Supplementary Material

Reward Anticipation in the Adolescent and Aging Brain

Computation of literature based probabilistic region of interests

Regions of Interest (ROIs) for the ventral striatum ventromedial prefrontal cortex, anterior cingulate cortex and insula were created combining anatomical hypotheses with functional findings as reported in the literature for comparable experimental designs. To this end, firstly we created an anatomical ROIs for each region using the Automated Anatomical Labeling (AAL) brain atlas [Tzourio-Mazoyer et al., 2002]. Secondly, spatial coordinates for these ROIs were taken from fMRI publications from reward anticipation contrasts for healthy volunteers. Based on this data set, we created the ROIs in a three-step process [Schubert et al., 2008]:

(1) The probability that a voxel at a given position within an anatomical ROI showed neural activity regarding the corresponding literature was estimated by calculating a 3D normal (Gaussian) distribution G(x, y, z) as follows [Turkeltaub et al., 2002]:

$$G(x,y,z) = \frac{1}{2\pi\sqrt{|Det(C)|}} \exp\left(-\frac{1}{2}\begin{bmatrix} x-\bar{x} & y-\bar{y} & z-\bar{z} \end{bmatrix} C^{-1} \begin{bmatrix} x-\bar{x} \\ y-\bar{y} \\ z-\bar{z} \end{bmatrix} \right)$$

where C is the covariance matrix for all coordinate triples x, y, z from the underlying literature and $\bar{x}$, $\bar{y}$, $\bar{z}$ are the mean values of the x, y, and z coordinates, respectively [Nielsen and Hansen, 2002].

(2) The outer limits of the final ROI were defined by the outer limits of the anatomical ROI and a threshold of two standard deviations of the resulting 3D distribution.

(3) Finally, a binary mask including all voxels within these boundaries was formed.

Note: The script for generating the probabilistic ROIs is an in-house software extension for SPM8. The full lists of coordinates used for ROI generation can be obtained from the authors upon request.

References

Nielsen FA, Hansen LA (2002): Automatic anatomical labeling of Talairach coordinates and generation of volumes of interest via the BrainMap database. Neuroimage 16.

Schubert R, Ritter P, Wustenberg T, Preuschhof C, Curio G, Sommer W, Villringer A (2008): Spatial Attention Related SEP Amplitude Modulations Covary with BOLD Signal in S1-A Simultaneous EEG-fMRI Study. Cereb Cortex 18:2686–2700.

Turkeltaub PE, Eden GF, Jones KM, Zeffiro TA (2002): Meta-analysis of the functional neuroanatomy of single-word reading: Method and validation. Neuroimage 16:765–780.

Tzourio-Mazoyer N, Landeau B, Papathanassiou D, Crivello F, Etard O, Delcroix N, Mazoyer B, Joliot M (2002): Automated anatomical labeling of activations in SPM using a macroscopic anatomical parcellation of the MNI MRI single-subject brain. Neuroimage 15:273–289.

Table S1: Effect of gain anticipation against no gain anticipation for each of the three age groups are reported using Monte Carlo corrected significance threshold of p<0.05. Only clusters within the regions of interest are listed.

Brain structure	Hem	Cluster size (voxel)	T (peak voxel)	MNI coord. (mm)		
				x	y	z
Ventral Striatum						
Adolescents	L	45	10.03	-15	8	-8
	R	63	11.01	15	11	-5
Younger Adults	L	33	7.0	-9	11	-2
	R	48	7.47	9	11	-2
Older Adults	L	41	7.67	-12	11	-2
	R	56	8.47	18	8	-5
Ventromedial Prefrontal Cortex						
Adolescents	L/R	125	4.77	3	44	1
Younger Adults	L/R	no sig				
Older Adults	L/R	20	4.17	0	47	4
Insula						
Adolescents	L	202	7.53	-30	20	-8
	R	120	8.81	33	17	-8
Younger Adults	L	99	7.36	-30	23	1
	R	88	6.77	30	23	-8
Older Adults	L	196	10.80	-30	20	-2
	R	137	10.92	33	20	-5
Anterior Cingulate Cortex						
Adolescents	L/R	286	5.63	6	41	7
Younger Adults	L/R	36	4.80	9	38	13
Older Adults	L/R	237	6.69	3	8	31
Dorsolateral Prefrontal Gyrus						
Adolescents	L	42	9.48	-27	-7	49
	R	112	8.92	39	-7	55
Younger Adults	L	34	8.89	-27	-7	52
	R	91	7.42	27	-4	55
Older Adults	L	308	8.42	-27	-7	52
	R	754	9.56	30	-4	52
Inferior Parietal Lobule						
Adolescents	L	148	8.78	-24	-52	52
	R	32	7.08	27	-49	52
Younger Adults	L	136	7.14	-24	-52	52
	R	27	5.99	30	-43	52
Older Adults	L	546	9.86	-27	-55	46
	R	275	8.41	30	-55	46

Table S2: Group comparisons of the effect of gain anticipation against no gain anticipation using Monte Carlo corrected significance threshold of p<0.05.

Brain structure	Hem	Cluster size (voxel)	T (peak voxel)	MNI coord. (mm) x	y	z
Younger Adults > Adolescents						
no significant results						
Younger Adults > Older Adults						
no significant results						
Adolescents > Younger Adults						
Lingual Gyrus	R	139	4.31	9	-79	1
Calcarine Gyrus	R		3.97	6	-70	10
Putamen	R	89	4.36	33	14	-5
Ventral Striatum	R		4.19	18	17	-5
Calcarine Gyrus	R	84	4.02	12	-94	1
Inferior Occipital Gyrus	R		3.75	39	-91	-2
Middle Cingulate Cortex	R	76	4.22	6	-19	40
Middle Cingulate Cortex	R		4.21	18	-37	43
Dorsal Striatum	R	74	4.55	21	20	16
Ventral Striatum	L	60	3.98	-15	8	-11
Putamen	L		3.49	-24	14	4
Middle occipital gyrus	R	52	4.27	39	-58	4
Cuneus	R	48	3.80	9	-85	34
Paraventricular white matter	L	44	4.01	-27	-58	16
Cerebellum Vermis	R	36	4.19	0	-55	-2
Middle Occipital Gyrus	L	35	3.69	-30	-91	-5
Inferior Occipital Gyrus	L		4.01	-27	-94	-11
Superior Temporal Gyrus	L	30	3.90	-63	-49	16
Middle Temporal Gyrus	L		3.63	-48	-43	10
Middle Occipital Gyrus	R	27	4.02	33	-88	22
Calcarine Gyrus	R		3.59	21	-85	10
Ventromedial Prefrontal Cortex	L	24	3.94	-6	38	-14
Adolescents > Older Adults						
Inferior Occipital Gyrus	R	23	3.79	33	-88	-8
Corpus Callosum	L	19	4.10	-3	-22	25
Older Adults > Adolescents						
Inferior Parietal Lobule	R	1626	6.58	42	-46	46
Inferior Parietal Lobule	L		6.30	-36	-52	46
Inferior Parietal Lobule	R		5.99	54	-40	55
Angular Gyrus	R		5.84	30	-61	46
Postcentral Gyrus	R		5.31	57	-25	49
Precuneus	L		4.99	-9	-67	46
Superior Parietal Lobule	R		4.64	15	-67	52
Precuneus	R		4.43	6	-58	46
Precuneus	L		4.28	-3	-52	49
Middle Frontal Gyrus	L	390	5.98	-48	23	34
Middle Orbital Gyrus	L		4.50	-42	44	-2
Inferior Frontal Gyrus (p. Triangularis)	L		4.32	-48	44	10
Precentral Gyrus	L		4.10	-42	11	31
Precentral Gyrus	L		3.59	-48	5	34
Inferior Frontal Gyrus (p. Opercularis)	R	223	5.10	45	14	31

Inferior Frontal Gyrus (p. Triangularis)	R		4.11	54	32	19
Middle Frontal Gyrus	R		3.84	51	26	34
Superior Medial Gyrus	L	39	4.09	-6	26	46
Superior Medial Gyrus	R		3.61	6	38	40
Superior Medial Gyrus	R	27	4.05	3	38	58
Superior Temporal Gyrus	R	24	3.82	45	2	-11
Middle Frontal Gyrus	R	20	3.86	45	29	46
Older Adults > Younger Adults						
Inferior Parietal Lobule	R	2049	6.47	42	-46	46
Angular Gyrus	R		6.26	33	-61	46
Precuneus	L		5.64	-9	-64	49
Middle Cingulate Cortex	R		4.00	9	-40	46
Middle Occipital Gyrus	R		5.35	45	-76	25
Precuneus	R		5.28	9	-70	49
SupraMarginal Gyrus	R		4.89	57	-31	43
Middle Cingulate Cortex	L		4.82	-9	-37	43
Precuneus	L		4.56	-9	-46	52
Inferior Parietal Lobule	L	808	7.22	-36	-55	46
Inferior Parietal Lobule	L		6.15	-30	-73	43
Middle Occipital Gyrus	L		3.99	-39	-82	25
SupraMarginal Gyrus	L		3.82	-54	-31	34
Middle Frontal Gyrus	R	758	5.16	42	38	34
Inferior Frontal Gyrus (p. Opercularis)	R		4.86	45	14	34
Thalamus	L	484	4.87	-3	-16	4
Thalamus	R		4.58	12	-19	13
Insula Lobe	R		4.58	36	-22	4
Superior Medial Gyrus	R	281	5.30	6	35	40
SMA	R		4.39	0	17	49
Middle Cingulate Cortex	R		3.59	6	2	34
SMA	L		3.58	-9	8	52
Anterior Cingulate Cortex	L		3.53	-3	5	31
Middle Cingulate Cortex	R		3.51	0	5	40
Middle Frontal Gyrus	L	259	4.72	-48	17	40
Inferior Frontal Gyrus (p. Triangularis)	L		4.57	-51	26	28
Precentral Gyrus	L		3.54	-48	2	34
Temporal Pole	R	244	4.94	54	8	-8
Insula Lobe	R		4.66	33	17	-5
Inferior Frontal Gyrus (p. Opercularis)	R		3.74	51	17	-2
Inferior Frontal Gyrus (p. Orbitalis)	L	188	5.03	-42	17	-5
Temporal Pole	L		4.42	-48	8	-11
Temporal Pole	L		4.10	-48	17	-17
Inferior Frontal Gyrus (p. Triangularis)	L	168	4.52	-42	47	4
Middle Frontal Gyrus	L		4.04	-36	56	19
Inferior Frontal Gyrus (p. Orbitalis)	R	36	3.88	33	47	-8
Inferior Temporal Gyrus	R	34	4.30	54	-43	-11
Superior Temporal Gyrus	L	32	4.84	-39	-13	-8
Superior Orbital Gyrus	R	29	4.29	18	29	-14
Caudate Nucleus	R	21	3.62	12	2	16
Superior Temporal Gyrus	L	20	3.92	-60	-43	16
Superior Frontal Gyrus	R	18	3.85	27	2	70
Cerebellum Vermis	R	18	3.98	0	-55	-2
Inferior Temporal Gyrus	L	18	3.84	-54	-52	-11

Table S3: Results of the ROI analysis. Follow-up ANOVAs are presented with mean value (M) per group in arbitrary units, F- and p-values.

	AD M (SD)	YA M (SD)	OA M (SD)	F(2)	p	Significant differences
VS	2.23 (1.7)	1.22 (1.1)	1.54 (1.2)	5.1	0.008	AD>YA
VMPFC	0.94 (1.4)	0.06 (1.4)	0.58 (1.4)	3.5	0.035	AD>YA
insula	1.27 (1.0)	0.72 (0.9)	1.59 (1.2)	6.0	0.003	AD>YA, OA>YA
ACC	0.91 (1.2)	0.18 (1.0)	0.85 (1.2)	4.4	0.015	AD>YA, OA>YA
DLPFC	0.11 (0.8)	-0.17 (0.7)	0.65 (0.9)	9.2	<0.001	OA>YA, OA>AD
IPL	0.20 (1.0)	0.12 (0.9)	1.58 (1.1)	22.7	<0.001	OA>YA, OA>AD

ANOVA = analysis of varicance, M = mean, SD = standard deviation, ROI = region of interest, VS = ventral striatum, VMPFC = ventromedial prefrontal cortex, ACC = anterior cingulate cortex, DLPFC = dorsolateral prefrontal cortex, IPL = inferior parietal lobule, AD = adolescents, YA = younger adults, OA = older adults.

Table S4: Post-hoc results within the ROIs using least significant difference (LSD) test.

ROI	T	Mean difference	p (LSD)
Adolescents vs. Younger Adults			
VS	2.97	1.02	0.002**
VMPFC	2.60	0.88	0.010*
insula	2.34	0.55	0.031*
ACC	2.72	0.74	0.009**
DLPFC	1.53	0.28	0.152
IPL	0.36	0.08	0.735
Older Adults vs. Younger Adults			
VS	1.20	0.33	0.316
VMPFC	1.54	0.52	0.124
insula	3.39	0.87	0.001***
ACC	2.52	0.67	0.017*
DLPFC	4.24	0.82	<0.001***
IPL	6.07	1.47	<0.001***
Older Adults vs. Adolescents			
VS	-1.95	0.69	0.036*
VMPFC	-1.08	0.36	0.290
insula	1.17	0.31	0.219
ACC	-0.23	0.07	0.813
DLPFC	2.61	0.54	0.007**
IPL	5.34	1.38	<0.001***