Supplementary Material for:

Functional corticostriatal connection topographies predict goal directed behaviour in humans

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Supplementary Methods

We provide below a list of the behavioural variables from the Human Connectome Project dataset that we included in the canonical correlation analysis described in the main text. Most measures are self-explanatory but full descriptions of each measure can be found in the HCP data dictionary available online (https://wiki.humanconnectome.org/display/PublicData/HCP+Data+Dictionary+Public-+500+Subject+Release)

Clinical (variables 1-28): ASR_Anxd_Raw, ASR_Witd_Raw ASR_Soma_Raw, ASR_Soma_Pct ASR_Thot_Raw, ASR_Attn_Raw, ASR_Attn_Pct, ASR_Aggr_Raw, ASR_Rule_Raw, ASR_Rule_Pct, ASR_Intr_Raw, ASR_Intr_Pct, ASR_Oth_Raw, ASR_Crit_Raw, ASR_Intn_T, ASR_Extn_T, ASR_Totp_T, DSM_Depr_Raw, DSM_Depr_Pct, DSM_Anxi_Raw, DSM_Anxi_Pct, DSM_Somp_Raw, DSM_Somp_Pct, DSM_Avoid_Raw, DSM_Avoid_Pct, DSM_Adh_Raw, DSM_Adh_Pct, DSM_Inat_Raw MMSE_Score,

Executive function (variables 29-44 and 65-68): PicSeq_Unadj, PicSeq_AgeAdj, CardSort_Unadj, CardSort_AgeAdj, Flanker_Unadj, Flanker_AgeAdj, PMAT24_A_CR, PMAT24_A_SI, PMAT24_A_RTCR, ReadEng_Unadj, ReadEng_AgeAdj, PicVocab_Unadj, PicVocab_AgeAdj, ProcSpeed_Unadj, ProcSpeed_AgeAdj, IWRD_TOT, IWRD_RTC, IWRD_TOT, IWRD_RTC, ListSort_Unadj, ListSort_AgeAdj

Delay discounting (variables 45-57): DDisc_SV_1mo_200, DDisc_SV_6mo_200, DDisc_SV_1yr_200, DDisc_SV_3yr_200, DDisc_SV_5yr_200, DDisc_SV_10yr_200, DDisc_SV_6mo_40K, DDisc_SV_1yr_40K, DDisc_SV_3yr_40K, DDisc_SV_5yr_40K, DDisc_SV_10yr_40K, DDisc_AUC_200, DDisc_AUC_40K,

Spatial orientation processing (variables 58-60): VSPLOT_TC, VSPLOT_CRTE, VSPLOT_OFF

Sustained attention (variables 61-64): SCPT_TPRT, SCPT_SEN, SCPT_SPEC, SCPT_LRNR,

Emotion recognition (variables 69-79): ER40_CR, ER40_CRT, ER40ANG, ER40FEAR, ER40SAD, AngAffect_Unadj, AngHostil_Unadj, AngAggr_Unadj, FearAffect_Unadj, FearSomat_Unadj, Sadness_Unadj,

Psychological Wellbeing (variables 80-92): LifeSatisf_Unadj, MeanPurp_Unadj, PosAffect_Unadj, Friendship_Unadj, Loneliness_Unadj, PercHostil_Unadj, PercReject_Unadj, EmotSupp_Unadj, InstruSupp_Unadj, PercStress_Unadj, SelfEff_Unadj, Emotion_Median_RT, PSQI_Score,

Emotional processing (fMRI, variables 93-96): Emotion_Face_Acc, Emotion_Face_Median_RT, Emotion_Shape_Acc, Emotion_Shape_Median_RT

Incentive processing (fMRI, variables 97-107): Gambling_Perc_Larger, Gambling_Perc_Smaller, Gambling_Median_RT_Larger, Gambling_Median_RT_Smaller Gambling_Reward_Perc_Larger, Gambling_Reward_Median_RT_Larger, Gambling_Reward_Perc_Smaller, Gambling_Reward_Median_RT_Smaller, Gambling_Punish_Perc_Larger, Gambling_Punish_Median_RT_Larger, Gambling_Punish_Median_RT_Smaller

Language (fMRI, variables 108-114): Language_Acc, Language_Median_RT, Language_Story_Median_RT, Language_Story_Avg_Difficulty_Level, Language_Math_Acc, Language_Math_Median_RT, Language_Math_Avg_Difficulty_Level,

Relational processing (fMRI, variables 115-120): Relational_Acc, Relational_Median_RT, Relational_Match_Acc, Relational_Match_Median_RT, Relational_Rel_Acc, Relational_Rel_Median_RT,

Social processing (fMRI, variables 121-125): Social_Perc_Random, Social_Median_RT_Random, Social_Median_RT_TOM, Social_Random_Median_RT_Random, Social_TOM_Median_RT_TOM,

Working memory (fMRI, variables 126-169): WM_Acc, WM_Median_RT, WM_2bk_Acc WM_2bk_Median_RT, WM_0bk_Acc , WM_0bk_Median_RT, WM_0bk_Body_Acc,

WM_0bk_Body_Acc_Target, WM_0bk_Body_Acc_Nontarget, WM_0bk_Tool_Acc, WM_2bk_Body_Acc,

WM_2bk_Body_Acc_Target, WM_2bk_Body_Acc_Nontarget, WM_2bk_Face_Acc,

WM_2bk_Face_Acc_Target, WM_2bk_Face_Acc_Nontarget,WM_2bk_Place_Acc ,

WM_2bk_Place_Acc_Target, WM_2bk_Tool_Acc , WM_2bk_Tool_Acc_Nontarget,

WM_0bk_Body_Median_RT, WM_0bk_Body_Median_RT_Target,

WM_0bk_Body_Median_RT_Nontarget, WM_0bk_Face_Median_RT,

WM_0bk_Face_Median_RT_Target, WM_0bk_Face_Median_RT_Nontarget,

WM_0bk_Place_Median_RT, WM_0bk_Place_Median_RT_Target,

WM_0bk_Place_Median_RT_Nontarget, WM_0bk_Tool_Median_RT,

WM_0bk_Tool_Median_RT_Target, WM_0bk_Tool_Median_RT_Nontarget,

WM_2bk_Body_Median_RT, WM_2bk_Body_Median_RT_Target,

WM_2bk_Body_Median_RT_Nontarget, WM_2bk_Face_Median_RT,

WM_2bk_Face_Median_RT_Target, WM_2bk_Face_Median_RT_Nontarget,

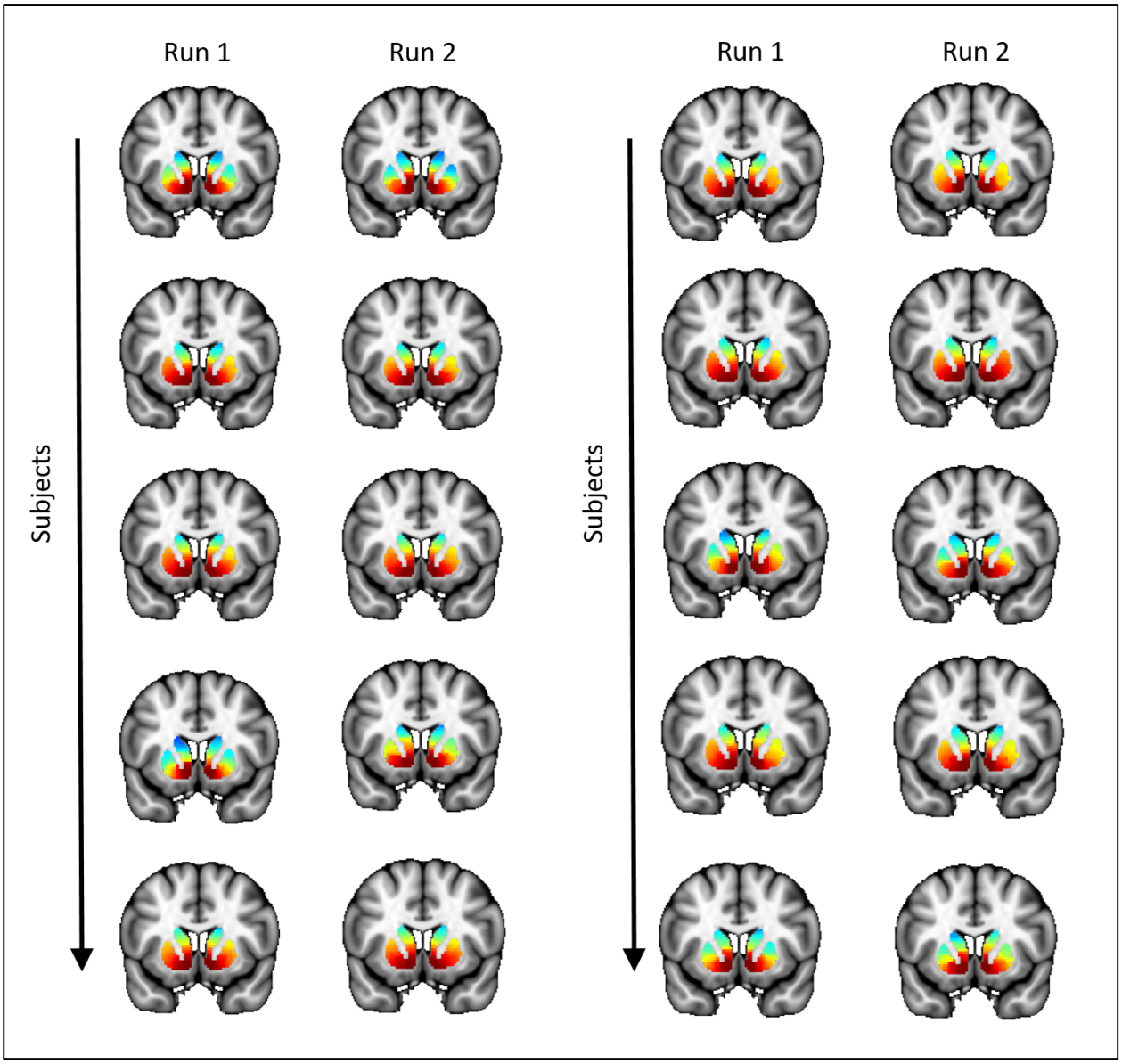
WM_2bk_Place_Median_RT, WM_2bk_Place_Median_RT_Target,

WM_2bk_Place_Median_RT_Nontarget, WM_2bk_Tool_Median_RT,

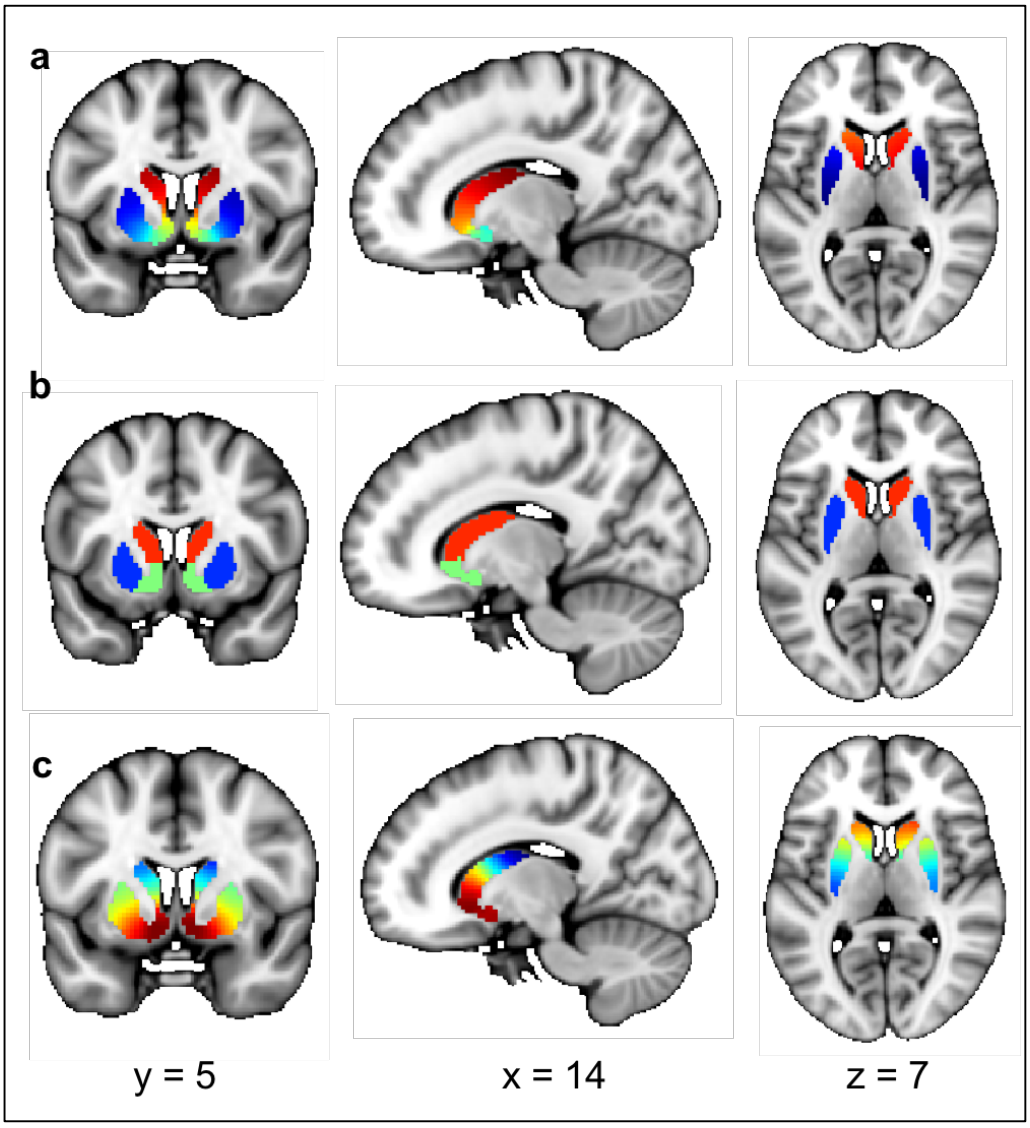
WM_2bk_Tool_Median_RT_Target, WM_2bk_Tool_Median_RT_Nontarget,

Personality (variables 170-174): NEOFAC_A NEOFAC_O, NEOFAC_C, NEOFAC_N, NEOFAC_E

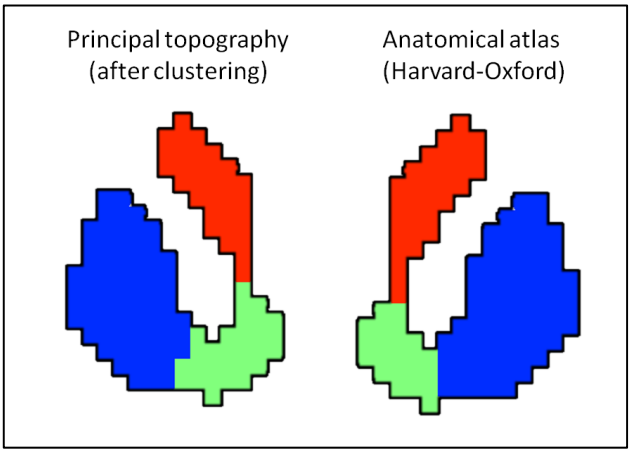
Supplementary Figures



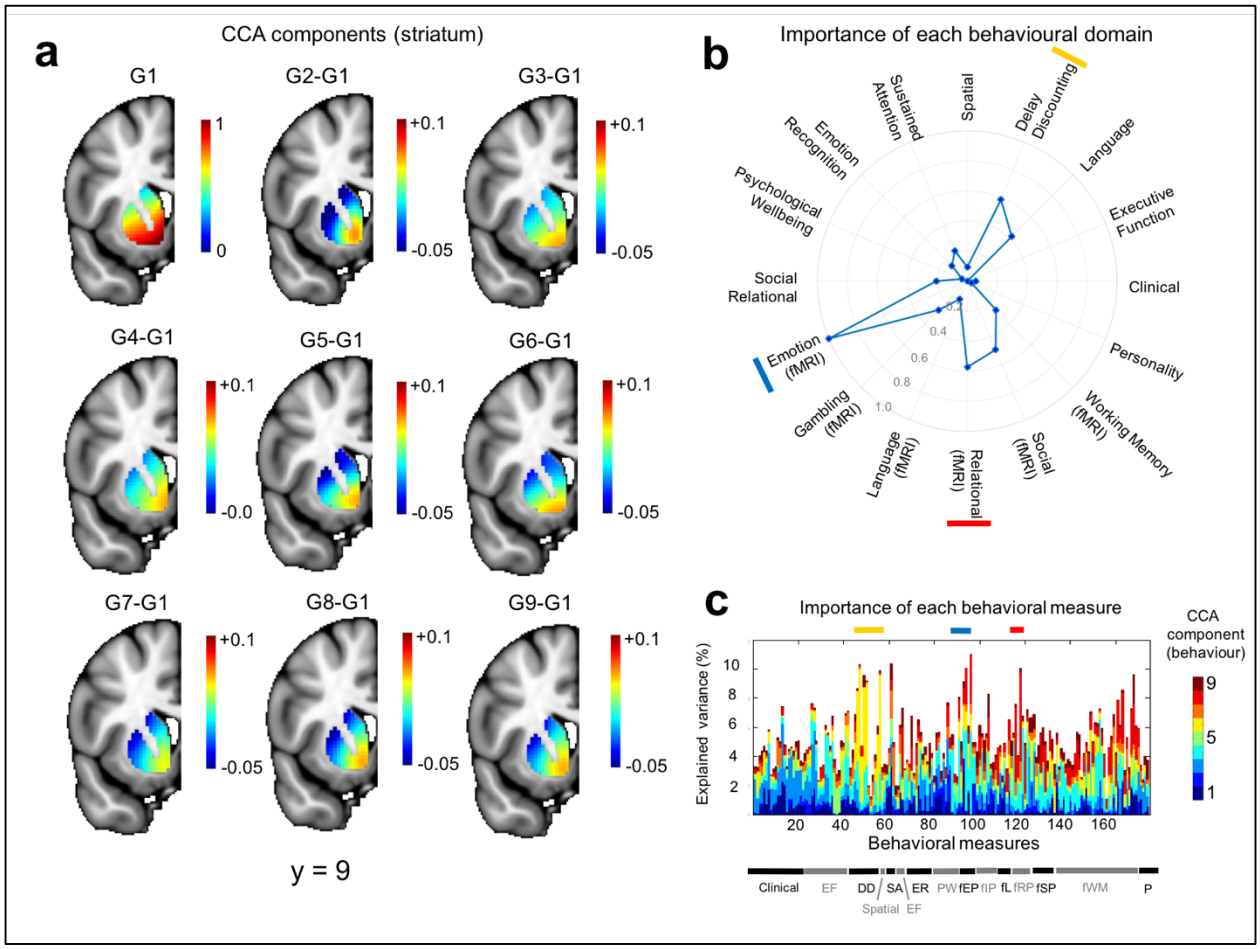
Supplementary Figure 1: Individual-subject reconstructed connection topographies for 20 randomly selected subjects (from a total of 466). This figure shows both the inter-subject variations in these connection topographies and their consistency within subjects (i.e. across repeated fMRI runs).



Supplementary Figure 2: Panel a: The dominant connection topography. Panel b: The same dominant connection topography after K-means clustering has been applied, with the number of clusters set to 3 on the basis of the predicted anatomy. This shows a strong correspondence with the predicted anatomy (Supplementary Figure 3). Panel c: The second dominant connectivity gradient. In all cases, the colour scale is arbitrary but similar colours denote voxels with similar connectivity patterns to regions outside the striatum.



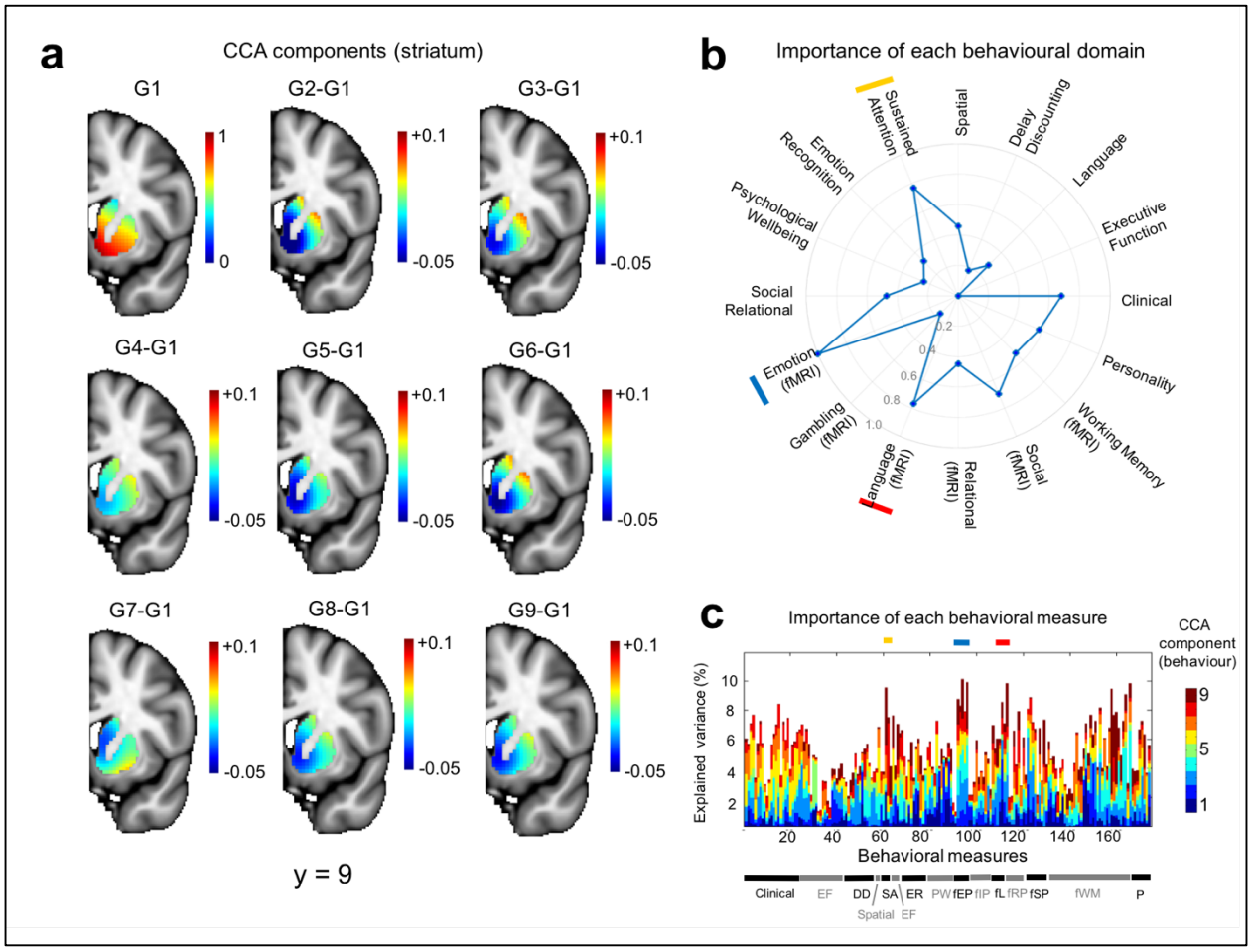
Supplementary Figure 3: After applying a clustering algorithm, the dominant connection topography (left) shows a strong piecewise correspondence to the anatomical distinction between caudate, putamen and accumbens (right), here visualized using the Harvard-Oxford atlas provided with the FSL software v5.0.9 (http://fsl.fmrib.ox.ac.uk/fsl/)



Supplementary Figure 4: Relative importance of different variables in driving the multivariate correspondence between the topography from the left striatum (second fMRI run) and the behavioural battery (derived from all 466 subjects used in the analysis). Panel a: Importance of connectivity gradients in predicting the behavioural scores. The top left panel (G1) shows structure coefficients corresponding to the principal predictive gradient estimated by CCA. These are rescaled such that the maximum in the image is equal to one and can therefore be considered to be in arbitrary units (a.u.). The remaining panels show differences between the rescaled principal CCA gradient and each successive rescaled predictive gradient (a.u. delta). For example, G2-G1 is the difference between the second gradient and the first. This helps to highlight the differences between the predictive gradients. Panel b: Predictive pattern of measures contributing to the CCA predictions. These are the structure coefficients aggregated across behavioural domains (see Methods) and are also rescaled such that the maximum behavioural domain has a value of 1, here represented by a point on the outermost circle. The top three domains are indicated by red, yellow and blue bars. Panel c: Structure coefficients for all of the 174

individual behavioural items. Behavioural domains are indicated by the bar at the bottom and a full list of individual items is provided in the supplementary Methods. Coloured bars indicate the top three domains (see panel b).

Abbreviations: CCA = canonical correlation analysis; DD = Delay discounting; EF = executive function; fEP = emotion processing (fMRI); fIP = incentive processing (fMRI); fL = Language (fMRI) fRP = relational processing (fMRI); fSP = social processing; fWM = working memory (fMRI); ER = emotion regulation; PW= psychological wellbeing; SA = sustained attention; P = personality.



Supplementary Figure 5: Relative importance of different variables in driving the multivariate correspondence between the topography from the right striatum (second fMRI run) and the behavioural battery (derived from all 466 subjects used in the analysis). Panel a: Importance of connectivity gradients in predicting the behavioural scores. The top left panel (G1) shows structure coefficients corresponding to the principal predictive gradient estimated by CCA. These are rescaled such that the maximum in the image is equal to one and can therefore be considered to be in arbitrary units (a.u.). The remaining panels show differences between the rescaled principal CCA gradient and each successive rescaled predictive gradient (a.u. delta). For example, G2-G1 is the difference between the second gradient and the first. This helps to highlight the differences between the predictive gradients. Panel b: Predictive pattern of measures contributing to the CCA predictions. These are the structure coefficients aggregated across behavioural domains (see Methods) and are also rescaled such that the maximum behavioural domain has a value of 1, here represented by a point on the outermost circle. The top three domains are indicated by red, yellow and blue bars. Panel c: Structure coefficients for all of the 174

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Supplementary References

1 Haber, S. N., Fudge, J. L. & McFarland, N. R. Striatonigrostriatal pathways in primates form an ascending spiral from the shell to the dorsolateral striatum. *Journal of Neuroscience* **20**, 2369-2382 (2000).