Brain (1997), **120,** 2029–2038

Impaired recognition of disgust in Huntington's disease gene carriers

J. M. Gray,[1,2] A. W. Young,[4] W. A. Barker,[1,2] A. Curtis[3] and D. Gibson[3]

[1]*Neurobehavioural Service, St Nicholas Hospital, Gosforth,* [2]*Department of Psychiatry, School of Neurosciences and Psychiatry, University of Newcastle upon Tyne,* [3]*Northern Region Genetics Service, Royal Victoria Infirmary, Newcastle upon Tyne and* [4]*MRC Applied Psychology Unit, 15 Chaucer Road, Cambridge, UK*

Correspondence to: Dr John Gray, Neurobehavioural Service, Hartside, St Nicholas Hospital, Jubilee Road, Gosforth, Newcastle upon Tyne NE3 3XT, UK

Summary

Face processing and facial expression recognition were investigated in the earliest stages of Huntington's disease, by studying 40 people who presented for genetic testing. Twenty-three of these 'at risk' individuals turned out not to carry the gene for Huntington's disease (the AR^- group). Seventeen were found to be gene carriers (the AR^+ group); 15 from genetic testing, and two who showed signs of early stages of Huntington's disease. A number of standard tasks were used to provide background information, including recognition memory for words, picture naming, verbal fluency, and figure copying; none revealed significant differences between the AR^+ and AR^- groups. Face processing abilities were investigated using tests of identification of familiar (famous) faces, unfamiliar face matching, recognition memory for faces, and recognition of facial expressions of emotion. No statistically significant differences between the AR^+ and AR^- groups were found for any of these tests, but the AR^+ group showed a borderline overall impairment in recognizing facial expressions of emotion ($0.05 < P < 0.1$). When recognition of each of the six basic emotions used was examined separately, only disgust was found to be significantly impaired. This highly selective deficit in the recognition of disgust was confirmed in the subgroup of 15 individuals shown by genetic testing to be Huntington's gene carriers; it was therefore found in people who were free from clinical symptoms and did not perform significantly more poorly than non-carriers on any of the background tests, on any of the other face processing tasks, and even for recognition of any other basic emotion. This points strongly to the importance of the basal ganglia in the emotion of disgust.

Keywords: Huntington's disease; facial expression recognition; disgust

Abbreviation: RMT = recognition memory test

Introduction

Acquired brain damage can selectively affect different aspects of facial information processing. For instance, impairments affecting the processing of facial expressions of emotion are dissociable from impairments affecting the processing of facial identity (Etcoff, 1984; Young *et al.*, 1993). The existence of such dissociations has been used to create highly articulated 'box and arrow' models, where each box is held to represent the neural system (whether localizable or not) responsible for the processing of that particular type of information (Hay and Young, 1982; Bruce and Young, 1986; Ellis, 1986). Within such models, no further dissociations are possible (i.e. no dissociation within any box), though models do develop and differentiate.

Across many investigations, strong evidence has accumulated that the recognition of identity from the face involves a discrete set of processes (Benton, 1990; Young, 1992; Young *et al.*, 1993). It is clear that name retrieval and access to stored semantic information can break down separately from recognition of the face *per se*, but problems involving impaired retrieval of semantics or names are found to affect recognition from voice or name as well as from the face (Young, 1992). There is no evidence for dissociation within familiar face recognition itself: no cases have been found, for instance, where a person can recognize male faces but not female, or *vice versa*.

Given the evidence of dissociable deficits affecting the

recognition of identity and expression from the face, and the fact that familiar face recognition itself does not seem subject to further fractionation (implying a common visual recognition system for all familiar faces), a natural starting point for contemporary theoretical models of face processing has been to assume, by analogy, that the recognition of all facial expressions of emotion is also handled by a common mechanism capable of dealing with all emotions (Hay and Young, 1982; Bruce and Young, 1986; Ellis, 1986). However, within the domain of facial expression recognition, this assumption has been challenged by recent reports of differentially severe deficits for the recognition of basic emotions of fear and disgust.

Recognition of fear has been the most studied, with reports of three people with bilateral lesions to the amygdala who showed impairment in interpreting facial expressions of fear, with processing of other emotional expressions relatively (but not completely) preserved (Adolphs *et al.*, 1994, 1995; Calder *et al.*, 1996). One of these patients (S.M.) suffered from lipoid proteinosis (Urbach-Wiethe disease), a condition that causes progressive bilateral destruction of the amygdala whilst sparing adjacent hippocampal and cortical structures (Tranel and Hyman, 1990). Two of the patients suffered damage less precisely located in terms of space and structure, but more precisely located in time: one due to surgical amygdalotomy (D.R.), and one due to herpes simplex encephalitis (S.E.). All showed impairment in recognizing fear in facial expressions. In contrast, unilateral amygdala destruction has not been found to cause any impairment to recognition of facial expressions of emotion (Adolphs *et al.*, 1995).

Although recognition of fear was the most affected emotion for S.M., D.R. and S.E., they all showed evidence of problems in recognizing some other emotions too; surprise and anger for S.M, anger and disgust for D.R., and a borderline impairment of anger recognition for S.E. The consistent finding of some difficulties in recognizing anger as well as fear for these three people may be important; certainly, it fits with the animal literature suggesting that the amygdala is involved in the appraisal of danger (LeDoux, 1995). In line with this suggestion, recent work with D.R. has established that she is impaired in the recognition of fear and anger from vocally as well as facially expressed signals of emotion (Scott *et al.*, 1997).

The importance of the amygdala in fear recognition has been confirmed with PET (Morris *et al.*, 1996) and fMRI (Breiter *et al.*, 1996).

There are also grounds for thinking that bilateral amygdala damage affects not only the recognition of emotion, but the ability to experience certain emotions oneself. Patients with bilateral amygdala damage due to Urbach-Wiethe disease are known to present with neuropsychiatric symptoms, including paranoia (Emsley and Paster, 1985). The three patients discussed above also show abnormalities of affective and social behaviour. S.M is described as having 'a history of defective personal and social decision making' (Adolphs *et al.*, 1994), and shows abnormal fear conditioning (Bechara *et al.*, 1995). D.R. sometimes makes inappropriate social and emotional responses, and S.E. has suffered profound disruption of his previously happy interpersonal relations.

From studies of the amygdala, then, there is evidence for some degree of independent processing of facial expressions of specific basic emotions. However, other explanations remain possible. For the neuropsychological findings, the most obvious alternative is that perhaps fear is a particularly difficult emotion to recognize, and the supposed specificity represents nothing more than the easier expressions remaining unaffected because they are still at ceiling level in cases with mild overall impairment. Both sets of authors discount this on the grounds of comparative data from normal subjects. However, a study of two further cases of bilateral amygdala damage due to encephalitis did not reveal deficits in the recognition of fear (Hamann *et al.*, 1996), leaving open the possibility of idiosyncratic differences between patients and adding weight to the suspicion that other findings with fear recognition might reflect task difficulty.

Stronger evidence that certain basic emotions have distinct neural substrates would be a double dissociation, where another patient group showed relatively intact fear recognition in the context of more severely impaired recognition of another basic emotion. This has recently been reported in Huntington's disease (Sprengelmeyer *et al.*, 1996).

Huntington's disease is a dominantly inherited late onset neurological disease, initially affecting the basal ganglia and especially the caudate nucleus. Huntington's disease patients eventually suffer generalized intellectual deterioration (Butters *et al.*, 1978; Caine *et al.*, 1978; Brandt and Butters, 1986; Georgiou *et al.*, 1995; Sprengelmeyer *et al.*, 1995*a*, *b*), including impairments in the processing of faces and facial expressions of emotion (Jacobs *et al.*, 1995). However, Sprengelmeyer *et al.* (1996) have shown that symptomatic Huntington's disease patients have particularly severe difficulty interpreting facial and vocal expressions of disgust, being unable to recognize this emotion at levels of performance better than chance. Although symptomatic Huntington's disease patients have particularly severe difficulty recognizing facial expressions of disgust, recognition of other emotions is also affected (Sprengelmeyer *et al.*, 1996). Even so, Sprengelmeyer *et al.* (1996) suggested that impaired recognition of disgust in Huntington's disease may reflect a more central loss of this basic emotion, since parallel deficits were found for recognition of facially and vocally expressed emotion, and some abnormalities were noted in questionnaires concerning the experience of disgust. A possible reason why other emotions are affected as well as disgust in symptomatic individuals relates to the nature of the deterioration observed in Huntington's disease, in which there seems to be a progression from specific impairments to more general impairment of all cognitive functions as the disease progresses.

Sprengelmeyer *et al.*'s (1996) demonstration of differentially severely impaired recognition of disgust in

Huntington's disease suggests that task difficulty is not the only factor underlying findings of impaired recognition of different basic emotions, and their finding that facial and vocal interpretation of disgust were both affected also makes it more likely that there is an impairment of the emotion itself. Nevertheless, as regards facial expressions, although recognition of disgust was the most impaired for Sprengelmeyer *et al.*'s (1996) Huntington's disease group, other expressions including fear were also severely compromised. This does not, therefore, comprise what Shallice (1988) called a classical dissociation, in which performance of one ability would remain normal whilst the other was severely impaired. Instead, it is what Shallice (1988) called a trend dissociation; both fear and disgust were impaired, but one (disgust) was worse than the other.

As already noted, a possible reason why Sprengelmeyer *et al.* (1996) found a trend dissociation rather than a classical dissociation for recognition of disgust relates to the nature of the slowly progressive deterioration observed in Huntington's disease. Given the findings of Jacobs *et al.* (1995) indicating that facial processing in general is eventually impaired in symptomatic Huntington's disease, Sprengelmeyer *et al.*'s (1996) results might reflect the outcome of two processes; one specific to the perception of disgust, whatever the modality, and one related more generally to all face processing tasks, including emotion recognition.

One possibility, then, is to look for a specific impairment of disgust recognition at the earliest stages of Huntington's disease. Since the relevant gene was identified and sequenced in 1993, it has been possible to identify those carrying the gene with theoretical accuracy of 100% before the onset of clinical symptoms or signs (Huntington's Disease Collaborative Research Group, 1993). Thus, the very earliest and most specific changes to cognitive or other functions can be examined, free from the confusing overlay of more general cognitive deterioration found in later stages of Huntington's disease.

In addition to its importance for theoretical understanding of cognitive mechanisms involved in emotion recognition, further investigation of the deficit in recognition of disgust in Huntington's disease is potentially informative concerning the neural substrates of emotion.

To explain the patterns of impairment of emotion recognition found in Huntington's disease and after bilateral amygdala damage, Sprengelmeyer *et al.* (1996) suggested that the possibility that certain basic emotions may have dedicated neural substrates needs to be seriously considered. Among these, disgust and fear are prime candidates with distinct evolutionary histories (Öhman, 1993; Rozin *et al.*, 1993). In the case of disgust, the different stimuli which elicit the emotion can be linked to a notion of 'core disgust' involving a rejection response to bad tastes (Rozin *et al.*, 1993). The feeling of revulsion associated with disgust is akin to nausea, and the facial expression can be seen as a vestigial component of rejecting bad tastes or smells (Darwin, 1872; Rozin *et al.*, 1993).

Given their findings, Sprengelmeyer *et al.* (1996) noted that the basal ganglia are obvious contenders for a role in the mediation of disgust. However, Sprengelmeyer *et al.* (1996) also pointed out that the basal ganglia are not the only possibility. Rozin *et al.* (1993) argued that different forms of disgust are learnt by accretion to a 'core disgust' system which can be traced back to rejections of bad tastes and smells. From this point of view, a neural structure has to be identified which is able to integrate olfactory information with other modalities. Candidates are amygdala, the medial dorsal nucleus of the thalamus, orbital frontal cortex, insula, those parts of rhinal cortex adjacent to the temporal pole, and piriform cortex.

In Huntington's disease there is a substantial loss of volume in the prepiriform and periamygdalar regions, and in the amygdala (Lange, 1981; Lange and Aulich, 1986). Given that it is the recognition of fear rather than disgust which is more severely compromised by amygdala damage (Adolphs *et al.*, 1994, 1995; Calder *et al.*, 1996), the amygdala itself does not seem to be especially involved in mediating recognition of disgust, but other regions in close proximity, such as periamygdalar and piriform cortex, may be important to this emotion.

Sprengelmeyer *et al.* (1996) were unable to determine which of these hypotheses was correct, since people with symptomatic Huntington's disease will have suffered some degeneration of all regions. However, any evidence of impaired recognition of disgust in the early stages of Huntington's disease would point strongly to the importance of the basal ganglia.

We therefore decided to look for a more specific impairment of disgust recognition in the early stages of Huntington's disease, by investigating face processing and facial expression recognition in individuals at risk of having the defective gene who presented for genetic testing. We were then able to compare the performance of individuals who were found to have the genetic defect with those without it.

Method

Subjects and genetic testing

Forty people with a parent affected by Huntington's disease took part in the study. This was an unselected group consisting of those from a consecutive series of people presenting for genetic testing in 1993 and 1994 who (i) gave informed consent to the predictive testing protocol, including neuropsychological testing, (ii) completed all or most of the neuropsychological tests, including background measures and the face processing battery, and (iii) proceeded to genetic testing (38 people) or were clinically diagnosed as suffering from early stages of Huntington's disease (two people). The data were collected during routine neuropsychological examination as part of the Northern Region Genetics Service predictive testing protocol based on the UK common protocol (Crauford and Tyler, 1992).

These individuals can nominally be considered at 50% risk of developing the disease, though in practice the risk begins to reduce as a person gets older and has not developed clinical symptoms. In the event, two people were diagnosed as gene carriers without genetic testing. One of these showed some early clinical symptoms of Huntington's disease when he presented at the genetic clinic, and diagnosis was made on this basis and family history. The second person was asymptomatic at initial presentation but did not proceed to genetic testing; he was later found to develop symptoms of Huntington's disease.

The remaining 38 people proceeded to genetic testing. Polymerase chain reaction amplification across the CAG repeat region was carried out, followed by an electrophoretic separation of alleles. Expanded and normal range alleles were amplified by polymerase chain reaction in a total reaction volume of 25 µl containing 100 ng genomic DNA, each primer at 0.5 mM, 200 mM dNTPs (dATP, dCTP, dGTP, dTTP) 2 mCi [^{32}P]dCTP, 10% DMSO, 1 U Taq polymerase and the supplier's reaction buffer (Promega). The primers used in reaction are described by Warner *et al*. (1993). These flank the polymorphic CAG repeat region but do not include the two adjacent polymorphic CCG rich stretches (Rubinsztein *et al.*, 1993). The mix was heated to 94°C for 4 min followed by 35 cycles of 30 s at 65°C, 45 s at 72°C, and finally one cycle of 72°C for 10 min. Products were resolved on 6% denaturing polyacrylamide gels. A known standard of 36 repeat units was used to demonstrate a clear distinction between the normal (gene –ve) and expanded (gene +ve) allele sizes in every case.

Twenty-three people turned out not to carry the gene (the AR^- group), and 15 were gene carriers (the AR^+ group). The two people referred to the genetic clinic for whom a clinical diagnosis of Huntington's disease was made (*see* above) were also included in the AR^+ group, giving a total of 17 individuals. These groups did not differ in age (AR^+ group, mean age = 38.53 years, SD = 11.24, range, 25–57 years; AR^- group, mean age = 38.26 years, SD = 11.82, range, 19–63 years).

The computerized version of the Composite International Diagnostic Interview (World Health Organisation, 1993) was given to everyone who underwent genetic testing. There were two lifetime psychiatric diagnoses for participants in the AR^- group. These diagnoses were both 'mild depressive episode without somatic symptoms' (ICD code F32.00); one of them was in the recent past (symptoms within last year), and one of them was current (symptoms within last fortnight). Apart from a case of 'tobacco dependence syndrome' (ICD code 17.2) in the recent past (symptoms within last year), nothing untoward was noted for the AR^+ group.

Background neuropsychological tests

A number of standard tasks were used to provide background information, against which to evaluate any problems in face processing. These standard tasks included recognition memory for words (Warrington, 1984), the Graded Naming Test (McKenna and Warrington, 1983), verbal fluency (letters F, A, S, for 1 min each), and figure copying (Coughlan and Hollows, 1985).

Investigation of face processing abilities

To investigate face processing abilities, we used a small battery of tests. These were chosen to tap a range of abilities known to be subject to dissociable impairment from studies of the effects of brain injury (Young, 1992, 1993). The tasks involved identification of familiar (famous) faces, unfamiliar face matching (Benton *et al.*, 1983), recognition memory for faces (Warrington, 1984), and recognition of facial expressions of emotion.

These tests were used in a previous study of face processing impairments following bilateral amygdala damage for case D.R. (Young *et al.*, 1995), and therefore form a useful and systematic point of comparison for an investigation of any deficits in clinically pre-symptomatic individuals carrying the gene for Huntington's disease. We will describe each task in turn.

Identification of familiar faces

Identification of familiar faces was assessed with 30 highly familiar faces (famous people) and 10 unfamiliar faces, presented in pseudo-random order. For each face, the subject was asked whether or not it was a familiar person and, if so, his or her occupation and name. An additional four trials with familiar faces and two trials with unfamiliar faces were given first, as practice. The measures of performance involved the number of highly familiar faces recognized as familiar, the number given correct occupation, the number named correctly, and the number of unfamiliar faces correctly recognized as unfamiliar (correct rejections).

Unfamiliar face matching

The Benton test of facial recognition (Benton *et al.*, 1983) was given. In this test, subjects have to choose which of six photographs of unfamiliar faces are pictures of the same person as a simultaneously presented target face photograph. The test includes items involving choice of identical photographs, as well as transformations of orientation or lighting, which are pooled to give an overall total.

Recognition memory for faces

The Warrington recognition memory test (RMT) was used (Warrington, 1984), in which recognition memory is tested separately for faces and words. In the faces part of the RMT, 50 faces are shown at the rate of one every 3 s for a 'pleasant or unpleasant' decision, and recognition memory is then tested immediately by presenting each of the faces paired with a distractor, with the subject having to choose which

has been seen before. A similar procedure is used to test recognition memory for words, which was adopted here as one of our background measures.

Recognition of facial expressions of emotion

The expression recognition task used photographs of faces from the Ekman and Friesen (1975) series, each displaying a facial expression appropriate for one of six basic emotions (happiness, sadness, surprise, disgust, anger, fear). These faces were presented one at a time. The names of the six emotions were printed below the photograph in a vertical alignment, with the order of these emotion names randomized across trials. The task was to identify each expression by deciding which of the emotion names best described the facial expression shown. There were six practice trials and 24 experimental trials (four for each of the six emotions), leading to an accuracy score out of a possible maximum of 24 correct choices overall, or a score out of four for each emotion. The photographs of facial expressions used as targets in this task were chosen because they were all accurately recognized in the norms published by Ekman and Friesen (1975; mean accuracies for our chosen targets are happiness = 100%, sadness = 96%, surprise = 96%, disgust = 96%, anger = 98%, fear = 93%). Because of the importance of this test in the present context, the identifiers for the stimuli in the Ekman and Friesen (1975) series are listed in an Appendix to this report.

Results

Although 40 people participated in our study, 17 of whom turned out to be Huntington's gene carriers (15 with genetic and two with clinical diagnoses) and 23 non-carriers, the circumstances of testing during presentation for genetic screening meant that not all participants were able to complete all tasks. Our data summary tables therefore state in each case the number of people in the AR^+ and AR^- groups who completed each test. Importantly, all participants completed the test of facial expression recognition.

Genetic testing is a stressful event, during which people may well be worried and preoccupied, and thus perform below their best on many tests. For this reason, we have not used the conventional comparison with an age-matched control group as our first-choice analysis, and instead rely mainly on direct tests between the people who turned out to be Huntington's gene carriers or non-carriers. Since all participants were initially at risk of carrying the gene, and the genetic diagnosis was only available after neuropsychological testing was completed, there is no reason to suspect any difference between the AR^+ and AR^- groups in the extent to which they were subject to worry or other extraneous factors which might have limited their performance.

First, we consider the background neuropsychological measures. Means, standard deviations and ranges for the AR^+ and AR^- groups are presented in Table 1, together with numbers of subjects for each group on each test. Possible differences in performance between the AR^+ and AR^- groups were tested by using one-way analyses of variance for each measure. These did not reveal any statistically significant differences [recognition memory for words, $F < 1$; graded naming test, $F < 1$; verbal fluency, $F(1,38) = 1.77$, $P = 0.19$; figure copying, $F(1,34) = 2.64$, $P = 0.11$].

Results on the background neuropsychological tests (Table 1) therefore show that the groups were reasonably well-matched regarding premorbid and current ability on a range of basic cognitive functions. We do not seek to claim that they were exactly equivalent on all cognitive functions, but our results are in line with other findings indicating no differences on current standard assessment measures (Blackmore *et al.*, 1995). In Table 1 there is a hint in the group means and ranges that performance may have been slightly poorer for the AR^+ group for verbal fluency and figure copying, which might be considered consistent with some degree of 'frontal' involvement; but this did not reach either conventional (0.05) or borderline (0.1) levels of statistical significance on either measure.

These background test results thus demonstrate that there was no general or widespread cognitive deterioration in the AR^+ group, and that they were comparable with the AR^- group on a wide range of cognitive functions.

Next, we turn to consider the results of the face processing tests. These are summarized in Table 2, which gives means, standard deviations, and ranges for the AR^+ and AR^- groups, together with numbers of subjects for each group on each test. Again, possible differences in performance between the AR^+ and AR^- groups were tested by using one-way analysis of variance for each measure.

For identification of familiar faces, measures taken included recognition of the familiarity of highly familiar faces, and retrieval of their occupations and names, together with a 'false alarm' measure derived by examining the rate at which unfamiliar faces were correctly rejected as unfamiliar. None of these measures revealed differences which were anywhere near statistical significance [high familiarity faces: recognized as familiar, $F < 1$; occupation, $F(1,32) = 1.27$, $P > 0.25$; name, $F < 1$; unfamiliar faces: correct rejections, $F < 1$].

Unfamiliar face matching was tested with the Benton test of facial recognition (Benton *et al.*, 1983). There was no hint of any poorer performance by the AR^+ group ($F < 1$). The means and SDs were closely comparable for AR^+ and AR^- groups, with the bottom end of the range of scores for non-carriers being, if anything, slightly lower. This result is important because the Benton test is a difficult perceptual task which is sensitive to impairment in a range of neuropsychological conditions (Benton, 1980, 1990), and it is known to be impaired in the later stages of Huntington's disease (Jacobs *et al.*, 1995; Sprengelmeyer *et al.*, 1996).

Recognition memory for faces was tested with the Faces part of the Recognition Memory Test (Warrington, 1984). Although both groups performed poorly in comparison with

Table 1 *Background neuropsychological information for all subjects*

	HD gene carriers (AR^+)				Non-carriers (AR^-)			
	Mean	SD	*n*	Range	Mean	SD	*n*	Range
Recognition memory for words	45.4	14.56	17	36–50	44.04	6.47	23	23–50
Graded naming test	21.64	4.42	17	15–29	20.78	4.01	23	15–28
Verbal fluency	29.88	14.06	17	11–71	35.57	12.81	23	15–67
Figure copying	75.88	4.46	16	66–80	77.70	2.11	20	73–80

Table 2 *Performance of tests of face processing by all subjects*

	HD gene carriers (AR^+)				Non-carriers (AR^-)			
	Mean	SD	*n*	Range	Mean	SD	*n*	Range
Identification of familiar faces								
High familiarity faces								
Recognized as familiar	28.86	1.61	14	25–30	28.00	3.03	20	18–30
Occupation	28.50	1.99	14	23–30	27.20	3.97	20	17–30
Name	24.86	4.88	14	12–30	23.85	5.75	20	11–30
Unfamiliar faces								
Correct rejections	8.57	1.34	14	5–10	8.10	1.48	20	5–10
Unfamiliar face matching								
Benton test	44.88	4.71	16	37–52	45.50	4.98	20	34–55
Recognition memory (RMT)								
Faces	37.47	5.23	17	27–45	36.61	5.37	23	26–48
Recognition of facial expressions of emotion								
Forced–choice	19.29	2.57	17	15–24	20.57	2.04	23	17–24

the test's published norms, possibly because of the distraction inherent in being tested whilst presenting for genetic screening, there was again no sign of any difference in performance between the AR^+ and AR^- groups (RMT Faces, $F < 1$).

The only task from the battery we employed which produced any clear suggestion of a difference between the performance of AR^+ and AR^- groups was recognition of facial expressions of emotion, for which there was a borderline ($0.05 < P < 0.1$) difference in overall scores [$F(1,38) = 3.04$, $P = 0.09$]. However, these overall scores for emotion recognition involve an aggregate of all six basic emotions from the Ekman and Friesen (1975) series, whereas Sprengelmeyer *et al.* (1996) found that it was the recognition of disgust which was most severely impaired in their group of people with Huntington's disease. We therefore proceeded to examine the performance of the AR^+ and AR^- groups with each of the six basic emotions used in our test: happiness, sadness, surprise, disgust, anger and fear.

These comparisons involve scores which can range from 0–4 for recognition of each basic emotion, so non-parametric statistics were used (Mann–Whitney *U* test). The figure shows the distributions of scores for recognition of each basic emotion; to remove the effects of the unequal group sizes, percentages of people in the AR^+ or AR^- groups who achieved each possible score are shown. There is a clear synchrony between the distributions of scores for the AR^+ and AR^- groups for all emotions except disgust. There was a ceiling effect in recognition of happiness, with all 40 participants achieving the maximum score of four for recognition of this emotion. The recognition of disgust was found to be poorer in the AR^+ group (disgust, $U = 97.0$, $z = -2.97$, $P = 0.002$), but the groups did not differ on recognition of any other emotion ($P > 0.1$ for all other emotions: sadness, $U = 183.0$, $= -0.44$, $P = 0.33$; surprise, $U = 166.5$, $Z = -1.14$, $P = 0.13$; anger, $U = 176.5$, $Z = -0.55$, $P = 0.29$; fear, $U = 158.5$, $Z = -1.04$, $P = 0.15$). Because we predicted the impairment of recognition of disgust, these comparisons are based on one-tailed probabilities. However, the pattern is just as clear if two-tailed probabilities are used.

Since two people in the AR^+ group were diagnosed clinically as being in the early stages of Huntington's disease, we carried out a subsidiary analysis of recognition of each emotion for the 38 people (23 AR^-, 15 AR^+) who were both clinically asymptomatic and proceeded to genetic testing. This confirmed the pattern already described, with impaired recognition of disgust in the AR^+ group (disgust, $U = 89.0$, $Z = -2.76$, $P = 0.003$), and no differences for recognition of any other emotion (happiness at ceiling, and $P > 0.1$ for all other emotions: sadness, $U = 165.5$, $Z = -0.27$, $P = 0.39$; surprise, $U = 149.5$, $Z = -0.97$, $P = 0.17$; anger, $U = 161.0$, $Z = -0.37$, $P = 0.36$; fear, $U = 146.5$, $Z = -0.80$, $P = 0.21$). Therefore, impaired recognition of disgust was found in clinically pre-symptomatic individuals carrying the gene for Huntington's disease.

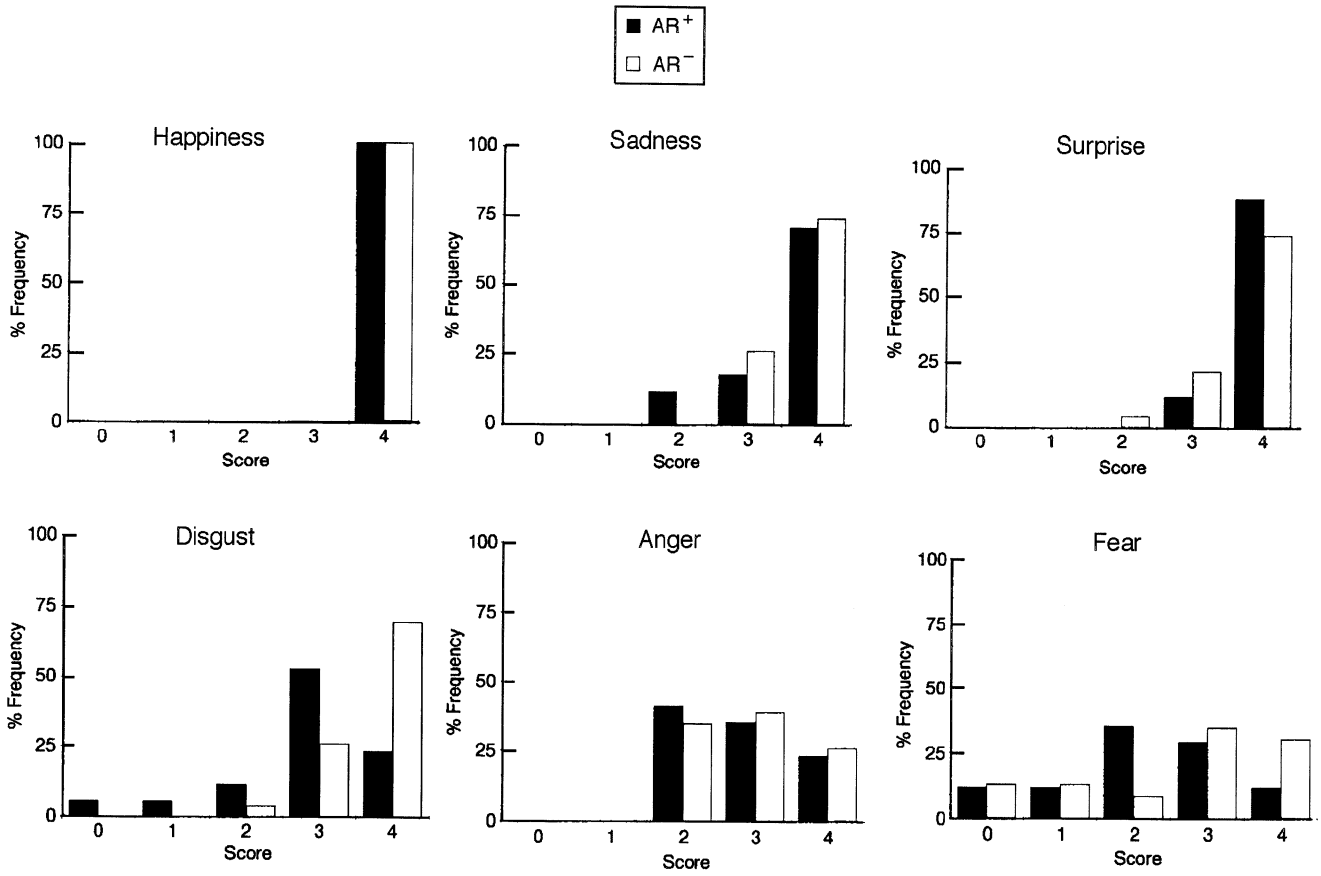

Fig. 1 Distributions of scores for recognition of basic emotions of happiness, sadness, surprise, disgust, anger and fear, for people who were found to be Huntington's disease gene carriers (AR^+) or non-carriers (AR^-). Each histogram shows the percentages of individuals in each group achieving each possible score. The emotions are ordered (1–6) in terms of their ease of recognition (mean number correct) for the AR^- group.

In Fig. 1 the emotions are ordered in terms of their ease of recognition (mean number correct) for the AR^- group. The impairment of recognition of disgust does not therefore seem to reflect task difficulty *per se*, since this emotion was at an intermediate level of difficulty for the AR^- group. In addition, the effect held across stimulus items. When recognition of the four different disgust faces used in the test was examined separately, the AR^+ group performed less well than the AR^- group for all four faces, and this also held for the fifth disgust face used in practice trials. Consistent group differences across individual test items were not found for any of the other emotions.

Although we consider the direct comparison of performance between AR^+ and AR^- groups as more instructive than comparison to a normal control group who would not be subject to the stress inherent in genetic testing, it is worth knowing whether or not the AR^- group were performing the test of emotion recognition at a normal level of performance. We therefore compared the performance of the 23 people in the AR^- group with that of an age-matched group of 40 'not at risk' controls aged 20 59 years (mean age 40.35 years, SD = 12.45). There was a ceiling effect in recognition of happiness, no significant differences for surprise ($U = 431.0$, $Z = -0.57$, $P = 0.28$) or sadness ($U = 447.5$, $Z = -0.23$, $P = 0.41$), borderline differences for fear ($U = 363$, $Z = -1.46$, $P = 0.07$) and disgust ($U = 386$, $Z = -1.55$, $P = 0.06$), and a significant difference for recognition of anger ($U = 311$, $Z = -2.29$, $P = 0.02$). There are thus some grounds for thinking that worry and other factors did indeed limit the performance of the AR^- group, but no hint that this was in any way more severe for disgust than the other negative emotions of fear and anger.

Discussion

The results of this study show a highly selective deficit in the recognition of disgust in people who were found to be Huntington's gene carriers. These people did not perform significantly more poorly than non-carriers on any of the background tests we used, on any of the other face processing tasks, and even for recognition of any other basic emotion. Recognition of disgust was still found to be impaired when the two individuals with early symptoms of Huntington's disease were taken out of the analysis.

These findings confirm Sprengelmeyer *et al.*'s (1996) observations of defective recognition of disgust in

Huntington's disease. In some ways, the impairment seems even more specific than was noted by Sprengelmeyer *et al.* (1996). However, this direct comparison needs to be viewed cautiously because the present study used a shorter test of emotion recognition than Sprengelmeyer *et al.* (1996).

The more important point is that our findings show deficits in the recognition of disgust in clinically pre-symptomatic individuals who do not show general cognitive deterioration. In particular, recognition of disgust was impaired at a time when none of the other face processing deficits documented in the later stages of Huntington's disease (Jacobs *et al.*, 1995) were evident. For unfamiliar face matching (Benton *et al.*, 1983) there was no hint of any poorer performance by the AR^+ group ($F < 1$); yet the Benton test is a difficult perceptual task which is sensitive to impairment in a range of neuropsychological conditions (Benton, 1980, 1990), and is known to be impaired in the later stages of Huntington's disease (Jacobs *et al.*, 1995; Sprengelmeyer *et al.*, 1996). Neither was there a significant impairment of any other emotion; instead, recognition of disgust was differentially affected in the AR^+ group even though it was not a difficult emotion for the AR^- group. This points strongly to the importance of the basal ganglia in the emotion of disgust, since the basal ganglia are widely recognized as showing the earliest pathological changes in Huntington's disease.

Although Huntington's disease is a dominantly inherited genetic disorder, we would caution against the immediate extrapolation to a gene for disgust. We have already pointed out that it is likely that different forms of disgust are learnt by accretion to a 'core disgust' system which involves the rejection of bad tastes and smells (Rozin *et al.*, 1993), so candidate neural structures should be able to integrate olfactory information with other modalities. Current conceptions of the neurophysiology of the basal ganglia emphasize an arrangement involving separable functional 'loops' interconnecting these to different regions of cerebral cortex (Alexander *et al.*, 1986). The limbic loop through the ventral striatum, linking medial temporal lobe structures to orbito-frontal cortex, thus merits further investigation for its potential involvement in the neural substrate of disgust. From this perspective, loss of disgust may be an early sign of the disintegration of certain learning mechanisms–especially those involved in establishing associations to bad tastes or smells.

The results reported here and by Sprengelmeyer *et al.* (1996) regarding the processing of the facial expression of disgust, taken together with findings on recognition of facial expressions of fear after amygdala damage (Adolphs *et al.*, 1994; Adolphs *et al.*, 1995; Calder *et al.*, 1996), represent a double dissociation between the recognition of facial expressions of two basic emotions. At first sight, this is inconsistent with the assumption of a common analysis system for all facial expressions in the widely used Bruce and Young (1986) model of face processing. It is conceivable that the expression analysis module proposed by Bruce and Young (1986) might need to be replaced by more specific modules each concerned with one basic emotion, or perhaps with a cluster of emotions. However, Sprengelmeyer *et al.*'s (1996) results on the association of deficits affecting the interpretation of facial and verbal prosodic expressions of disgust, and recent parallel findings for auditory recognition of fear and anger after amygdala damage (Scott *et al.*, 1997), suggest either that emotion recognition mechanisms are intrinsically multimodal or that these deficits affect recognition by compromising more central aspects of the ability to experience particular emotions under appropriate circumstances. These different possibilities merit further investigation, since they offer the promise of fundamental insights into the nature of emotion.

Impaired recognition of disgust in Huntington's disease could have important implications for social behaviour. Accurate perception of others' disgust is powerfully involved in social learning, whether through direct learning under social reinforcement (or punishment) or through vicarious learning or modelling. If the impairment in Huntington's disease extends to the experience of disgust (as well as the recognition of disgust in others) then direct, empathic understanding of the basis of others' reactions will be precluded, leaving sufferers with only 'cold' memories of the propositional content of what it means to be disgusted to guide their behaviour. Abnormalities of social behaviour are, along with intellectual decline, a cardinal feature of Huntington's disease. These social abnormalities have usually been attributed to generalized changes, involving impulsiveness, disinhibition and loss of frontal lobe control. Yet, for example, failure to maintain acceptable standards of personal hygiene could as readily be interpreted as arising from loss of disgust. The possibility that abnormalities in the perception and experience of disgust play a part in some of the social abnormalities found in Huntington's disease provides a perspective which may turn out to be important.

References

Adolphs R, Tranel D, Damasio H, Damasio A. Impaired recognition of emotion in facial expressions following bilateral damage to the human amygdala. [see comments]. Nature 1994; 372: 669–72. Comment in: Nature 1994; 372: 613–4.

Adolphs R, Tranel D, Damasio H, Damasio AR. Fear and the human amygdala. J Neurosci 1995; 15: 5879–91.

Alexander GE, DeLong MR, Strick PL. Parallel organization of functionally segregated circuits linking basal ganglia and cortex. [Review]. Annu Rev Neurosci 1986; 9: 357–81.

Bechara A, Tranel D, Damasio H, Adolphs R, Rockland C, Damasio AR. Double dissociation of conditioning and declarative knowledge relative to the amygdala and hippocampus in humans. Science 1995; 269: 1115–8.

Benton AL. The neuropsychology of facial recognition. Am Psychol 1980; 35: 176–86.

Benton AL. Facial recognition 1990. [Review]. Cortex 1990; 26: 491–9.

Benton AL, Hamsher KS, Varney NR, Spreen O. Contributions to neuropsychological assessment: a clinical manual.New York: Oxford University Press, 1983.

Blackmore L, Simpson SA, Crawford JR. Cognitive performance in UK sample of presymptomatic people carrying the gene for Huntington's disease. J Med Genet 1995; 32: 358–362.

Brandt J, Butters N. The neuropsychology of Huntington's disease. Trends Neurosci 1986; 9: 118–20.

Breiter HC, Etcoff NL, Whalen PJ, Kennedy WA, Rauch SL, Buckner RL, et al. Response and habituation of the human amygdala during visual processing of facial expression. Neuron 1996; 17: 875–87.

Bruce V, Young A. Understanding face recognition [see comments]. Br J Psychol 1986; 77: 305–27. Comment in: Br J Psychol 1990; 81: 361–80.

Butters N, Sax D, Montgomery K, Tarlow S. Comparison of the neuropsychological deficits associated with early and advanced Huntington's disease. Arch Neurol 1978; 35: 585–9.

Caine ED, Hunt RD, Weingartner H, Ebert MH. Huntington's dementia: clinical and neuropsychological features. Arch Gen Psychiatry 1978; 35: 377–84.

Calder AJ, Young AW, Rowland D, Perrett DI, Hodges JR, Etcoff NL. Facial emotion recognition after bilateral amygdala damage: differentially severe impairment of fear. Cogn Neuropsychol 1996; 13: 699–745.

Coughlan AK, Hollows SE. The Adult Memory and Information Processing Battery (AMIPB). Leeds: University of Leeds, 1985.

Darwin C. The expression of the emotions in man and animals. London: John Murray, 1872.

Ekman P, Friesen WV. Pictures of facial affect. Palo Alto CA: Consulting Psychologists Press, 1976.

Ellis HD. Processes underlying face recognition. In: Bruyer R, editor. The neuropsychology of face perception and facial expression. Hillsdale, N J: Lawrence Erlbaum, 1986: 1–27.

Emsley RA, Paster L. Lipoid proteinosis presenting with neuropsychiatric manifestations. J Neurol Neurosurg Psychiatry 1985; 48: 1290–2.

Etcoff NL. Selective attention to facial identity and facial emotion. Neuropsychologia 1984; 22: 281–95.

Georgiou N, Bradshaw JL, Phillips JG, Bradshaw JA, Chiu E. The Simon effect and attention deficits in Gilles de la Tourette's syndrome and Huntington's disease. Brain 1995; 118: 1305–18.

Hamann SB, Stefanacci L, Squire LR, Adolphs R, Tranel D, Damasio H *et al*. Recognizing facial emotion [letter]. Nature 1996; 379: 497.

Hay DC, Young AW. The human face. In: Ellis AW, editor. Normality and pathology in cognitive functions. London: Academic Press, 1982: 173–202.

Huntington's Disease Collaborative Research Group. A novel gene containing a trinucleotide repeat that is expanded and unstable on Huntington's disease chromosomes [see comments]. Cell 1993; 72: 971–83. Comment in: Cell 1993; 72: 817–8.

Jacobs DH, Shuren J, Heilman KM. Impaired perception of facial identity and facial affect in Huntington's disease. Neurology 1995; 45: 1217–8.

Lange HW. Quantitative changes of telencephalon, diencephalon, and mesencephalon in Huntington's chorea, postencephalitic, and idiopathic Parkinsonism. Verh Anat Gesellschaft 1981; 75: 923–5.

Lange HW, Aulich A. Die Hirnatrophie bei der Huntingtonschen Krankheit: neuroanatomische und neuroradiologische Untersuchungen. In: Oepen H, editor. Die Huntingtonische Krankheit. Stuttgart: Hippokrates, 1986: 25–41.

LeDoux JE. Emotion: clues from the brain. [Review]. Annu Rev Psychol 1995; 46: 209–35.

McKenna P, Warrington EK. Graded Naming Test. Windsor (UK): NFER-Nelson, 1983.

Morris JS, Frith CD, Perrett DI, Rowland D, Young AW, Calder AJ, *et al*. A differential neural response in the human amygdala to fearful and happy facial expressions. Nature 1996; 383: 812–5.

Öhman A. Fear and anxiety as emotional phenomena: clinical phenomenology, evolutionary perspectives, and information-processing mechanisms. In: Lewis M, Haviland JM, eds. Handbook of emotions. New York: Guilford Press, 1993: 511–36.

Rozin P, Haidt J, McCauley CR. Disgust. In: Lewis M, Haviland JM, eds. Handbook of emotions. New York: Guilford Press, 1993: 575–94.

Rubinsztein DC, Barton DE, Davison BCC, Ferguson-Smith MA. Analysis of the huntingtin gene reveals a trinucleotide-length polymorphism in the region of the gene that contains two CCG-rich stretches and a correlation between decreased age of onset of Huntington's disease and CAG repeat number. Hum Mol Genet 1993; 2: 1713–5.

Scott SK, Young AW, Calder AJ, Hellawell DJ, Aggleton JP, Johnson M. Impaired auditory recognition of fear and anger following bilateral amygdala lesions. Nature 1997; 385: 254–7.

Shallice T. From neuropsychology to mental structure. Cambridge: Cambridge University Press, 1988.

Sprengelmeyer R, Canavan AGM, Lange HW, Hömberg V. Associative learning in degenerative neostriatal disorders: contrasts in explicit and implicit remembering between Parkinson's and Huntington's diseases. Mov Disord 1995a; 10: 51–65.

Sprengelmeyer R, Lange HW, Hömberg V. The pattern of attentional deficits in Huntington's disease. Brain 1995b; 118: 145–52.

Sprengelmeyer R, Young AW, Calder AJ, Karnat A, Lange HW, Hömberg V, *et al*. Loss of disgust: perception of faces and emotions in Huntington's disease. Brain 1996; 119: 1647–65.

Tranel D, Hyman BT. Neuropsychological correlates of bilateral amygdala damage. Arch Neurol 1990; 47: 349–55.

Warner JP, Barron LH, Brock DJH. A new polymerase chain reaction (PCR) assay for the trinucleotide repeat that is unstable and expanded on Huntington's disease chromosomes. Mol Cell Probes 1993; 7: 235–9.

Warrington EK. Recognition Memory Test. Windsor (UK): NFER-Nelson, 1984.

World Health Organisation. Composite International Diagnostic Interview 1.1 – computer manual. Geneva: World Health Organisation, 1993.

Young AW. Face recognition impairments. [Review]. Phil Trans R Soc Lond B Biol Sci 1992; 335: 47–54.

Young AW, Newcombe F, de Haan EHF, Small M, Hay DC. Face perception after brain injury: selective impairments affecting identity and expression. Brain 1993; 116: 941–59.

Young AW, Aggleton JP, Hellawell DJ, Johnson M, Broks P, Hanley JR. Face processing impairments after amygdalotomy. Brain 1995; 118: 15–24.

Received November 25, 1996. Revised April 25, 1997. Accepted June 5, 1997

Appendix

Photographs used in emotion recognition test

Practice photographs: identifier in Ekman and Friesen (1976) series:

Happiness 74 PE-2-12; Sadness 76 PE-5-07; Surprise 90 PF-1-16; Disgust 5 A-1-25; Anger 106 WF-3-04; Fear 104 WF-3-16.

Test photographs: identifier in Ekman and Friesen (1976) series, and percentage recognition as this emotion in their norms:

Happiness (mean = 100%): 29 JB-1-09; 34 JJ-4-07; 48 MF-1-06; 57 MO-1-04Sadness (mean = 96%): 36 JJ-5-05; 43 JM-3-11; 67 NR-2-15; 87 PF-2-16
Surprise (mean = 96%): 11 C-1-10; 39 JJ-4-13; 45 JM-1-16; 54 MF-1-09
Disgust (mean = 96%): 20 EM-4-17; 91 PF-1-24; 98 SW-1-30; 108 WF-3-11
Anger (mean = 98%): 3 A-1-14; 53 MF-2-07; 62 MO-2-13; 96 SW-1-09
Fear (mean = 93%): 16 EM-5-21; 59 MO-1-23; 79 PE-3-21; 88 PF-2-30