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Cerebellar and Cerebral Volumes Coevolve Throughout Primate Evolution

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The human brain and its disproportionately expanded neocortex have been considered crowning achievements of evolution. However, in recent years it has become appreciated that the entire cerebro-cerebellar system may be one of the primary driving factors behind the primate cognitive evolution (Smaers and Vanier, 2019). Here, we performed comparative analysis of cerebellar volume in the primate phylogenetic tree, as well as allometric analysis of cerebellar and neocortical volumes in magnetic resonance imaging data from 34 primate species (65 individuals) (Heuer et al., 2019).

Together with cerebral measures, cerebellar volumes argued for Brownian Motion (BM) phenotypic evolution (λ=1.0; AIC=-1097.338), significantly outperforming all other models (next-best supported model: Ornstein-Uhlenback (single α, AIC=-1089.255)). Direct testing of the BM model with λ=1.0 (trait data fully explained by phylogeny) versus with λ=0.0 (complete star-phylogeny) yielded log-likelihood values of 620.67 (BM) and 593.30 (star), respectively (Chi-square=54.73>3.84 (critical value)). Therefore, we used the BM model for subsequent analyses. Next, we mapped the cerebellar volumes to the consensus phylogenetic tree (Arnold et al., 2010; Goolsby et al., 2017), which allowed us to reconstruct ancestral states and compare the evolutionary dynamics to those of the cerebral cortex. PGLS regression (cerebellar volume ~ cerebral volume) showed that cerebellar and cerebral volumes are highly correlated throughout primate evolution, even when accounting for primate shared ancestry (cerebral volume: coefficient=0.987, standard error=0.027, p<2e-16***). Phylogenetic canonical correlation analysis (PCCA) in the same data with λ=1.0 similarly revealed coevolution of the volumes (coefficient=0.959, p=5.22e-19, log-likelihood=13.43), but were more significant when allowing λ to vary (λ=0.924, coefficient=0.969, p=4.02e-21, log-likelihood=15.41).

Our data indicate that the cerebellum and cerebral cortex strongly coevolve over primate evolution, and offer suggestions for great ape exceptionality, which can be further explored by subsequent analyses in the same data.

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