Title

Uncinate fasciculus disruption relates to poor recognition of negative facial emotions in Alzheimer's disease: A cross-sectional diffusion tensor imaging study.

Short running title

The neural basis in facial recognition

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Abstract

Background:

Recognizing facial emotions involves the visual and emotional information processing. Patients with dementia, including dementia of Alzheimer's disease (DAT), are known poorly recognize facial emotions, especially negative facial emotions. In this study, we aimed to assess if DAT patients exhibit poor facial emotional recognition, and to identify a neural basis for how poor facial emotional recognition might occur.

Methods:

Magnetic resonance imaging and diffusion tensor imaging (DTI) analysis were conducted in 20 DAT patients and 15 cognitive normal (CN) subjects. The uncinate fasciculus (UF), inferior longitudinal fasciculus, and inferior fronto-occipital fasciculus were delineated by deterministic tractography. DTI parameters were calculated for each fiber. Facial emotion recognition was evaluated with the Facial Emotion Selection Test (FEST). The relationships between FEST scores and DTI parameters in each fiber were measured by partial correlation analyses with age, sex, and the Mini-Mental State Examination as covariates. Group-wise comparisons between DAT and CN subjects were performed for each DTI parameter in each fiber.

Results:

DAT patients showed lower FEST negative emotion scores than CN subjects ($p < 0.05$). The score of negative emotion subscale was negatively correlated ($r = -0.770$, $p < 0.001$) to mean diffusivity of the left UF in DAT patients. There were no

relationships between negative emotion subscale and the other fiber tracts. DAT patients showed no differences in the DTI parameters for each fiber compared to CN subjects.

Conclusions:

DAT-related prefrontal-limbic network dysfunction is associated with poor recognition of unpleasant emotions; consequently, worse facial recognition of negative emotion is observed in DAT patients.

Key words

Alzheimer's disease; diffusion tensor imaging; facial emotion recognition; tractography; uncinate fasciculus

Introduction

Dementia of Alzheimer's disease (DAT) represents the largest cause of dementia globally and after the age of 65 years, the prevalence doubles with every five years of age. Over the course of the disease, patients will experience characteristic cognitive dysfunctions, including memory impairment, disorientation, executive dysfunction, deficits of attention and visuospatial functions, and as a consequence, a reduced ability to engage in activities in daily life[1]. Additionally, behavioral and psychological symptoms associated with dementia (BPSD) cause burdens for caregivers [2,3].

In addition to core clinical symptoms, DAT patients have social cognitive deficits which impair facial emotion recognition[4]. Recognizing expressions of emotions is considered an important prerequisite for interpersonal functioning. According to previous research, recognizing emotional expressions can be examined by presenting photographs of faces expressing the six universal emotions: positive emotion (happiness), negative emotions (fear, disgust, anger and sadness), and surprise[5]. Of these, the capacities to recognize negative facial emotions is prominently attenuated in older adults[6]. In dementia, recognition of negative facial emotions is also known to decrease, and by a greater extent than aging alone. For example, patients with frontotemporal dementia (FTD) possess an impaired ability to recognize sadness, fear and anger[7]. Patients with DAT are likewise less able to recognize sadness and anger[8]. For patients with dementia, the decline in detecting facial emotions can cause problems with non-verbal communication and may be attributable to deteriorating BPSDs such as emotional instability, depression, and anxiety. These problems cause increased caregiver burden and make it difficult to properly treat and care for patients suffering from dementia.

The underlying neural basis for recognizing emotions in facial expression has been investigated through magnetic resonance imaging (MRI) analyses. Structural MRI analyses have reported that the gray matter volume of the right inferior frontal gyrus was positively correlated with the total accuracy of facial expression recognition in healthy subjects[9]. Functional MRI (fMRI) studies have shown that the fusiform facial area located in the ventral temporal lobe was strongly activated while looking at photographs of faces[10]. Other fMRI activation studies and positron emission tomography studies have demonstrated that the medial prefrontal cortex plays an important role in processing emotions which are induced by visual stimulus relayed by the activated occipital cortex and the amygdala. In addition, the amygdala is responsible for processing fear-related emotions, the subcallosal cingulate cortex is known to process sadness, and basal ganglia processes happiness and disgust[11]. On the other hand, for to understand the relationship between facial emotion recognition and neural activity, diffusion tensor imaging (DTI) studies have reported that involvement of long-range association fiber tracts that connect visual and emotion-related structures, such as the inferior longitudinal fasciculus (ILF) and the inferior fronto-occipital fasciculus (IFOF), are likely critical for these regions to communicate to achieve recognition[12]. The ILF connects the occipital cortex with the anterior temporal lobe and amygdala, whereas the IFOF begins in the occipital cortex, continues medially through the temporal cortex dorsal the uncinate fasciculus (UF), terminating in the orbito-frontal cortex. The UF connects the prefrontal cortex with the temporal lobe, including the temporal pole and amygdala, and the UF was of critical importance for the regulation of facial expression processing[13]. In Parkinson's disease, decreased fractional anisotropy (FA) in the frontal portion of the right IFOF was significantly correlated with a

decreased ability to identify sadness[14]. In semantic dementia, a subtype of FTD, emotion recognition impairment resulted from disruption of the right UF[15]. To the best of our knowledge, however, there have been no DTI studies which have directly examined the relationships between neural network activity and facial emotion recognition in DAT patients.

Elucidating the neural basis for the poor recognition of emotions within facial expressions is of critical importance for determining appropriate treatments and daily-care for DAT patients. In particular, the disruption of neural networks associated with visual information and emotional processing may serve as critical mechanisms for the poor recognition of emotions in facial expression within DAT patients. In this study, we explored the relationships between facial recognition and the activities of white matter bundles associated with visual information and emotion processing in DAT patients. We hypothesized that DAT patients would show white matter abnormalities which will in turn correlate with negative emotion processing.

Methods

Subjects

We enrolled 20 patients with DAT and 15 cognitive normal (CN) subjects in a cross-sectional study. Patients with DAT were recruited from the outpatients at the Department of Psychiatry, Nara Medical University hospital, who had received a medical examination between May 2015 and May 2018. Patients with DAT were diagnosed with probable DAT by trained psychiatrists in accordance with the criteria of the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association. Exclusion criteria included a

history of substantial brain injury, other neurological or psychiatric diseases, visual or hearing disorders, and difficulty with speaking Japanese. CN subjects had no dementia and no history of any neurological and psychiatric diseases.

We evaluated the ability to recognize emotion in of facial expression using the Facial Emotion Selection Test (FEST), an adaptation of an experimental task developed by Hagiya et al[16]. The FEST consists of 21 facial photographs of Japanese trainee actors and actresses, each depicting one of the six emotions (happiness, sadness, anger, disgust, surprise, fear) or a neutral expression. After observing each photo, the participants are asked to choose which of the seven expressions the photo represents. There are no time constraints so as to reduce the burden on processing speed. The score for each facial expression was the number of correct responses (range: 0 - 3). The total score was the sum of the scores from all emotions (range: 0 - 21). We further determined a score for positive (range: 0 - 3) and negative (range: 0 - 12) emotions. Happiness represented the lone positive emotion, while scores for sadness, anger, disgust, and fear were summed to determine the negative emotion score. General cognitive function was evaluated by the Mini-Mental State Examination (MMSE). This study was approved by the institutional review board of Nara Medical University, and all participants gave their written informed consent.

MRI acquisition

All participants underwent brain MRI using a 3T scanner equipped with a 32 phased-array head coil (Magnetom Verio; Siemens, Erlangen, Germany). DTI was acquired with an echo-planar imaging sequence using a GeneRalized Autocalibrating Partially Parallel Acquisition factor of 2. Imaging parameters were as follows: repetition time

(TR) = 14 sec, echo time (TE) = 84 msec, b value = 1000 s/mm^2, matrix = 128 × 128, field of view (FOV) = 256 x 256 mm, slice thickness = 2.0 mm, no intersection gap, 79 sections. The reconstruction matrix was the same as the acquisition matrix, and 2 × 2 × 2 mm isotropic voxel data were obtained. A motion probing gradient was applied in 12 directions. High-resolution 3-dimensional T1-weighted images were acquired by using a magnetization-prepared rapid gradient-echo sequence (TR = 1800 msec, TE = 2.4 msec, flip angle = 10°, FOV = 256 x 256 mm, 208 sections in the sagittal plane, matrix = 256 × 256, and acquired resolution = 1 × 1 × 1 mm).

Image processing

DTI is a noninvasive technique that enables the user to visualize in three dimensions and quantify the organization and integrity of white matter fiber tracts in the human brain in vivo. Diffusion tensor-derived parameters such as FA and mean diffusivity (MD) can thus describe the microarchitectural characteristics of local brain tissue, and mapping of these parameters can be used to depict pathological changes in the cerebral white matter. Lower FA or higher MD means white matter degeneration. DTI processing was performed using ExploreDTI (http://exploredti.com/) software. DTI processing included corrections for head motion and eddy current-induced geometric distortions of raw diffusion-weighted data[17]. The diffusion tensor was estimated using a non-linear least square approach[18]. Using deterministic tractography analyses, we delineated the UF, IFOF, and ILF which are associated with emotion and visual information processing (Figure 1). Setting the regions of interest for each tractography was conducted in accordance with the previous study[19]. For each tract, FA and mean diffusivity (MD) were calculated.

Statistical analyses

For demographic and psychological data, unpaired two-tailed t tests were conducted to compare group-wise differences between DAT patients and CN subjects for age, years of educational period, MMSE, the FEST total score, and each FEST emotion and subscale (i.e. positive and negative emotion, and neutral expression) score. The Fisher's exact test was used to assess sex differences. For FEST scores which were significantly reduced in DAT patients, partial correlation analyses between the FEST score and each of the diffusion parameter were performed using age and sex as covariates. In order to eliminate the influence of the FEST score by cognitive function, MMSE was also adjusted as a covariate. Total cognitive function Unpaired two-tailed t tests were used with a Bonferroni correction to avoid type I errors due to multiplicity. As such, $p < 0.0083$ was considered significant for group comparisons of diffusion parameters and partial correlation analysis between recognition of unpleasant emotions and diffusion parameters between DAT patients and CN subjects. Statistical analyses were performed using Statistical Package for Social Sciences version 25 (IBM Corp., Armonk, NY).

Results

Table 1 summarizes the demographic and clinical information for the participants in this study. There were no significant differences in age, sex and years of education between the two groups. DAT patients showed significant lower MMSE scores than CN subjects ($p < 0.05$). Figure 2 shows the group-wise comparisons of the total score, and the negative, positive, and neutral emotion/expression subscales for the FEST scores between DAT patients and CN subjects. In the FEST, DAT patients showed significantly lower scores for negative emotions and the total score than CN subjects (p

< 0.05). By contrast, score for positive emotions and neutral expressions showed no significant differences between the two groups ($p > 0.05$).

In group-wise comparisons of DTI parameters, there were no significant differences in the mean FA (DAT patients; 0.374 ± 0.025, CN subjects; 0.386 ± 0.020, df = 33, t = -1.49, p = 0.145) or the mean MD (DAT patients; 0.815 ± 0.031 x 10^{-3}mm/sec, CN subjects; 0.797 ± 0.030 x 10^{-3}mm/sec, df = 33, t = 1.75, p = 0.089) values of the left UF between DAT patients and CN subjects (Figure 3b, c). As well, the diffusion parameters of the right UF, bilateral IFOF or ILF did not significantly differ between DAT patients and CN subjects (Supplemental table 1).

Partial correlation analyses found that mean MD values of the left UF negatively correlated with the negative emotion score ($r = -0.770$, $p < 0.001$) in DAT patients (Figure 3a). No significant correlations were found between the mean FA values of the left UF and the negative emotion score ($r = 0.360$, $p = 0.155$). CN subjects showed no significant relationships between the negative emotion and either the mean FA ($r = -0.334$, $p = 0.289$) or MD ($r = 0.381$, $p = 0.222$) values of the left UF. In both DAT patients and CN subjects there were no significant relationships between the negative emotion score and each diffusion parameter of the right UF, bilateral IFOF or ILF (Supplemental table 2).

In our sub-analysis, among eight DAT patients with severe deficits in recognizing negative facial emotions (DAT patients whose negative emotion score were 1.5 SD below the mean negative emotion score of CN subjects), twelve DAT patients with mild deficits in recognizing negative emotions, and CN subjects we found significant between-group differences in mean MD values of the left UF ($F=7.29$, $p=0.002$, ANCOVA) (Supplemental table 3). After Bonferroni adjustment for multiple

comparisons, DAT patients with severe deficits had significantly higher mean MD values than DAT patients with mild deficits and CN subjects ($p = 0.008$, $p=0.003$).

When we didn't consider the severity of deficits in DAT patients and compared the DTI parameters of all them with CN subjects, we found no differences of the DTI parameters for each fiber compared to CN subjects. However, when we considered the severity of deficits in DAT and divided them into two groups, we found the significant differences of MD between DAT patients with severe deficits and DAT patients with mild deficits and CN subjects.

Discussion

In this study, patients with DAT demonstrated a reduced capacity to recognize facial displays of negative emotion when compared with CN subjects. However, there was no difference in the capacity to recognize positive emotions and neutral expressions. These results are consistent with those of previous studies, and suggest that DAT patients show neuropathological alterations associated with a decreased ability to recognize negative facial emotions[5]. Moreover, we found that higher mean MD values of the left UF were associated with a decreasing capacity to recognize negative facial emotions in DAT patients. This relationship was not observed in CN subjects. A previous report has shown that the poor facial recognition ability specifically in recognizing negative emotions was related to reductions in gray matter volume of the temporal lobe, the amygdala, and the frontal lobe[20]. The UF connects to all of them and the frontal lobe in turn is known to connect to the UF in DAT and FTD patients. Our results suggest that deteriorations of neural network function based on the UF plays a critical role in decreasing the ability to recognize negative facial emotions by DAT patients.

The UF connects the prefrontal cortex to the anteromedial temporal lobe, and has a hook-shaped morphology that curves around the posterior insula within the temporal stem. The temporal component further connects with the uncus, the anterior temporal pole, and the basolateral amygdala[21,22]. Portions of the anterior temporal lobe are involved in the storage and retrieval of social memories, including personal memories, as well as the theory of the mind[23]. The UF interconnects with cortical regions related to visual and emotional processing and makes decisions based on the emotional feelings[21]. In our study, among various facial expressions, only negative emotions were significantly correlated with the left UF in DAT patients. The amygdala has been associated with negative facial emotions such as expression conveying anger and fear[24]. The prefrontal cortex is situated to mediate top-down regulation of the amygdala during the cognitive evaluation of fearful stimuli[24]. Therefore, disruptions in the white matter microstructure of the UF, which connects these regions, can lead to inaccurate validation of negative emotions, and as a consequence, a poor ability to recognize negative facial emotions, such as in DAT patients.

Unlike with negative emotions, there no significant difference in the recognition of positive facial emotions between DAT patients and CN subjects. A previous study has reported that the recognition of positive emotions is associated with the basal ganglia, including the ventral striatum and the putamen[11]. These regions were rarely influenced by neuropathological abnormalities in the early stages of DAT. Furthermore, the recognition of positive emotions seems to be less affected by declines in cognitive performance than that of negative emotion[6]. As the clinical stage of the DAT patients in this study was comparatively early, our data, that the recognition of positive emotions was preserved, is in accordance with the literature.

In contrast to MD, there was no associations between the mean FA values of the

left UF and the recognition of negative facial emotions. FA has been determined to be indicative of white matter integrity, and is used to explore white matter abnormalities in neurodegenerative diseases. Previous studies, however, have reported that MD was more sensitive for capturing white matter abnormalities than FA during the early stages of DAT[25,26]. Thus, pathological changes of MD are considered to precede those of FA in early DAT. Since the patients in this study were at the comparatively early clinical stages of DAT, MD serves as a better metric than FA, and was in turn correlated with the decreased capacity for negative facial recognitions.

Emotion processing is lateralized to the right or non-dominant hemisphere of the brain[27]. However, there is also multimodal system of emotion which takes into account neural substrates for processing of specific emotions. Negative emotion recognition such as anger is associated with the left orbitofrontal region which is connected to the left temporal lobe by the left UF. Therefore, high MD of left UF is associated with poor recognition of negative facial emotions.

Facial emotion recognition had no association with the diffusion parameters of the ILF or IFOF in this study. The ILF connects the occipital cortex with the anterior temporal cortex, and associates the processing of perceptual aspects of visual stimuli with the processing of memory and emotions[12]. The IFOF begins in the ventral occipital lobe and terminates in ventral and lateral aspects of the frontal cortex. The IFOF plays a significant role in facial expression processing, and decreases in the white matter integrity of the tract was associated with poor face perception in healthy individuals[28]. One possibility for this discordance is that in the early stages of DAT, neuropathological abnormalities may not have spread to the lateral frontal, temporal, or occipital cortices. Thus, network dysfunction through the ILF and IFOF may not have been able to affect facial emotion

recognition. The UF, however, serves as a critical link between structures that have been implicated in components of emotional empathy such as the orbitofrontal cortex, temporal pole, and amygdala. Neuropathological changes, such as neurofibrillary tangles, appear in these regions early in the course of DAT[29]. Therefore, impaired recognition of negative facial emotions can be attributable to the white matter disruption of the UF during early phase of the DAT.

Although there was a significant correlation between poor facial expression recognition scores and the DTI measurements, there were no significant differences in the mean left UF FA or MD values between DAT patients and CN subjects. One possibility is that our study was not powered highly enough in lieu of the substantial variation demonstrated by the DAT patients in recognizing negative emotions. Our sub-analysis indicates that DAT patients whose UF white matter microstructure was preserved, could retain facial emotional recognition. Conversely, DAT patients who performed poorly at recognizing negative facial emotions at the early stages of their disease are considered to have advanced neuropathological alterations, and consequently, are speculated to have poor dementia outcomes.

There are several limitations in this study. First, this study employs small sample size, and there is no guarantee that the results of this study won't be applied to all DAT patients. Second, as we had no information for amyloid β accumulation in the brain, and as such, we cannot rule out that some patients in our sample have non-DAT related dementia. Third, we cannot rule out that other non-UF, ILF or IFOF network abnormalities could affect poor facial emotion recognition in DAT patients. Future analyses are expected to address these issues.

In conclusion, white matter disruption in the left UF was associated with the poor recognition of negative facial emotions in DAT patients. Fronto-limbic network dysfunction causes a reduced ability to use visual information for emotional processing, thereby resulting in a reduced capacity to recognize negative facial expressions. Recognizing the altered cognition in DAT patients makes it possible to adapt care strategies and lead to decrease burden for caregivers.

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Disclosure statement:

The authors have no potential conflicts of interest to disclose.

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Tables

Table 1. Demographic and psychological data of the current study.

	DAT (n=20)	CN (n=15)	t or χ^2	p
Age, mean (SD)	76.6 (5.26)	74.5 (6.24)	1.06	0.296
Sex, male (%)	9 (45.0)	9 (60.0)	0.863	0.394
Years of schooling, mean (SD)	11.9 (2.94)	12.1 (3.24)	-0.159	0.875
MMSE, mean (SD)	23.4 (1.79)	29.1 (0.88)	-12.4	< 0.001*
FEST, mean (SD)				
total	10.5 (3.44)	12.8 (2.91)	-2.13	0.040*
negative emotion	4.55 (2.16)	6.13 (1.92)	-2.25	0.032*
positive emotion	2.05 (0.83)	2.33 (0.62)	-1.11	0.273
neutral expression	1.95 (0.95)	1.87 (0.99)	0.253	0.802

DAT; dementia of Alzheimer's disease, CN; cognitive normal, MMSE; Mini-Mental State Examination, FEST; Facial Emotion Selection Test, SD; standard deviation.
*$p < 0.05$.

Figure legends

Figure 1.

Representative fiber tracts delineated by the deterministic tractography for the (a) uncinate fasciculus, (b) the inferior fronto-occipital fasciculus, and (c) the inferior longitudinal fasciculus. The solid arrows represent the seed region of interests (ROIs) and the dotted arrows represent the target ROIs.

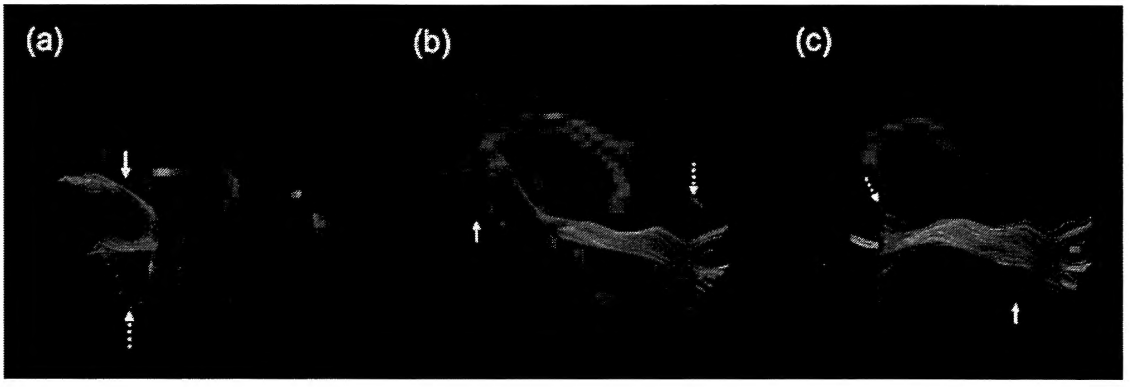
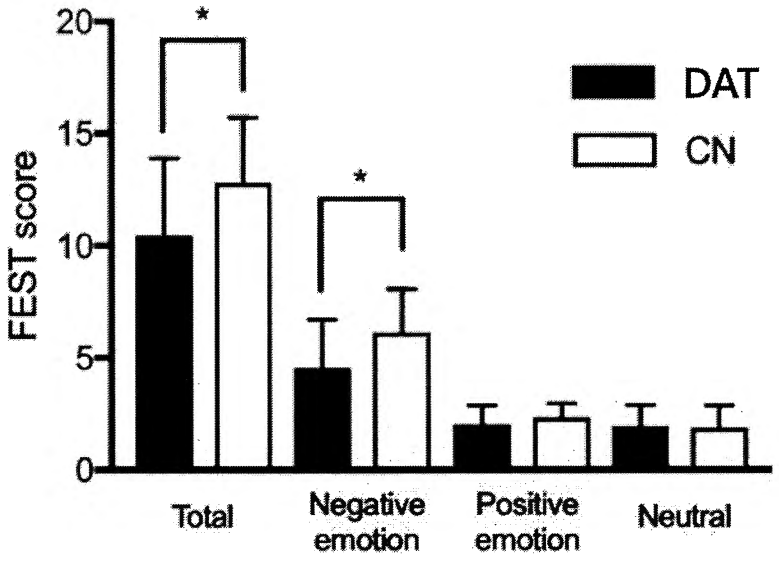


Figure 2.

Group-wise comparisons of the score of total, and the negative, positive, and neutral emotion/expression subscales for the FEST scores between DAT patients and CN subjects. DAT patients showed a lower score for the expression recognition of negative facial emotions than CN subjects ($p < 0.05$). There were no differences in other scores between the two groups.

FEST; Facial Emotion Selection Test, DAT; dementia of Alzheimer's disease, CN; cognitive normal.

*$p < 0.05$

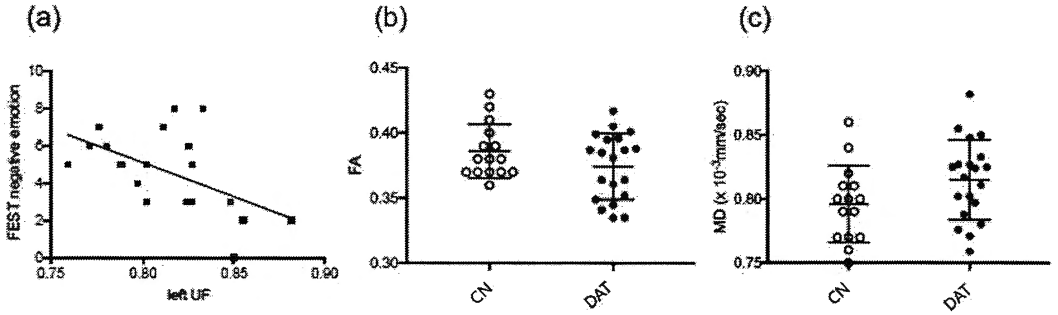


FEST; Facial Emotion Selection Test, DAT; dementia of Alzheimer's disease, CN; cognitive normal.

*$p < 0.05$

Figure 3.

The relationship between mean MD values of the left UF and FEST negative emotion subscale scores in DAT patients (a). Group comparisons showed that there were no significant differences in left UF mean FA (b) and MD (c) values between DAT patients and CN subjects.



UF; uncinate fasciculus, FA; fractional anisotropy, MD; mean diffusivity, FEST; Facial Emotion Selection Test, DAT; dementia of Alzheimer's disease, CN; cognitive normal.

Supplementary materials

Supplementary table 1. Group comparisons of the diffusion parameters in the right UF, bilateral IFOF and ILF between DAT patients and CN subjects.

	DAT (n=20)	CN (n=15)	t	P
right UF				
FA, mean (SD)	0.372 (0.026)	0.382 (0.021)	-1.15	0.260
MD, mean (SD)	0.812 (0.029)	0.798 (0.035)	1.33	0.192
right IFOF				
FA, mean (SD)	0.426 (0.026)	0.428 (0.019)	-0.325	0.747
MD, mean (SD)	0.837 (0.029)	0.843 (0.050)	-0.393	0.697
left IFOF				
FA, mean (SD)	0.423 (0.024)	0.429 (0.021)	-0.666	0.510
MD, mean (SD)	0.878 (0.034)	0.845 (0.042)	2.61	0.014
right ILF				
FA, mean (SD)	0.421 (0.023)	0.413 (0.025)	0.963	0.342
MD, mean (SD)	0.834 (0.036)	0.831 (0.052)	0.231	0.819
left ILF				
FA, mean (SD)	0.427 (0.016)	0.423 (0.035)	0.477	0.637
MD, mean (SD)	0.852 (0.035)	0.840 (0.054)	0.797	0.431

DAT; Dementia of Alzheimer's type, CN; cognitive normal, UF; uncinate fasciculus, IFOF; inferior fronto-occipital fasciculus, ILF; inferior longitudinal fasciculus, FA; fractional anisotropy, MD; mean diffusivity, SD; standard deviation.

$p < 0.0083$.

Supplemental table 2. Partial correlation analyses between the score of negative emotion and right UF, bilateral IFOF and ILF in DAT patients and CN subjects.

	DAT (n = 20)		CN (n = 15)	
	r	p	r	p
right UF				
FA	0.144	0.580	-0.246	0.442
MD	-0.276	0.284	-0.189	0.556
right IFOF				
FA	-0.051	0.847	-0.271	0.395
MD	-0.080	0.760	0.410	0.186
left IFOF				
FA	0.388	0.124	0.229	0.474
MD	-0.117	0.655	0.458	0.134
right ILF				
FA	-0.217	0.402	0.148	0.646
MD	0.152	0.560	0.253	0.427
left ILF				
FA	-0.309	0.227	-0.357	0.255
MD	0.002	0.995	0.318	0.314

DAT; Dementia of Alzheimer's type, CN; cognitive normal, UF; uncinate fasciculus, IFOF; inferior fronto-occipital fasciculus, ILF; inferior longitudinal fasciculus, FA; fractional anisotropy, MD; mean diffusivity.

Supplementary table 3. Group comparisons of the diffusion parameters between DAT patients with mild deficits of negative emotion recognition, DAT patients with severe deficits, and CN.

	mild DAT (n=12)	severe DAT (n=8)	CN (n=15)	F	P

right UF					
FA, mean (SD)	0.375 (0.022)	0.369 (0.033)	0.382 (0.021)	0.784	0.465
MD, mean (SD)	0.802 (0.028)	0.827 (0.024)	0.798 (0.035)	2.502	0.098
left UF					
FA, mean (SD)	0.380 (0.025)	0.365 (0.025)	0.386 (0.020)	2.130	0.135
MD, mean (SD)	0.799 (0.024)	0.839 (0.025)	0.797 (0.030)	7.293	0.002*
right IFOF					
FA, mean (SD)	0.427 (0.030)	0.424 (0.021)	0.428 (0.019)	0.078	0.925
MD, mean (SD)	0.832 (0.036)	0.844 (0.022)	0.843 (0.050)	0.275	0.762
left IFOF					
FA, mean (SD)	0.429 (0.023)	0.415 (0.023)	0.429 (0.021)	1.222	0.308
MD, mean (SD)	0.876 (0.036)	0.882 (0.042)	0.845 (0.042)	3.358	0.047
right ILF					
FA, mean (SD)	0.419 (0.021)	0.423 (0.028)	0.413 (0.025)	0.502	0.610
MD, mean (SD)	0.835 (0.036)	0.833 (0.038)	0.831 (0.052)	0.034	0.966
left ILF					
FA, mean (SD)	0.426 (0.016)	0.430 (0.017)	0.423 (0.035)	0.155	0.857
MD, mean (SD)	0.847 (0.036)	0.861 (0.033)	0.840 (0.054)	0.556	0.579

mild DAT; DAT patients with mild deficits of negative emotion recognition, severe DAT; DAT patients with severe deficits of negative emotion recognition, DAT;

Dementia of Alzheimer's type, CN; cognitive normal, UF; uncinate fasciculus, IFOF; inferior fronto-occipital fasciculus, ILF; inferior longitudinal fasciculus, FA; fractional anisotropy, MD; mean diffusivity, SD; standard deviation.

*$p < 0.0083$.