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Cognitive Performance and Specific Deficits in OCD Symptom Dimensions: I. Olfactory Perception and Impaired Recognition of Disgust

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Abstract

Objective: To investigate the ability of patients with obsessive-compulsive disorder (OCD) in identifying pleasant and disgusting smells.
Methods: Participants were 55 OCD patients and 80 healthy controls, also matched for history of cigarette smoking. They were administered a smell identification test consisting of a subsample of 13 smells from the Pennsylvania Smell Identification Test (UPSIT) in addition to two new smells. Participants were exposed to smells from liquids in glass bottles.
Results: The OCD patients were significantly impaired compared to the healthy controls in identifying the smells. When controlling for anxiety, this group difference remained stable only for disgusting but not pleasant smells. An effect of patients in different symptom dimensions on smell identification was also found.
Conclusion: These findings suggest that in OCD, a specific dysfunction related to emotional appraisal of sensory stimuli, in the absence of a sensory deficit, may be apparent. This emotional deficiency could stem from disruption in processing related to the orbitofrontal cortex (OFC) (German J Psychiatry 2010; 13 (3): 127–139).

Keywords: Obsessive-compulsive disorder, symptom dimensions, emotion, olfaction, cognitive dysfunctions, anxiety

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Introduction

The core problem in obsessive-compulsive disorder (OCD) seems to be the inability to inhibit both obsessive thoughts and compulsive behaviors. Recent research has proposed that in OCD, the nature of cognitive deficits could stem from dysfunctional performance on tasks measuring response inhibition, tapping into overlapping cognitive domains such as set shifting and cognitive flexibility (Dittrich et al., 2010; Rubies et al., 2001; Watkins et al., 2005). These cognitive abnormalities are thought to involve dysfunctional processing in the prefrontal lobes and, more specifically, in the orbitofrontal cortex (OFC; e.g., Menzies et al., 2008). The OFC is thought to regulate our abilities to inhibit, evaluate, and act on social and emotional information (Gazzaniga et al., 2002). Behavioral problems in OCD may arise due to an affected OFC together with its interconnected brain structures (Graybiel & Rauch, 2000). It is also assumed that the OFC plays a major role in olfactory identification (Levy et al., 1998; Sobel et al., 1998). Olfactory recognition ability appears abnormal if the OFC is dysfunctional or possibly hyperactive in patients with OCD (e.g., Barnett et al., 1999). As the OFC is implicated in the disorder and emotional processing has been found to be abnormal in OCD (Barnett et al., 1999) it seemed important to investi-

gate olfactory identification as part of changes in the emotional processing abilities in OCD patients.

Certain smells can create emotional arousal due to the fact that the olfactory bulb (where the olfactory nerves enter) has a direct neural link with the limbic system of the brain, which is a center for emotional experience as well as memory. The amygdala, part of the limbic system, plays a significant role in the recognition of the emotion fear shown in functional neuroimaging (Calder, 2003). Neuroanatomical findings (Calder, 2003; Calder et al., 2000, 2001; Husted et al., 2006) have confirmed earlier postulations that processing of different emotions is mediated by different brain mechanisms (e.g., Dittrich, 1991, 1993, 1999; Dittrich & Atkinson, 2008).

The role of disgust has become the focus for proving specific processing (Husted et al., 2006). It has been suggested that OCD is associated with both a dysfunction in recognizing disgust in visual displays (Sprengelmeyer et al., 1997) as well as experiencing exaggerated feelings of disgust, which equals higher disgust sensitivity and thus a greater ability to detect disgust or a tendency to become disgusted (Husted et al., 2006; Power & Dalgleish, 1997; Woody & Tolin, 2002). Nevertheless, little is known about emotion and smell recognition in OCD and the only emotion reported to be impaired is disgust (Corcoran et al., 2008; Sprengelmeyer et al., 1997). However, these findings have all involved facial recognition of different emotions and most studies have failed to replicate this finding (Buhlmann et al., 2004; Corcoran et al., 2008; Parker et al., 2004; Rozin et al., 2005). It was therefore decided to focus on olfactory identification to provide an independent measure of emotional deficiencies in OCD, compared to studying directly patients' responses to different emotional stimuli.

In OCD, two studies have found impairments in smell identification (Barnett et al., 1999; Goldberg et al., 1991) whereas two studies have found intact identification performance (Fenger et al., 2005; Locatelli et al., 1996). Initially, smell identification in OCD was based on five highly obsessional patients and five healthy controls (Goldberg et al., 1991). Both groups consisted only of women and using the University of Pennsylvania Smell Identification Test (UPSIT; Doty et al., 1984), the average performance on the smell identification test was better in the healthy controls compared to the obsessional patients. Although this study reports clear differences between the two groups, methodological problems such as recruiting only five females is both unsatisfactory and problematic in terms of generalization of the findings. The current study improved on this methodological issue by recruiting a large sample size in both the experimental group and the healthy control group consisting of both males and females. Also employing the UPSIT, more robust results were reported by Barnett et al. (1999). Olfactory recognition was investigated in 20 patients with OCD and 23 healthy controls and results revealed that the OCD group recognized significantly fewer smells than the healthy controls. It is worth noting that the performance in the OCD group on the UPSIT was not associated with severity of obsessive-compulsive, anxiety, and depression symptoms (Barnett et al., 1999). This study did not report performance levels by the OCD patients on disgusting smells, while the present study investigated the performance on both disgusting and pleasant smells. Contrary to the two previous studies, no difference was found in performance on the UPSIT between 15 OCD patients and 17 healthy controls in Fenger et al. (2005). However, the cross-cultural smell identification test (Doty et al., 1996), which is the brief 12-item version of the UPSIT, was administered, compared to Barnett et al. (1999) and Goldberg et al. (1991) who administered the full 40-item version. It was argued that the 40-item version may be more sensitive to olfactory inacuity (Fenger et al., 2005). Akin to Barnett et al. (1999), this study did not distinguish between pleasant and disgusting smells. Lastly, Locatelli et al. (1996) compared 37 medication free OCD patients to 30 healthy controls on five odors (cinnamon, sweet orange, lavender, lemon, mint). It was found that the OCD group did not exhibit any difficulties in odor discrimination compared to the healthy control group. Considering the previous inconsistencies, the present study is an attempt to resolve the conflicting findings which presented methodological shortcomings and did not investigate performance on disgusting smells (e.g., Barnett et al., 1999). Consequently, the present OCD group's ability to identify disgusting smells was investigated.

According to previous findings it was hypothesized that the OCD patients would identify fewer odors compared to the healthy control group. Of particular interest was the hypothesis that the OCD group would be impaired in identifying disgusting smells. However, if the model of increased sensitivity to disgust is correct then higher identification rates would be assumed. Furthermore, it was predicted that the groups would not differ in identifying the pleasant smells. It was also expected that there would be a differences in identification rate between the two groups regarding disgusting and pleasant smells. The participants in the OCD group were also grouped according to their primary symptom dimensions (Henderson & Dittrich, 1993; Mataix-Cols et al., 2005; Rosario-Campos et al., 2006) to investigate differences in emotional performance. Olfactory identification had not been previously investigated in patients of different OC (obsessive-compulsive) symptom dimensions. It has been suggested that patients with mainly contamination obsessions and compulsions might either be sensitive to detect disgust (e.g., Olatunji et al., 2007; Power & Dalgleish, 1997) or otherwise being impaired in the detection of disgust (Sprengelmeyer et al., 1997). This study aimed to make a contribution towards solving the opposing views whether patients in the symptom dimension contamination have a difficulty in identifying disgust.

Methods

Participants

In this study, 55 participants (38 female, 17 male) meeting criteria for a DSM-IV diagnosis of OCD (American Psychiatric Association, 1994) and 80 healthy controls (42 female, 38 male) participated. Patients were recruited via an outpatient

mental health centre after being screened by a consultant psychiatrist (NAF). OCD patients who presented with a co-morbid Axis I diagnosis, current or history of alcohol or other substance abuse, neurological illness, head injury, Tourette's syndrome, tic-spectrum disorders, attention-deficit/hyperactivity disorder and schizo-obsessive disorder were excluded. The healthy control group was matched to the OCD group according to age, gender, handedness, predicted verbal IQ, years in formal education, and history of cigarette smoking.

The OCD patients were grouped into four symptom dimensions based on their current primary obsessions and/or compulsions as defined by the Dimensional Yale-Brown Obsessive-Compulsive Scale (DY-BOCS; Rosario-Campos et al., 2006). In this study the DY-BOCS symptom dimension 'obsessions about harm due to aggression/injury/violence/natural disasters and related compulsions' has been further divided into two sub-dimensions related mainly either to idiocentric (self-related safety) or allocentric (aggression) obsessions and compulsions. Aggression in the dimension aggression is used in the sense of directed to others, whereas aggression in the dimension safety is inferred through the concerns related to the protection of self. These two dimensions are what the OCD literature would normally label as classical 'checkers'. The following OC symptom dimensions were established from the patient sample:

(1) Obsessions about harm to self, urge to feel safe and protect the self and related compulsions (safety, n = 19)

(2) Obsessions about harm due to aggression/injury/violence/natural disasters to family members, others, and the self and related compulsions (aggression, n = 8)

(3) Obsessions about symmetry/'just-right' perceptions, and compulsions to count or order/arrange (symmetry/order, n = 14)

(4) Contamination obsessions and cleaning compulsions (contamination, n = 14)

The study was approved by the Hertfordshire Partnership NHS Trust Local Research Ethics Committee, UK and the Ethics Committee at the University of Hertfordshire, UK. Written informed consent was given by all participants after they had been fully informed about the study. Data in this manuscript were obtained in compliance with the Helsinki Declaration.

Materials

The materials section outlines separately the clinical and psychological testing instruments and the olfactory test administered to the participants.

Clinical and psychological testing

The severity of OCD was quantified with the Yale-Brown Obsessive-Compulsive Scale (Y-BOCS; Goodman et al., 1989) and the extended clinical interview was supplemented with the Mini International Neuropsychiatric Interview (Sheehan et al., 1998). Depression mood was quantified with the Montgomery-Åsberg Depression Rating Scale (MADRS; Montgomery & Åsberg, 1979) and anxiety was assessed with the State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983). Cognitive Assessment Instrument of Obsessions and Compulsions (CAIOC) assessed the cognitive and executive impairments that are hypothesized to underpin the impact of OCD symptoms on functioning (Fineberg et al., submitted). Obsessive-Compulsive Personality symptoms was rated with the Compulsive Personality Assessment Scale (CPAS; Fineberg et al., 2007) and psychosocial impairment was quantified with the Sheehan Disability Scale (SDS; Sheehan et al., 1996). Predicted verbal IQ was estimated using the National Adult Reading Test (NART; Nelson, 1982). The healthy control group was administered the same clinical and psychological background instruments as the patient group.

Olfactory testing

The administration of the smell stimuli and the grouping of individual smells into pleasant and disgusting smells comprised olfactory testing.

Smell stimuli

Olfactory identification performance was tested using a smell identification test consisting of a subset of 13 smells adopted from the UPSIT. Our smell identification test also consisted of sour milk and ripe banana. During the experimental testing session sour milk, ripe banana, smoke, and onion were replaced regularly (every second day) to ensure that the quality of the olfactory stimuli remained stable for all participants.

Smell grouping re-test

The pleasantness ratings of all the 13 odors were examined to confirm pleasant versus disgusting classification according to Doty et al. (1984) by eight independent observers prior to experimental testing. All ratings corresponded closely apart from the case of clove and pine where all 8 observers found clove to be unpleasant and pine to be pleasant. In Doty et al. (1984) clove is reported to be a neutral smell whereas pine is unpleasant. This discrepancy can be accounted for by using different substances and administration methods of the odors. Therefore, following Doty et al. (1984) as well as Herz et al. (1999), we grouped our items into pleasant smells (chocolate, cinnamon, coconut, lemon, mint, peach, rose, soap) and disgusting/unpleasant smells (onion, paint thinner, smoke). In contrast to Doty et al. (1984) clove was classified as a disgusting smell whereas pine was classified as pleasant. Two new additional smells, sour milk and ripe banana, were classified as disgusting smells.

Procedure

On the day of testing, the clinical interview lasting 25 minutes was first completed by the consultant psychiatrist.

Table 1. Demographic and clinical characteristics in the OCD and healthy control group

	OCD (n = 55)		Healthy Controls (n = 80)		
Variable					X^2-test
N (female : male)	38 : 17		42 : 38		n.s.
Hand (right : left)	48 : 7		74 : 6		n.s.
Smoke (yes : no)	11 : 44		18 : 62		n.s.
Variable	Mean	SD	Mean	SD	t-test
Age	40.7	12.8	37.4	15.4	n.s.
Education (years)	3.1	2.6	3.1	1.6	n.s.
Verbal IQ	113.8	5.1	114.9	4.8	n.s.
Y-BOCS	20.8	7.7	3.2	2.4	19.301***
MADRS	14.7	7.5	4.6	2.4	11.335***
STAI-state	52.1	12.4	35.0	11.0	8.445***
STAI-trait	55.4	10.6	39.1	10.6	8.764***
CAIOC	61.8	17.3	28.0	14.8	12.166***
CPAS	14.7	5.6	8.9	4.5	5.459***
SDS	16.7	7.2	3.3	4.9	10.267***

Note. CAIOC, Cognitive Assessment Instrument of Obsessions and Compulsions; CPAS, Compulsive Personality Assessment Scale; MADRS, Montgomery and Åsberg Depression Rating Scale; OCD, Obsessive-Compulsive Disorder; SD, Standard Deviation; SDS, Sheehan Disability Scale; STAI, State-Trait Anxiety Inventory; Y-BOCS, Yale-Brown Obsessive Compulsive Scale; Degrees of freedom (df; X^2-test) = 1; df (t-test) = 133; ***p < .001

Then the self-rated background instruments (STAI, CAIOC, SDS) taking 25 minutes were completed followed by the smell identification test, which took 20 minutes to administer. The smell identification test items were presented to the participants in 10 ml brown glass bottles covered with a white sticker to make sure the visual appearance of the liquid was concealed. The odors were 100% essential oils with extractions from the natural products to create the scent. The odors are commercially available from Baldwin & Co, London, UK, apart from sour milk, ripe banana, smoke, paint thinner, and onion. The individual glass bottles were labeled A to O and were administered to the participants alternatively in two orders (A to O or O to A). The bottles were briefly uncapped while held at about 2 centimeters from the participants' nostrils. The participants were exposed to each odor for an average of 20 seconds (+/- 10 seconds) and were permitted to smell the olfactory stimuli as many times as necessary to identify them. There was approximately a 1 minute inter-trial interval between each odor presentation, during which time the participants provided their assessment of the stimulus just smelled. This involved naming the smell and giving written responses for ratings of confidence, pleasantness, quality, and intensity on a 9-point Likert scale. For example, a score of 3 would indicate that the participants were not being very confident that they had identified the correct smell, finding the smell unpleasant, being of low quality, and intensity (maximum score = 135 (highest score 9 x 15 items) for each of the four response variables). Identification ability was scored according to a strict criterion, with 0 = incorrect or no response and 1 = accurate description or accurate label (e.g., 'gone off milk' for 'sour milk' or 'peppermint' for 'mint'; maximum score = 15). Lastly, it was noted whether the participants smoked or not, although not clearly established, smoking has been found to be detrimental to olfactory sensory function (e.g., Katotomichelakis et al., 2007).

Data Analysis

A two-way repeated-measures analysis of variance (ANOVA) was conducted to evaluate group (OCD, healthy controls) as the between-subjects factor and smell dimension (pleasant, disgusting) as the within-subjects factor. The L.S.D. tests were used for post hoc comparisons. Similar to Barnett et al. (1999), the performance of each participant on the smell identification test was compared to age- and gender-matched normative data available from Doty (1995) to obtain a percentile categorical ranking. This enabled us to distinguish the participants with a normal sense of smell (normosmia), mild microsmia, moderate microsmia, and a loss of smell (anosmia). A between groups chi-square analysis was conducted to analyse the distribution of participants in these categories. The test scores of confidence, pleasantness, quality, and intensity were compared between groups using independent-samples t tests. All means related to the smell identification test are reported in percentages. Chi-square analyses were used for comparison of groups on female : male ratio, handedness, smokers : non-smokers and individual smell identification rates, which refers to the number of participants in the OCD and healthy control group correctly identifying each smell. Correlation analyses, Pearson's *r*, were computed between smell and clinical and psychological variables. The level of significance was set on a two-tailed p-value ≤ 0.05.

Results

The two groups did not differ significantly in age, education, and verbal IQ (Table 1). Mean age in the OCD group was 40.7 years (standard deviation (SD) = 12.8) and in the healthy control group it was 37.4 years (SD = 15.4). Mean

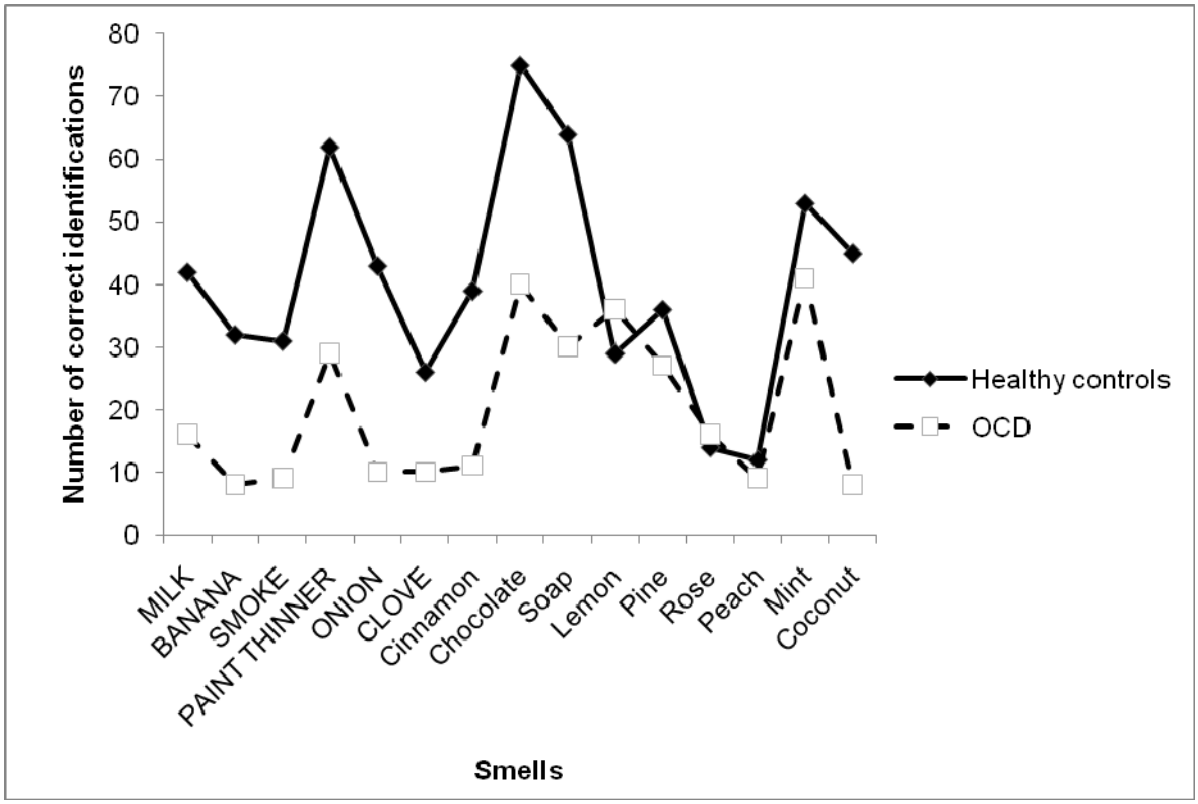

Figure 1. The number of participants correctly identifying each smell in healthy control and OCD group. Disgusting smells are indicated in capital letters

years in formal education was respectively 3.1 (SD = 2.6) and 3.1 (SD = 1.6) in the OCD and healthy control group whereas the mean predicted verbal IQ was 113.8 (SD = 5.1) in the OCD group and 114.9 (SD = 4.7) in the healthy controls. There were no significant group differences in terms of female : male ratio, handedness, and number of smokers : non-smokers. As expected, the mean score in the OCD group was significantly higher than the healthy control group on the measures Y-BOCS, MADRS, STAI-state, STAI-trait, CAIOC, CPAS, and SDS ($p < .001$ for all).

The individual smell identification rates are shown in Figure 1 and results revealed that significantly more healthy control participants compared to OCD patients identified the disgusting smells sour milk (controls: n = 42; OCD: n = 16; X^2 (1, N = 135) = 7.3, p = .007), banana (controls: n = 32; OCD: n = 8; X^2 (1, N = 135) = 10.1, p = .001), smoke (controls: n = 31; OCD: n = 9; X^2 (1, N = 135) = 7.8, p = .005), paint thinner (controls: n = 62; OCD: n = 29; X^2 (1, N = 135) = 9.1, p = .003), and onion (controls: n = 43; OCD: n = 10; X^2 (1, N = 135) = 17.3, $p < .001$). Similar results were found for the pleasant smells cinnamon (controls: n = 39; OCD: n = 11; X^2 (1, N = 135) = 11.6, p = .001), chocolate (controls: n = 75; OCD: n = 40; X^2 (1, N = 135) = 11.4, p = .001), soap (controls: n = 64; OCD: n = 30; X^2 (1, N = 135) = 10.0, p = .002), and coconut (controls: n = 45; OCD: n = 8; X^2 (1, N = 135) = 23.8, $p < .001$). On the other hand, significantly more OCD patients (n = 36) compared to healthy control participants (n = 29) identified lemon, X^2 (1, N = 135) = 11.1, $p < .001$. On the remaining smells, the healthy controls were numerically better at correctly identifying pine (controls: n = 36; OCD: n = 27), peach (controls: n = 12; OCD: n = 9), mint (controls: n = 53; OCD: n = 41), and clove (controls: n = 26; OCD: n = 10), whereas the OCD patients were numerically better in identifying rose (OCD: n = 16; controls: n = 14).

For all smells, an independent-samples t test revealed that the OCD group identified 36.5% (SD = 14.0) and this was significantly fewer compared to the healthy control group at 50.3% (SD = 16.5), t (133) = 5.092, $p < .001$. On the smell identification test variables (Table 2), the OCD group was significantly less confident that they had identified the correct smells, t (133) = 4.063, $p < .001$, but rated the smells on the variables pleasantness, quality, and intensity similarly to the healthy control group.

There was a significant difference between the groups in their ability to identify the smells by category, X^2 (3) = 59.9, $p < .001$ (Table 2). According to the individual scores, the majority of the OCD participants were moderately microsmic (58%), whereas 18% demonstrated mild microsmia, and 22% fell into the category normosmia. There was one patient who was found to be anosmic according to the normative scores. The majority of the healthy participants were classified as mildly microsmic. In cases of misidentification, patients often reported that they were familiar with the smell but had difficulty identifying particular smells. All data analyses were performed excluding the anosmic patient and significance levels did not change.

The ability to identify the pleasant and disgusting smells indicated group differences. The overall mean scores in the OCD and healthy control group on the pleasant and disgusting smells were 44.0% / 24.9% (SD = 17.2 / SD = 16.6) and

Table 2. Means (%) and Standard Deviation (SD) for smell variables in the OCD and healthy control group and distribution of participants (%) according to olfactory categories

	OCD (n = 55)		Healthy controls (n = 80)		
Variable	Mean (%)	SD	Mean (%)	SD	t-test
All smells (15 items)					
Confidence	55.3	15.5	65.9	14.5	4.063***
Pleasantness	60.0	12.3	56.5	12.0	n.s.
Quality	63.2	11.4	62.4	13.5	n.s.
Intensity	70.5	12.6	70.2	13.6	n.s.
Disgusting smells (6 items)					
Confidence	50.8	16.1	65.1	18.1	4.679***
Pleasantness	49.0	15.0	39.5	14.5	3.680***
Quality	57.9	13.0	54.6	16.9	n.s.
Intensity	65.8	15.4	72.2	17.8	2.182*
Pleasant smells (9 items)					
Confidence	58.2	16.6	66.4	15.0	3.008**
Pleasantness	67.2	12.9	67.8	13.4	n.s.
Quality	66.7	12.0	67.6	13.2	n.s.
Intensity	73.6	12.7	68.8	13.4	2.078*
Olfactory categories (%)					X^2-test
Normosmia	22		28		
Microsmia - mild	18		70		
Microsmia - moderate	58		2		
Anosmia	2		0		X^2 59.9***

Note: OCD, Obsessive-Compulsive Disorder; df (t-test) = 133; df (X^2-test) = 3; *p < .05; **p < .01; ***p < .001

51.0% / 49.2% (SD = 16.2 / SD = 25.6) respectively. The repeated-measures ANOVA revealed a main effect for smell dimension, F (1, 133) = 27.531, p < .001, η^2_p = .172, and a group and smell dimension interaction, F (1, 133) = 18.876, p < .001, η^2_p = .124 (Figure 2). Post hoc tests demonstrated that the OCD group had a significantly lower mean percent identification score on the disgusting smells (p < .001). The OCD patients were also significantly impaired in identifying the pleasant smells compared to the healthy control group (p = .019).

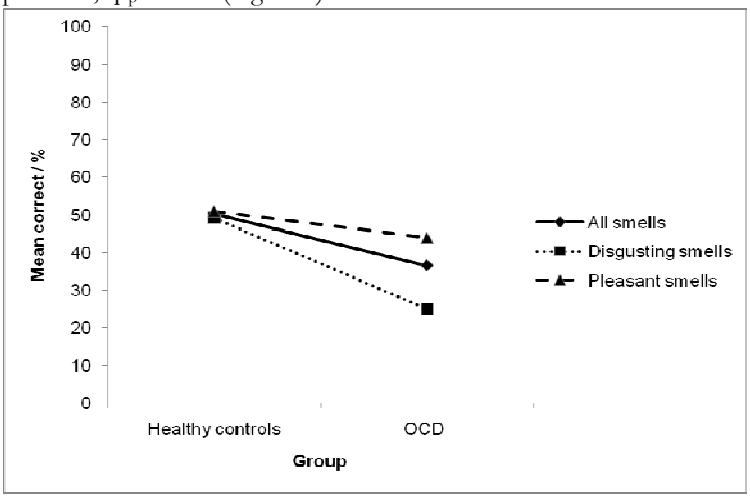

Figure 2. Mean correct identification (%) of all the smells, the pleasant smells, and the disgusting smells in the healthy control and OCD group

Two one-way analysis of covariance (ANCOVA) controlling for state and trait anxiety in the two groups were conducted to investigate the participants' ability to identify the disgusting and pleasant smells because anxiety scores in the OCD group correlated significantly with the smell identification test variables. Results revealed that the significant difference between the groups in identifying the disgusting smells remained, F (1, 131) = 17.896, MSE = 503.444, p < .001, η^2p = .120, whereas, for the pleasant smells, the ANCOVA did not reveal a significant group difference, F (1, 131) = 2.197, MSE = 279.309, p = .141, η^2p = .016.

In Table 2 it can be seen that the patient group compared to the healthy control group was significantly less confident that they had identified correctly the disgusting smells, t (133) = 4.679, p < .001, rated the disgusting smells to be significantly less disgusting, t (133) = 3.680, p < .001, and found them less intense, t (133) = 2.182, p = .031.

Symptom Dimension Analysis

The patients in the OC symptom dimensions and the healthy control group did not differ significantly in age, years in education, and predicted verbal IQ and there were no differences in gender, handedness, and the number of smokers either (Table 3). For the Y-BOCS scores, it turned out that patients in the symptom dimension aggression had significantly higher ratings compared to patients in the other symptom dimensions (p < .05 for all). For the depression scores, patients in the dimension aggression were significantly more depressed compared to patients in the dimensions safety (p = .008) and contamination (p = .050). On the same rating, the patients in the dimension symmetry/order had significantly higher scores compared to patients in the dimension safety (p = .028).

Three separate one-way ANVOCAs controlling for state and trait anxiety were conducted to analyse the ability to identify all smells, the disgusting smells, and the pleasant smells according to patients in the OC symptom dimensions (Figure 3). The ANCOVAs for the identification of all smells, F (4, 128) = 3.199, MSE = 245.177, p = .015, η^2p = .091, and the disgusting smells were significant, F (4, 128) = 4.875, MSE = 508.214, p = .001, η^2p = .132. Post hoc analysis revealed that the healthy control group (adjusted mean = 47.8%, SE = 2.8) had a significantly higher identification score for the disgusting smells compared to patients in the symptom dimensions safety (adjusted mean = 29.4%, SE = 5.5; p = .006), symmetry/order (adjusted mean = 23.2%, SE = 6.2; p = .001), and contamination (adjusted mean = 23.5%, SE = 6.3; p = .001).

Table 3. Demographic and clinical characteristics for patients in the OC symptom dimensions (SA, safety; AG, aggression; SO, symmetry/order; CO, contamination) and the healthy control group (HC)

	SA (n = 19)		AG (n = 8)		SO (n = 14)		CO (n = 14)		HC (n = 80)			
Variable											X^2-test	post-hoc (p < .05)
N (female : male)	12 : 7		4 : 4		10 : 4		12 : 2		42 : 38		n.s.	
Hand (right : left)	17 : 2		8 : 0		12 : 2		11 : 3		74 : 6		n.s.	
Smoke (yes : no)	7 : 12		1 : 7		2 : 12		1 : 13		18 : 62		n.s.	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	F-value	
Age	40.1	11.7	36.5	12.9	43.6	16.6	40.9	10.4	37.4	15.4	n.s.	
Education (years)	3.2	2.1	2.3	2.7	3.4	3.5	3.1	2.5	3.1	1.6	n.s.	
Verbal IQ	112.7	3.5	114.3	3.3	113.8	5.8	115.1	7.0	114.9	4.8	n.s.	
Y-BOCS	20.5	7.1	25.3	6.3	19.2	6.7	20.4	9.7	3.2	2.4	98.168***	HC<SA,AG,SO,CO AG>SA,SO,CO
MADRS	12.6	7.0	18.3	6.5	16.5	8.5	13.9	7.2	4.6	2.4	36.139***	HC<SA,AG,SO,CO AG>SA,CO SO>SA
STAI-state	52.3	12.8	55.8	4.5	50.6	13.6	51.2	14.4	35.0	11.0	17.842***	HC<SA,AG,SO,CO
STAI-trait	55.1	8.8	60.5	6.2	52.5	14.1	55.6	10.8	39.1	10.6	19.915***	HC<SA,AG,SO,CO
CAIOC	60.0	14.4	67.5	12.8	62.9	20.2	59.9	20.9	28.0	14.8	36.980***	HC<SA,AG,SO,CO
CPAS	13.5	5.7	16.3	4.7	15.0	5.1	15.1	6.5	8.9	4.5	7.819***	HC<SA,AG,SO,CO
SDS	16.2	6.3	19.4	3.7	17.6	8.4	15.0	8.4	3.3	4.9	27.047***	HC<SA,AG,SO,CO

Note. CAIOC, Cognitive Assessment Instrument of Obsessions and Compulsions; CPAS, Compulsive Personality Assessment Scale; MADRS, Montgomery-Åsberg Depression Rating Scale; SD, Standard Deviation; SDS, Sheehan Disability Scale; STAI, State-Trait Anxiety Inventory; Y-BOCS, Yale-Brown Obsessive Compulsive Scale; df (X^2-test) = 4; df (one-way ANOVA) = (4,134); <, lower score than; >, higher score than; ***p < .001

Table 4. Means (%) and Standard Deviation (SD) of smell ratings for patients in the OC symptom dimensions (SA, safety; AG, aggression; SO, symmetry/order; CO, contamination) and the healthy control group (HC)

	SA (n = 19)		AG (n = 8)		SO (n = 14)		CO (n = 14)		HC (n = 80)			
Variable	M (%)	SD	M (%)	SD	M (%)	SD	M (%)	SD	M (%)	SD	F-value	Post-hoc (p < .05)
All smells												
Confidence	58.3	15.0	50.6	13.4	54.9	16.5	54.1	16.9	65.9	14.5	4.502**	HC>SA,AG,SO,CO
Pleasantness	60.2	9.2	59.5	10.7	64.4	16.2	55.2	12.1	56.5	12.0	n.s.	SO>CO,HC
Quality	66.1	9.5	62.7	13.2	61.3	13.4	61.4	11.3	62.4	13.5	n.s.	
Intensity	72.1	10.4	71.6	12.3	67.4	15.9	70.9	12.7	70.2	13.6	n.s.	
Disgusting												
Confidence	55.4	17.2	44.4	12.4	48.9	17.6	50.3	14.7	65.1	18.1	6.094***	HC>SA,AG,SO,CO
Pleasantness	48.5	12.6	46.1	12.4	52.7	18.5	47.5	16.3	39.5	14.5	3.677**	HC<SA,SO
Quality	61.3	11.5	56.5	14.1	55.8	15.5	56.2	12.2	54.6	16.9	n.s.	
Intensity	67.5	12.3	69.2	16.2	61.0	19.3	66.1	15.0	72.2	17.8	n.s.	SO<HC
Pleasant												
Confidence	60.3	15.5	54.6	15.5	58.8	16.9	56.7	19.5	66.4	15.0	2.450*	HC>AG,CO
Pleasantness	68.0	10.5	68.5	11.4	72.3	16.1	60.4	11.4	67.8	13.4	n.s.	CO<SO
Quality	69.3	10.6	66.8	13.4	65.0	13.2	64.9	12.4	67.6	13.2	n.s.	
Intensity	75.1	11.4	73.2	11.1	71.6	15.1	74.0	13.7	68.8	13.4	n.s.	

Note. df (one-way ANOVA) = (4,134); <, lower score than; >, higher score than; *p < .05; **p < .01; ***p < .001

Table 5. Correlations between clinical and psychological test scores and smell variables in the OCD group (all, 15 smells; plea, pleasant smells; disg, disgusting smells; ID, identification; C, confidence; P, pleasantness; Q, quality; I, intensity)

Variable	ID all	ID plea	ID disg	C all	C plea	C disg	P all	P plea	P disg	Q all	Q plea	Q disg	I all	I plea	I disg
Y-BOCS	-.24	-.25	-.11	**-.31***	**-.30***	**-.28***	-.20	-.18	-.17	-.09	-.04	-.13	-.07	-.11	-.02
MADRS	-.19	-.11	-.23	.00	.03	-.04	.11	..14	.06	.12	.19	.01	.16	.21	.07
STAI-state	.00	-.01	.01	-.05	.04	-.18	.09	.16	-.03	.23	**.29***	.11	.24	**.33***	.08
STAI-trait	.03	.01	.05	-.05	.02	-.16	.08	.14	-.01	.22	**.26***	.12	.22	**.28***	.10
CAIOC	-.07	-.05	-.04	-.03	.03	-.11	.04	.07	-.01	.13	.21	-.01	.12	.20	.01
Identification all															
Identification pleasant	**.89*****														
Identification disgust	**.70*****	**.30***													
Confidence all	**.31***	**.33***	.17												
Confidence pleasant	**.31***	**.38****	.09	**.97*****											
Confidence disgust	**.28***	.20	**.28***	**.92*****	**.78*****										
Pleasantness all	.05	.16	-.14	**.69*****	**.71*****	**.56*****									
Pleasantness pleasant	.14	**.28***	.14	**.62*****	**.69*****	**.44*****	**.92*****								
Pleasantness disgust	-.08	-.03	-.12	**.61*****	**.58*****	**.58*****	**.87*****	**.61*****							
Quality all	**.28***	.26	.16	**.70*****	**.71*****	**.60*****	**.57*****	**.55*****	**.47*****						
Quality pleasant	.25	**.31***	.04	**.66*****	**.72*****	**.48*****	**.56*****	**.61*****	**.37****	**.95*****					
Quality disgust	.26	.15	**.30***	**.63*****	**.55*****	**.66*****	**.48*****	**.37****	**.51*****	**.89*****	**.69*****				
Intensity all	.19	.14	.19	**.50*****	**.43*****	**.53*****	**.41****	**.39****	**.35****	**.63*****	**.51*****	**.67*****			
Intensity pleasant	.21	.21	.10	**.58*****	**.57*****	**.53*****	**.52*****	**.52*****	**.39****	**.68*****	**.63*****	**.62*****	**.93*****		
Intensity disgust	.14	.01	.26	**.29***	.18	**.43*****	.21	.28	.24	**.44*****	.26	**.61*****	**.89*****	**.67*****	

Note. CAIOC, Cognitive Assessment Instrument of Obsessions and Compulsions; MADRS, Montgomery-Åsberg Depression Rating Scale; STAI, State-Trait Anxiety Inventory; Y-BOCS, Yale-Brown Obsessive Compulsive Scale; *p < .05; **p < .01; ***p < .001

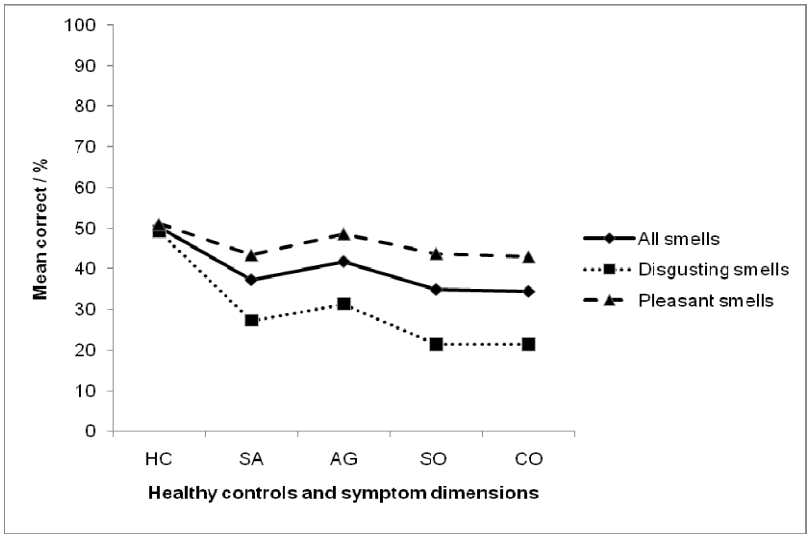

Figure 3. Mean correct identification (%) in the study groups (HC, healthy controls; SA, safety; AG, aggression; SO, symmetry/order CO, contamination) of all smells, the pleasant smells, and the disgusting smells

Some differences between patients in the OC symptom dimensions and the healthy controls emerged in ratings on the variables confidence, pleasantness, quality, and intensity for all smells, the disgusting smells, and the pleasant smells (Table 4).

In Table 5, correlations in the OCD group revealed that elevated Y-BOCS scores negatively affected the confidences ratings whereas state and trait anxiety were associated with higher quality and intensity ratings for the pleasant smells. Higher identification rates were associated with higher confidence scores and confidence correlated positively and strongly with pleasantness, quality, and intensity. Pleasantness correlated strongly with quality and intensity (not for disgusting items) and quality and intensity also correlated strongly.

Discussion

Our study is the first report comparing patients with OCD to matched healthy controls in their ability to identify different smell dimensions (pleasant, disgusting). The primary hypothesis of the current study, that the OCD group would be impaired in their ability to identify the smells compared to the healthy control group, was confirmed. This is in accordance with two previous studies (Barnett et al., 1999; Goldberg et al., 1991) but in contrast to the results of two others (Fenger et al., 2005; Locatelli et al., 1996). Interestingly, the OCD patients, when controlling for state and trait anxiety were impaired in their ability to identify the disgusting smells but not the pleasant smells. The OC symptom dimension analysis revealed that patients in the dimensions safety, symmetry/order and contamination were impaired in identifying the disgusting smells but not the pleasant ones. Therefore, new evidence relating to the perception and appraisal of emotional stimuli has shown that patients in the dimension contamination are not the only patients impaired in the identification of disgust. This contradicts the assumption as previously suggested that individuals with contamination fear exhibit higher disgust sensitivity, i.e. the ability to detect disgust more frequently, compared to patients in other OC symptom dimensions (e.g., Olatunji et al., 2007; Woody & Tolin, 2002). Our finding of impairments in the symptom dimension contamination provides additional evidence that patients in this symptom dimension have been associated with abnormal ventromedial prefrontal cortex activity during symptom provocation (Mataix-Cols et al., 2004). This builds on the assumption that the OFC is thought to be dysfunctional in OCD (Menzies et al., 2008). Therefore, the overall impairment on the smell identification test in the OCD group point towards a general dysfunction related to the emotional appraisal of sensory stimuli and this is suggestive of being specific to selective symptom dimensions within the OCD group. Furthermore, these findings assume an abnormal experience of disgust in OCD related to both recognition and perception and which others have proposed could be involved in the genesis of obsessions and compulsions (Power & Dalgleish, 1997).

Interestingly, the OCD group rated the disgusting smells as less disgusting and being less intense compared to the healthy control group, whereas for the pleasant smells there was no difference between the groups in their ratings on the pleasantness variable. These results raise the question whether the OCD participants in the current study exhibited an abnormal sensory olfactory function. However, it has been shown previously that patients with OCD do not exhibit such a deficit (Barnett et al., 1999; Gross-Isseroff et al., 1994) or suffer from an inability to discriminate between smells (Hermesh et al., 1999).

A breakdown in emotional processing of disgusting smells as elucidated by the smell identification test could be seen as an important yet neglected symptom in OCD. Testing for olfactory identification abilities is thought to provide an independent measure of emotional deficiencies in OCD. This breakdown could results in vital perceptual and cognitive information not being filtered through to the appropriate interconnected brain structures thought to be involved in OCD (Graybiel & Rauch, 2000) and processed adequately and efficiently for the production of specific behaviors of concern.

In terms of the pleasant smells, the OCD group identified significantly fewer items compared to the healthy control group. However, when state and trait anxiety were included as covariates in the analysis, a similar ability to identify the pleasant smells was revealed. This analysis was done because state and trait anxiety correlated with aspects of the smell identification test. This would indicate that the elevated

anxiety symptoms in the patient group may have underpinned their inability to identify the pleasant smells compared to the healthy control group. The bigger picture appears to represent a similar performance on the pleasant items. Therefore, the current findings point towards impairment in identifying the disgusting and not the pleasant smells in the OCD group. In agreement with previous findings of reduced confidence levels in OCD under conditions of high responsibility (Moritz et al., 2009; Muller & Roberts, 2005) our findings showed considerable lower confidence ratings in OCD compared to the healthy control group when identifying disgusting and pleasant smells.

The question why the OCD group was unable to identify the disgusting items administered in the current study and why they appeared to experience the disgusting smells differently from the healthy control group remain largely unanswered. However, it has been found that OCD patients are unable to recognize disgust on human faces (e.g., Sprengelmeyer et al., 1997) and this is in accordance with the current finding of impairment in olfactory identification associated with disgust. The development of cognitive brain-behaviour models in OCD (e.g., Kuelz et al., 2004) may prove fruitful taking into account emotional processing. Traditionally, the emotion of fear has been shown to activate the amygdala whereas disgust has been found to activate the anterior insula and structures linked to the limbic cortico striatal thalamic circuitry (Calder et al., 2000; Phillips et al., 1997). However, these findings are related to the recognition of facial expression of disgust. Brain structures involved in OCD regarding olfactory identification of disgust is yet to be fully explored but can be assumed to involve the OFC and the basal ganglia (Graybiel & Rauch, 2000). Sprengelmeyer et al.'s (1997) finding that only OCD patients as opposed to other patient groups with anxiety showed impaired recognition of facial expressions of disgust has not been consistently replicated (Bulhmann et al., 2004; Corcoran et al., 2008; Parker et al., 2004; Rozin et al., 2005) except in the most severe OCD cases (Corcoran et al., 2008; Parker et al., 2004), which suggest that illness severity may be linked to the recognition of disgusting stimuli (faces and smells).

It has been suggested that the more disgust sensitive an OCD patient is, the more likely that the individual has contamination fear (Husted et al., 2006; Olatunji et al., 2007; Olatunji et al., 2004). Greater disgust sensitivity assumes greater abilities in detecting disgust or as stated in Olatunji et al. (2007, p. 265) 'a general predisposition towards experiencing disgust'. Although it has rightly been pointed out that disgust sensitivity in OCD patients with contamination fear may only apply to certain domains (Woody & Tolin, 2002) these assumptions have not considered the appraisal of olfactory stimuli. In addition to patients in the symptom dimension contamination, patients in the dimensions safety and symmetry/order were also impaired in their ability to identify the disgusting smells. Contrary to suggestions that OCD patients with contamination fear are more disgust sensitive, our data showed, however, that patients in the dimensions safety and symmetry/order rated the disgusting items as less disgusting compared to the healthy control group. This indicates that the neurocircuitry involved in the processing of disgust may be involved in different symptom dimensions in different ways, i.e. not only relevant to patients in the dimension contamination as described by Phillips et al. (2000). Future research is encouraged to investigate differences in emotional processing between patients in different OC symptom dimensions using a range of multisensory stimuli, e.g. olfactory, vocal, facial, and body stimuli (Atkinson et al., 2004; Dittrich, 1993; Ruffman et al., 2009; Sprengelmeyer et al., 2010) leading to behavioural treatment strategies related to different emotional symptom profiles.

One of the aims of the current study was to overcome a methodological shortcoming in previous studies investigating olfactory identification in OCD by recruiting a large clinical group and a healthy control group to ensure satisfactory statistical power. The main limitation of the present study was that smoking could have contributed to the inabilities of identifying the smells despite that groups were matched on this variable. No restrictions were put on the smokers in how close to testing they were allowed to smoke. However, additional analyses indicated that the ability to identify the smell dimensions did not differ between smokers and non-smokers in the OCD and healthy control group. Also, the present paper did not include another clinical control group, e.g. a group of anxiety or depression patients. It is also worth noting that the administration of our smell test was in contrast to the UPSIT (Doty et al., 1984), which is a "scratch and sniff" test.

In summary, the main finding of the current study report an inability of patients with OCD to identify disgusting smells. It has previously been suggested that dysfunctional higher level processing in the OFC may be linked to abnormal olfactory performance in patients with OCD (Fenger et al., 2005). It would be important for prospective studies to elucidate whether impairments in the identification of disgust is specific to OCD in general, whether it is specifically related to patients in the symptom dimension contamination or as reported in the present study, to patients in the symptom dimensions safety, symmetry/order, and contamination. Clarifications about the issue of disgust sensitivity would also be welcome as disgust impairments may also stem from low disgust sensitivity following the findings reported here.

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