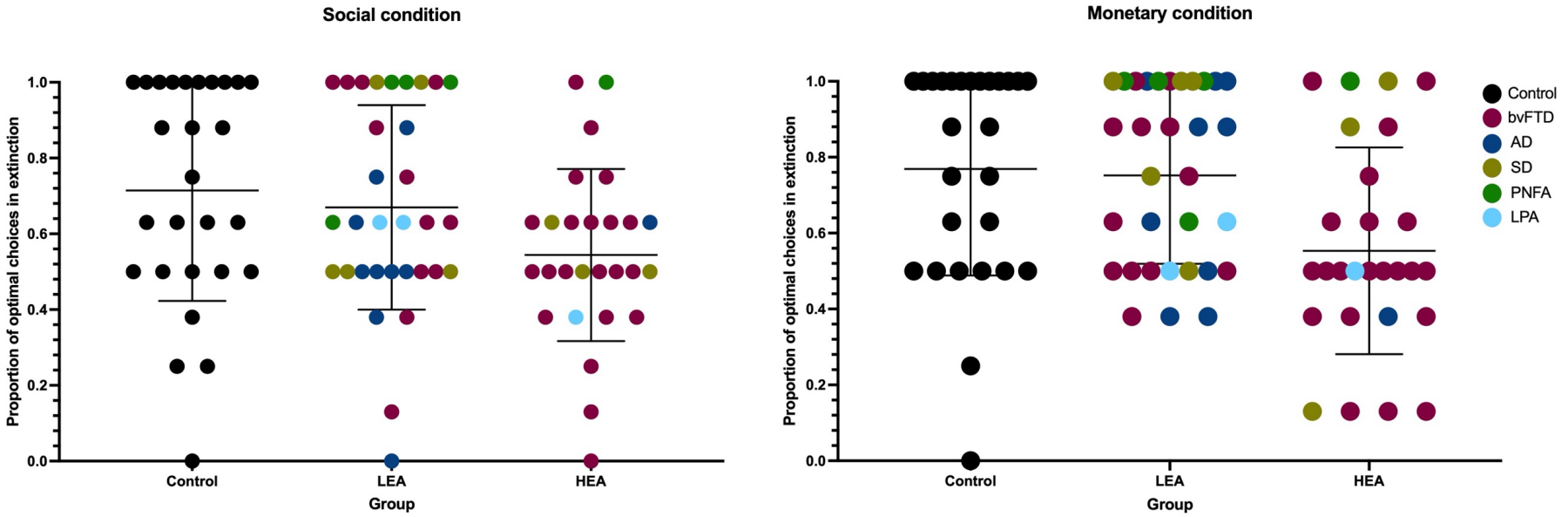
Supplementary Materials

Supplementary Table 1. Demographic and clinical characteristics of diagnostic groups.

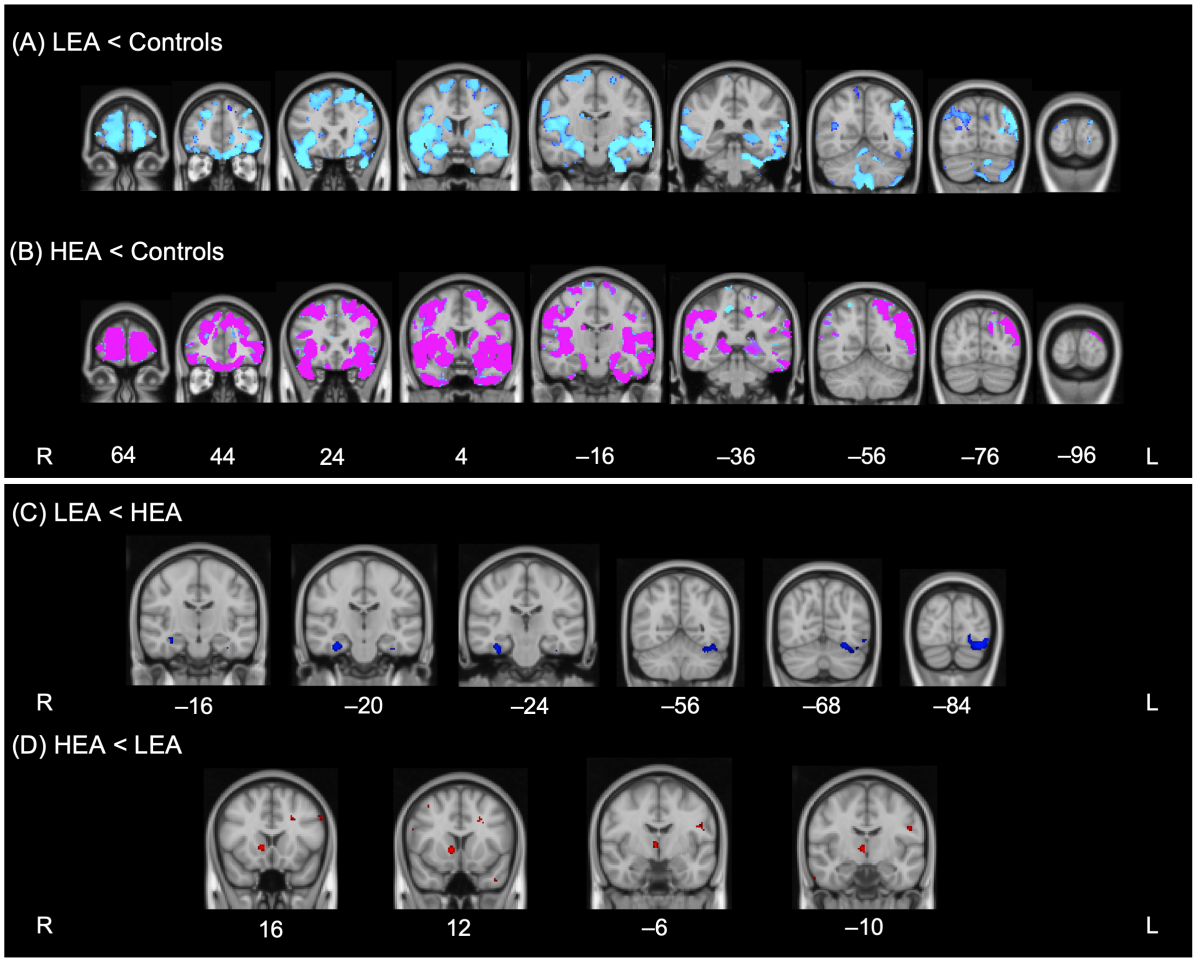
	Control	bvFTD	AD	SD	PNFA	LPA	Group difference (*p*-value)	*Post hoc* group comparisons
N	27	33	14	8	6	3		
Sex (M:F)	10:17	26:7	9:5	5:3	2:4	3:0	.012	
Age (years)	65.99 ± 7.62	63.23 ± 8.35	65.44 ± 8.88	62.38 ± 4.64	65.24 ± 9.38	69.56 ± 4.20	.409	
Education (years)	13.40 ± 2.72	11.67 ± 3.87	13.89 ± 2.87	13.06 ± 2.57	11.46 ± 1.89	11.58 ± 2.50	.078	
Disease duration (years)	.	6.65 ± 4.87	4.25 ± 1.07	4.52 ± 1.60	5.57 ± 3.97	2.03 ± 1.11	.146	
FRS Rasch score	.	-0.33 ± 1.37	0.74 ± 1.26	1.34 ± 1.50	3.39 ± 1.16	2.53 ± 0.47	<.001	bvFTD < SD, PNFA, LPA; AD < PNFA
ACE-III total [100]	94.30 ± 3.26	82.03 ± 9.93	71.00 ± 11.94	69.00 ± 12.69	85.00 ± 6.99	64.67 ± 11.24	<.001	Con > bvFTD, AD, SD, LPA
DASS depression [42]	1.04 ± 1.29	10.2 ± 9.42	6.43 ± 6.28	8.57 ± 7.37	8.00 ± 8.85	5.33 ± 6.11	<.001	Con < bvFTD
DASS anxiety [42]	1.26 ± 1.85	8.07 ± 6.18	4.46 ± 6.59	3.14 ± 3.44	6.33 ± 4.97	2.67 ± 4.62	<.001	Con < bvFTD
DASS stress [42]	3.93 ± 4.69	12.2 ± 10.31	9.29 ± 7.75	7.00 ± 5.33	8.67 ± 6.02	8.67 ± 9.02	.012	Con < bvFTD
DAS total [72]	18.04 ± 10.33	50.39 ± 11.21	40.86 ± 10.08	35.38 ± 16.02	26.50 ± 8.38	32.33 ± 13.80	<.001	Con < bvFTD, AD; PNFA < bvFTD
DAS executive [24]	3.68 ± 3.80	16.45 ± 5.32	14.07 ± 4.38	10.75 ± 5.42	7.33 ± 4.03	7.33 ± 1.53	<.001	Con < bvFTD, AD; PNFA < bvFTD
DAS emotional [24]	7.16 ± 4.01	16.52 ± 4.84	11.64 ± 3.46	12.50 ± 6.57	7.17 ± 4.12	12.67 ± 4.73	<.001	Con < bvFTD; PNFA < bvFTD
DAS initiation [24]	7.20 ± 5.13	17.42 ± 4.24	15.14 ± 3.94	12.13 ± 6.03	12.00 ± 3.79	12.33 ± 7.77	<.001	Con < bvFTD, AD; PNFA < bvFTD
Emotional apathy group (LEA:HEA)	.	12:21	12:2	5:3	5:1	2:1	.015	
Emotion perception [42]	39.00 ± 3.06	32.38 ± 5.72	32.17 ± 4.71	34.50 ± 4.87	36.00 ± 5.15	34.0 ± 5.66	<.001	Con < bvFTD, AD

Values are mean ± standard deviation. Maximum scores on each measure shown in brackets. FRS = Frontotemporal dementia Rating Scale; ACE-III = Addenbrooke's Cognitive Examination, Third Edition; DASS = Depression, Anxiety and Stress Scale; DAS = Dimensional Apathy Scale
Missing data: DAS (3 controls); Emotion perception (2 Controls, 4 bvFTD, 2 AD, 1 PNFA, 1 LPA)

Supplementary Figure 1. Overall social and monetary reward learning performance, denoted by proportion of optimal choices made in extinction on the post-learning choice test for the social and monetary conditions across the control, LEA and HEA groups. Data points indicate individual participant scores, with colours denoting diagnosis group. Error bars represent standard error of the mean.



Supplementary Figure 2. Regions of significant grey matter intensity decrease in (A) LEA and (B) HEA patient groups relative to controls (C) LEA relative to HEA patients and (D) HEA relative to LEA patients. Coloured voxels indicate regions that emerged as significant in the voxel-based morphometry analyses, at $p<.005$ corrected for family-wise error in (A) and (B) and $p<.005$ uncorrected for (C) and (D). All clusters reported at $t > 2.660$. Clusters are overlaid on the Montreal Neurological Institute (MNI) standard brain. Numbers are MNI coordinates for coronal sections. R = right; L = left.



Supplementary Table 2. Group differences in grey matter intensity across LEA and HEA groups

Contrast	Regions	Hemisphere	Peak MNI coordinates			Cluster size
			X	Y	Z	
LEA < Controls	Cerebellum, fusiform cortex, inferior, middle and superior temporal gyri, hippocampus, amygdala, temporal pole, caudate, putamen, insular cortex, orbitofrontal cortex, frontal medial cortex, paracingulate cortex, anterior cingulate cortex, frontal pole, inferior middle and superior frontal gyri, supramarginal gyrus, angular gyrus, lateral occipital cortex, planum temporale, central and parietal opercular cortex	L	-8	-56	-64	35568
	Temporal pole, orbitofrontal cortex, insular cortex, putamen, caudate, thalamus, amygdala, hippocampus, inferior and middle frontal gyri, inferior, middle and superior temporal gyri, Heschl's gyrus, planum temporal, central and parietal opercular cortex, supramarginal gyrus	R	40	20	-42	11913
	Lateral occipital cortex (superior), cuneal cortex	R	24	-84	34	1537
	Precuneus cortex	R	8	-48	64	274
	Superior frontal gyrus	L	-6	52	38	214
HEA < Controls	Fusiform gyrus, inferior temporal gyrus, middle temporal gyrus, superior temporal gyrus, insular cortex, amygdala, hippocampus, paracingulate cortex, anterior cingulate cortex, orbitofrontal cortex, medial frontal cortex, frontal pole, inferior frontal gyrus, middle frontal gyrus, superior frontal gyrus, precentral gyrus, postcentral gyrus, supramarginal gyrus, precuneus, lateral occipital cortex, occipital pole, caudate, putamen, thalamus	B	30	-6	-52	61458
	Precentral gyrus	R	14	-16	76	258
LEA < HEA*	Lateral occipital cortex, occipital fusiform cortex, temporal-occipital fusiform cortex	L	-34	-84	-20	927
	Temporal fusiform cortex, parahippocampal gyrus, hippocampus	R	34	-22	26	127
HEA < LEA*	Caudate, nucleus accumbens	R	12	12	9	66
	Postcentral gyrus, precentral gyrus	L	-48	-12	26	58
	Thalamus	R	42	58	37	55

Clusters were Family Wise Error corrected at p<.005 and at a cluster extent threshold of >200 contiguous voxels.
**Clusters were uncorrected at p<.005 and at a cluster extent threshold of >50 contiguous voxels.*
L = left; R = right; B = bilateral; MNI = Montreal Neurological Institute.

Grey matter correlates of emotional apathy

Supplementary Figure 2 and Table 3 display the results from the voxel-based morphometry analysis exploring associations between regions of grey matter intensity decrease and emotional apathy on the DAS across all patients. Higher levels of emotional apathy were associated with grey matter intensity decrease across the left insular cortex, orbitofrontal cortex and lateral occipital cortex, as well as the right striatum (including nucleus accumbens, caudate and putamen), postcentral gyrus and cerebellum. Bilateral regions in the supramarginal gyri were also implicated.

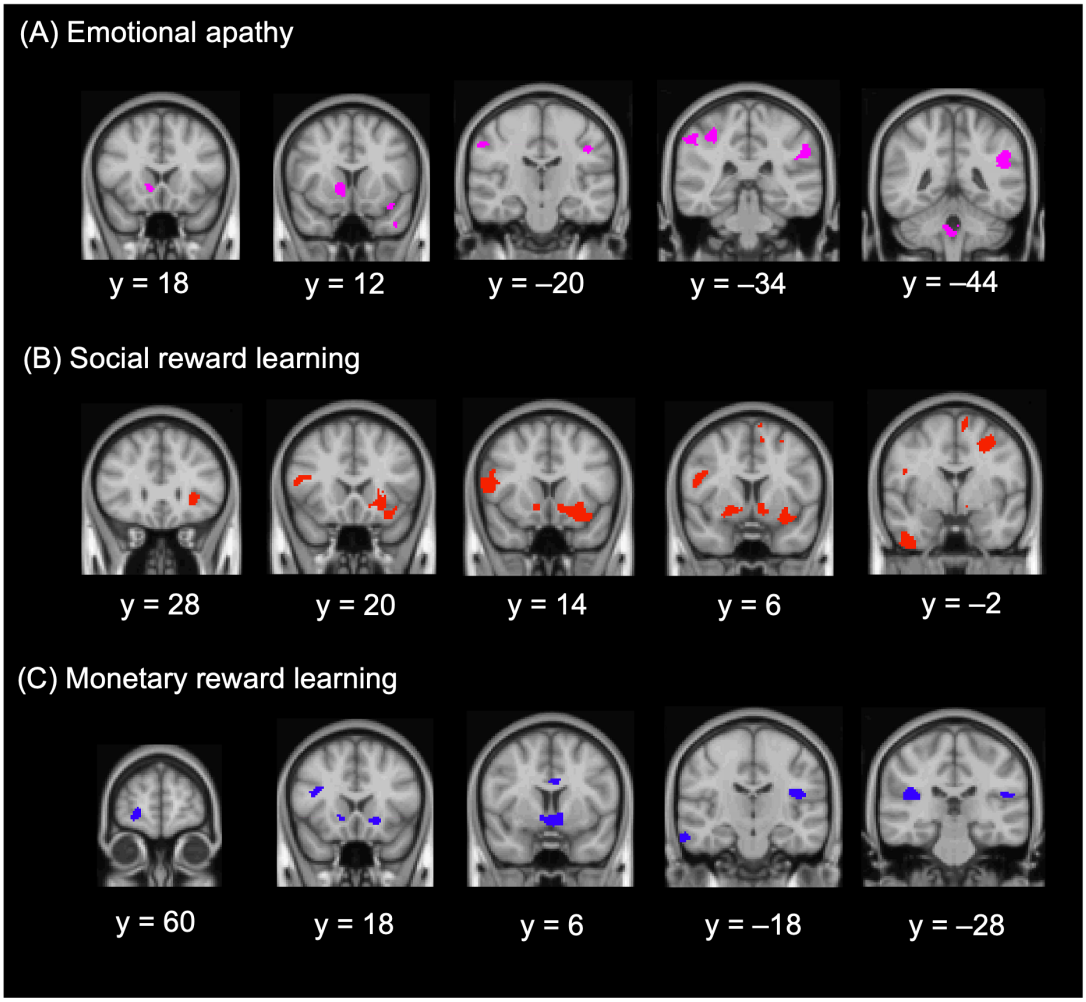
Grey matter correlates of social reward learning

As shown in Supplementary Figure 2 and Table 3, lower scores on the choice test in the social condition, reflecting poorer learning from social rewards, were associated with grey matter intensity decrease in the orbitofrontal and insular cortices and striatum (nucleus accumbens, caudate and putamen) bilaterally. Furthermore, regions in the left lateral prefrontal cortex (middle and superior frontal gyri, extending into supplementary motor cortex) and the right inferior frontal gyrus (extending into the precentral gyrus) and inferior temporal gyrus were also implicated.

Grey matter correlates of monetary reward learning

As shown in Supplementary Figure 2 and Table 3, lower scores on the choice test in the monetary condition, reflecting poorer learning from monetary rewards, were associated with grey matter intensity decrease in the nucleus accumbens, subcallosal cortex and anterior cingulate bilaterally, as well as the right insular cortex, extending into Heschl's gyrus and parietal operculum cortex, and the right forntal pole, lateral prefrontal cortex (inferior and middle frontal gyri) and middle temporal gyrus. Regions in the left central and parietal opercular cortices were also involved.

Supplementary Figure 3. Grey matter correlates of (a) emotional apathy, (b) social reward learning and (c) monetary reward learning across all patients. Coloured voxels indicate regions that emerged as significant in the voxel-based morphometry analyses, corrected for false discovery rate at $p<.05$. All clusters reported $t>2.63$. Clusters are overlaid on the Montreal Neurological Institute (MNI) standard brain. Numbers are MNI coordinates for coronal sections. R = right; L = left.



Supplementary Table 3. Voxel-based morphometry results showing regions of significant grey matter intensity decrease that covary with (a) emotional apathy, (b) social reward learning and (c) monetary reward learning across all patients combined. (See also Supplementary Figure 3).

		Peak MNI coordinates			
Regions	Hemisphere	X	Y	Z	Cluster size
(a) Emotional apathy					
Supramarginal gyrus (anterior and posterior), parietal operculum cortex	L	-46	-44	24	578
Supramarginal gyrus (anterior and posterior)	R	54	-34	44	315
Postcentral gyrus	R	36	-32	48	147
Cerebellum	R	8	-48	-42	143
Insular cortex, orbitofrontal cortex	L	-36	10	-18	136
Nucleus accumbens, caudate, putamen	R	12	10	-2	134
Lateral occipital cortex (superior)	L	-16	-88	44	105
(b) Social reward learning					
Orbitofrontal cortex, putamen, caudate, nucleus accumbens, insular	L	-22	14	-14	827
Inferior frontal gyrus, precentral gyrus	R	58	10	4	407
Inferior temporal gyrus (anterior)	R	48	-4	-46	195
Superior frontal gyrus, middle frontal gyrus	L	-22	-2	44	176
Insular cortex, orbitofrontal cortex, nucleus accumbens, putamen	R	34	10	-18	164
Superior frontal gyrus, supplementary motor cortex	L	-8	2	72	118
(c) Monetary reward learning					
Nucleus accumbens, subcallosal cortex	B	0	2	-16	569
Central opercular cortex, parietal operculum cortex	L	-40	-18	20	230
Parietal operculum cortex, Heschl's gyrus, insular cortex	R	38	-26	20	150
Anterior cingulate cortex	B	6	-12	24	138
Frontal pole	R	22	62	-6	127
Inferior frontal gyrus, middle frontal gyrus	R	42	20	16	117
Middle temporal gyrus (posterior)	R	68	-16	-26	100

Clusters were extracted voxel-wise corrected for false discovery rate at p<.05. All clusters reported t >2.63, with a cluster extent threshold of >100 contiguous voxels. L = left; R = right; B = bilateral; MNI = Montreal Neurological Institute