

The shared genetic architecture and evolution of human language and musical rhythm

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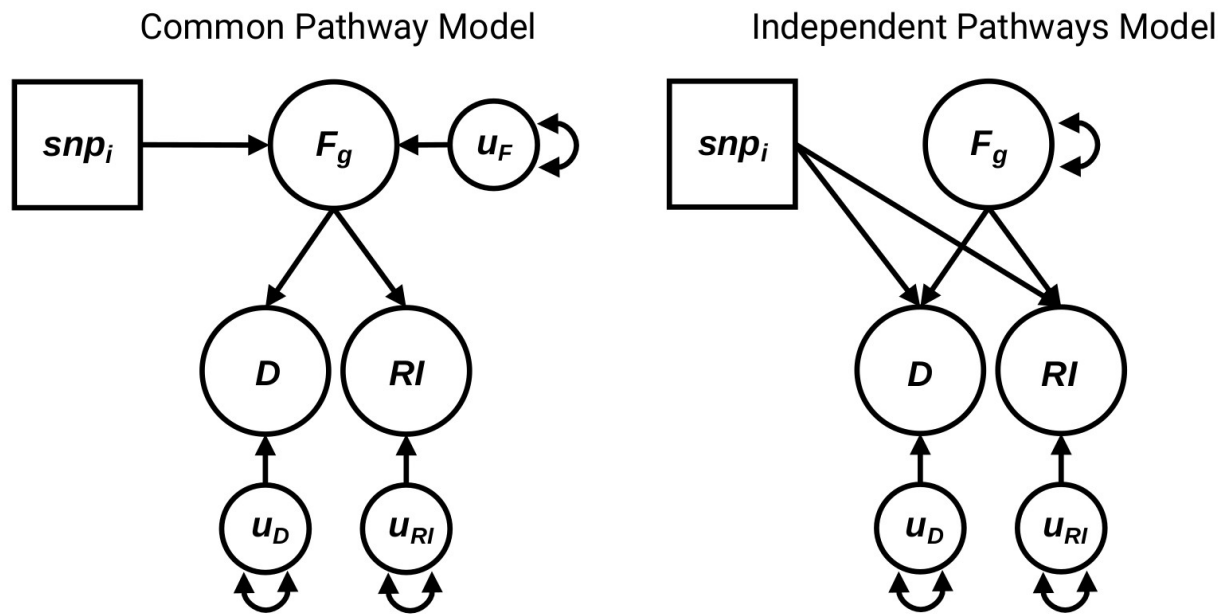
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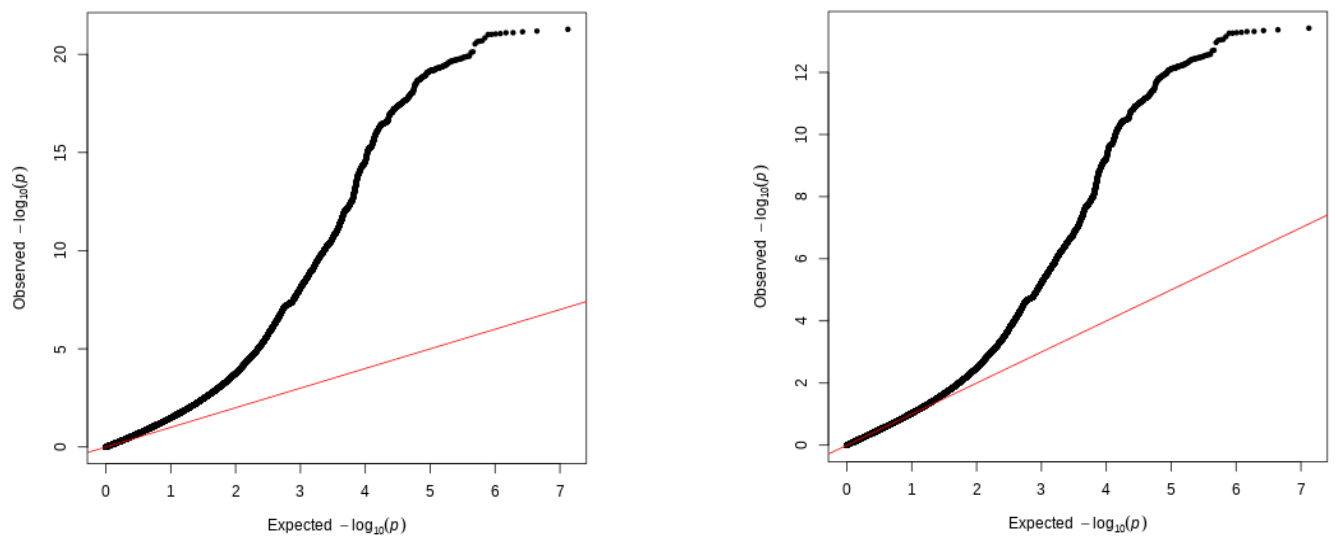
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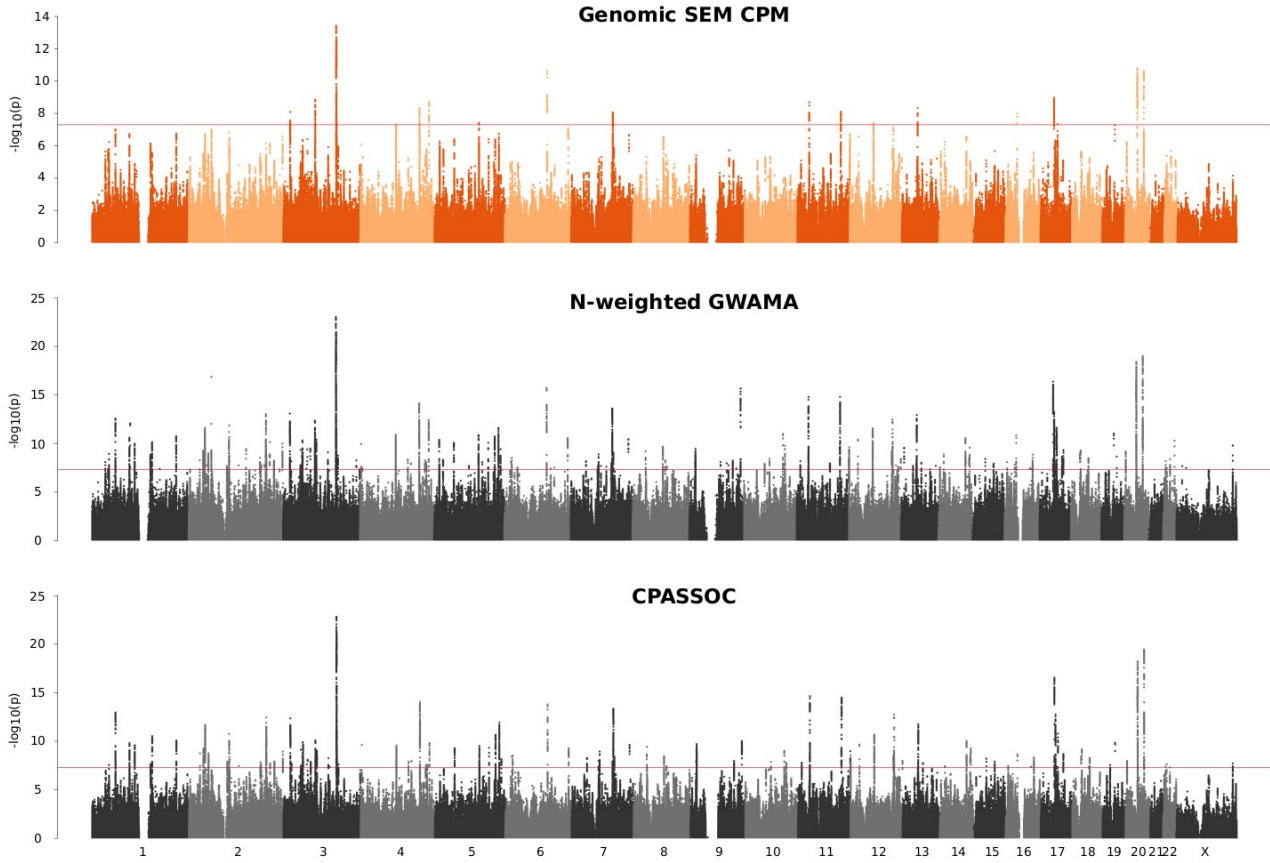
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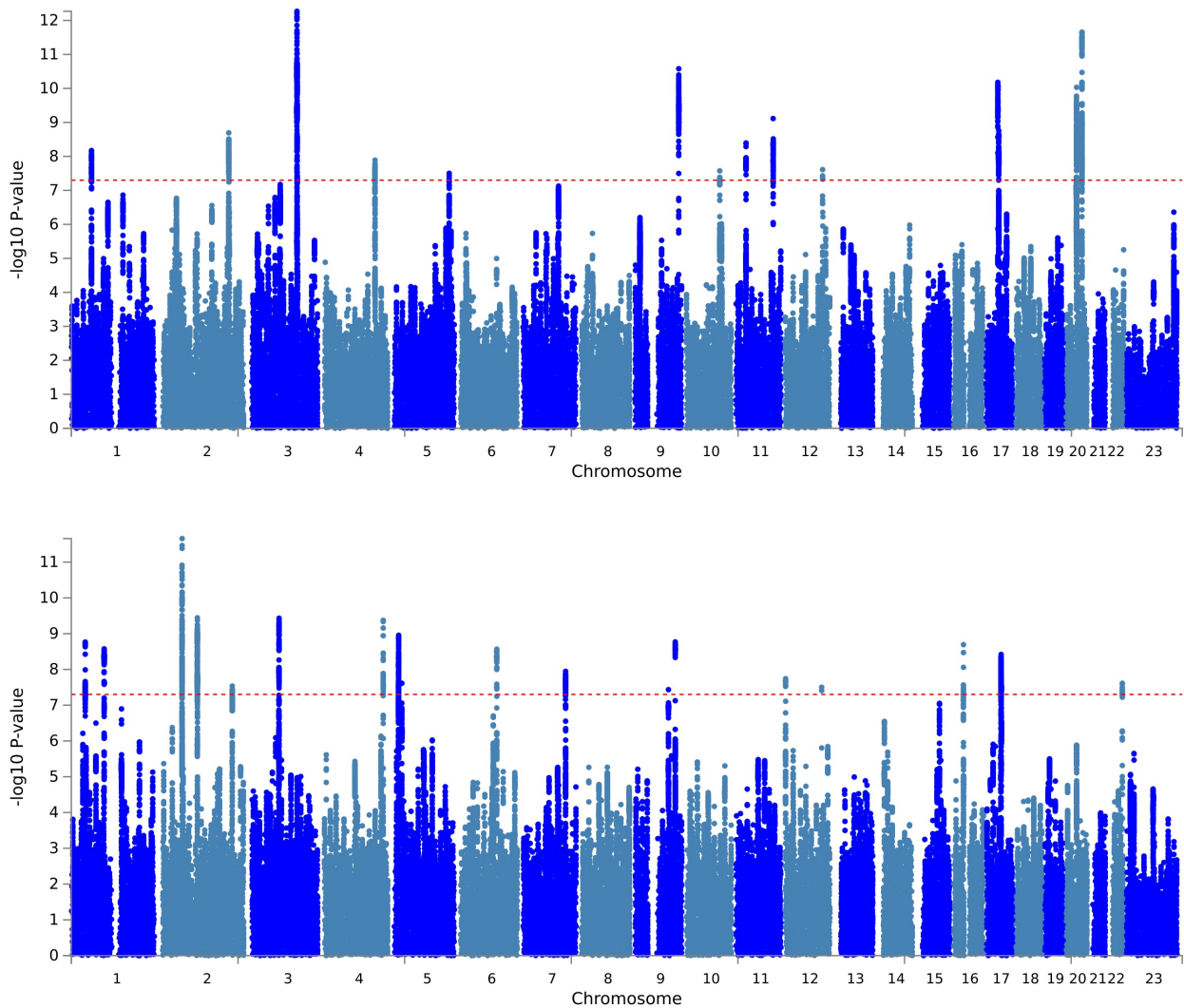
Supplementary Figure 1: Genomic SEM model diagrams for common pathway (left) and independent pathways (right) models. The models were used to perform a bivariate GWAS using Genomic SEM, and for the identification of common and independent genetic factors. D: dyslexia, RI: rhythm impairment, F_g : Common factor, u_D : residual variance of dyslexia, u_{RI} : residual variance of musical rhythm impairment, u_F : residual variance of the common factor, snp_i : i^{th} SNP regression.



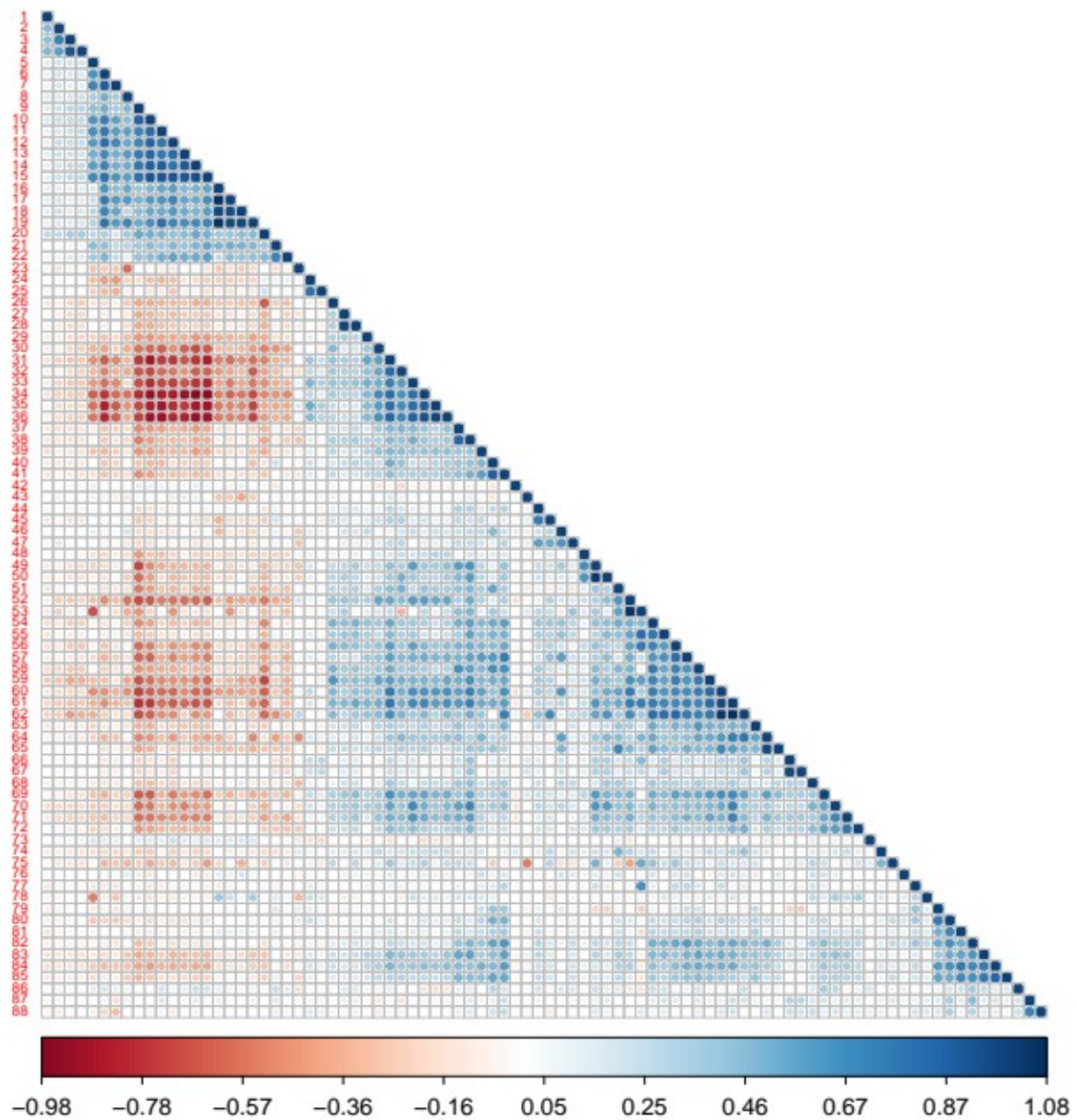
Supplementary Figure 2: The Quantile-Quantile (QQ) plots of $F_{\text{gRI-D}}$ mvGWAS show observed (y axis) and expected (x axis) $-\log_{10}(P)$ values *prior to* (left) and *after* (right) GC correction.



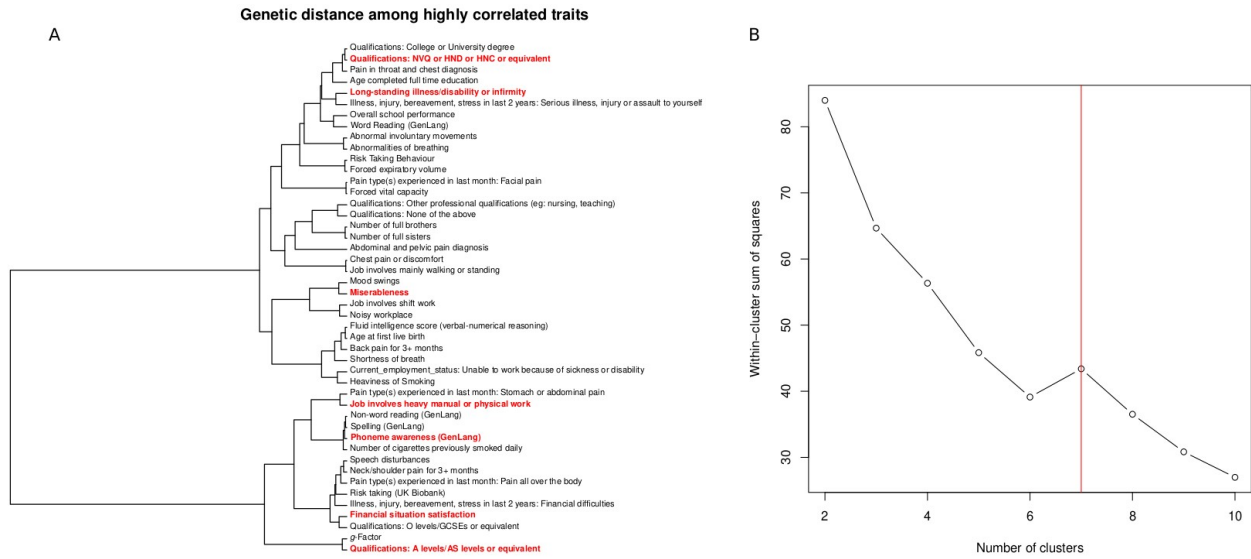
Supplementary Figure 3: Manhattan plots for Genomic SEM CPM ($F_{\text{gRI-D}}$), N-weighted GWAMA, and CPASSOC (see *Multivariate genome-wide association studies* in the Methods for details of each method). Each data point represents a SNP. The y axes show $-\log_{10}(P)$ values, and the x axes show genomic coordinates. The red lines correspond to the genome-wide significance threshold ($P < 5 \times 10^{-8}$). $N_{\text{rhythm impairment}} = 606,825$, $N_{\text{dyslexia}} = 1,138,870$.



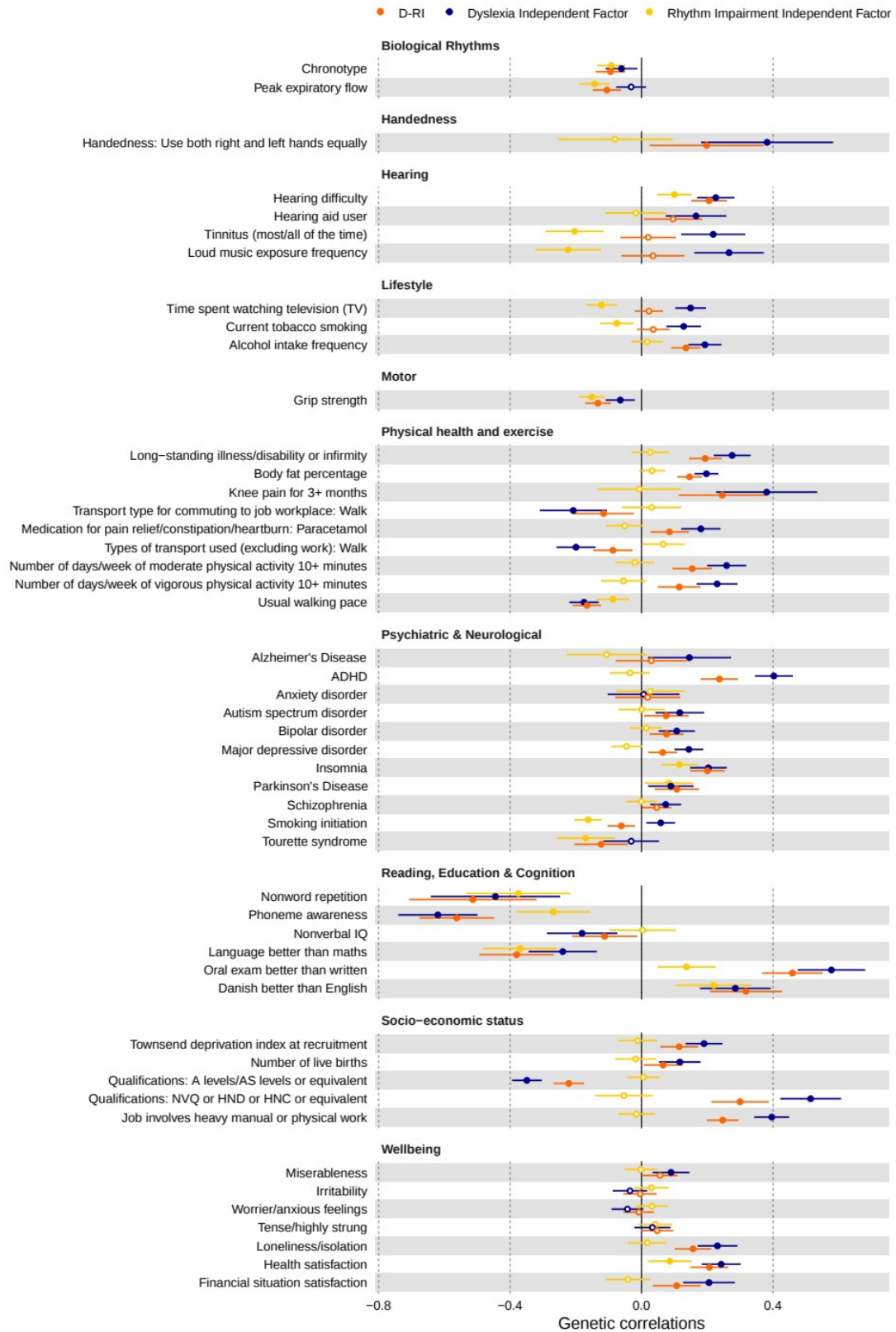
Supplementary Figure 4: Manhattan plots for the independent factors of dyslexia (top) and rhythm impairment (bottom). The bivariate GWAS was performed using Genomic SEM. Each data point represents a SNP. The y axes show $-\log_{10}(P)$ values, and the x axes show genomic coordinates. The red lines correspond to genome-wide significance threshold ($P < 5 \times 10^{-8}$). $N_{\text{rhythm impairment}}=606,825$, $N_{\text{dyslexia}}=1,138,870$.



Supplementary Figure 5: The genetic correlation (r_g) matrix among 88 traits that are significantly correlated ($P_{\text{FDR}} < 0.05$) with either dyslexia or musical rhythm. Traits were curated from Doust et al. (2022) and Niarchou et al. (2022). Genetic correlations were estimated using LDSC. The colour code in each cell represent the r_g between the intersecting traits. The numbers on the left-hand side correspond to the ID of each trait (see Table S13 for a full list of traits and trait IDs). The colour code bar at the bottom indicates the magnitude and direction of r_g (red: negative correlation; blue: positive correlation; white: no correlation).

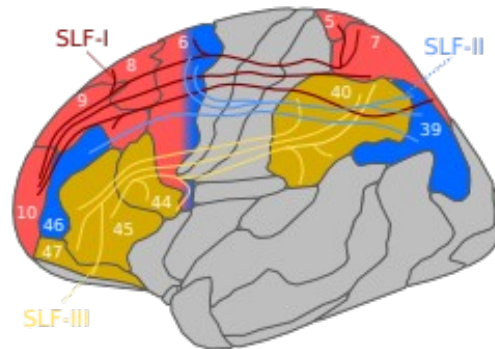


Supplementary Figure 6: (A) Dendrogram showing the hierarchical clustering of highly genetically correlated ($|r_g| > 0.80$) traits. (B) Knee-point algorithm plot showing seven representative clusters. For each cluster, one representative trait (shown in bold red) was used in the genetic correlation analysis with the F_{gRI-D} .

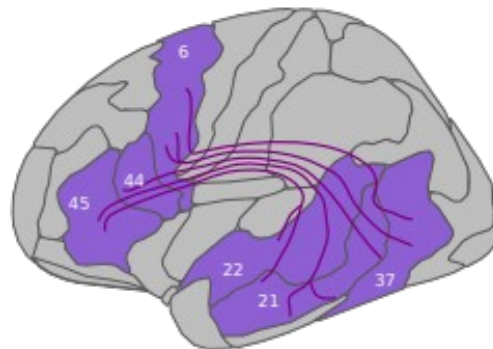


Supplementary Figure 7: Genetic correlations (r_g) between 49 selected traits and F_{gRI-D} (D-RI) (orange), and dyslexia (blue) and musical rhythm impairment (yellow) independent factors. Genetic correlations were estimated using LDSC. Full circles indicate significant correlations after FDR correction for 49 tests ($P_{FDR} < 0.05$). Error bars represent standard errors of the mean, with whiskers extending one SEM below/above the r_g . The sample size of each trait is shown in Table S13.

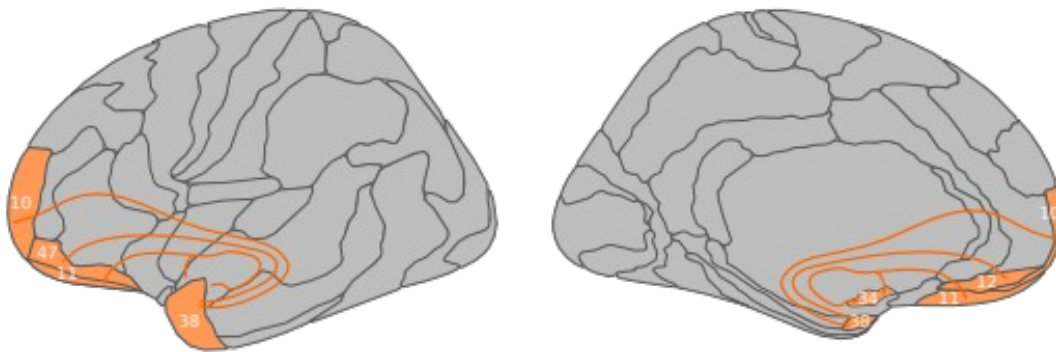
Superior Longitudinal Fasciculus



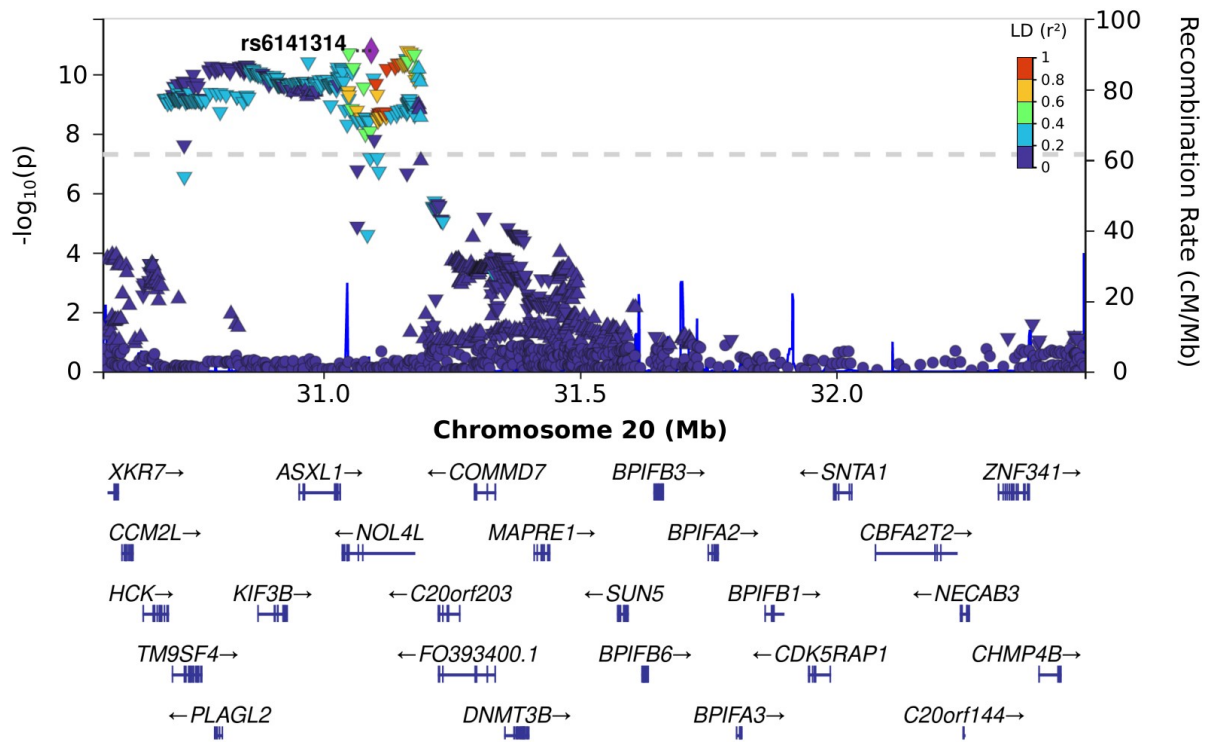
Arcuate Fasciculus - long segment



Uncinate Fasciculus



Supplementary Figure 8: Brain plots showing five left hemisphere white-matter tracts investigated in our local genetic correlation analysis with $F_{\text{gRI-D}}$. Note that only the left hemisphere of the brain is shown here from the lateral view for the superior longitudinal fasciculus and the arcuate fasciculus long segment. For the uncinate fasciculus, both lateral (left) and medial (right) views of the left hemisphere are shown. Each white-matter tract has the same colour with the Brodmann Areas that it connects. Numbers correspond to Brodmann Area IDs. Brodmann Area 6 is connected to both SLF-I and SLF-II, thus it is depicted as both red and blue.



Supplementary Figure 9: LocusZoom plot of the chr20: 30,569,660-32,484,506 locus, the region which is identified by local genetic correlation analysis of F_{gRI-D} and Superior Longitudinal Fasciculus I. The x axis shows genomic locations, and the y axis shows F_{gRI-D} $-\log_{10}(P)$ -values on the left-hand side and recombination rates (centiMorgan per megabase) on the right-hand side. Direction of the triangles represent effect directions (upwards: positive; downwards: negative). LD (r^2) levels with rs6141314 are colour-coded. Grey dashed line indicates the genome-wide significance level ($P < 5 \times 10^{-8}$).