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ORIGINAL ARTICLE

Regional cerebral blood flow correlates eating abnormalities in frontotemporal dementia

Zhi Zhou[1] · Xudong Li[2,3] · Yi Jin[4] · Yumin Zheng[5] · Shuhong Jia[4] · Jinsong Jiao[4] · Xiaoyun Zheng[1]

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Abstract

Background Eating abnormalities are one of the core symptoms of frontotemporal dementia (FTD), especially for behavioral variant FTD (bvFTD), and semantic variant primary progressive aphasia (svPPA).

Methods A group of FTD patients (43 bvFTD, 29 svPPA) underwent single-photon emission CT (SPECT) to measure the region cerebral blood flow (rCBF). The Cambridge Behavioral Inventory (CBI) was used to measure the eating abnormalities. A whole-brain voxel-based correlation between eating abnormalities and rCBF was investigated.

Results In bvFTD, the sweet preference was correlated with decreased rCBF in the bilateral gyrus rectus and temporal pole, and eating the same food was correlated with the left ventral anterior cingulate cortex. In svPPA, decreased rCBF in the left inferior temporal gyrus was correlated with eating the same food.

Conclusions These findings showed that either different symptoms in the same subtype or the same symptom in different subtypes of FTD may be correlated with different regions, indicating different neural mechanisms behind them.

Keywords Frontotemporal dementia · Eating abnormalities · Regional cerebral blood flow · Single-photon emission CT · Voxel-based morphometry

Introduction

Frontotemporal dementia (FTD), also called frontotemporal lobar degeneration (FTLD), represents a heterogeneous clinical, genetic, and pathological neurodegenerative entity, especially common in early-onset dementia patients. Behavioral variant FTD (bvFTD), semantic variant primary progressive aphasia (svPPA), and nonfluent/agrammatic variant primary progressive aphasia (nfvPPA) represent the most frequently recognized clinical syndromes [1, 2].

Eating abnormalities include alterations in food preference (especially eating only a particular type of food or sweet food), appetite, and eating behaviors [3, 4]. Alterations in eating behavior have previously been observed in 60% of FTD patients and are one of the core symptoms for the diagnosis of bvFTD [5, 6]. Although most previous studies focused on bvFTD, similar symptoms, such as stereotype eating behavior and increased appetite, have also increasingly been reported in svPPA patients [7, 8].

As a neurodegenerative disorder mainly affects the behavior, FTLD is a good model to investigate the mechanism of eating abnormalities, providing insights into the mechanism of eating abnormalities in other conditions. Previous neuroimaging studies have identified a number of areas correlating with eating abnormalities in FTD. For instance, eating disorders in bvFTD are predominantly correlated with areas of the frontal lobe, insular cortex, striatum, and hypothalamus [4, 9–12].

Single-photon emission CT (SPECT) is a well-established functional neuroimaging technique that provides information on regional cerebral blood flow (rCBF) [13]. The rCBF is

Zhi Zhou and Xudong Li contributed equally to this work.

✉ Xiaoyun Zheng
neurozhengxiaoyun@163.com

[1] Department of Geriatrics, China-Japan Friendship Hospital, 2 Yinghuayuan Dongjie, Beijing 100029, China

[2] Department of Cognitive Disorder, Beijing Tiantan Hospital, Capital Medical University, Beijing, China

[3] China National Clinical Research Center for Neurological Diseases, Beijing, China

[4] Department of Neurology, China-Japan Friendship Hospital, Beijing, China

[5] Department of Nuclear Medicine, China-Japan Friendship Hospital, Beijing, China

coupled with regional metabolism. The intensity of neuronal activity determines the amount of oxygen and glucose which are provided to each region according to the metabolic activity. As the rCBF can reflect the neuronal activity, SPECT is widely used in evaluating the mechanisms of neurological disorders [14]. Sometimes, the SPECT can be more sensitive than structural neuroimaging techniques such as magnetic resonance imaging (MRI), because functional changes often precede structural changes. Until now, most neuroimaging studies have used structural MRI to assess the relationship between brain structural changes and eating abnormalities. To our knowledge, no studies have used rCBF to investigate the association.

Moreover, despite numerous neuroimaging studies on the relationship between eating abnormalities and brain changes, there have been limited studies clarifying the contribution of rCBF changes to each component of eating abnormalities [8]. In this study, we aimed to investigate the correlation between eating abnormalities and rCBF in bvFTD and svPPA patients using SPECT with voxel-based whole-brain quantitative analysis.

Methods

Subjects

Forty-seven subjects (43 with bvFTD, 29 with svPPA) were recruited from memory disorder clinics of China-Japan Friendship Hospital between 2013 and 2018. All subjects met current clinical diagnostic criteria for probable bvFTD and svPPA [2, 5]. The exclusion criteria were as follows: previous stroke, cerebrovascular disorders, intracranial mass, or normal pressure hydrocephalus shown by MRI or CT; other psychiatric disorders including bipolar disorder, schizophrenia, or mental retardation meeting the criteria of the DSM-IV; other significant medical problems (i.e., chronic heart failure and chronic respiratory insufficiency) potentially leading to encephalopathy.

Neuropsychological assessment

Subjects were evaluated by a series of neuropsychological assessments. Cognition was evaluated by the Mini-Mental State Examination (MMSE) and the Montreal Cognitive Assessment (MoCA), which focuses more on executive function than the MMSE [15]. The FTD-specific clinical dementia rating (FTD-CDR) sum of boxes score was used to evaluate disease severity. Compared with standard CDR, the FTD-CDR has improved its sensitivity for FTD due to its inclusion of the behavior and language domains [16].

Eating abnormalities were measured using a caregiver-based questionnaire: the Cambridge Behavioral Inventory (CBI). The CBI measures the frequency of a number of different everyday activities and was initially developed to detect unique behavior abnormalities, including eating habits [17]. The questions related to eating behavior in CBI include four items: sweet preference (prefers sweet foods more than before), eating same food (wants to eat the same foods repeatedly), overeating (her/his appetite is greater, she/he eats more than before), and declined table manners (table manners are declining, e.g., stuffing food into mouth.) Each item is scored on a 5-point scale by identifying the frequency of each specific behavior ("never", "a few times per month", "a few times per week", "daily", "constantly").

This study was approved by the China-Japan Friendship Hospital, and study procedures were followed in accordance with the ethical standards of the hospital. Written informed consent was obtained from all of the subjects prior to any study procedures.

SPECT scan

SPECT scans were performed 20 min after an intravenous injection of 30 mCi of 99mTc-ECD, and patients were placed at rest with their eyes closed. SPECT images were acquired by a double-headed rotating γ-camera (Symbia, Siemens, Germany) equipped with a low-energy fan-beam collimator. The images covered a total of 360° and were taken in 6° steps at a rate of 25 s per frame. The images were displayed in a 128 × 128 matrix (pixel size = 3.9 × 3.9 × 3.9 mm, slice thickness = 3.9 mm). Then the continuous transaxial images were reconstructed, followed by a back projection with a Butterworth filter (cutoff, 0.4 cycle/pixel; order 5). The attenuation correction was done with Chang's attenuation correction method.

SPECT analysis

The spatial preprocessing and statistical analysis of all SPECT images were performed using SPM12 (Wellcome Department of Cognitive Neurology, Institute of Neurology http://www.fil.ion.ucl.ac.uk/spm) implemented in the MATLAB version R2018a (MathWorks Inc., Sherborn, MA). All SPECT images were spatially normalized with the Montreal Neurological Institute (MNI) template and reformatted to a voxel size of 2 × 2 × 2 mm. To control the individual variation, the cerebellar cortex was chosen as the reference region for the intensity normalization. The images were smoothed using a Gaussian filter (12-mm full width at half maximum [FWHM]) prior to statistical analysis, in order to increase the signal-to-noise ratio and minimize the individual anatomical variations.

The unbiased whole-brain voxel-based correlations were analyzed using a general linear model (GLM) method in the bvFTD and SD groups separately. The score of each CBI subscale was entered in a multiple regression model to

Table 1 Demographics, clinical scores, and CBI results

Characteristic	bvFTD ($N = 43$)	svPPA ($N = 29$)	p
Age at evaluation, years	70.63 ± 1.60	69.66 ± 1.58	0.6789
Disease duration, years	3.12 ± 0.39	3.38 ± 0.47	0.6684
Gender, male %	27, 62.8%	11, 37.9%	0.0544
Education, years	11.28 ± 0.66	11.55 ± 0.76	0.7887
MMSE	21.42 ± 0.83	19.59 ± 0.90	0.1477
FTD-CDR, sum	8.81 ± 0.75	7.45 ± 0.98	0.2640
CBI eating abnormalities, total	7.12 ± 0.61	5.86 ± 0.83	0.2168
Sweet preference	2 (1,4)	1 (0,3)	0.0258
Eating same food	2 (0,3)	2 (0,4)	> 0.9999
Overeating	1 (0,3)	0 (0,4)	0.5859
Declined table manners	0 (0,3)	1 (0,2)	> 0.9999

bvFTD behavioral variant frontotemporal dementia, *svPPA* semantic variant primary progressive aphasia, *MMSE* Mini-Mental State Examination, *FTD-CDR* frontotemporal dementia specific clinical dementia rating. *CBI* Cambridge Behavioral Inventory

identify the brain areas correlated with rCBF. Age, gender, and disease duration were included as nuisance variables.

Statistical analysis

Statistical analyses were performed using SPSS (v. 17.0, Chicago, IL, USA). Kolmogorov-Smirnov tests were used to determine the suitability of variables for parametric analyses. Normally distributed continuous variables were expressed as means ± standard deviation (SD). Medians (interquartile range) were used for abnormally distributed continuous variables. For normally distributed variables, group comparisons were performed using Student's t test for continuous variables and the chi-square test for categorical variables. Due to their non-normal distribution, group differences in CBI scores in each subdomain were analyzed using nonparametric the Mann–Whitney test ($p < 0.05$ was regarded as significant).

In voxel-based analysis by SPM, the results were considered statistically significant at peak-level threshold $p < 0.001$ and corrected for multiple comparisons on the voxel level ($p < 0.05$, family-wise error), in conjunction with a cluster filter of 50 voxels. All significant results were listed with the cluster size, brain regions, the Brodmann area (BA) involved, the MNI coordinates, the peak t and z values, and the FWE-corrected p value. The significant clusters were overlaid on the Montreal Neurological Institute standard T1-weighted MRI using MRIcroGL (http://www.mccauslandcenter.sc.edu/mricrogl/).

Results

Table 1 shows the demographic data, neuropsychological test results, and CBI eating behavior scores of the bvFTD and svPPA groups. The bvFTD and svPPA groups were comparable in age, gender, disease duration, education, and general cognitive assessment, but bvFTD patients had a significantly higher score on the NPI. The bvFTD group had a higher score in preference for sweets than the svPPA group. However, no significant difference in the total CBI score or subdomain scores was found between the two groups.

The results of voxel-based correlation analysis of SPECT images are shown in Table 2 and Fig. 1. We found a negative correlation between rCBF and the preference for sweet food and same food in a number of cortical and subcortical areas. The areas that were significantly correlated with the sweet preference included the bilateral gyrus rectus and temporal pole (Fig. 1A). In bvFTD, the preference for the same food was negatively related with the rCBF in the left ventral anterior cingulate cortex (ACC; Fig. 1B). The left inferior temporal gyrus was found to be negatively correlated with the preference for the same food in svPPA (Fig. 1B). No positive correlation was found. Our analysis did not show any significant cluster correlated with the other domains of the CBI.

Discussion

In this exploratory study, we described the characteristics of eating abnormalities in bvFTD and svPPA and provided an insight into the related rCBF change. Eating abnormality is considered an important behavior symptom in FTD [7, 8, 18–20]. In our study, both bvFTD and svPPA patients showed prominent eating abnormalities, such as sweet preference and stereotypic eating. Sweet preference was the most prominent change in bvFTD, while stereotypic eating was the prominent change in svPPA. No significant differences in increased appetite or abnormal table manners were found between the bvFTD and svPPA patients.

Table 2 Significant clusters of negative correlation between CBI score and rCBF

		Region	Peak location MNI coordinate			Cluster size	*T* max	*Z* max	*p* (FWE-corr)
			x	*y*	*Z*				
bvFTD	Sweet preference	Left temporal pole (BA 38)	− 38	18	− 36	165	4.839	4.245	0.0097
		Bilateral rectus gyrus (BA 11)	6	26	− 28	96	4.614	4.085	0.0166
		Right temporal pole (BA 38)	46	14	− 26	195	4.305	3.861	0.0330
	Eating same food	Left anterior corona radiate left ventral anterior cingulate cortex (BA 24)	− 18	22	26	245	4.726	4.165	0.0143
svPPA	Eating same food	Left inferior temporal gyrus (BA 20)	− 50	− 24	− 32	184	5.735	4.508	0.0066

p (*FWE-corr*) family-wise error corrected *p* value at voxel level, *BA* Brodmann area, *bvFTD* behavioral variant frontotemporal dementia, *svPPA* semantic variant primary progressive aphasia

Most previous studies used the Neuropsychiatric Inventory (NPI) or Frontal Behavioral Inventory (FBI) to conduct an overall assessment of eating abnormalities; however, they did not specifically characterize the different components of eating behavior [19–22]. The CBI, which includes four specific components of eating disorder, is considered a suitable short screening questionnaire for detecting specific eating abnormalities. It has to be noted that as caregiver questionnaires might be limited by overestimates or underestimates, an objective and reliable method for quantifying eating abnormalities is needed in the future.

In the voxel-based morphometry (VBM) correlation analysis, we found that the hypoperfusion in a number of cortical and subcortical regions correlated with eating abnormalities. For bvFTD, we identified a link between sweet preference and the decreased rCBF in bilateral gyrus rectus and temporal pole, which was consistent with previous structural studies [10, 11]. The orbital frontal cortex (OFC), including the gyrus rectus, was reported to be related to processing of rewards and disinhibition [23, 24]. The sweet preference in bvFTD may suggest that there is either an increase in the rewarding value of sweet food or an increase in the impulsiveness for sweet food. Moreover, as the temporal lobe is associated with semantic processing, the sweet preference in bvFTD may be related to the impaired semantic processing.

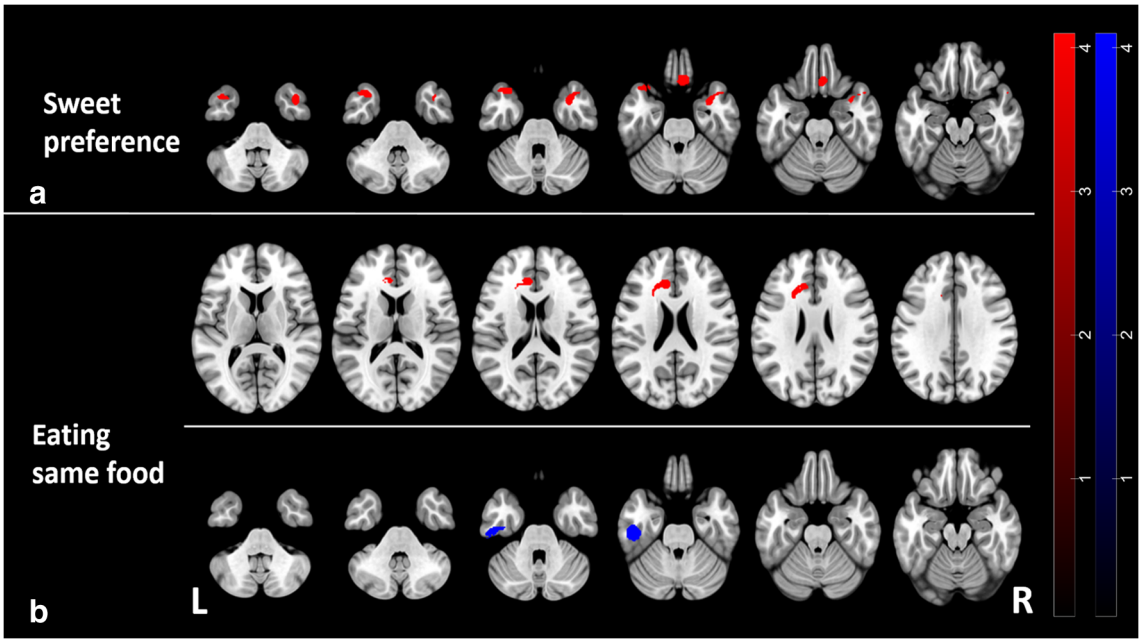

Fig. 1 Significant clusters of the negative correlation between rCBF and each CBI score. (A) The areas significantly correlated with sweet preference in bvFTD included the bilateral temporal pole (BA 38) and bilateral gyrus rectus (BA 11) (red). (B) The areas significantly correlated with eating the same food in bvFTD included the left ventral ACC (BA 24) and left anterior corona radiata. Red and blue indicate bvFTD and svPPA, respectively. rCBF regional cerebral blood flow, CBI Cambridge behavior index, bvFTD behavioral variant frontotemporal dementia, svPPA semantic variant primary progressive aphasia, L left, R right

Interestingly, when it comes to the preference for the same food, the related regions were different between the bvFTD and svPPA groups, suggesting different mechanisms behind the same symptoms in different subtypes. The right ventral ACC was found to be involved in bvFTD. A previous study suggested that the OFC and ACC play an important role in the emotional behavior, leading to obsessive–compulsive disorder [25]. Though we did not find an association between the OFC and eating the same food, the bilateral OFC would be involved with a less strict threshold ($p < 0.005$, uncorrected). In the svPPA, eating the same food was found to be correlated with the left temporal pole, which is the key region of semantic processing. It can thus be suggested that stereotyped eating might be related to stereotyped or compulsive behavior in bvFTD and related to semantic impairment in svPPA. However, as the sample size of the svPPA group was small, the conclusions need to be interpreted with caution.

In contrast to previous findings, we did not find any association between changed rCBF and increased appetite. This inconsistency may be partly due to the differences in specific tests used to measure eating abnormalities. Compared with quantitative methods for measuring eating abnormalities, the 5-point scale CBI questionnaire makes neuroimaging analysis more difficult [7]. Additionally, the mechanisms of eating abnormalities in FTD might be multifactorial. It is possible that some components of eating abnormalities are more sensitive to the reduction of rCBF than others, which suggests the possibility of a different neural mechanism correlated with each component of eating disorder.

One limitation of our study was that due to it being a retrospective study, the partial volume correction (PVC) could not be performed because of the lack of 3D-T1 MRI. As it is well known that reduced rCBF has an impact on brain structure, the lower rCBF in a voxel-based framework could be amplified by the underlying reduced gray matter density, which should be accounted for by PVC. The inclusion of MRI-based PVC will be necessary in the future. The low cost of SPECT still makes it an attractive choice in developing countries, as the imaging cost of MRI is still prohibitive for some patients.

Conclusions

Our findings suggest that the eating abnormalities in bvFTD and svPPA are correlated with a reduction of rCBF. The bilateral gyrus rectus is a key region associated with a preference for sweets in bvFTD. Eating the same food is correlated with the left ventral ACC in bvFTD and correlated with the left inferior temporal gyrus in svPPA. Either different symptoms in the same subtype in FTD or the same symptom in different subtypes may be correlated with different regions, indicating different neural mechanisms behind them.

Compliance with ethical standards

This study was approved by the China-Japan Friendship Hospital, and study procedures were followed in accordance with the ethical standards of the hospital. Written informed consent was obtained from all of the subjects prior to any study procedures.

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Neary D, Snowden JS, Gustafson L, Passant U, Stuss D, Black S, Freedman M, Kertesz A, Robert PH, Albert M, Boone K, Miller BL, Cummings J, Benson DF (1998) Frontotemporal lobar degeneration: a consensus on clinical diagnostic criteria. Neurology 51(6):1546–1554
2. Gorno-Tempini ML, Hillis AE, Weintraub S, Kertesz A, Mendez M, Cappa SF, Ogar JM, Rohrer JD, Black S, Boeve BF, Manes F, Dronkers NF, Vandenberghe R, Rascovsky K, Patterson K, Miller BL, Knopman DS, Hodges JR, Mesulam MM, Grossman M (2011) Classification of primary progressive aphasia and its variants. Neurology 76(11):1006–1014. https://doi.org/10.1212/WNL.0b013e31821103e6
3. Piguet O (2011) Eating disturbance in behavioural-variant frontotemporal dementia. J Mol Neurosci 45(3):589–593. https://doi.org/10.1007/s12031-011-9547-x
4. Piguet O, Petersen A, Yin Ka Lam B, Gabery S, Murphy K, Hodges JR, Halliday GM (2011) Eating and hypothalamus changes in behavioral-variant frontotemporal dementia. Ann Neurol 69(2):312–319. https://doi.org/10.1002/ana.22244
5. Rascovsky K, Hodges JR, Knopman D, Mendez MF, Kramer JH, Neuhaus J, van Swieten JC, Seelaar H, Dopper EG, Onyike CU, Hillis AE, Josephs KA, Boeve BF, Kertesz A, Seeley WW, Rankin KP, Johnson JK, Gorno-Tempini ML, Rosen H, Prioleau-Latham CE, Lee A, Kipps CM, Lillo P, Piguet O, Rohrer JD, Rossor MN, Warren JD, Fox NC, Galasko D, Salmon DP, Black SE, Mesulam M, Weintraub S, Dickerson BC, Diehl-Schmid J, Pasquier F, Deramecourt V, Lebert F, Pijnenburg Y, Chow TW, Manes F, Grafman J, Cappa SF, Freedman M, Grossman M, Miller BL (2011) Sensitivity of revised diagnostic criteria for the behavioural variant of frontotemporal dementia. Brain 134 (**Pt 9**:2456–2477. https://doi.org/10.1093/brain/awr179
6. Cerami C, Cappa SF (2013) The behavioral variant of frontotemporal dementia: linking neuropathology to social cognition. Neurol Sci 34(8):1267–1274. https://doi.org/10.1007/s10072-013-1317-9
7. Ahmed RM, Irish M, Kam J, van Keizerswaard J, Bartley L, Samaras K, Hodges JR, Piguet O (2014) Quantifying the eating abnormalities in frontotemporal dementia. JAMA Neurol 71(12):1540–1546. https://doi.org/10.1001/jamaneurol.2014.1931
8. Ahmed RM, Irish M, Henning E, Dermody N, Bartley L, Kiernan MC, Piguet O, Farooqi S, Hodges JR (2016) Assessment of eating behavior disturbance and associated neural networks in frontotemporal dementia. JAMA Neurol 73(3):282–290. https://doi.org/10.1001/jamaneurol.2015.4478
9. Yi DS, Bertoux M, Mioshi E, Hodges JR, Hornberger M (2013) Fronto-striatal atrophy correlates of neuropsychiatric dysfunction in frontotemporal dementia (FTD) and Alzheimer's disease (AD). Dement Neuropsychol 7(1):75–82. https://doi.org/10.1590/S1980-57642013DN70100012
10. Whitwell JL, Sampson EL, Loy CT, Warren JE, Rossor MN, Fox NC, Warren JD (2007) VBM signatures of abnormal eating

behaviours in frontotemporal lobar degeneration. Neuroimage 35(1):207–213. https://doi.org/10.1016/j.neuroimage.2006.12.006
11. Woolley JD, Gorno-Tempini ML, Seeley WW, Rankin K, Lee SS, Matthews BR, Miller BL (2007) Binge eating is associated with right orbitofrontal-insular-striatal atrophy in frontotemporal dementia. Neurology 69(14):1424–1433. https://doi.org/10.1212/01.wnl.0000277461.06713.23
12. Bocchetta M, Gordon E, Manning E, Barnes J, Cash DM, Espak M, Thomas DL, Modat M, Rossor MN, Warren JD, Ourselin S, Frisoni GB, Rohrer JD (2015) Detailed volumetric analysis of the hypothalamus in behavioral variant frontotemporal dementia. J Neurol 262(12):2635–2642. https://doi.org/10.1007/s00415-015-7885-2
13. Catafau AM (2001) Brain SPECT in clinical practice. Part I: perfusion. J Nucl Med 42(2):259–271
14. McArthur C, Jampana R, Patterson J, Hadley D (2011) Applications of cerebral SPECT. Clin Radiol 66(7):651–661. https://doi.org/10.1016/j.crad.2010.12.015
15. Freitas S, Simoes MR, Alves L, Duro D, Santana I (2012) Montreal cognitive assessment (MoCA): validation study for frontotemporal dementia. J Geriatr Psychiatry Neurol 25(3):146–154. https://doi.org/10.1177/0891988712455235
16. Knopman DS, Kramer JH, Boeve BF, Caselli RJ, Graff-Radford NR, Mendez MF, Miller BL, Mercaldo N (2008) Development of methodology for conducting clinical trials in frontotemporal lobar degeneration. Brain 131 (**Pt 11**:2957–2968. https://doi.org/10.1093/brain/awn234
17. Wear HJ, Wedderburn CJ, Mioshi E, Williams-Gray CH, Mason SL, Barker RA, Hodges JR (2008) The Cambridge behavioural inventory revised. Dement Neuropsychol 2(2):102–107. https://doi.org/10.1590/S1980-57642009DN20200005
18. Bozeat S, Gregory CA, Ralph MA, Hodges JR (2000) Which neuropsychiatric and behavioural features distinguish frontal and temporal variants of frontotemporal dementia from Alzheimer's disease? J Neurol Neurosurg Psychiatry 69(2):178–186
19. Schroeter ML, Vogt B, Frisch S, Becker G, Seese A, Barthel H, Mueller K, Villringer A, Sabri O (2011) Dissociating behavioral disorders in early dementia-an FDG-PET study. Psychiatry Res 194(3):235–244. https://doi.org/10.1016/j.pscychresns.2011.06.009
20. Snowden JS, Bathgate D, Varma A, Blackshaw A, Gibbons ZC, Neary D (2001) Distinct behavioural profiles in frontotemporal dementia and semantic dementia. J Neurol Neurosurg Psychiatry 70(3):323–332
21. Rosen HJ, Allison SC, Ogar JM, Amici S, Rose K, Dronkers N, Miller BL, Gorno-Tempini ML (2006) Behavioral features in semantic dementia vs other forms of progressive aphasias. Neurology 67(10):1752–1756. https://doi.org/10.1212/01.wnl.0000247630.29222.34
22. Bathgate D, Snowden JS, Varma A, Blackshaw A, Neary D (2001) Behaviour in frontotemporal dementia, Alzheimer's disease and vascular dementia. Acta Neurol Scand 103(6):367–378
23. Murray EA, Rudebeck PH (2018) Specializations for reward-guided decision-making in the primate ventral prefrontal cortex. Nat Rev Neurosci 19(7):404–417. https://doi.org/10.1038/s41583-018-0013-4
24. Finlayson G, Bordes I, Griffioen-Roose S, de Graaf C, Blundell JE (2012) Susceptibility to overeating affects the impact of savory or sweet drinks on satiation, reward, and food intake in nonobese women. J Nutr 142(1):125–130. https://doi.org/10.3945/jn.111.148106
25. Uher R, Murphy T, Brammer MJ, Dalgleish T, Phillips ML, Ng VW, Andrew CM, Williams SC, Campbell IC, Treasure J (2004) Medial prefrontal cortex activity associated with symptom provocation in eating disorders. Am J Psychiatry 161(7):1238–1246. https://doi.org/10.1176/appi.ajp.161.7.1238