ns	False
Alzheimer	eyes_EC_vs_EO	—	—	—	False
FTD	eyes_EC_vs_EO	—	—	—	False
Anxiety	eyes_EC_vs_EO	0.157	0.009	**	True
PTSD	eyes_EC_vs_EO	0.035	0.805	ns	False

Supplementary Table S9: Regional Binary Classification AUC

Dx	L.Fr	L.Oc	L.Pa	L.Te	M.Fr	M.Oc	M.Pa	R.Fr	R.Oc	R.Pa	R.Te
ADHD	0.559 ± 0.033	0.543 ± 0.045	0.563 ± 0.059	0.560 ± 0.048	0.566 ± 0.051	0.546 ± 0.053	0.573 ± 0.033	0.552 ± 0.035	0.542 ± 0.043	0.558 ± 0.068	0.570 ± 0.049
ASD	0.577 ± 0.061	0.573 ± 0.079	0.571 ± 0.042	0.546 ± 0.081	0.576 ± 0.086	0.567 ± 0.065	0.567 ± 0.057	0.575 ± 0.076	0.568 ± 0.084	0.583 ± 0.059	0.580 ± 0.086
Alzheimer	0.896 ± 0.136	0.939 ± 0.102	0.917 ± 0.095	0.902 ± 0.107	0.931 ± 0.081	nan ± nan	0.914 ± 0.096	0.881 ± 0.134	0.956 ± 0.075	0.904 ± 0.085	0.924 ± 0.107
Anxiety	0.552 ± 0.049	0.520 ± 0.055	0.527 ± 0.045	0.544 ± 0.045	0.539 ± 0.052	0.542 ± 0.044	0.533 ± 0.050	0.553 ± 0.048	0.521 ± 0.073	0.524 ± 0.067	0.551 ± 0.065
FTD	0.851 ± 0.187	0.928 ± 0.116	0.877 ± 0.165	0.901 ± 0.150	0.800 ± 0.198	nan ± nan	0.817 ± 0.264	0.703 ± 0.257	0.900 ± 0.115	0.890 ± 0.138	0.799 ± 0.178
PTSD	0.510 ± 0.120	0.514 ± 0.087	0.487 ± 0.106	0.504 ± 0.133	0.559 ± 0.105	0.534 ± 0.136	0.510 ± 0.151	0.513 ± 0.101	0.462 ± 0.096	0.544 ± 0.132	0.494 ± 0.111

Supplementary Table S10: Complete LDA Classification Results

Area under the receiver operating characteristic curve (AUC) and permutation-test p-values for all classifier variants.

Comparison	AUC	p-value	Sig.	Type
Reference (OvR)	0.631	< 0.0001	***	multiclass_OvR
ADHD (OvR)	0.590	< 0.0001	***	multiclass_OvR
ASD (OvR)	0.621	0.011	*	multiclass_OvR
Alzheimer (OvR)	0.841	< 0.0001	***	multiclass_OvR
FTD (OvR)	0.743	< 0.0001	***	multiclass_OvR
Anxiety (OvR)	0.556	0.098	n.s.	multiclass_OvR
PTSD (OvR)	0.490	0.550	n.s.	multiclass_OvR
micro-average (OvR)	0.852	< 0.0001	***	multiclass_OvR
macro-average (OvR)	0.639	< 0.0001	***	multiclass_OvR
Overall accuracy	0.542 / 0.529	< 0.0001	***	multiclass_accuracy
ADHD vs Reference	0.592	< 0.0001	***	binary
ASD vs Reference	0.614	0.0002	***	binary
Alzheimer vs Reference	0.945	< 0.0001	***	binary
FTD vs Reference	0.910	< 0.0001	***	binary
Anxiety vs Reference	0.568	0.006	**	binary
PTSD vs Reference	0.553	0.138	n.s.	binary
ADHD vs ASD	0.582	0.0045	**	binary
Alzheimer vs FTD	0.515	0.749	n.s.	binary
Anxiety vs PTSD	0.528	0.713	n.s.	binary

Supplementary Table S11: LOFO Feature Importance

Per-diagnosis change in AUC when each feature is removed (ΔAUC = AUC_baseline − AUC_without_feature, expressed as a percentage). Positive values indicate the feature aids discrimination (removing it drops AUC); negative values indicate the feature is redundant or confounded. Green shading: ΔAUC ≥ +1%. Red shading: ΔAUC ≤ −1%. Bold: |ΔAUC| ≥ 2%.

Dx	PAF	1/fs	1/fi	δ	θ	α	β	γ	θ/β	θ/α	f/s
ADHD	**-0.35%**	**+0.03%**	**+0.23%**	**-0.15%**	**-0.15%**	**-0.19%**	**-0.14%**	**+0.32%**	**+0.24%**	**+0.07%**	**+0.20%**

Dx	PAF	1/fs	1/fi	δ	θ	α	β	γ	θ/β	θ/α	f/s
ASD	+0.28%	-0.24%	-0.36%	+0.19%	-0.50%	+0.05%	-0.09%	+1.21%	+0.49%	-0.19%	+0.58%
Alzheimer	+0.43%	+0.87%	-0.02%	+1.76%	-0.23%	+0.31%	+1.76%	+2.11%	+1.55%	+0.22%	+0.98%
FTD	+0.37%	0.00%	+0.30%	+2.26%	-1.25%	0.00%	+2.31%	+1.30%	+1.39%	+0.63%	+1.30%
Anxiety	-0.77%	-0.48%	+4.03%	-0.23%	-0.25%	-0.05%	-0.13%	-0.40%	-0.16%	-0.20%	-0.16%
PTSD	+2.47%	-1.51%	+3.14%	+0.43%	-0.54%	-0.08%	-0.02%	-0.72%	-1.51%	+0.16%	-0.10%

Baseline binary-vs-Reference AUCs (for context): ADHD 0.592, ASD 0.614, Alzheimer 0.945, FTD 0.910, Anxiety 0.568, PTSD 0.553.

Supplementary Table S12: Summary Table (Figure 5 data)

Feature	Lifespan	σ	AD	FTD	ADHD	ASD	Anx	PTSD
δ [dB]	decrease	↑σ→	+0.44 *** ✓	+0.33 * ✓	-0.15 *** →	-0.17 ** →	-0.07 n.s.	-0.10 n.s.
θ [dB]	non-monotonic	→σ	+0.65 *** ✓	+0.60 *** ✓	+0.14 *** ✓	+0.21 *** →	+0.06 n.s.	+0.16 n.s.
α [dB]	non-monotonic	↑σ↓	-0.66 *** ✓	-0.52 *** ✓	+0.18 *** ✗	+0.15 ** →	+0.12 * →	+0.08 n.s.
β [dB]	increase	↑σ→	-0.60 *** ✓	-0.38 ** ✓	+0.07 n.s. →	+0.12 n.s. →	+0.04 n.s.	-0.01 n.s.
γ [dB]	increase	↑σ	+0.22 n.s. ✓	+0.09 n.s.	+0.03 n.s.	+0.13 * ✓	+0.03 n.s.	-0.00 n.s.
PAF	non-monotonic	→σ	-0.28 * ✓	+0.05 n.s. →	-0.02 n.s.	-0.09 n.s.	-0.03 n.s.	-0.21 n.s.
1/f slope	decrease	~σ	+0.35 ** ★	+0.14 n.s.	-0.01 n.s.	-0.08 n.s.	+0.00 n.s.	-0.02 n.s.
1/f int.	decrease	~σ	+0.57 *** ★	+0.41 ** ★	+0.12 ** ★	+0.07 n.s.	+0.15 ** ★	+0.16 n.s.
θ/β	decrease	~σ	+0.66 *** ✓	+0.51 *** ✓	+0.03 n.s. ✗	+0.03 n.s.	+0.01 n.s.	+0.16 n.s.
θ/α	non-monotonic	~σ	+0.79 *** ✓	+0.72 *** ✓	-0.12 ** →	-0.07 n.s.	-0.10 n.s. →	+0.01 n.s.
Fast/Slow	increase	~σ	-0.69 *** ✓	-0.59 *** ✓	+0.15 *** →	+0.15 ** →	+0.11 * ✓	+0.05 n.s.

Supplementary Table S13: Extended Deviation Statistics by Diagnostic Category

Supplementary Table S13. Extended univariate deviation statistics for each diagnostic cohort versus the held-out normative reference. For each spectral feature: median and mean z-score, standard deviation, rank-biserial correlation (r), Cohen's d, and FDR-corrected significance. Features are presented in narrow-band dB scale. Significance uses global BH-FDR correction across all diagnosis-feature comparisons (* q<0.05, ** q<0.01, *** q<0.001), concordant with the main manuscript.

Table S13 – Alzheimer's disease and FTD

Diagnosis	Feature	N	Median z	Mean z	SD	r	Cohen's d	q	Sig.
AD	δ [dB]	36	+0.888	+0.803	1.195	+0.442	+1.041	5.98e-05	***
AD	θ [dB]	36	+1.625	+1.586	1.415	+0.650	+1.833	1.39e-09	***
AD	α [dB]	36	-2.410	-2.014	1.745	-0.664	-2.249	7.87e-10	***
AD	β [dB]	36	-1.208	-1.070	1.188	-0.597	-1.298	3.24e-08	***
AD	γ [dB]	36	+0.316	+0.202	0.745	+0.219	+0.352	0.0574	n.s.
AD	PAF	36	-0.408	-0.240	0.878	-0.284	-0.419	0.0113	*
AD	1/f slope	36	+0.559	+0.541	0.905	+0.348	+0.767	0.0017	**

AD	1/f int.	36	+0.884	+0.889	0.926	+0.574	+1.396	1.07e-07	***
AD	θ/β	36	+1.565	+1.436	1.238	+0.662	+1.724	7.87e-10	***
AD	θ/α	36	+3.611	+2.798	1.940	+0.787	+3.011	3.39e-13	***
AD	F/S	36	-2.281	-1.905	1.550	-0.686	-2.171	3.10e-10	***
FTD	δ [dB]	22	+0.535	+0.522	1.013	+0.331	+0.735	0.0197	*
FTD	θ [dB]	22	+1.023	+1.067	1.369	+0.603	+1.271	1.24e-05	***
FTD	α [dB]	22	-0.932	-1.255	1.510	-0.518	-1.528	1.86e-04	***
FTD	β [dB]	22	-0.860	-0.722	1.146	-0.378	-0.906	0.0074	**
FTD	γ [dB]	22	+0.058	+0.035	0.821	+0.095	+0.108	0.5680	n.s.
FTD	PAF	22	+0.022	+0.058	0.819	+0.050	+0.042	0.7629	n.s.
FTD	1/f slope	22	+0.104	+0.485	1.289	+0.143	+0.668	0.3618	n.s.
FTD	1/f int.	22	+0.652	+0.795	1.406	+0.413	+1.194	0.0033	**
FTD	θ/β	22	+0.693	+0.968	1.085	+0.513	+1.211	1.98e-04	***
FTD	θ/α	22	+1.600	+1.886	1.620	+0.718	+2.247	1.16e-07	***
FTD	F/S	22	-1.176	-1.284	1.319	-0.588	-1.571	2.07e-05	***

Table S13 – ADHD and ASD

Diagnosis	Feature	N	Median z	Mean z	SD	r	Cohen's d	q	Sig.
ADHD	δ [dB]	1034	-0.270	-0.271	0.600	-0.147	-0.274	7.43e-05	***
ADHD	θ [dB]	1034	+0.188	+0.184	0.562	+0.138	+0.267	1.98e-04	***
ADHD	α [dB]	1034	+0.253	+0.254	0.578	+0.176	+0.307	1.66e-06	***
ADHD	β [dB]	1034	+0.079	+0.096	0.592	+0.071	+0.096	0.0663	n.s.
ADHD	γ [dB]	1034	+0.045	+0.003	0.491	+0.031	+0.076	0.4587	n.s.
ADHD	PAF	1034	+0.004	+0.004	0.503	-0.021	-0.049	0.6381	n.s.
ADHD	1/f slope	1034	-0.031	-0.025	0.505	-0.014	-0.041	0.7629	n.s.
ADHD	1/f int.	1034	+0.133	+0.108	0.443	+0.123	+0.242	0.0011	**
ADHD	θ/β	1034	+0.008	+0.027	0.597	+0.033	+0.082	0.4450	n.s.
ADHD	θ/α	1034	-0.177	-0.175	0.580	-0.120	-0.186	0.0014	**
ADHD	F/S	1034	+0.228	+0.248	0.613	+0.149	+0.261	6.00e-05	***
ASD	δ [dB]	174	-0.320	-0.290	0.670	-0.168	-0.261	0.0038	**
ASD	θ [dB]	174	+0.321	+0.280	0.676	+0.209	+0.350	2.41e-04	***
ASD	α [dB]	174	+0.230	+0.255	0.712	+0.155	+0.257	0.0081	**
ASD	β [dB]	174	+0.182	+0.158	0.758	+0.115	+0.157	0.0561	n.s.
ASD	γ [dB]	174	+0.110	+0.121	0.620	+0.135	+0.242	0.0220	*
ASD	PAF	174	-0.135	-0.064	0.651	-0.090	-0.150	0.1523	n.s.
ASD	1/f slope	174	-0.057	-0.103	0.613	-0.076	-0.152	0.2265	n.s.
ASD	1/f int.	174	+0.060	+0.070	0.525	+0.072	+0.140	0.2484	n.s.
ASD	θ/β	174	+0.032	+0.041	0.831	+0.026	+0.084	0.7060	n.s.
ASD	θ/α	174	-0.126	-0.130	0.722	-0.074	-0.098	0.2348	n.s.
ASD	F/S	174	+0.284	+0.257	0.717	+0.153	+0.234	0.0087	**

Table S13 – Anxiety and PTSD

Diagnosis	Feature	N	Median z	Mean z	SD	r	Cohen's d	q	Sig.
Anxiety	δ [dB]	272	-0.212	-0.179	0.764	-0.074	-0.115	0.1748	n.s.
Anxiety	θ [dB]	272	+0.107	+0.085	0.679	+0.059	+0.094	0.2791	n.s.
Anxiety	α [dB]	272	+0.231	+0.193	0.774	+0.122	+0.174	0.0167	*
Anxiety	β [dB]	272	+0.084	+0.056	0.728	+0.045	+0.030	0.4345	n.s.

Anxiety	γ [dB]	272	+0.022	-0.018	0.618	+0.025	+0.032	0.6827	n.s.
Anxiety	PAF	272	-0.026	+0.002	0.609	-0.033	-0.047	0.5712	n.s.
Anxiety	1/f slope	272	-0.009	-0.000	0.615	+0.004	+0.002	0.9615	n.s.
Anxiety	1/f int.	272	+0.161	+0.142	0.556	+0.145	+0.261	0.0038	**
Anxiety	θ/β	272	+0.034	-0.006	0.725	+0.014	+0.028	0.8130	n.s.
Anxiety	θ/α	272	-0.202	-0.169	0.728	-0.096	-0.149	0.0635	n.s.
Anxiety	F/S	272	+0.252	+0.185	0.780	+0.106	+0.142	0.0410	*
PTSD	δ [dB]	35	-0.239	-0.185	0.699	-0.103	-0.120	0.4295	n.s.
PTSD	θ [dB]	35	+0.069	+0.250	0.785	+0.157	+0.298	0.1935	n.s.
PTSD	α [dB]	35	+0.139	+0.124	0.806	+0.076	+0.086	0.5680	n.s.
PTSD	β [dB]	35	-0.054	-0.048	0.869	-0.013	-0.099	0.9442	n.s.
PTSD	γ [dB]	35	+0.079	-0.068	0.613	-0.001	-0.043	0.9905	n.s.
PTSD	PAF	35	-0.261	-0.213	0.584	-0.214	-0.394	0.0662	n.s.
PTSD	1/f slope	35	+0.045	+0.018	0.651	-0.015	+0.030	0.9382	n.s.
PTSD	1/f int.	35	+0.146	+0.163	0.512	+0.159	+0.289	0.1902	n.s.
PTSD	θ/β	35	+0.333	+0.252	1.053	+0.160	+0.338	0.1902	n.s.
PTSD	θ/α	35	-0.099	+0.029	0.864	+0.007	+0.102	0.9615	n.s.
PTSD	F/S	35	+0.162	+0.084	0.812	+0.054	+0.016	0.6897	n.s.

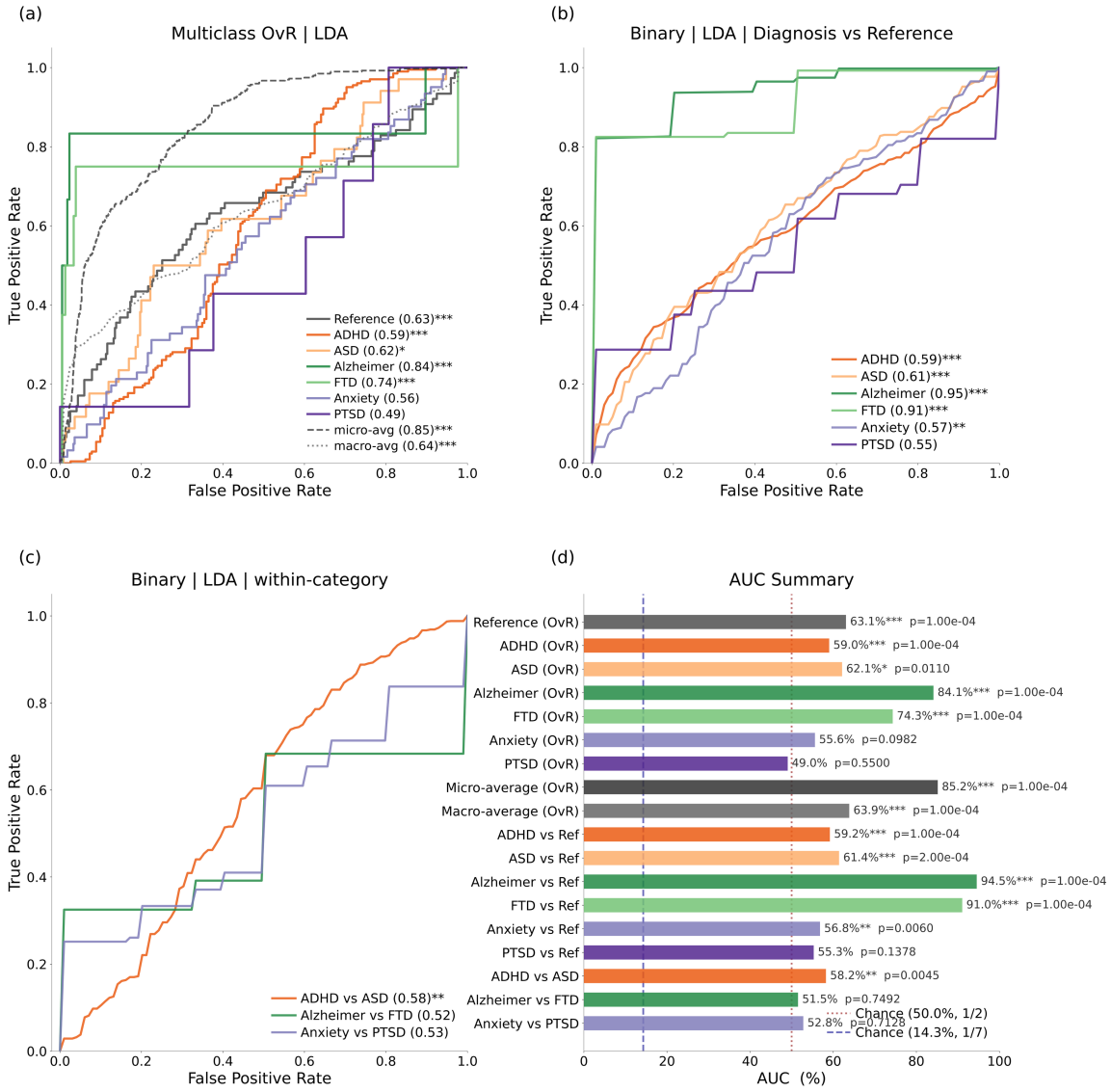
Table S14. – Feature-wise normative trajectories and disorder-specific group-level deviations

Normative trajectories with literature consensus comparison and reference ↑: Increase; ↓: Decrease.. Disorder-specific group-level deviation trends with effect sizes (rank-biserial r), significance, and literature consensus comparison. Per-result consensus is reported via symbols: ✓: agreed; →: extended; ✕: disputed; ★: novel results. * q<0.05; ** q<0.01; *** q<0.001; n.s.: non-significant.

	Median Trend	Variance Trend	Alzheimer's (n=36)	FTD (n=22)	ADHD (n=1034)	ASD (n=174)	Anxiety (n=272)	PTSD (n=35)	Consensus
δ [dB]	Steep decrease childhood/adolescence (−9.3×10⁻³ FBP/yr); deceleration from ~20 yr; net −0.22 FBP (−1.48 dB) ✓[14–15–65–69]	↑ until ~20 yr, then stable	+0.44 *** ✓	+0.33 * ✓	−0.15 *** →	−0.17 ** →	−0.07 n.s.	−0.10 n.s.	Developmental ↓ universally confirmed. AD/FTD: δ↑ (cortical slowing; AD > FTD). ADHD/ASD: δ↓ (opposes simple slowing). Anxiety: mild δ↓. PTSD: underpowered.
θ [dB]	U-like: Early life decline with midlife increase (−0.9×10⁻³ FBP/yr); net −0.04 FBP (−2.21 dB); smallest of slow bands ✓[14–15–65–69]	Near-constant; slight ↓ parietal/occipital ~15-20 yr	+0.65 *** ✓	+0.60 *** ✓	+0.14 *** ✓	+0.21 *** →	+0.06 n.s.	+0.16 n.s.	Lifespan U-like confirmed. AD: θ↑ (strongest signature). FTD: θ↑ (general dementia). ADHD: θ↑ (replicated, heterogeneous). ASD: θ↑. Anxiety/PTSD: n.s.
α [dB]	Inverted-U: fast ↑ childhood (+3×10⁻³ FBP/yr, 1-20 yr); peak ~20-30 yr; slow ↓ after; net ~0 FBP ✓[15–65–67–70–72]	↑, peaks ~20 yr, then ↓	−0.66 *** ✓	−0.52 *** ✓	+0.18 *** ✕	+0.15 ** →	+0.12 * →	+0.08 n.s.	Inverted-U trajectory confirmed. AD: α↓ (cholinergic loss). FTD: α↓ (stronger than expected). ADHD/ASD/Anxiety: α↑

									(opposes traditional view). PTSD: n.s.
β [dB]	Rapid ↑ early life (0.6×10^{-3} FBP/yr until 20 yr; +8.10 dB); slower after ~20 yr ✓[15–66–67]	Developmental rise then stabilization	−0.60 *** ✓	−0.38 ** ✓	+0.07 n.s. →	+0.12 n.s. →	+0.04 n.s.	−0.01 n.s.	Developmental ↑ confirmed. AD: β↓ (strong). FTD: β↓ (partial). ADHD: mild β↑ (challenges traditional β↓). ASD: mild β↑. Anxiety/PTSD: n.s.
γ [dB]	Slow monotonic ↑ (1.2×10^{-3} FBP/yr; net +0.06 FBP, +11.28 dB); sustained slopes through adulthood ✓[15–66–67]	↑ with regional plateaus	+0.22 n.s. ✓	+0.09 n.s.	+0.03 n.s.	+0.13 * ✓	+0.03 n.s.	−0.00 n.s.	Monotonic ↑ normatively. ASD: γ↑ significant. No other disorder showed significant γ deviation. Remains heterogeneous and understudied.
PAF	Rise in childhood; peak ~20-30 yr; slow ↓; local minimum ~60 yr; late-life rebound ✓[65–70–72]	Constant across lifespan	−0.28 * ✓	+0.05 n.s. →	−0.02 n.s.	−0.09 n.s.	−0.03 n.s.	−0.21 n.s.	PAF slowing confirmed in AD (hallmark); FTD preserves PAF vs AD (key differential). No reliable marker in neurodevelopmental/psychiatric conditions.
1/f slope	Monotonic ↓; steeper <20 yr; deceleration early adulthood; subtle inflection ~50 yr ✓[72–75–76]	Follows trend pattern	+0.35 ** ★	+0.14 n.s.	−0.01 n.s.	−0.08 n.s.	+0.00 n.s.	−0.02 n.s.	Monotonic ↓ confirmed. AD: steeper 1/f (novel, normative-referenced). All other cohorts: n.s.
1/f int.	Monotonic ↓; parallel to slope; steeper <20 yr; inflection ~50 yr ✓[72–75–76]	Follows trend pattern	+0.57 *** ★	+0.41 ** ★	+0.12 ** ★	+0.07 n.s.	+0.15 ** ★	+0.16 n.s.	Monotonic ↓ confirmed. AD/FTD: elevated broadband power (novel). ADHD/Anxiety: significant elevation (novel aperiodic finding). ASD/PTSD: n.s.
θ/β	Consistent ↓ across lifespan; dominated by θ decline and β rise ✓[9–57–58]	Follows component patterns	+0.66 *** ✓	+0.51 *** ✓	+0.03 n.s. ✕	+0.03 n.s.	+0.01 n.s.	+0.16 n.s.	Lifespan ↓ confirmed. AD: θ/β↑ (strong). FTD: θ/β↑. ADHD: n.s. (challenges FDA-approved TBR). ASD/Anxiety/PTSD: n.s.
θ/α	↓; mirrors θ decline relative to α trajectory ✓[37–48–53–77–78]	Follows component patterns	+0.79 *** ✓	+0.72 *** ✓	−0.12 ** →	−0.07 n.s.	−0.10 n.s. →	+0.01 n.s.	Lifespan ↓ confirmed, θ–α interplay. AD: θ/α↑ (largest effect, r=+0.79). FTD: θ/α↑ (strongest). ADHD: θ/α↓ (novel). Anxiety: trend. PTSD: underpowered.
Fast/Slow	Steady ↑; dominated by δ decline and α/β rise; steep first half of lifespan, decelerates after ✓[37–48–53–77–78]	Follows component patterns	−0.69 *** ✓	−0.59 *** ✓	+0.15 *** →	+0.15 ** →	+0.11 * ✓	+0.05 n.s.	Lifespan ↑ confirmed. AD/FTD: F/S↓ (spectral slowing). ADHD/ASD/Anxiety: F/S↑ (integrates elevations). PTSD: underpowered.

Supplementary Figure S1: LDA Classification

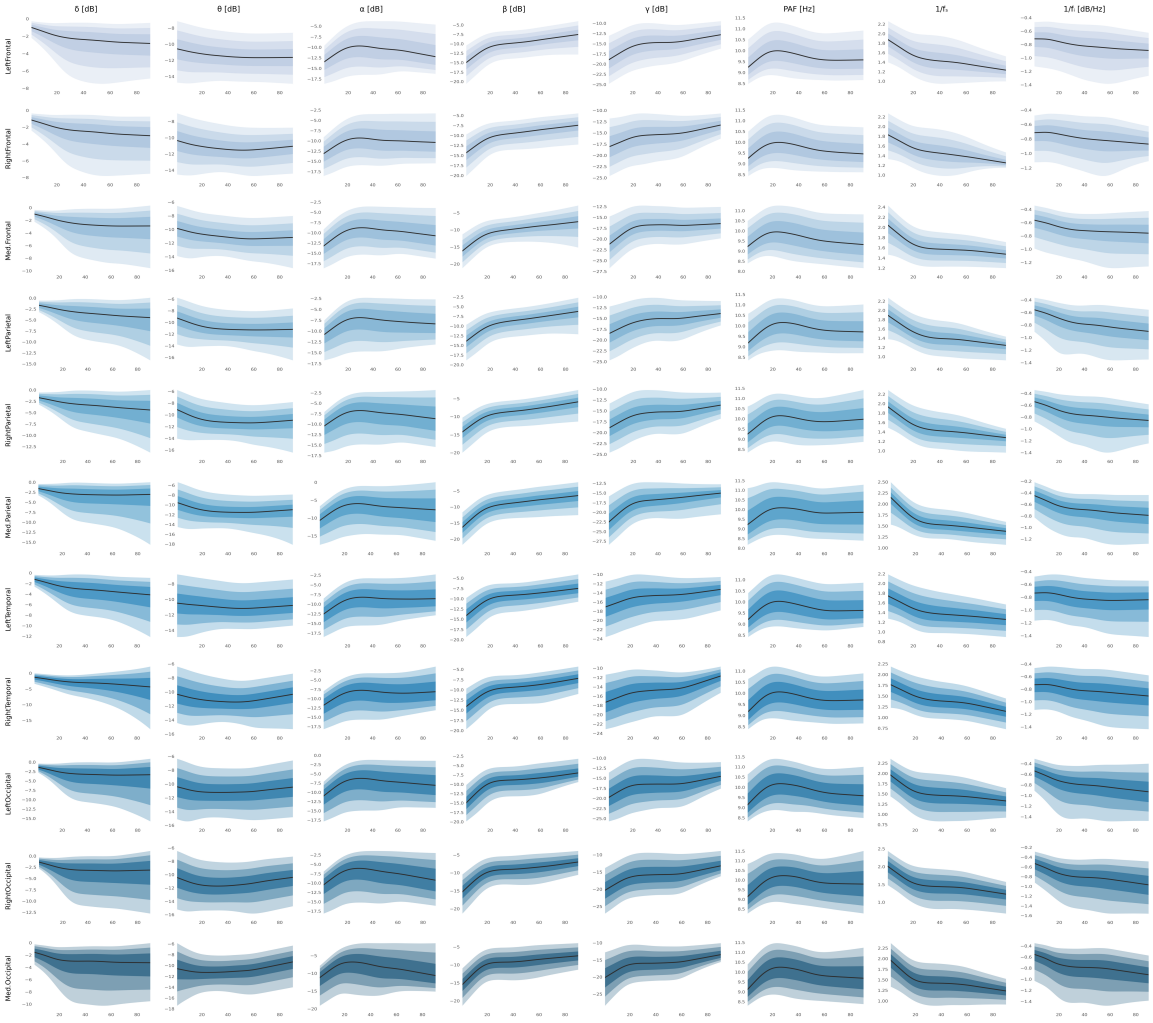


Supplementary Figure S1. Evaluation of LDA classifiers on EEG normative z-score features across diagnostic groups. Three classification strategies were compared using Linear Discriminant Analysis with 10-fold group-aware cross-validation on 11 subject-level EEG z-score features, pooled across the 11 lobar regions (mean). The analysis comprised N subjects from seven groups: Reference, ADHD, ASD, Alzheimer's disease, FTD, anxiety disorders, and PTSD (per-group counts in Table S10). **(a)** Multiclass one-vs-rest (OvR) ROC curves from a single 7-class classifier. Neurodegenerative conditions showed the strongest separability (Alzheimer's AUC = 0.84, FTD = 0.74), whereas neurodevelopmental and mental-health groups remained near chance. The micro-averaged ROC (AUC = 0.85) pools all binarised predictions and is dominated by the most prevalent classes; the macro-average (AUC = 0.64) provides a class-balanced summary. **(b)** Binary ROC curves from six independent classifiers, each trained to discriminate one diagnosis from the held-out reference cohort. Alzheimer's (AUC = 0.95) and FTD (AUC = 0.91) were again most separable. ADHD (0.59), ASD (0.61), anxiety (0.57), and PTSD (0.55) showed limited separability. **(c)** Within-category pairwise classifiers: ADHD vs ASD (AUC = 0.58), Alzheimer's vs FTD (0.52), anxiety vs PTSD (0.53), all at or near chance. **(d)** Summary of AUC values across all classifier variants with permutation-test p-values. Dashed lines indicate chance level (50% binary, 14.3% multiclass).

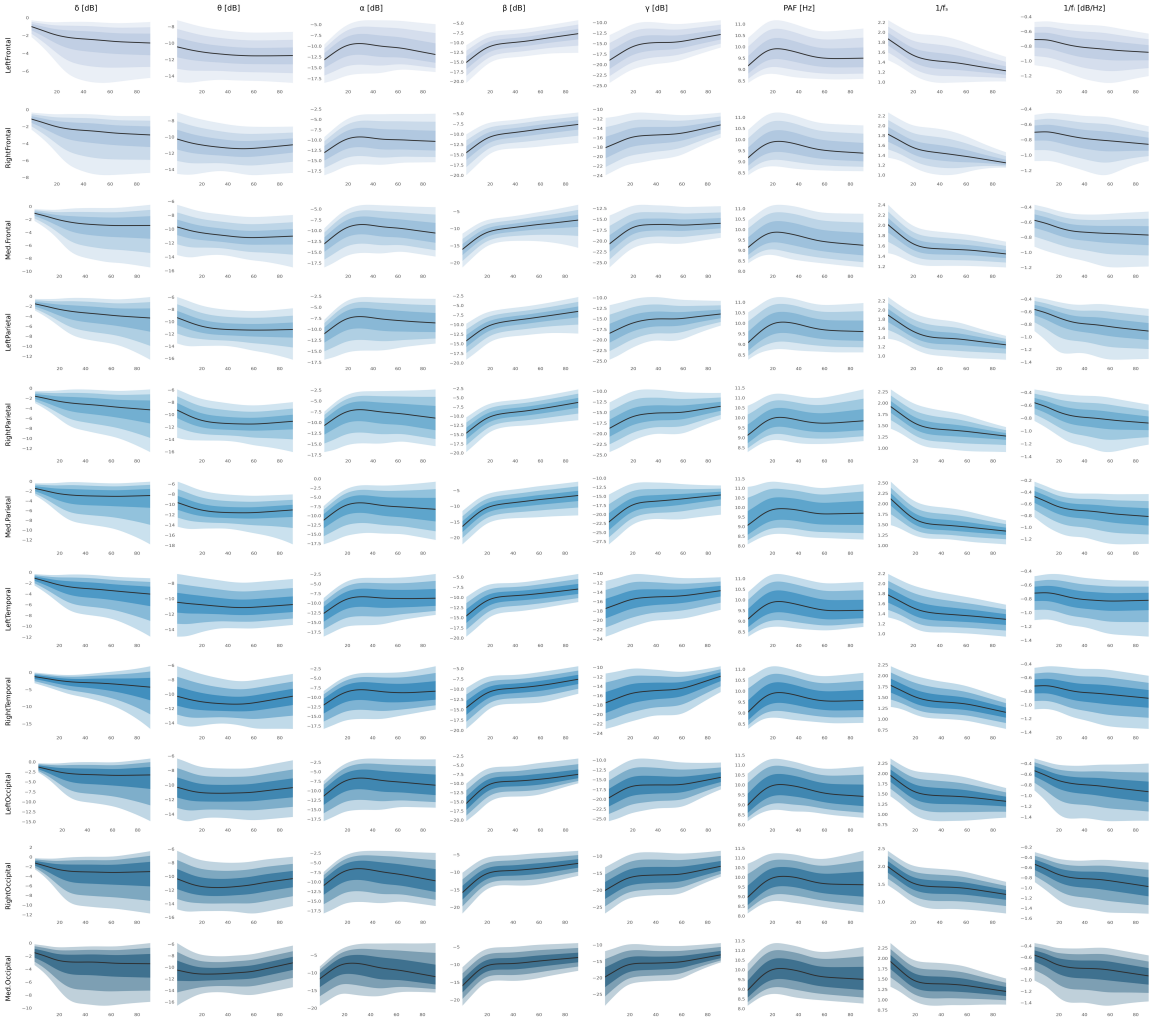
Supplementary Figure S2: Full Trajectory Atlas

Supplementary Figure S2. Normative lifespan trajectories for all spectral features across cortical regions. Shaded bands represent the 25–75, 10–90, and 2.5–97.5 centile ranges for (a) female and (b) male trajectories separately. Features include narrow-band relative powers (δ, θ, α, β, γ in FBP and dB), peak alpha frequency (PAF), aperiodic components (1/f slope and intercept), and band ratios (θ/β, θ/α, Fast/Slow). Trajectories are averaged across the 11 cortical regions.

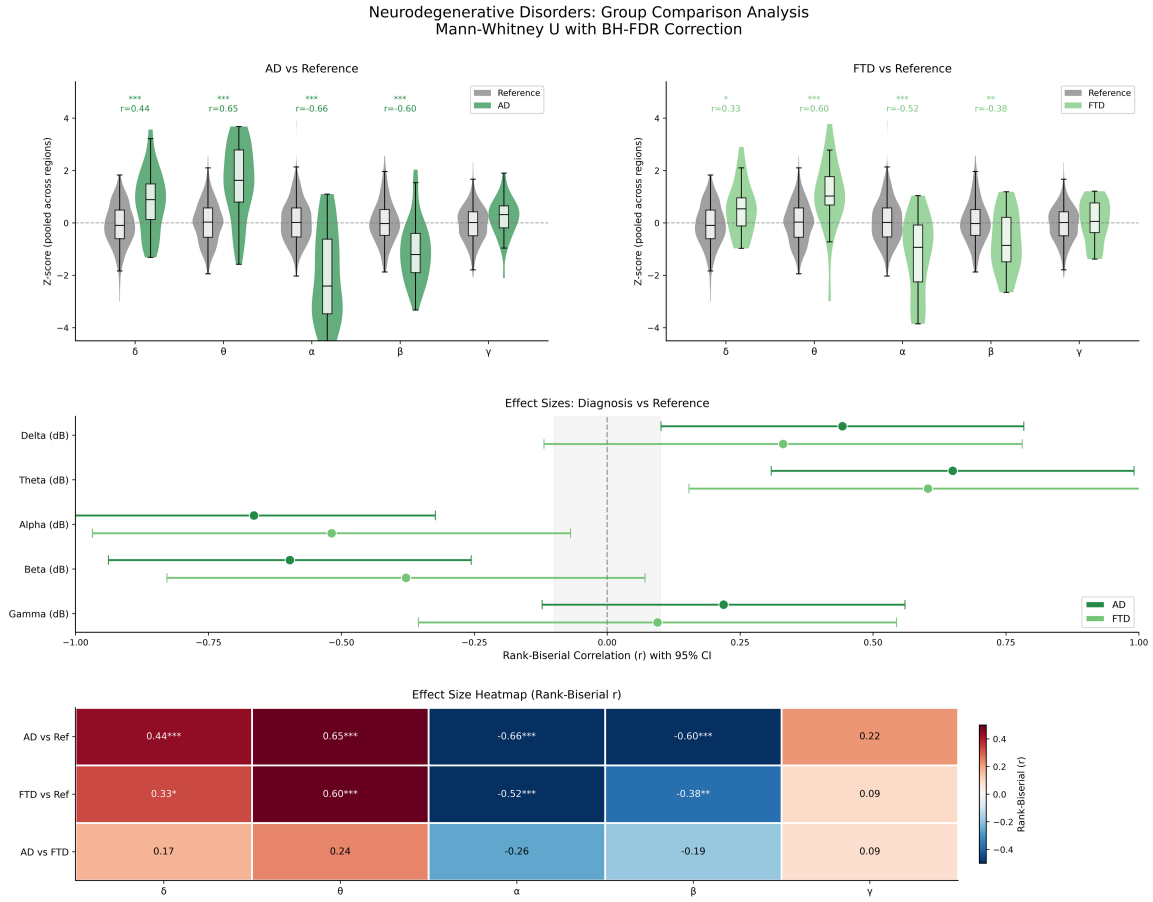
Sup. Figure S2a Female normative trajectories and ranges



Sup. Figure S2b Male normative trajectories and ranges

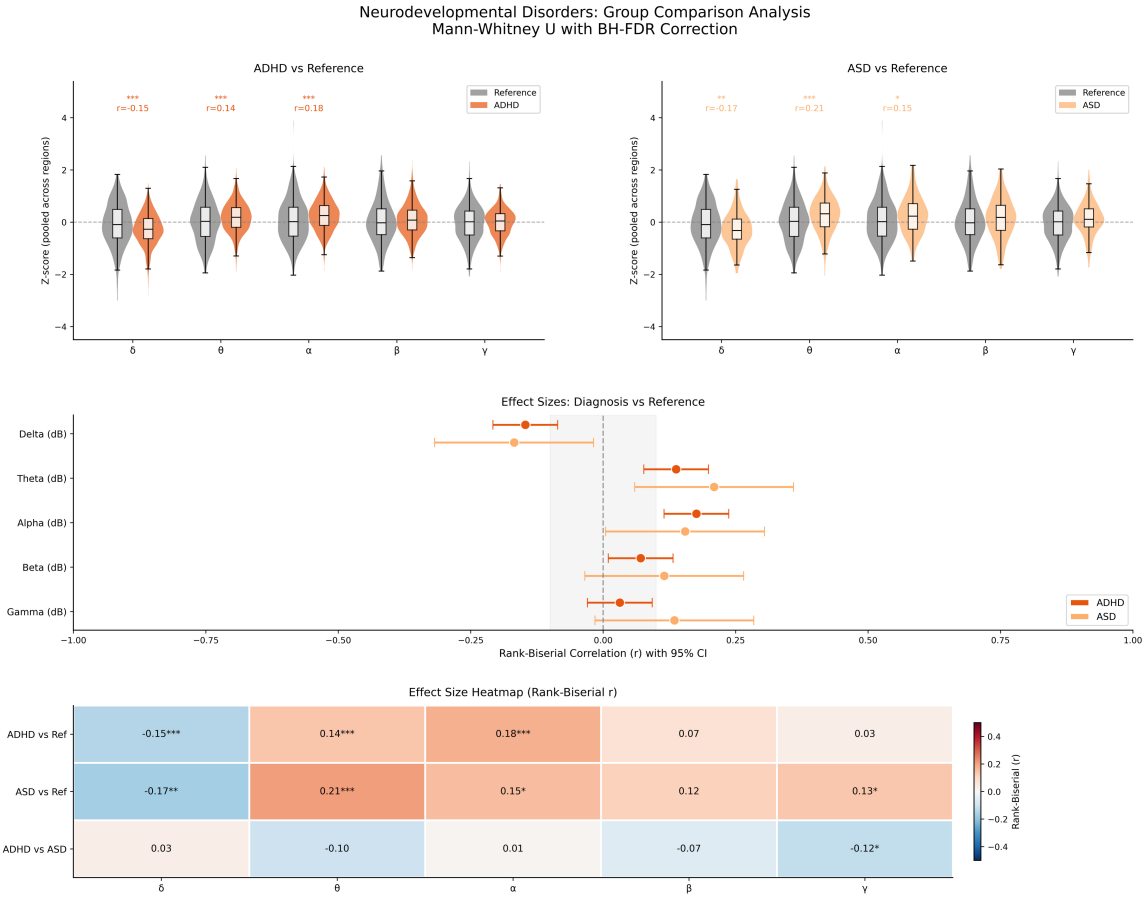

δ [dB]
θ [dB]
α [dB]
β [dB]
γ [dB]
PAF [Hz]
1/fₛ
1/f [dB/Hz]
LeftFrontal
RightFrontal
Med.Frontal
LeftParietal
RightParietal
Med.Parietal
LeftTemporal
RightTemporal
LeftOccipital
RightOccipital
Med.Occipital

Supplementary Figure S3: Neurodegenerative cohorts group Comparisons



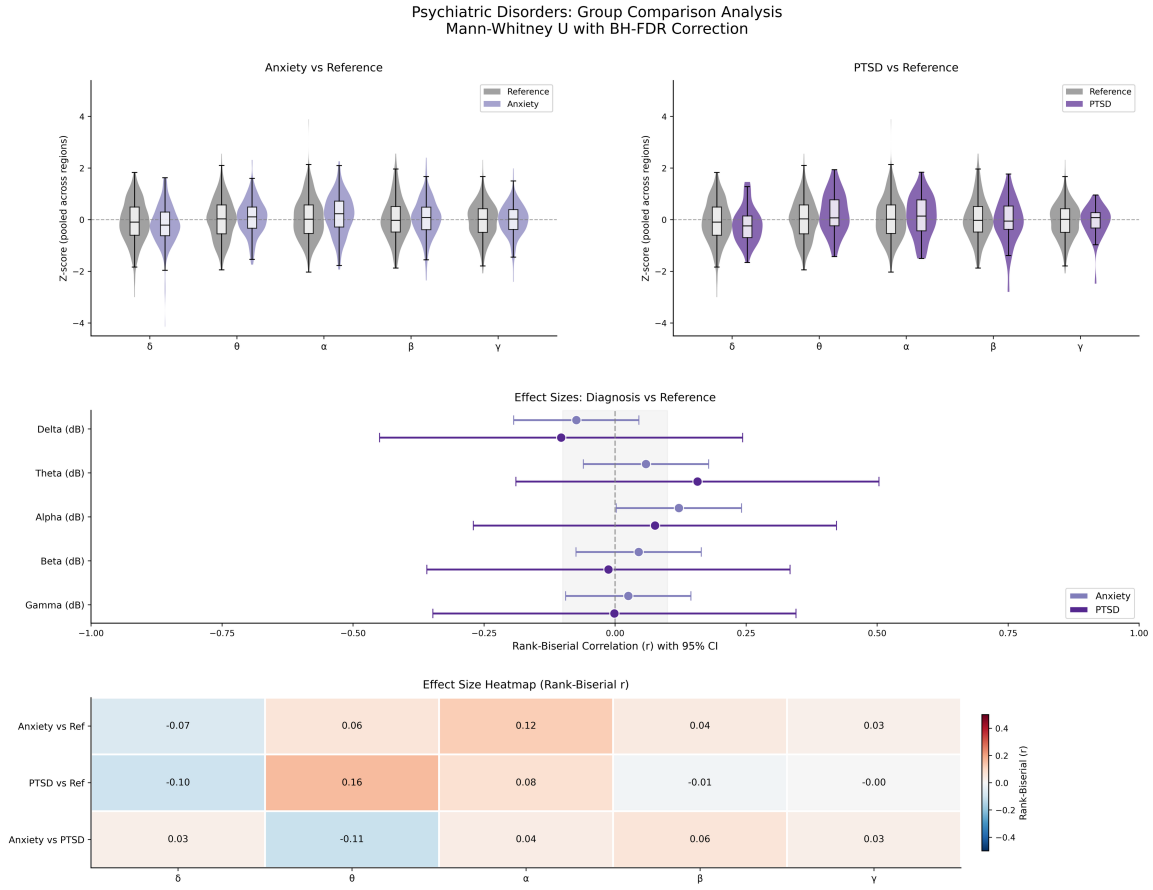
Supplementary Figure S3. Neurodegenerative cohort group comparisons. Z-score deviation profiles for Alzheimer's disease (n=36) and frontotemporal dementia (FTD, n=22) compared against the held-out normative reference, shown per spectral feature and cortical region. Box plots show the distribution of z-scores; significance markers indicate FDR-corrected comparisons (BH; * q<0.05, ** q<0.01, *** q<0.001).

Supplementary Figure S4: Neurodevelopmental cohorts group Comparisons



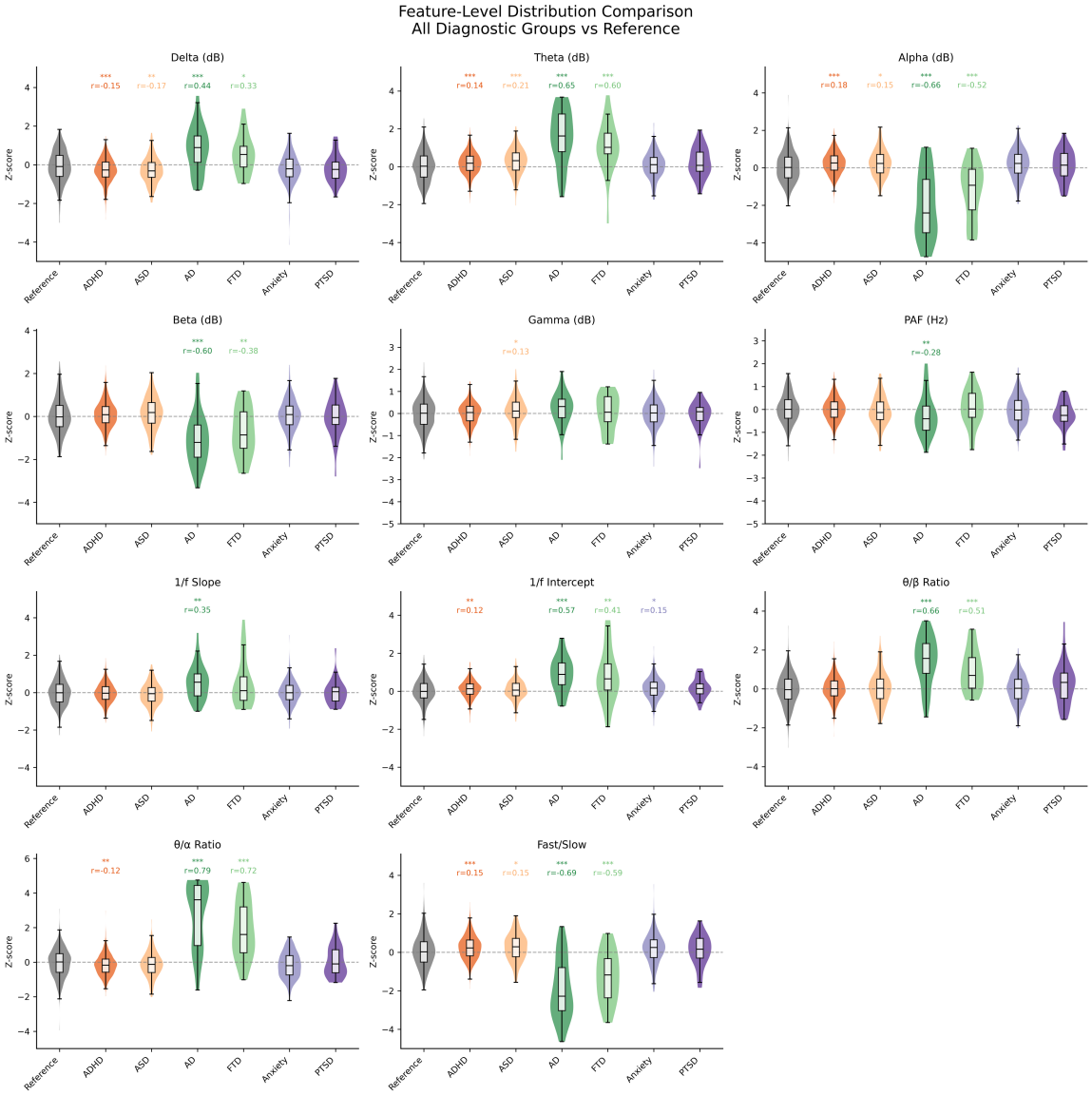
Supplementary Figure S4. Neurodevelopmental cohort group comparisons. Z-score deviation profiles for ADHD (n=1,034) and ASD (n=174) compared against the held-out normative reference, shown per spectral feature and cortical region. Box plots show the distribution of z-scores; significance markers indicate FDR-corrected comparisons (BH; * q<0.05, ** q<0.01, *** q<0.001).

Supplementary Figure S5: Psychiatric cohorts group Comparisons



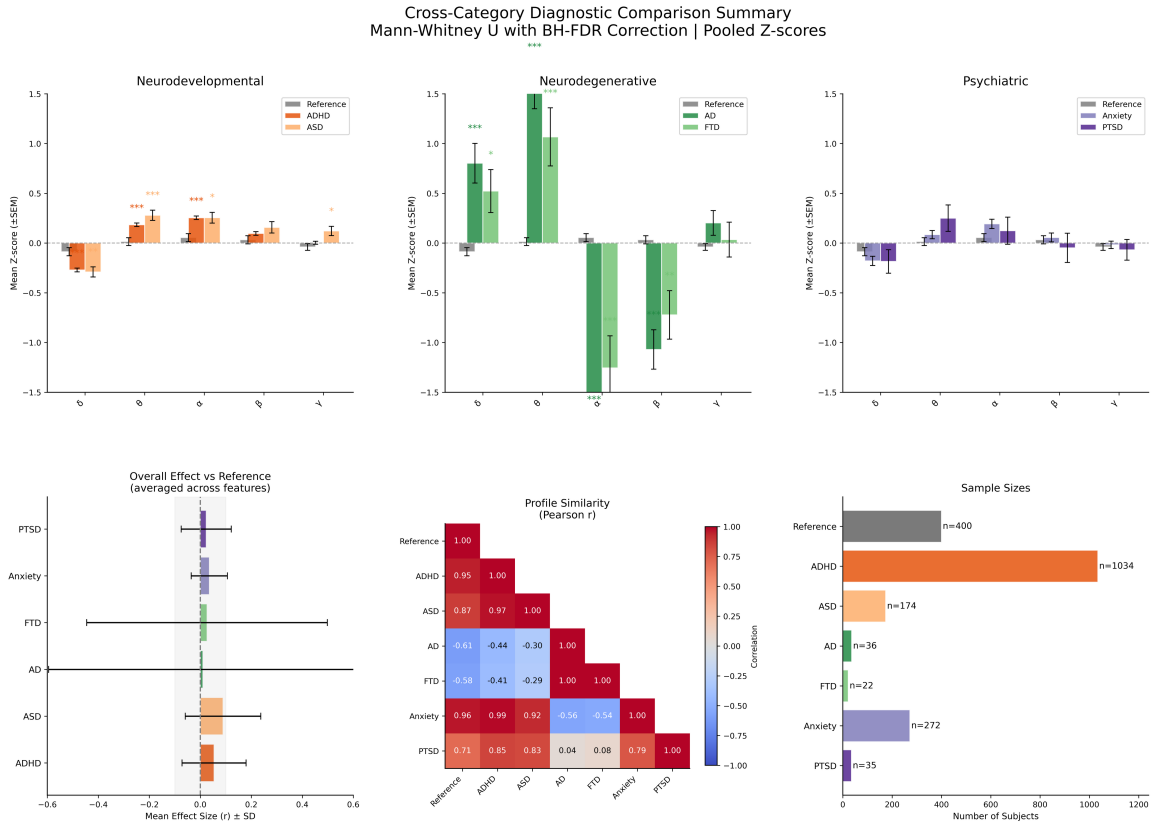
Supplementary Figure S5. Psychiatric cohort group comparisons. Z-score deviation profiles for anxiety (n=272) and PTSD (n=35) compared against the held-out normative reference, shown per spectral feature and cortical region. Box plots show the distribution of z-scores; significance markers indicate FDR-corrected comparisons (BH; * q<0.05, ** q<0.01, *** q<0.001).

Supplementary Figure S6: Feature-level deviation profiles per diagnosis



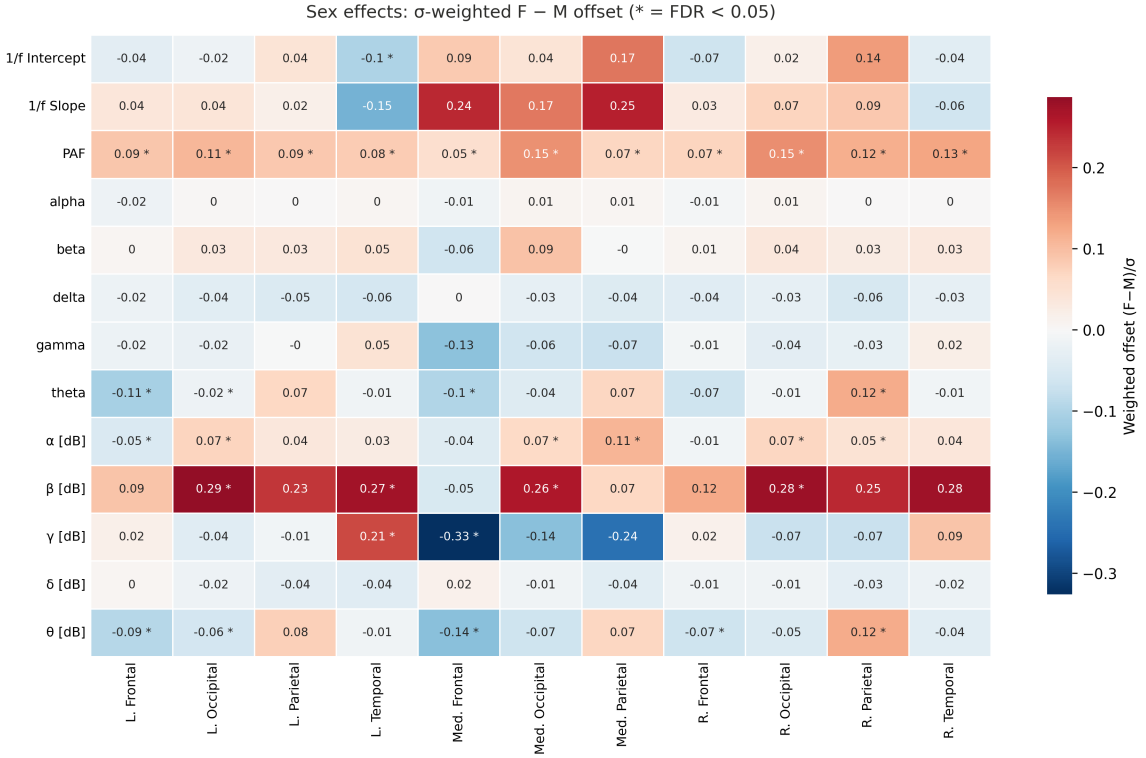
Supplementary Figure S6. Feature-level deviation profiles per diagnosis. Compact visualization of z-score deviations across all 11 spectral features for each diagnostic cohort, pooled across cortical regions. Each panel shows the deviation direction and magnitude relative to normative expectations, enabling direct visual comparison of spectral signatures across conditions.

Supplementary Figure S7: Cross-category Comparisons



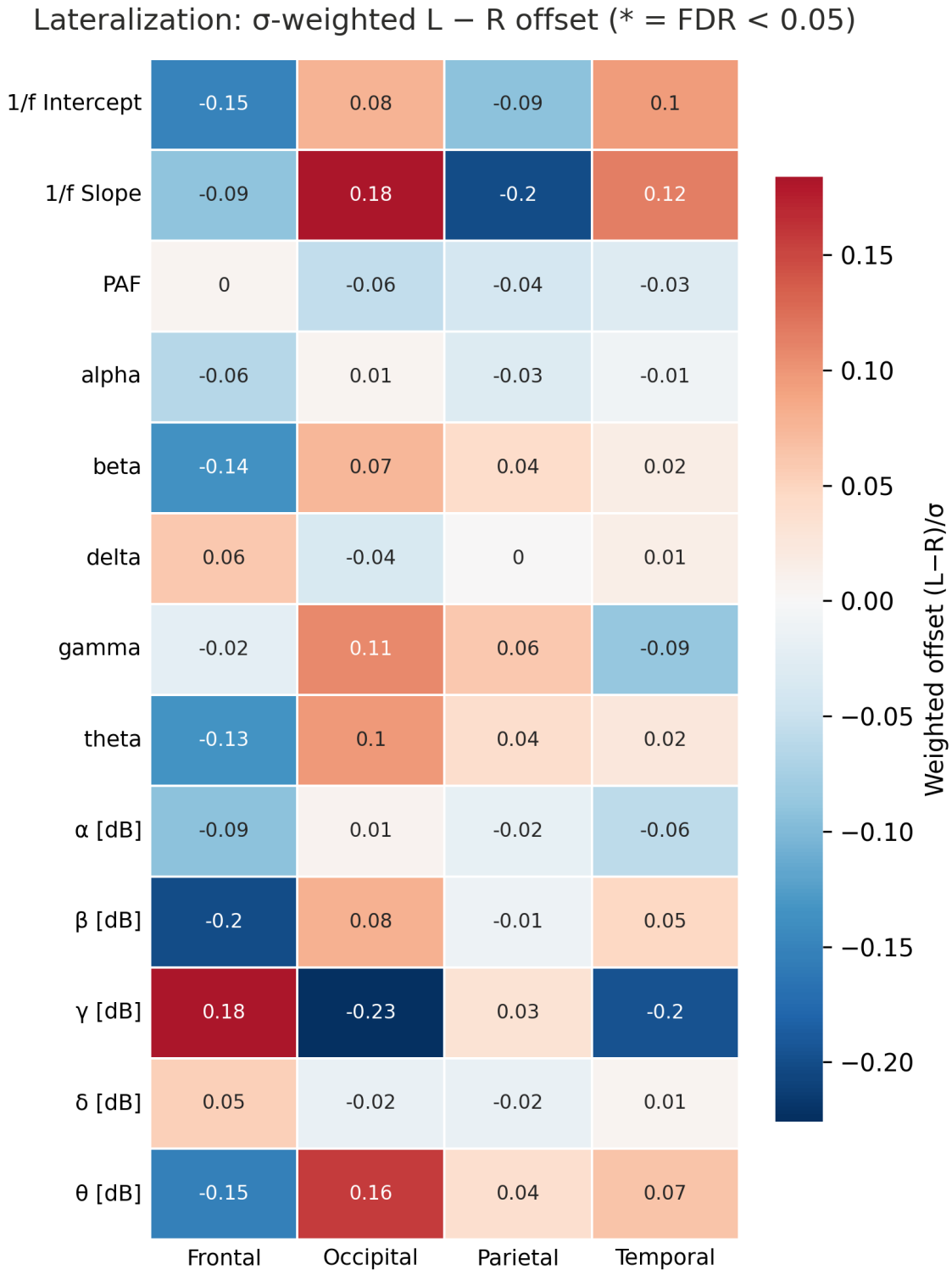
Supplementary Figure S7. Cross-category comparisons. Summary visualization comparing deviation profiles across all diagnostic categories simultaneously. Panels show (a) within-category pairwise comparisons (ADHD vs ASD, Alzheimer's vs FTD, anxiety vs PTSD) and (b) cross-category overlap in the multivariate deviation space, illustrating the degree of spectral convergence and divergence across nosological boundaries.

Supplementary Figure S8: Sex Effects on Normative Trajectories



Supplementary Figure S8. Sex effects on normative lifespan trajectories. Heatmap of trajectory comparison metrics between female and male normative models across all feature–region combinations. Circular-shift permutation testing (2,000 permutations) on the absolute-area statistic was used to assess shape (q_shape) and level (q_level) differences, with FDR correction (Benjamini–Hochberg). No trajectory shape differences survived correction (0/143; min q = 0.55). Small but significant level offsets were detected in 33/143 comparisons (23.1%; min q = 0.003), though these were feature- and region-specific rather than globally consistent. Dispersion (σ) trajectory comparisons showed no significant shape differences (0/143).

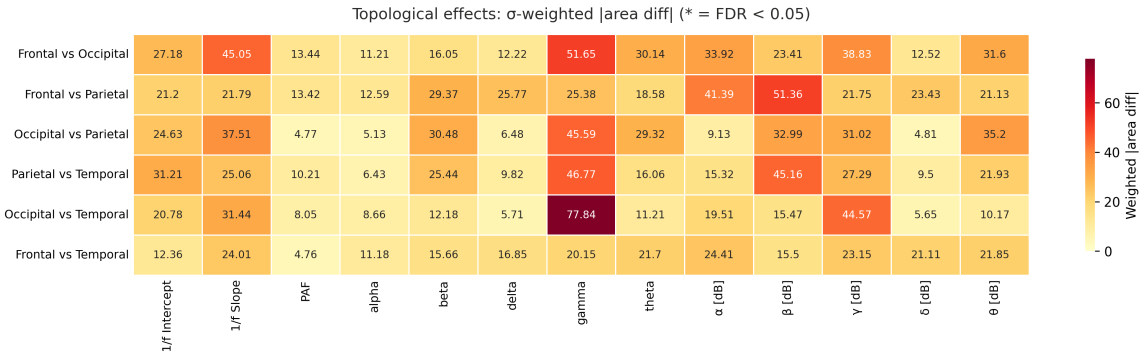
Supplementary Figure S9: Hemispheric Lateralization



Supplementary Figure S9. Hemispheric lateralization of normative trajectories. Heatmap of left–right homologue trajectory comparisons across all feature–lobe–sex combinations. Permutation testing (2,000 permutations) on the absolute-area statistic between left and right hemispheric trajectories, FDR-corrected. No lateralization effects survived

multiple-comparison correction (0/104 comparisons; mean permutation p = 0.94; all FDR-corrected q = 1.0), indicating that normative spectral trajectories are bilaterally symmetric at the lobar aggregation level used in this study.

Supplementary Figure S10: Intra-hemispheric Topological Comparisons



Supplementary Figure S10. Intra-hemispheric topological comparisons of normative trajectories. Heatmap of pairwise region–region trajectory comparisons within each hemisphere, across all feature–sex combinations. Curve-distance metrics (mean absolute difference, RMSE, absolute area between curves, maximum deviation) and permutation-based significance testing were used to quantify regional differences in spectral trajectory shape. After FDR correction, no intra-hemispheric region pairs showed significant trajectory shape differences, consistent with the spatially distributed nature of spectral dynamics at the lobar aggregation scale.

Supplementary Data Files

sex_effects_table.csv – Full sex effects (143 comparisons) with permutation tests and FDR q-values.

lateralization_table.csv – Left-right hemispheric comparisons with permutation tests.

topology_table.csv – Intra-hemispheric region-pair comparisons.

trajectory_summary.csv – Quantitative trajectory summary: slopes, turning points, inflection ages.

all_diagnoses_stats_globalFDR.csv – Covariate-stratified z-score comparisons (sex × eyes × diagnosis).

statistical_comparisons.csv – Extended within-category statistical comparisons.