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The relation between anger and different forms of disgust: Implications for emotion recognition impairments in Huntington's disease

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ABSTRACT

Initial reports of emotion recognition in Huntington's disease (HD) found disproportionate impairments in recognising disgust. Not all subsequent studies have found this pattern, and a review of the literature to date shows that marked impairments in recognising anger are also often seen in HD. However, the majority of studies have based their conclusions on a single test of facial expression recognition. In the current study we revisit this issue of emotion recognition in HD to address whether the pattern found on one test of facial expression recognition generalised to another, and to different modalities using tests of emotion recognition from facial expressions, vocal expressions, and short verbal vignettes. The results showed evidence of impairments in recognising anger, fear and disgust across the three domains, with recognition of anger the most severely impaired. Given work identifying different subtypes of disgust that are associated with different facial features, a second study examined the recognition of three disgust expressions that healthy participants reliably associate with unpleasant tastes, unpleasant smells, and a more general elaborated or expanded form of disgust that includes reactions to violations of moral standards. The results showed a disproportionate impairment in recognising faces associated with the expanded form, the subtype most closely aligned with anger. We conclude that the related emotions of disgust and anger associated with social disapproval are frequently impaired in HD and discuss factors that might cause one emotion to show more severe impairments than the other.

1. Introduction

Huntington's disease (HD) is a trinucleotide repeat disorder that classically results in cognitive impairments, motor disorders, and psychiatric and emotional symptoms. The emotional and psychiatric impairments have a dramatic impact on family life and include altered behaviour and impaired interpretation of others' emotional states (Craufurd & Snowden, 2002). Here we focus on the latter.

Sprengelmeyer et al. (1996) were the first to report that the recognition of facial expressions of disgust was particularly compromised in patients with manifest HD, although marked but less severe impairments were also found for other emotions, in particular anger and fear. Similar results were found in a study investigating a small group ($n = 6$) of Chinese patients with manifest HD (Wang, Hoosain, Yang, Meng, & Wang, 2003). A third study by Montagne et al. (2006) found impaired recognition of disgust and anger from animated sequences of morphed facial expressions ranging between neutral and each of six target expressions; however, the anger deficit was restricted to low-intensity morphs and disgust alone was impaired for sequences ranging between neutral and 100% of the target emotions.

Not all studies have found evidence of a disproportionate disgust deficit in manifest patients, however. Milders, Crawford, Lamba, and Simpson (2003) found impairments for facial expressions of anger, fear, disgust, and sadness, but there was no evidence that the disgust deficit was more severe, and fear showed a more severe impairment than disgust. More recently, Henley et al. (2008) and Snowden et al. (2008) have found disproportionate impairments in recognising angry facial expressions.

Less severe but more selective disgust impairments have been found in premanifest individuals that tested positive for the HD gene mutation (Gray, Young, Barker, Curtis, & Gibson, 1997; Hennenlotter et al., 2004; Sprengelmeyer, Schroeder, Young, & Epplen, 2006). Some of these studies compared a group of premanifest gene positive individuals with their partners or a group of gene negative at-risk individuals (Gray et al., 1997; Henley

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et al., 2008; Johnson et al., 2007; Kipps, Duggins, McCusker, & Calder, 2007; Sprengelmeyer et al., 2006). In other studies the controls were unrelated, healthy, neurologically intact individuals (Hennenlotter et al., 2004; Milders et al., 2003). The clearest evidence of a disgust impairment is from Sprengelmeyer et al. (2006) who found impaired recognition of facial expressions of disgust on three separate testing sessions, separated by approximately 6–7 months. Only on the third occasion was another facial expression (surprise) impaired. Other studies have also found impaired recognition of disgust in asymptomatic Huntington's participants (Gray et al., 1997; Hennenlotter et al., 2004); although Hennenlotter et al. (2004) also found a borderline impairment for anger ($p = 0.052$) using the one-tailed criterion they applied to the disgust contrast.

As in the case of manifest HD, not all studies investigating premanifest individuals have found disproportionate problems in recognizing disgust (Henley et al., 2008; Kipps et al., 2007; Milders et al., 2003). The only effect found by Kipps et al. (2007) was a borderline impairment for facial expressions of anger. However, of more interest, they demonstrated that disgust recognition in premanifest HD was significantly correlated with grey matter volume in the anterior insula estimated using voxel-based morphometry (VBM) (Kipps et al., 2007), with decreasing insula volume associated with worse recognition of disgust facial expressions. Similarly, using fMRI, Hennenlotter et al. (2004) showed decreased insula activation to disgust facial expressions in premanifest HD. These findings accord with other research demonstrating the role of the insula in disgust processing using functional imaging (Calder et al., 2007; Phillips et al., 1997; Wicker et al., 2003), intracerebral recording (Krolak-Salmon et al., 2003) and following focal brain damage (Adolphs, Tranel, & Damasio, 2003; Calder, Keane, Cole, Campbell, & Young, 2000); for a review see Calder, Lawrence, and Young (2001).

In the largest study of facial expression recognition in premanifest HD to date, Johnson et al. (2007) investigated facial expression recognition in a group of 475 participants that tested positive for the gene but were yet to manifest the condition. The results showed impaired recognition of negative facial expressions (anger, disgust, fear, and sadness), but no evidence that disgust was disproportionately impaired. The premanifest group in this study was divided into four sub-groups on the basis of a standard motor disorder examination (Unified Huntington's Disease Rating Scale, UHDRS; Kieburtz et al., 1996) relating to the clinicians' confidence that any motor abnormalities were related to HD. Anger was the only emotion impaired in all four subgroups, with the first subgroup (minimal evidence of motor impairments) showing impaired recognition of anger only. The three other subgroups were impaired at recognising anger, fear, and sadness, while the second and third subgroups were impaired on disgust. A comparable analysis of response times to categorise expressions showed slower RTs for anger for all but the first (least evidence of motor impairments) subgroup, whereas subgroups 2 and 3 also showed reduced RTs to happy expressions.

The absence of a disproportionate impairment in recognising disgust in Johnson et al.'s (2007) study, the largest investigation of facial expression recognition in premanifest HD to date, demonstrates that it is in no sense diagnostic of HD. Instead, like many other behavioural deficits associated with this complex neuropsychiatric condition, emotion recognition deficits may show variability in premanifest and manifest gene positive HD individuals (Craufurd & Snowden, 2002). However, from our review it is clear that where deficits have been observed, these usually encompass more than one emotion, particularly disgust, anger, and fear. Moreover, disproportionate impairments have been reported for disgust and also for anger, although the significance of disproportionate anger impairments is generally not emphasised.

These conclusions are drawn from research that has focused largely on recognition of emotion from faces rather than other

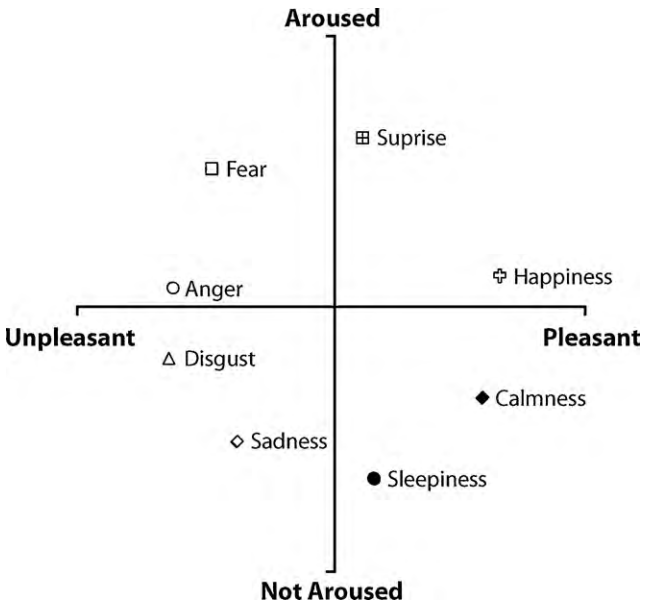

Fig. 1. The Circumplex model of emotion representation in which emotions are coded in terms of their degree of arousal and unpleasantness; modified from Bullock and Russell (1986).

cues, and conclusions are frequently based on the results of a single test, such that it is unclear whether the variability among studies relates to differences in stimulus materials, subject populations, or whether variable performance might also be observed in a single population across different stimulus materials. There are exceptions, however. Sprengelmeyer et al.'s (1996) and Snowden et al.'s (2008) investigations of manifest HD used at least two tests of facial expression recognition, and both Sprengelmeyer et al. (1996) and Hayes, Stevenson, and Colheart (2007) found disproportionate disgust impairments on tests of vocal emotion recognition. Sprengelmeyer et al.'s (2006) report of impaired recognition of disgust facial expressions in premanifest HD also tested recognition of emotion in the vocal modality but found no evidence of impaired recognition of vocal expressions of any emotion. Impaired perception of disgust from olfactory cues has also been demonstrated (Hayes et al., 2007); see also Mitchell, Heims, Neville, and Rickards (2005). However, these data need to be interpreted in light of more general olfactory impairments associated with HD (Moberg & Doty, 1997). Hayes et al. (2007) also demonstrated impaired access to conceptual knowledge of disgust in the form of fewer generated examples of disgust situations and impaired identification of disgust from pictures of emotional scenes. However, in a study addressing emotion recognition from facial and vocal signals together with emotion recognition from verbal scenarios, Snowden et al. (2008) found the most consistent impairments for anger. Similarly, an investigation of emotion from animated bodies, that did not include stimuli depicting disgust, reported impaired recognition of anger (de Gelder, Van den Stock, de Diego Balaguer, & Bachoud-Lévi, 2008).

So from cues other than faces, there is initial evidence that disgust *and anger* show evidence of disproportionate impairments. It is therefore of note that these two emotions are often confused, a fact that is reflected by their proximal locations in two-dimensional models of emotion, such as Russell's (1980). Circumplex model in which emotions are coded in terms of the degree to which they evoke arousal and their relative pleasantness/unpleasantness (Fig. 1).

In the current study, we revisited the issue of emotion recognition in manifest HD patients. Since the majority of studies have evaluated emotion recognition using a single test, we addressed

whether deficits on one test of facial expression recognition generalized to another, and whether impairments in the facial domain generalized to the vocal modality and to semantic knowledge of emotion. On the basis of previous research, we expected impaired recognition of a number of emotions, particularly disgust, anger, and fear, with more severe problems for disgust and/or anger. In addition, we were interested in whether a similar pattern of impairments was found across different modalities. Group comparisons were conducted as in previous studies. However, following Sprengelmeyer et al. (2006), for each test we also calculated the number of patients that demonstrated marked impairments in recognizing each emotion to provide an estimate of the most frequently affected emotion in each test.

In a follow-up study, we focussed on disgust processing alone. Theories of disgust suggest a distinction between core, sensory forms of disgust related to reactions to unpleasant tastes or smells that are evident across mammalian species, and a more complex distinctly human form that incorporates a repugnance of violations of social norms or moral standards (e.g., sexual/physical abuse, war crimes). This latter form of disgust is closely aligned with anger — for example, we are both disgusted and angered by child abuse — so addressing distinct forms of disgust is particularly pertinent to the observation that disgust and anger are more likely to show disproportionate impairments in HD than other emotions. In a detailed analysis of facial expressions of disgust in healthy volunteers, Rozin, Lowery, and Ebert (1994) showed that three different facial features are reliably associated with different disgust subtypes. The first subtype is associated primarily with the rejection of unpleasant tastes and is signalled by mouth gape and tongue protrusion. The second is associated with the rejection of unpleasant smells, signalled by nose wrinkle, while the third relates to the violations of social and moral standards and interpersonal contamination and is signalled by upper lip curl.

To address HD participants' recognition of these different subtypes of disgust facial expression, we used a test adapted from Rozin et al. (1994) in which participants were presented with a series of short scenarios each depicting one of the three distinct disgust subtypes. For each scenario, participants were required to select which of the three disgust facial configurations provided the most appropriate facial reaction. Previous research has shown that healthy controls select the intended expression with above chance accuracy (Rozin et al., 1994). This enabled us to address whether recognition of a particular subtype of disgust expression might be impaired in HD.

Previous reports of facial expression recognition in HD have tended to use the Ekman and Friesen (1976) pictures of facial affect that include disgust expressions with upper lip curl and wrinkled nose; two features that tend to co-occur as a result of the face's musculature. These 'canonical' disgust expressions have been used in the vast majority of studies investigating facial expression recognition in HD and other neurological conditions, as well as neuroimaging studies addressing the neural correlates of viewing disgust expressions (Hennenlotter et al., 2004; Phillips et al., 1998, 1997; Sprengelmeyer, Rausch, Eysel, & Przuntek, 1998). Although the neural mechanisms involved in processing each of the three disgust features discussed above have not been addressed, in a recent functional magnetic resonance imaging (fMRI) study, we compared the neural response to canonical disgust expressions, comprising upper lip curl and nose wrinkle, with expressions displaying mouth gape and tongue protrusion (von dem Hagen et al., 2009). Results showed that only the upper lip curl/nose wrinkle expressions engaged the anterior insula and frontal operculum. Since recognition of these canonical disgust expressions in HD has also been linked to insula function (Hennenlotter et al., 2004; Kipps et al., 2007), we expected that expressions with upper lip raise and possibly the nose wrinkle expressions, would show the most severe impairments. Moreover, the association of the upper lip curl variant of disgust with anger suggested that impairments should be more apparent for this variant of disgust. By contrast, mouth gape expressions should be associated with comparatively spared performance.

Table 1
Demographic data for participants with Huntington's disease.

	Huntington's (n = 21)		
	Mean	SD	Range
Age (in years)	50.38	8.71	28–65
Years since diagnosis	6.50	3.05	1.5–14
NART-R Estimated IQ	107.38	8.40	87–120
MMSE/30[a]	27.67	2.15	23–30
Chorea/28[b]	7.57	5.47	0–20
Dystonia/20[b]	1.38	2.31	0–8
Overall motor score/124[b]	30.45	13.10	14–50
Independence/100[b]	85.24	9.15	70–100
Functional assessment/50[b]	25.14	3.25	20–31
Functional capacity/13[b]	9.45	2.25	6–12

[a] MMSE = Mini mental state examination (Folstein et al., 1975).
[b] From UHDRS (Kieburtz et al., 1996).

2. Study 1

2.1. Method

2.1.1. Participants

The study included 21 patients with manifest HD (9 females; mean age = 50.43, SD = 8.70). Matched controls were used for each test; their age and IQ are reported in the results section below.

2.1.1.1. Background information. Intelligence was estimated with revised version of the National Adult Reading Test (NART-R) (Nelson, 1991). Table 1 also summarises demographic details, performance on the Mini Mental State Exam (MMSE) (Folstein, Folstein, & McHugh, 1975), and selected components from the Unified Huntington's Disease Rating Scale (UHDRS) (Kieburtz et al., 1996)—Chorea, Dystonia, Overall motor score, Independence score, Total Functional assessment and Functional capacity. Basic visual processing was assessed using the VISTECH VCTS 6000 contrast sensitivity chart. Two patients showed slightly low scores on mid-range of spatial frequencies, otherwise performance was in the normal range.

3. Design and procedure

3.1. Unfamiliar face matching and familiar face recognition

Ability to match pictures of unfamiliar faces was assessed with the Benton Test of Facial Recognition (Benton, Hamsher, Varney, & Spreen, 1983). On each trial of this test, the participant is shown a target face and array of six faces. The task is to find one or more examples of the target face amongst the array of six. Changes in head orientation and lighting can occur between the target and array faces.

Recognition of familiar faces was assessed with pictures of 30 celebrities' faces intermixed with 10 unfamiliar face foils (Calder et al., 1996; Young et al., 1995). The faces were presented individually in a pseudo-random order. For each face, participants were asked whether the person was familiar, and if so, to provide identifying information (i.e., their occupation, nationality, films they have been associated with, etc.) and their name.

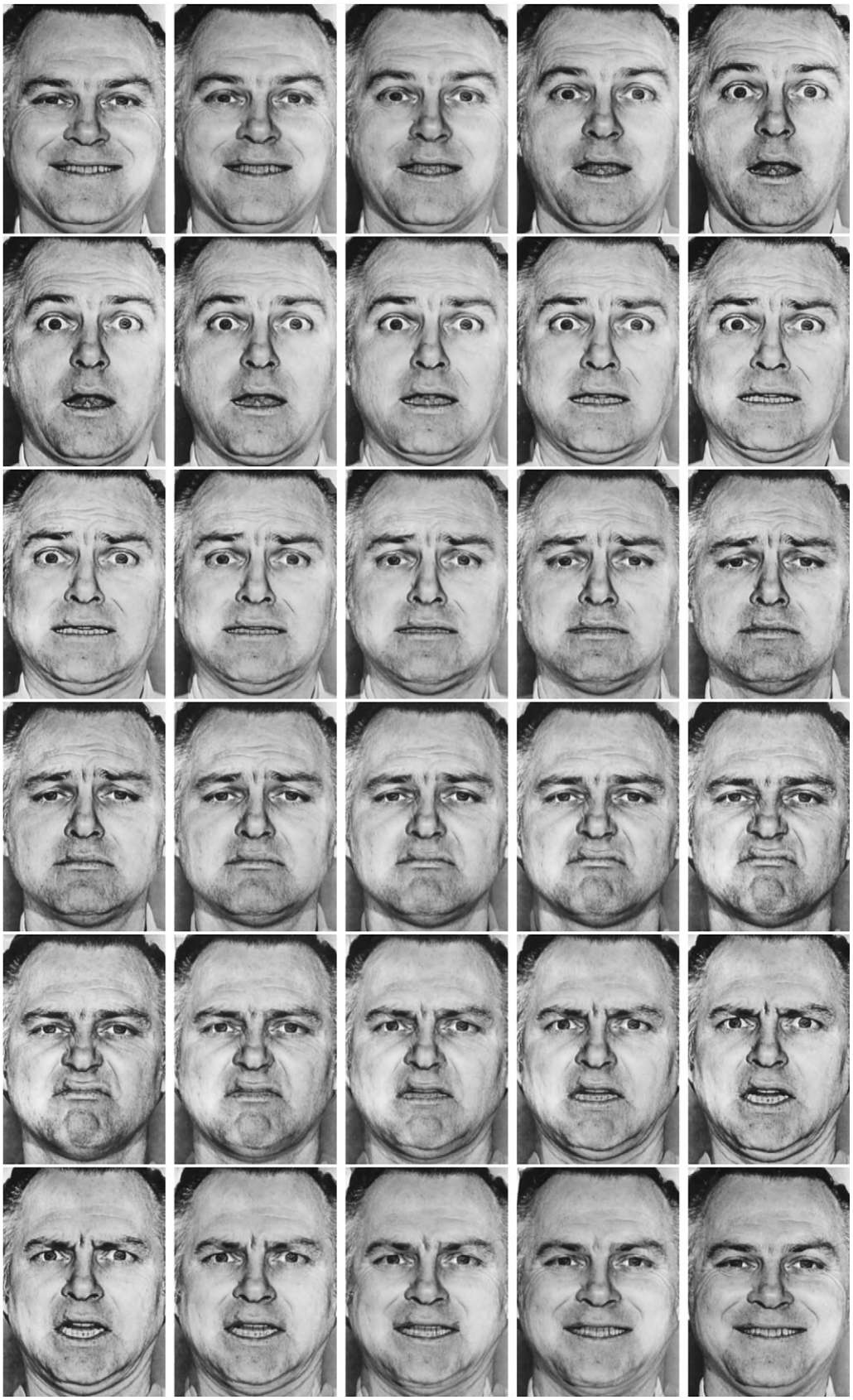

Fig. 2. The Emotion Hexagon test of facial-expression recognition. The six rows of this illustration contain morphed (blended) continua ranging between the following six expression pairs. From top to bottom, the continua shown in each row are happiness–surprise (top row), surprise–fear (second row), fear–sadness (third row), sadness–disgust (fourth row), disgust–anger (fifth row), anger–happiness (bottom row). Going from left to right, the columns show 90%, 70%, 50%, 30% and 10% morphs along each continuum. For example, from left to right, the top row of images contain the following percentages of the happy and surprised expressions: 90% happy–10% surprise, and then 70–30%, 50–50%, 30–70% and 10–90% of the same two expressions.

Table 2
Performance of the Huntington's patients and matched healthy controls on a test of unfamiliar face matching (Benton) and a test addressing recognition of famous celebrities' faces, recalling their occupations and names, and correct rejection of unfamiliar faces. Percentage (and number) of patients showing severe impairments ($z > 2.33$, $p < 0.01$) is also shown.

	Huntington's ($n = 21$)			Controls	
	Mean	SD	$p < 0.01$	Mean	SD
Benton unfamiliar face matching/54	41.95	6.21	19.0% (4)	46.97	4.24
Famous face recognition					
Familiar/30	27.71	2.49	5.0% (1)	28.20	2.59
Occupation/30	26.29	3.08	5.0% (1)	27.70	3.05
Name/30	23.76	4.12	5.0% (1)	25.23	4.22
Unfamiliar/10	8.10	2.17	24.0% (5)	9.37	0.81

3.2. Facial expression recognition

Facial expression recognition was assessed with two tests, the Ekman 60 and the Emotion Hexagon (Calder et al., 1996; Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002).

3.2.1. Ekman 60

Photographs of six facial expressions (happiness, sadness, anger, fear, disgust and surprise), posed by each of 10 models (6 female, 4 male), were taken from Ekman and Friesen's (1976) pictures of facial affect series; a total of 60 pictures. The 10 models were selected so that each emotion was well recognised in Ekman and Friesen's (1976) norms. Each face was presented on a computer monitor for a maximum of 3 seconds and participants were asked to select one of the six expression labels (listed above) that best described the expression shown on each face. The labels were visible throughout testing and participants were given as much time as they required to respond.

3.2.2. Emotion Hexagon

This experiment contained morphed (blended) facial expressions posed by model JJ from the Ekman and Friesen (1976) pictures of facial affect series (Fig. 2). A detailed description of the test can be found in Calder et al. (1996). Briefly, the test comprised morphed continua ranging between the following six facial expression pairs, happiness–surprise, surprise–fear, fear–sadness, sadness–disgust, disgust–anger, and anger–happiness. Each continuum contained five morphed images moving from one end of the continuum to the other in 20% steps. For example, the images in the happy–surprised continuum contained the following percentages of the happy and surprised expressions, 90% happy–10% surprise, and then 70–30%, 50–50%, 30–70%, and 10–90% of the same two expressions. The stimulus set consisted of 30 images in total (6 continua × 5 morphed faces).

The 30 morphed images were presented individually for five seconds each on a computer monitor in random order (i.e., they were not grouped into the underlying continua). The task was to decide which of six emotion labels (happy, sad, anger, fear, disgust, and surprise) best described each facial expression. The labels were visible throughout testing and participants were given as much time as they required to make their selection. Participants undertook a total of 6 blocks of trials. Each block contained one presentation of each of the 30 morphed faces in random order. The first block of trials was discounted as practice, leaving 5 blocks of 30 trials for analysis.

Data from healthy volunteers shows that stimuli containing 90% or 70% of an expression are consistently identified as the intended emotion (Calder, Keane, Cole, et al., 2000; Calder, Keane, Manes, Antoun, & Young, 2000; Calder, Rowland, et al., 2000; Calder et al., 1996; Sprengelmeyer et al., 1996; Young et al., 1997). Consequently, the data were scored by dividing the morphed faces into six 'target expression' sections. Each section included two morphs containing 90% of the target expression and two containing 70%. For example, the surprise section contained the morphs 70% surprised–30% happy, 90% surprised–10% happy, 90% surprised–10% fear, and 70% surprised–30% fear. Performance was based on five presentations of each image, giving a total score out of 20 for each emotion. An identical scoring procedure has been used in previous research (Calder, Keane, Manes, et al., 2000; Calder et al., 1996; Sprengelmeyer et al., 1996).

3.3. Vocal expression recognition

3.3.1. Non-verbal emotional sounds

Vocal expression recognition was assessed with a test comprising non-verbal emotional sounds (e.g., laughter for happiness, screams for fear, etc.) (Calder, Keane, Lawrence, & Manes, 2004; Calder, Keane, Cole, et al., 2000; Calder, Keane, Manes, Antoun, & Young, 2000; Calder, Rowland, et al., 2000; Keane, Calder, Hodges, & Young, 2002; Scott et al., 1997). It contained examples of non-verbal vocalisations associated with six basic emotions, happiness, sadness, anger, fear, disgust, and surprise. For example, laughter for happiness, crying for sadness, growls for anger, "yuk" sounds and retching for disgust, and exclamations of astonishment for surprise. The stimuli were presented individually in random order and the participants were required to select which of the six emotion labels (listed above) best described the emotion conveyed. Labels were visible throughout testing.

3.4. Conceptual understanding of emotion

3.4.1. Emotional vignettes

This consisted of a series of short descriptions of emotion-provoking scenarios. Each described a situation associated with one of five emotions, happiness, sadness, anger, fear, and disgust. Participants were asked to categorise the emotion conveyed by selecting one of the five emotion labels. An example of an anger sentence was as follows. "You are at work with a colleague. You are both in the canteen when someone pushes in front of your colleague. How does your colleague feel?" Vignettes were presented in random order and participants were given as much time as they required to respond.

Tests were completed in counterbalanced order in two or three sessions. The entire test battery took four to five hours to complete.

4. Results and discussion

Data were analysed using ANOVA and simple effects or *t*-tests with Bonferroni correction for multiple comparisons. Where appropriate, Greenhouse–Geisser correction was used for ANOVA, and *t*-tests were corrected for unequal variance. To highlight the severity of the impairments for each emotion, the percentage of patients showing impaired scores corresponding to $z > 2.33$ ($p < 0.01$) are shown in the summary table for each emotion task. Demographic

details of the control groups for each test are provided at the end of each corresponding section. Controls were matched to HD participants for age and IQ, which did not significantly differ.

Data were available for all 21 HD patients for all tasks except the Emotion Hexagon and Emotional vignettes, for which 20 patients' data were collected.

4.1. Unfamiliar face matching and familiar face recognition

The HD patients' performance on the face perception tasks is summarised in Table 2. Independent sample *t*-tests showed that patients performed significantly less well on the Benton test of unfamiliar face matching, $t(32.8) = -3.21$, $p < 0.01$, relative to matched controls, consistent with previous research (Henley et al., 2008; Snowden et al., 2008; Sprengelmeyer et al., 1996; Wang et al., 2003).

For recognition of familiar faces, the HD group showed no significant reduction in recognising faces as familiar ($t < 1$) and recalling identifying information, $t(42.9) = -1.62$, $p = 0.113$. However, they did show mild impairments in rejecting unfamiliar faces, $t(23.9) = -2.57$, $p < 0.05$, and in recalling celebrities' names, $t(43.9) = -2.09$, $p = 0.043$.

Research has suggested that correct recognition of familiar faces and incorrect recognition of unfamiliar faces (i.e., false positives to unfamiliar faces) may rely on separate mechanisms (Rapcsak, Reminger, Glisky, Kaszniak, & Comer, 1999). In line with this hypothesis, we found no correlation between the HD participants' scores for correct rejection of unfamiliar faces and the following face processing measures—Benton unfamiliar face matching, recognition of famous identities from their face, and recall of an identity's occupation or name from their face (all p's > 0.2). In contrast, all other face processing measures were intercorrelated (r's 0.55–0.92, p's < 0.01). Controls: 15 females, 15 males, mean age (SD) = 48.80 (6.79), mean IQ (SD) = 112.13 (11.10).

4.2. Emotion recognition

Data from each of the facial and vocal emotion recognition tests and emotional vignettes test were submitted to two factor ANOVAs with Greenhouse–Geisser correction investigating emotion category (repeated measure) and group (HD participants and controls; between subjects).

4.3. Facial expression recognition

4.3.1. Ekman 60

The HD and control participants' performance for the Ekman 60 is summarised in Table 3. Results of the ANOVA showed a significant effect of emotion category, $F(4.1,285) = 49.17$, $p < 0.001$, $\eta_p^2 = 0.42$, qualified by a significant interaction between emotion category and group, $F(4.1,285) = 9.19$, $p < 0.001$, $\eta_p^2 = 0.12$. Simple effects of the emotion category factor with Bonferroni correction for six comparisons (corrected p-values reported throughout) showed significant effects for all emotions—anger ($F(1,69) = 57.93$), disgust ($F(1,69) = 23.60$), fear ($F(1,69) = 37.33$), happiness ($F(1,69) = 8.66$), sadness ($F(1,69) = 27.16$), and surprise ($F(1,69) = 8.59$), p's < 0.05; however, as illustrated in Table 3, certain emotions were affected more than others. Controls: 25 females, 25 males, mean age = 51.78 (SD = 5.68), mean IQ = 107.40 (SD = 6.78).

4.3.2. Emotion Hexagon

The HD and control participants' performance for the Emotion Hexagon is summarised in Table 3. Results of the ANOVA showed a significant effect of emotion category, $F(3.9,276) = 21.76$, $p < 0.001$, $\eta_p^2 = 0.24$, qualified by a significant interaction between emotion category and group, $F(3.9,276) = 7.05$, $p < 0.001$, $\eta_p^2 = 0.09$. Simple effects of the emotion category factor with Bonferroni correction showed significant effects for all emotions—anger ($F(1,70) = 58.77$), disgust ($F(1,70) = 33.80$), and fear ($F(1,70) = 24.28$), happiness ($F(1,70) = 32.92$), sadness ($F(1,70) = 31.78$), and surprise ($F(1,70) = 14.56$), p's < 0.005; however, certain emotions were affected more than others (Table 1). Controls: 26 females, 26 males, mean age = 48.10 (SD = 6.87), mean IQ = 107.92 (SD = 7.45).

Table 3
Performance of the Huntington's patients and matched healthy controls on two tests of facial expression recognition, the Ekman 60 and the Emotion Hexagon. Percentage (and number) of patients showing severe impairments ($z > 2.33$, $p < 0.01$) is also shown.

	Huntington's			Controls	
	Mean	SD	$p < 0.01$	Mean	SD
Ekman 60 (HD $n = 21$)					
Ang/10	4.62	1.96	62% (13)	8.10	1.67
Dis/10	6.43	2.64	33% (7)	8.80	1.46
Fea/10	4.00	2.53	38% (8)	7.28	1.84
Hap/10	9.33	1.10	14% (3)	9.86	0.41
Sad/10	5.86	2.43	29% (6)	8.42	1.62
Sur/10	7.52	1.33	5% (1)	8.56	1.37
Emotion Hexagon (HD $n = 20$)					
Ang/20	9.40	5.99	70% (14)	17.6	3.1
Dis/20	13.86	3.38	15% (3)	18.5	2.9
Fea/20	10.45	6.00	35% (7)	16.5	4.1
Hap/20	16.60	3.80	60% (12)	19.7	0.7
Sad/20	12.35	5.92	45% (9)	18.5	3.2
Sur/20	15.20	3.86	35% (7)	17.9	2.0

Although the group analyses showed disgust impairments on both tests of facial expression recognition, neither test showed evidence of a disproportionate impairment in recognising facial expressions of this emotion. In fact, for each test, anger showed the greatest number of severe emotional impairments ($p < 0.01$) (Table 3). Patients' recognition of facial expressions on the two tests was correlated ($r = 0.59$, $p < 0.01$).

4.4. Vocal expression recognition

4.4.1. Non-verbal emotional sounds

The HD and control participants' performance for the non-verbal emotion sounds is summarised in Table 4. Results of the ANOVA showed a significant effect of emotion category, $F(3.7,145) = 19.53$, $p < 0.001$, $\eta_p^2 = 0.33$, qualified by a significant interaction between emotion category and group, $F(3.7,145) = 5.97$, $p < 0.001$, $\eta_p^2 = 0.13$. Simple effects of the emotion category factor with Bonferroni correction showed significant effects for anger ($F(1,39) = 33.01$), disgust ($F(1,39) = 9.37$), and fear ($F(1,39) = 21.98$), p's < 0.05. Happiness ($F(1,39) = 3.03$), sadness $F(1,39) = 7.00$, and surprise $F(1,39) = 3.03$ did not reach statistical threshold, p's > 0.05.

Table 4
Performance of the Huntington's patients and matched healthy controls on a test of emotion recognition from non-verbal emotional sounds. Percentage (and number) of patients showing severe impairments ($z > 2.33$, $p < 0.01$) is also shown.

	Huntington's			Controls	
	Mean	SD	$p < 0.01$	Mean	SD
Non-verbal emotional sounds (HD $n = 21$)					
Ang/10	4.38	2.46	62% (13)	7.95	1.32
Dis/10	8.57	1.75	33% (7)	9.80	0.41
Fea/10	5.57	2.18	29% (6)	8.30	1.45
Hap/10	7.24	1.55	14% (3)	7.95	1.00
Sad/10	6.81	1.44	19% (4)	7.85	1.04
Sur/10	7.67	2.35	24% (5)	8.70	1.26

Table 5
Performance of the Huntington's patients and matched healthy controls on a test addressing recognition of emotion from short verbal vignettes. Percentage (and number) of patients showing severe impairments ($z > 2.33$, $p < 0.01$) is also shown.

	Huntington's			Controls	
	Mean	SD	$p < 0.01$	Mean	SD
Emotional vignettes ($n = 20$)					
Ang/10	7.95	2.28	30% (6)	9.45	0.95
Dis/10	9.10	0.85	20% (4)	9.60	0.60
Fea/10	9.00	1.49	25% (5)	9.80	0.52
Hap/10	9.75	0.44	0% (0)	9.85	0.37
Sad/10	7.65	1.31	0% (0)	8.40	1.79

Controls: 10 females, 10 males, mean age = 47.80 (SD = 6.82), mean IQ = 112.30 (SD = 9.85).

Consistent with the tests of facial expression recognition, the group analyses showed impairments for anger, disgust, and fear. Once again, anger showed the greatest number of severe impairments in the Huntington's patients (Table 4). It is also worth noting that although controls found vocal signals of disgust the easiest emotion to recognise, and vocal signals of sadness and happiness the most difficult, the group analyses showed impairments in the HD group for disgust but not sadness or happiness. Consequently, the pattern of deficits in the HD group are unlikely to reflect exaggerated problems in recognising emotions that the controls had most difficulty with.

4.5. Conceptual understanding of emotion

4.5.1. Emotional vignettes

The HD and control participants' performance for the emotional vignettes is summarised in Table 5. Results of the ANOVA showed a significant effect of emotion category, $F(2.8,108) = 14.40$, $p < 0.001$, $\eta_p^2 = 0.28$. The interaction between emotion category and group did not reach statistical significance, $F(2.8,108) = 1.9$, $p = 0.13$, $\eta_p^2 = 0.05$. However, to provide a comparison with the individual emotion effects for the other tests, simple effects of the emotion category factor were conducted with Bonferroni correction for five comparisons. These showed a significant effect for anger only ($F(1,38) = 7.38$, $p < 0.05$); all other F's < 4.6, p's > 0.1. Controls: 10 females, 10 males, mean age = 49.45 (SD = 5.04), mean IQ = 112.05 (SD = 9.77).

Once again, the group analyses showed an impairment for anger in the Huntington's group, but this time deficits for disgust and fear were not observed. However, anger, disgust, and fear were the only three emotion categories showing severe impairments ($p < 0.01$) (Table 5); hence, the general pattern of more marked impairments for these three emotions was evident, but less marked. This may be partly explained by the fact that the Huntington's patients and controls showed better performance on this task than the tests of facial and vocal expression recognition.

In summary, it is clear that the Huntington's patients were impaired on a number of emotion processing tasks, and that anger, disgust, and fear, were the most consistently impaired emotions. However, anger showed the most consistent and severe impairment relative to control performance, in that more patients showed severe impairments for this emotion than any other. It is also worth noting that failure to recognise anger was most often expressed as a false positive for disgust on all tests, demonstrating that patients' errors were not random. Rather they showed an exaggerated form of the anger–disgust confusion often made by healthy controls.

A comparison of the total number of impairments for each of the five emotion categories (anger, disgust, fear, happiness, and sadness) that were represented in each of the four tests (Ekman 60, Emotion Hexagon, vocal expressions, and emotional vignettes) relative to an even distribution of these impairments across these five categories showed a significant effect, $\chi^2(4) = 20.69$, $p < 0.001$, reflecting a disproportionately greater number of anger impairments than would be expected by chance. The emotion battery included two tests of facial expression recognition. Hence it is possible that the marked impairment in recognising anger was driven by an impairment in basic face processing. Although this seems unlikely given similar patterns of disproportionate impairments for the non-verbal sounds and emotional vignettes, we conducted a second analysis in which we removed the data of three patients who showed impaired performance ($z = 1.65$, $p < 0.05$) on both the Benton unfamiliar face matching task and one or more components of identifying familiar faces in the face recognition task (recognising faces as familiar, providing identifying information, or naming). A very similar result was found, $\chi^2(4) = 22.96$, $p < 0.001$, indicating that the disproportionate anger deficit does not reflect an impairment in basic face perception skills.

The relative severity of impairments for different emotions was addressed in another way by submitting the patients' data for recognition of anger, disgust, fear, and sadness on each of the four emotion recognition tests to a repeated measures ANOVA. To allow for different control performance on the four tests, the patients' data on each test were z score transformed relative to each tests' control mean and SD. The results showed a significant effect of Emotion, $F(3,57) = 7.54$, $p < 0.001$, and no interaction with test ($p > 0.2$). Separate analyses comparing performance on anger with each of the three other negative emotions showed significantly worse performance for anger than for disgust, $F(1,19) = 7.54$, $p < 0.05$, or sadness, $F(1,19) = 19.67$, $p = 0.001$; a comparison with fear showed a borderline effect, $F(1,19) = 2.82$, $p = 0.1$. The same analysis was repeated excluding the three patients with impaired face recognition. The results were very similar, however, this time the comparison with fear also achieved significance, suggesting that impaired face perception may have masked this difference in the entire group—overall ANOVA, main effect of emotion, $F(3,48) = 8.73$, $p < 0.001$, emotion × test interaction, $p > 0.3$; anger vs. disgust, $F(1,16) = 7.99$, $p < 0.02$; anger vs. fear, $F(1,16) = 8.97$, $p < 0.01$; anger vs. sadness, $F(1,16) = 17.99$, $p < 0.001$.

5. Study 2

To date, neuropsychological research of facial expression recognition, and emotion generally, has regarded individual basic emotions, such as anger and disgust, as unitary constructs. However, research from comparative and social psychology has taken a different approach. Of particular relevance, Rozin et al. (1994) identify three subtypes of disgust that are associated with different combinations of facial action units (AUs) in the facial action coding system (FACS) (Ekman & Friesen, 1978). One form is signalled by mouth gape and tongue protrusion (AUs 26 19) and is associated with oral irritation, unpleasant tastes, and more generally food-related aversions. A second form is signalled by nose wrinkle (AU 9) and is associated primarily with offensive smells and reactions to negative olfactory and some gustatory events. The third form is signalled with a raised upper lip (AU 10) and relates to what the authors refer to as expanded or elaborated disgust—a distinctly human form of the emotion associated with violation of moral norms, interpersonal contamination, and more widely the rejection of all that reminds us of our animal origins. Rozin et al. (1994) point out that the link between this third subtype and the violation of moral norms means that it is linked to anger, in the sense that both signal disapproval of other's behaviour.

To investigate the different varieties of disgust and their associated facial expressions, Rozin et al. (1994) used a series of forced choice procedures in which participants were presented with disgust provoking scenarios and asked to select the most appro-

priate facial expression. From an initial study comprising multiple different facial expressions, a three-way choice procedure containing faces displaying one of the three disgust features (mouth gape/tongue protrusion, nose wrinkle, and upper lip curl) was produced. The participants' task was to select the most appropriate facial expression associated with each scenario. Results showed that for the majority of the scenarios, one of three facial expression types was selected significantly more often than the other two. Here we use an adapted version of Rozin et al.'s (1994) paradigm to address whether a particular subtype of disgust is disproportionately impaired in HD patients.

As outlined in the introduction, the form of disgust signalled by upper lip curl is closely aligned with anger. Hence, on the basis of the results of Study 1 showing a disproportionate anger impairment, we predicted that the upper lip expression should show a more severe impairment than the other two disgust expressions. Moreover, since our recent fMRI work has shown that viewing disgust expressions comprising mouth gape and tongue protrusion fails to engage the insula — a region whose structural and functional integrity is related to the recognition of canonical disgust facial expressions in HD (Hennenlotter et al., 2004; Kipps et al., 2007) — we predicted that recognition of this expression should be relatively preserved.

6. Method

6.1. Participants

The study included 19 of the Huntington's patients that participated in Study 1 (9 females; mean age = 49.89, SD = 8.40; mean IQ = 106.95, SD = 8.66). Controls comprised 9 females and 5 males (mean age 42.43, SD = 11.35). Patients and controls were matched for years of education.

7. Design and procedure

The experiment was presented on a VDU screen. Each trial comprised three photographs of a male or female model. In one photograph the model displayed mouth gape/tongue protrusion, in a second, nose wrinkle, and in the third, upper lip curl. On each trial a different short description of an emotional scenario was printed below the three horizontally arranged photographs, and the participants were required to select which emotional expression constituted the most appropriate facial reaction. Example of the scenario types included the following: mouth gape/tongue protrusion—thinking about the fact that yesterday you ate an apple with a worm in it; nose wrinkle—smelling a pure chemical in a bottle that smells like rotten eggs; upper lip curl—hearing that a famous politician has been arrested for sexually abusing his young daughter.

There were six examples of each of the three types of scenarios. Each scenario was presented twice in random order, once with the three facial expressions posed by the male model, and again with same expressions posed by the female model. The facial stimuli were identical to those in the original Rozin et al. (1994) study (Experiment 3). Some of the scenarios were taken from the original Rozin et al. (1994) experiment, others were modified or replaced with scenarios that were more suited to a UK participant population. Examples of the images can be found in Rozin et al. (1994). The experiment began with six practice trials, comprising two examples of each of three disgust scenarios not used in the main experiment and pictures of three disgust expressions posed by a different model to those included in the main experiment. Performance was scored by calculating the number of times that each of the three disgust expressions was selected as the most appropriate facial signal for each scenario. Data were then submitted to Chi-square analyses following the procedure used by Rozin et al. (1994).

Table 6
Performance of the Huntington's patients ($n = 19$) and matched healthy controls on a test addressing recognition of three types of disgust expression.

Scenario	Face selected		
	Nose	Mouth gape	Upper lip
Nose wrinkle			
HD	45%	31%	24%
Controls	57%	21%	23%
Mouth gape			
HD	28%	49%	24%
Controls	21%	63%	17%
Upper lip			
HD	28%	35%	38%
Controls	23%	17%	60%

8. Results

The HD and control participants' performance for this test is summarised in Table 6. Consistent with Rozin et al. (1994) we found that controls selected the appropriate disgust facial expression for each of the three scenario types with well above chance accuracy: Face 1 (nose wrinkle) $\chi^2 = 40.82$; Face 2 (mouth gape) $\chi^2 = 64.75$; Face 3 (upper lip curl) $\chi^2 = 54.96$; all analyses survived Bonferroni correction for three comparisons (significance threshold of $p < 0.017$). Next we compared the performance of the HD group to the performance of the controls again applying Bonferroni correction. Results showed a borderline but non-significant difference between HD and controls for nose wrinkle (face 1) and mouth gape (face 2) ($\chi^2 = 6.64$ and $\chi^2 = 7.49$, respectively; corrected p's > 0.08), and a highly significant discrepancy between HD and control performance for upper lip curl (face 3), $\chi^2 = 21.95$, corrected $p < 0.001$. Thus, the HD patients show the largest discrepancy from controls for scenarios relating to face 3 (upper lip curl), the face linked more to moral disgust. In fact, as shown in Table 6, the HD patients selected each of the three expression types with approximately equal frequency for the face 3 scenarios, illustrating that they did not show the association between upper lip curl and expanded disgust shown by the controls. Finally, we reanalysed the data excluding the three patients who were impaired on the Benton and one or more aspects of recognising famous faces as familiar, identifying occupations, and identifying names (the same criteria used in Study 1) and found that the same significant effects as above. The results were consistent with the first analysis: nose wrinkle, $\chi^2 = 5.54$; mouth gape/tongue protrusion, $\chi^2 = 3.15$ (corrected p's > 0.1), and upper lip curl, $\chi^2 = 19.66$ (corrected $p < 0.001$).

9. Discussion

Our control data support Rozin et al. (1994) proposal that certain facial action units are associated with different subtypes of disgust. In addition, we have shown that Huntington's patients show a significant impairment on the elaborated or expanded form of disgust (associated with upper lip curl) relative to controls, but not faces signalling reactions to unpleasant tastes or smells. However, given that the patients' recognition of each of the three types of facial expressions was somewhat reduced relative to the controls, we would not wish to claim that their recognition of expressions signalling unpleasant tastes and smells was intact. Nonetheless, it is of interest that the impairment is most clear for the expanded disgust (upper lip curl) subtype associated with interpersonal contamination and violations of socio-moral norms, of which the latter

is closely associated, or often accompanied by anger. Our findings also accord with recent functional imaging research showing that the insula cortex is responsive to disgust expressions comprising upper lip curl, but not disgust expressions comprising mouth gape and tongue protrusion (von dem Hagen et al., 2009).

10. General discussion

Our study found marked impairments in recognition of emotion from facial and vocal expressions in patients with manifest HD. In addition, the emotional vignettes task provided evidence of impaired conceptual understanding of emotion from verbal material. Anger, fear, and disgust, were impaired across all tests of facial and vocal expression recognition, whereas for the emotional vignettes task the impairment was restricted to anger. Across the different modalities, we found that the participants with HD showed a greater number of severe impairments for anger than for other emotions. In a second study focussing on the recognition of different facial action units associated with disgust, we found that HD individuals showed comparatively good recognition of disgust from facial configurations associated with 'core', sensory forms of disgust — unpleasant tastes or oral sensations (mouth gape/tongue protrusion) and unpleasant smells (nose wrinkle) — that did not significantly differ from control performance. In contrast, they showed severely impaired recognition of disgust from 'upper-lip curl' faces associated with the expanded form of disgust that includes reactions to violations of social and moral norms. Given the results of Study 1, it is of interest that expanded disgust is more closely aligned with anger than the other disgust expressions. To this extent, both the first and follow-up studies show evidence of anger-related impairments.

As outlined in Section 1, a number of previous investigations of facial expression recognition in manifest HD patients have found disproportionate impairments in recognising facial signals of disgust (Montagne et al., 2006; Sprengelmeyer et al., 1996; Wang et al., 2003). A fourth study showed a similar disgust impairment for vocal and olfactory cues, together with impaired classification of disgusting pictures and declarative knowledge of disgust elicitors (Hayes et al., 2007). In contrast, other studies of manifest HD have found no evidence of disproportionate disgust deficits (Henley et al., 2008; Milders et al., 2003; Snowden et al., 2008). However, it is of note that using a similar format to our own addressing recognition of emotion from short verbal vignettes and facial and vocal cues, Snowden et al. (2008) found impaired recognition of negative emotions, with anger showing the most consistent impairment. Likewise, Henley et al. (2008) also found a disproportionate impairment in recognising anger from facial expressions, and de Gelder et al. (2008) reported impaired recognition of anger, but not other emotions (though they did not test disgust) from animated bodies. Thus, of the nine investigations of emotion recognition in manifest HD to date, including our own, four out of the eight that included disgust stimuli found a 'disproportionate' impairment for disgust (Hayes et al., 2007; Montagne et al., 2006; Sprengelmeyer et al., 1996; Wang et al., 2003), whereas our own study and three additional studies have found disproportionate impairments for anger (de Gelder et al., 2008; Henley et al., 2008; Snowden et al., 2008).

In the seven studies investigating facial expression recognition in premanifest HD (Gray et al., 1997; Henley et al., 2008; Hennenlotter et al., 2004; Johnson et al., 2007; Kipps et al., 2007; Milders et al., 2003; Sprengelmeyer et al., 2006), selective disgust impairments have been reported in three (Gray et al., 1997; Hennenlotter et al., 2004; Sprengelmeyer et al., 2006). Of the remaining studies, it is of interest that Johnson et al. (2007) found that anger was the only emotion that was impaired in all premanifest patients, regardless of their probability of having early HD, whereas Kipps et al. (2007) reported a borderline impairment for anger, in the context of intact recognition of other emotions.

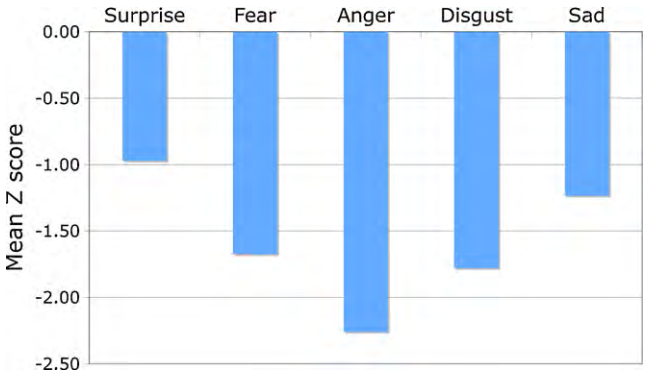

Fig. 3. Recognition of surprise, fear, anger, disgust, and sad emotions from the facial, vocal, and verbal tasks expressed as mean z scores calculated relative to control performance.

In summary, investigations of emotion recognition in HD to date have shown evidence of impaired recognition of emotion with some showing disproportionately severe impairments for disgust and others showing more marked impairments for anger. In the introduction, we noted that anger and disgust are confusable emotions that are positioned next to one another in Russell's (1980) Circumplex model of emotion. Fig. 3 summarises the magnitude of the deficits shown by the HD group from our first study for the five emotions (surprise, fear, anger, disgust, and sadness) tested in the facial, vocal, and verbal tasks. The deficits are expressed as mean *z* scores relative to control performance and happiness is omitted due to ceiling effects in the controls. It is striking that ordering the emotions according to their arrangement in the Circumplex model (Fig. 1) demonstrates that the deficit seems to centre on anger and gets progressively less severe with increasing distance from anger. This suggests that the Circumplex model may have some value in accounting for the pattern of emotion impairments in HD. However, there are good reasons why this model cannot provide a full account for emotion recognition and patterns of impairments found following brain injury or in neuropsychiatric disorders such as HD (Calder et al., 2001; Calder, Keane, Cole, et al., 2000; Calder, Keane, Manes, et al., 2000; Calder, Rowland, et al., 2000; Young et al., 1997). Foremost among these is that a system based on just two dimensions coding arousal and pleasantness cannot explain selective or disproportionate impairments in recognising distinct emotions, such as fear, following amygdala damage (Adolphs, Tranel, Damasio, & Damasio, 1994; Calder et al., 1996), or disgust following damage to the insula (Calder, Keane, Cole, et al., 2000; Calder, Keane, Manes, et al., 2000; Calder, Rowland, et al., 2000). This is because damage to either dimension (arousal or valence) would result in more general impairments affecting more than one emotion; for a discussion see Calder et al. (2001). However, the Circumplex model does provide an effective summary of the relationship or confusability of different emotions and Fig. 3 demonstrates that the impairment in our HD participants is maximal for anger and least evident for emotions that are most dissimilar to anger. Similarly, in Study 2, patients with HD showed an impairment for the disgust subtype most associated with anger.

It remains to be explained, however, why some studies have shown more severe impairments for disgust and others for anger. One interpretation is that essentially the same deficit is present in patients with HD. This deficit affects the interpretation of signals of social disapproval, such as disgust and anger, but the relative severity of impairments for these emotions derives from other factors, not the least of which may reflect the variants of disgust or anger emphasised in different tests of emotion recognition. As an expla-

nation of why only some studies of emotion recognition in HD show evidence of disgust impairments, Snowden et al. (2008) suggested that differences in the precise definitions of emotion labels used in different languages may be important. Five studies that show no evidence of disproportionate disgust impairments (including our own) were conducted in native English speaking groups (Henley et al., 2008; Johnson et al., 2007; Milders et al., 2003; Snowden et al., 2008), whereas a significant proportion of the work showing disgust impairments in premanifest and manifest HD has come from German groups (Hennenlotter et al., 2004; Sprengelmeyer et al., 2006, 1996, 1997). In particular, Snowden et al. (2008) point out that the German term for disgust used in these studies, "Ekel", refers to a more visceral disgust reaction, whereas the English term carries both visceral and moral connotations. Moreover, a study conducted in North America showed that the lay understanding of the word 'disgust' corresponds more to the moral form and is related closely, if not more so, to the meaning of anger as to that of disgust (Nabi, 2002). However, studies from countries other than Germany have also found evidence of disproportionate disgust impairments, including Wang et al.'s (2003) study conducted in China, Montagne et al.'s (2006) investigation in the Netherlands, Gray et al.'s (1997) investigation of premanifest HD participants in the UK, and Hayes et al.'s (2007) Australian study which addressed emotion recognition from modalities other than facial expressions. So it seems unlikely that different meanings alone could explain the different findings, but this point will need to be borne in mind in future studies addressing emotional processing.

It is also worth considering that disgust and anger impairments may have different neurological bases that could be compromised to differing degrees in cases of symptomatic HD. For example, a recent investigation of premanifest HD participants using a voxel-based morphometry (VBM) analysis of structural brain data showed that their disgust recognition was related to grey matter volume of the anterior insula (Kipps et al., 2007), a region with an established role in this emotion (Adolphs et al., 2003; Calder et al., 2007; Calder, Keane, Cole, et al., 2000; Calder, Keane, Manes, et al., 2000; Calder, Rowland, et al., 2000; Calder et al., 2001; Gallese, Keysers, & Rizzolatti, 2004; Krolak-Salmon et al., 2003; Phillips et al., 1997; Wicker et al., 2003). Thus, the presence of disgust recognition impairments may be governed by the extent of anterior insula atrophy in HD patients. Similarly, there is evidence that recognition of facial and vocal signals of anger is affected by damage to the ventral putamen (Calder et al., 2004), a region that is also reduced in premanifest HD (Kipps et al., 2005; Thieben et al., 2002). Hence, the relative proportion of damage to areas such as the insula and ventral putamen might determine whether the emotion recognition impairment in HD is more severe for anger or disgust.

Unfortunately, the lack of structural MRI scans in our study means that we are unable to address this question. However, it is also worth considering that HD affects areas of frontal cortex involved in processing multiple emotions, even in the premanifest stages of the disease (Thieben et al., 2002). Thus, any relationship between the recognition of disgust and insula volume or recognition of anger and putamenal volume may be affected (or masked) by the extent of frontal atrophy, particularly in the manifest form of the disease as frontal damage increases. In other words, any relationship between emotion recognition and the insula or striatum could interact with the effects of atrophy to other brain areas.

It is also worth noting that disgust and anger impairments have been observed in disorders of aggression and anti-social behaviour, such as conduct disorder (Fairchild et al., 2009), intermittent explosive disorder (Best, Williams, & Coccaro, 2002), or acquired sociopathy following brain injury (Blair & Cippolotti, 2000). It is therefore of particular note that aggressive outbursts and irritability are a common behavioural manifestation of HD (Craufurd & Snowden, 2002; Vassos, Panas, Kladi, & Vassilopoulos, 2007). Hence, it is possible that anger and disgust impairments in HD are modulated by the presence of aggressive/irritable behaviour, and it may be fruitful to explore this relationship in future research.

In line with the idea that impairments in disgust and anger recognition are associated with HD, it is of interest that Study 2 showed that the disgust subtype that is most often associated with anger, signalled by upper lip curl, was particularly impaired. Since this study involved selecting the most appropriate disgust expression for each verbal emotional scenario, it is difficult to tell whether the deficit is caused by impaired conceptual understanding of the verbal material associated with the relevant disgust subtype or impaired interpretation of its associated facial expression. However, since Study 1 showed evidence of impairments for the facial expression *and* emotional vignettes tasks, it is possible that both may contribute. As discussed, marked impairments for the upper lip curl expressions accords with our recent neuroimaging research showing that canonical disgust expressions comprising this feature engage the anterior insula, whereas the 'distaste' expressions signalled by mouth gape and tongue protrusion do not (von dem Hagen et al., 2009). We recognise that previous neuroimaging work has suggested that viewing facial reactions to unpleasant tastes also engages the insula (Jabbi, Swart, & Keysers, 2007). However, the examples of disgust expressions used by Jabbi et al. comprised nose wrinkle and upper lip curl, meaning that they were similar to the canonical disgust expressions used by von dem Hagen et al, and not the distaste (mouth gape/tongue protrusion) expressions.

Taken together with the reports of insula atrophy in HD, even in the premanifest stages (Kassubek et al., 2004; Kipps et al., 2005; Thieben et al., 2002), and work showing that the extent of insula atrophy in premanifest HD is correlated with recognition of canonical disgust expressions (Kipps et al., 2007), our results converge on the idea that HD affects a particular form of disgust that is related to insula function and closely aligned with anger. Moreover, the different factors we have discussed may explain why the deficit is sometimes expressed as a disproportionate disgust impairment and in other studies as a more severe impairment for anger.

In summary, our study shows evidence of impairments in recognising anger, fear and disgust in patients with manifest HD, with anger being the most severely affected. A review of other relevant studies showed that similar findings have been reported in other recent work. In addition, a sizeable number of studies have also reported disproportionate impairments in recognising disgust, and these two emotions show more marked impairments than any others across the literature addressing emotion processing in HD to date. The increased incidence of severe disgust and anger impairments in HD may pertain to the fact that a particular form of disgust linked to social disapproval that incorporates reactions to violations of moral standards is closely aligned with anger; an interpretation that was supported by the results of Study 2. However, subtle differences in the definition of emotion labels used for disgust in different languages may also help explain why these two emotions show interchangeable disproportionate impairments (Snowden et al., 2008), and this should be taken into consideration in future research. Finally, we have emphasised that anger and disgust impairments are also observed in disorders of aggression (Best et al., 2002; Fairchild et al., 2009). The presence of aggressive behaviour in HD is notable to this extent and the relationship between levels of aggression and anger/disgust impairments in HD may constitute an interesting avenue for future research.

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