Do I Misconstrue? Sarcasm Detection, Emotion Recognition, and Theory of Mind in Huntington Disease

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Objective: Emotion recognition has been widely studied in Huntington disease (HD), but only a few studies have investigated more complex social cognition and, when so, exclusively in manifest HD. The present study sought to investigate social–cognitive functions in a large, consecutive cohort of premanifest and manifest HD gene expansion carriers using tests assessing sarcasm detection, theory of mind (ToM), and emotion recognition. ***Method:*** Fifty manifest, 50 premanifest HD gene expansion carriers, and 39 at risk gene expansion negative healthy controls were included. All participants were tested with sarcasm detection, ToM, and emotion recognition tasks. Between-group comparisons of test performances and correlation analyses of test performances and disease burden scores were made. ***Results:*** Group comparisons showed significant differences in performances on the social–cognitive tests between manifest HD gene expansion carriers and healthy controls, but differences in performances between premanifest HD gene expansion carriers and healthy controls were not statistically significant. Correlation analysis showed that the worse test performances were associated with higher disease burden scores in all HD gene expansion carriers. ***Conclusion:*** Our findings support a theory of impaired social–cognitive functions in the early stages of HD. Test performances decreased with increasing disease burden in all HD gene expansion carriers, suggesting that social–cognitive tests may be useful for tracking disease progression. Simple emotion recognition tasks are just as sensitive for measuring social–cognitive deficits as more complex measures, but knowledge of the quality of social–cognitive impairments in HD can be of great importance to both patients and caregivers.

Keywords: social cognition, Huntington disease, emotion recognition, sarcasm detection, theory of mind

Huntington disease (HD) is an autosomal-dominant, inherited neurodegenerative disorder caused by an expanded CAG repeat on chromosome 4 (The Huntington's Disease Collaborative Research Group, 1993). The diagnosis of HD is based on the presence of motor symptoms, but it is well known that the appearance of cognitive decline and behavioral changes can develop many years before the onset of motor symptoms (Paulsen, Smith, Long, & the

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PREDICT HD Investigators and Coordinators of the Huntington Study Group, 2013; Paulsen et al., 2014; Tabrizi et al., 2013; Vinther-Jensen et al., 2014; Bates, Tabrizi, & Jones, 2014). Difficulties in recognizing emotional cues and understanding the mental states and intentions of others most likely change how a person perceives, and is perceived by, others, and can lead to problems with social interaction. In fact, HD has often been associated with personality changes and breakdown of interpersonal relationships (Naarding, Kremer, & Zitman, 2001; Snowden et al., 2003), and caregivers are often devastated and frustrated that the patients "are no longer who they used to be." Therefore knowledge and assessment of social–cognitive functions in HD gene expansion carriers are important in order to detect changes and to develop strategies for managing these changes.

Over the last two decades, an increasing number of studies have focused on the ability of HD patients to recognize emotional stimuli such as facial expressions, vocal cues, prosody, odor, and body language (Aviezer et al., 2009; Calder et al., 2010; Henley et al., 2008; Mitchell, Heims, Neville, & Rickards, 2005; Rees et al., 2014; Snowden et al., 2008; Sprengelmeyer et al., 1996; Sprengelmeyer, Schroeder, Young & Epplen, 2006; Stout et al., 2011). Most studies of emotion recognition in HD have studied facial expressions of canonical emotions (i.e., happiness, sadness, surprise, fear, anger, and disgust) using static pictures of faces. Findings have been diverse, some suggesting a disproportionate impairment in disgust recognition (Gray, Young, Barker, Curtis, & Gibson, 1997; Sprengelmeyer et al., 1996), others suggesting a more general impairment in recognition of negative emotional

stimuli (Henley et al., 2008; Johnson et al., 2007; Milders, Crawford, Lamb, & Simpson, 2003; Snowden et al., 2008), and few studies have found impairment in recognition of positive emotional cues (Robotham, Sauter, Bachoud-Lévi, & Trinkler, 2011; Calder et al., 2010; Henley et al., 2008). A recent review of emotion recognition in HD concluded that there is evidence of impaired recognition of facial expressions of all negative emotions, especially anger, in manifest HD gene expansion carriers, and that impairment in premanifest HD gene expansion carriers is inconsistent but may be seen in facial expressions of all negative emotions (Henley et al., 2012).

Within the last few years, a few studies have extended the research on social cognition in HD from simple recognition of basic emotions to more complex social–cognitive skills such as are involved in theory of mind (ToM). Studies of ToM have used cartoons, evaluation of eye gaze, pictures of eyes expressing emotions, and faux pas stories (Allain et al., 2011; Brüne, Blank, Witthaus, & Saft, 2011; Eddy, Sira Mahalingappa, & Rickards, 2012, 2014; Snowden et al., 2003), and have consistently found that manifest HD gene expansion carriers show difficulties in tasks that require interpretation of social situations and attribution of mental states to others. To our knowledge, no studies have yet investigated sarcasm detection in HD. The Awareness of Social Inference Test (TASIT) consists of videos of method actors in everyday situations portraying basic emotions and more complex exchanges such as sarcasm (McDonald, Flanagan, Rollins, & Kinch, 2003). Understanding sarcasm is complicated because it involves both comprehension of the facts of a situation and appreciation of the underlying mental state and intention of the speaker (McDonald, 1999). Patients with frontotemporal dementia and ventromedial prefrontal brain injury have been shown to perform poorly on tests of sarcasm detection (Channon et al., 2007; Kipps, Nestor, Acosta-Cabronero, Arnold, & Hodges, 2009; Shamay-Tsoory, Tomer, & Aharon-Peretz, 2005), and due to the dysfunction of frontostriatal circuits in HD (Alexander, DeLong, & Strick, 1986; Tabrizi et al., 2011), HD gene expansion carriers might be expected to have impairments in sarcasm detection.

The overarching aim of the present study was to investigate social–cognitive functions in both premanifest and manifest HD gene expansion carriers using an extensive battery of tests assessing sarcasm detection, ToM, and emotion recognition. The study aimed: (a) to compare performances on social–cognitive tests in a large consecutive cohort of premanifest and manifest HD gene expansion carriers with healthy controls and (b) to investigate whether performances on tests of sarcasm perception, ToM, and emotion recognition were associated with disease burden score. To our knowledge, this is the first study to investigate ToM in a large consecutive cohort of both premanifest and manifest HD gene expansion carriers. It is, we believe, also the first study to investigate sarcasm detection in HD.

Method

Participants

Participants were recruited from January 2012 to March 2013 from the Neurogenetics Clinic, Danish Dementia Research Centre, Rigshospitalet. One hundred HD gene expansion carriers with a CAG repeat of 39 or more, a Unified Huntington's Disease Rating Scale−99 total motor score (UHDRS-Motor; Huntington Study Group, 1996) of 35 or less, a Mini-Mental State Examination (MMSE) score of 24 or higher, and a Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) score of 19 or higher were included in the study. HD gene expansion carriers with a UHDRS-Motor score more than 5 were classified as *manifest HD gene expansion carriers* (N = 50). If the score was 5 or less, indicating no substantial motor signs, a classification of *premanifest HD gene expansion carrier* (N = 50) was used. The UHDRS-Motor scale was developed to standardize motor rating. Motor signs are evaluated on 31 items, each rated on a 4-point scale, ranging from *normal* to *severe impairment* (Huntington Study Group, 1996).

Exclusion criteria were other neurological illness, ongoing alcohol or drug abuse, and having a native language other than Danish. Thirty-nine at-risk gene expansion negative individuals (offspring of an HD gene expansion carrier and genetically tested with a CAG repeat length of less than 30) were included as healthy controls. This control group was chosen over unrelated healthy controls to better match for social and environmental factors. All individuals had gone through genetic counseling and were informed of their genetic status prior to (and independently of) study enrolment.

Procedure

The study was approved by the Ethics Committee of the Capital Region of Denmark (H2-2011−085), and written informed consent was obtained from each participant before enrollment. All participants had a minimum of two planned visits. At one visit, physical and neurological examinations were performed. At another visit, neuropsychological testing was performed. The two visits were preplanned and performed in random sequence; 83% of the evaluations were performed within 14 days of each other, and only three (2%) of the evaluations were performed more than 3 months apart. The same physician and the same neuropsychologist performed all examinations. The examination by the physician and the examination by the neuropsychologist were performed blinded to one another.

Neuropsychological Testing

All participants were tested with a 3-hr battery of neuropsychological tests, including tests of psychomotor speed, attention, memory, visuospatial functions, and executive functions. The results from these tests have been published elsewhere. (Vinther-Jensen et al., 2014; Larsen, Vinther-Jensen, Gade, Nielsen & Vogel, 2015) An Education Index score was calculated, and premorbid intelligence level was estimated using the Danish Adult Reading Test (DART), an equivalent of the National Adult Reading Test (Nelson & O'Connell, 1978). The battery of social–cognitive tests consisted of measures of emotion recognition, sarcasm detection, and ToM. Emotion recognition was measured using a paper version of the Emotion Hexagon (EH; Sprengelmeyer et al., 1996) and the Emotion Evaluation Task (EET) from TASIT (McDonald et al., 2003). Sarcasm detection was evaluated using the Social Inference−Minimal (SI-M) test from TASIT, and ToM was tested using the revised version of Reading the Mind in the Eyes (RME) test (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). The tests were administered in a fixed order.

Emotion Hexagon. The EH test (Sprengelmeyer et al., 1996 consists of 30 cards with pictures of morphed facial expressions of the six basic emotions: happiness, surprise, fear, sadness, anger, and disgust. Each of the six emotions was represented with four pictures; each picture was morphed with either 10% or 30% of the neighboring emotions (e.g., happiness is morphed with either 10% or 30% anger or surprise). Between two neighboring emotions was a picture morphed with 50% of each emotion; these served as neutral stimuli and were not counted in the raw score. A card with the six emotion words was presented, and each of the six emotions was explained before the pictures were shown to participants. The card with the six emotion words remained visible for participants during the test. The pictures were shown in random order, and participants were asked to choose which of the six emotions best described the facial expression. The pictures were shown only once, and no feedback was given. The total number of correct responses (0–24), the number of correct positive emotions, that is, happiness and surprise (0–8), and the number of correct negative emotions, that is, fear, sadness, anger, and disgust (0–16), were recorded.

Emotion Evaluation Task. The EET (McDonald et al., 2003) consists of 28 short videotaped vignettes (15–60 s) of actors interacting in everyday situations. In some scenes, there is one actor only, and in other scenes, there are two (the participant was told on whom to focus). Participants were asked to choose whether the actor was displaying one of the six basic emotions: happiness, surprise, sadness, anger, fear, or disgust or no particular emotion (neutral). The EET does not exist in a Danish version and therefore the video clips were shown without sound to overcome any differences in English-language abilities. Each video was shown once, and no feedback was given. The total number of correct responses (0–28), the number of correct positive emotions, that is, happiness, surprise, and neutral (0–12), and the number of correct negative emotions, that is, fear, sadness, anger, and disgust (0–16), were recorded.

Social Inference−Minimal. The SI-M (McDonald et al., 2003)[1] Danish version (Blixsted, Fagerlund, Weed, Frith, & Videbech, 2014) consists of short (15–53 s) videotaped vignettes with professional actors interacting in everyday situations. The exchanges are either *sincere* or *sarcastic*. The sarcastic vignettes are either with *simple sarcasm* or *paradoxical sarcasm. Simple sarcasm* means that the vignettes are acted in such a way as to imply the opposite meaning to what is actually being said. For example, one video portrays a male and a female talking about a movie and the male obviously did not like the movie. He shows this by looking very discontented and bored, and his intonation is irritated although he verbally expresses enthusiasm. *Paradoxical sarcasm* means that the exchange of words is meaningless unless one understands that one of the actors is being sarcastic. For example, two men are waiting for the train and one asks the other whether he has remembered his passport, to which the other responds that he tore it up and threw it away; and the first man then says "Good, that's OK then." After each video, the participant was asked four yes/no questions about the interaction. Correct answers to the questions for the sarcastic videos required interpretation of paralinguistic cues, such as tone of voice, and nonverbal cues, such as posture and facial expressions. The test comprises Part A2 and Part B2. Part A2 consists of five videos of paradoxical sarcasm and 10 vignettes that are either sincere or with simple sarcasm. Part B2

consists of the exact same dialogue as the 10 sincere or simple sarcastic videos from Part A2 but with sincerity and sarcasm switched. For this study, participants were shown all 25 videos. Each video was shown once, and no feedback was given. Number of correct yes/no answers for each type of video was recorded, resulting in four different outcomes: Paradoxical Sarcasm score (0–20), Sincere score (0–40), Simple Sarcasm score (0–40), and SI-M total (0–100).

RME test. The RME revised version (Baron-Cohen et al., 2001) consists of 36 photos of eyes expressing different emotional states. Participants were given four choices of words and were asked to pick the word that best described what the eyes were expressing (e.g., serious, ashamed, alarmed, bewildered). To pick the right emotion, the participant needed to attribute mental states to others, thereby using ToM. Participants were also given a list of explanations of all words in the test, and were encouraged to look up the words if they felt uncertain of the meaning of a word. The number of correct responses was recorded (0–36).

Statistical Analysis

Group comparisons were performed using either one-way analysis of variance or the Kruskal−Wallis test. To control for the risk of Type II errors, an alpha level of .05 and either Dunnett's t test (2-sided) or a Bonferroni correction were applied for post hoc comparisons. Between-group differences on the neuropsychological measures were evaluated using analyses of covariance (ANCOVAs), controlling for sex, education, age, DART score, and an Age $\times$ Status interaction effect.

Effect sizes (Cohen's d) were calculated by the following formula (Field, 2013):

Effect size = (Mean HD group − Mean control group)/(Pooled SD)

The CAG-Age Product Scaled (CAPs) score, formulated by the PREDICT-HD study (Zhang et al., 2011), is a disease burden score and can be interpreted as a surrogate measure of the cumulative toxicity of mutant huntingtin (Zhang et al., 2011). We calculated a CAPs score for all HD gene expansion carriers to investigate the correlation between disease burden and cognitive performance irrespective of motor symptoms (i.e., by which the HD groups were originally classified).

The CAPs was calculated by the following equations:
$CAPs = age_0 \times (CAG - 33.6600)$ and $CAPs = CAPs/432.3326$
Pearson's r and Spearman's rho (r_s used for skewed distributions) were used to assess the level of significance of correlations between the CAPs score and performances on the RME, EH total, SI-M total, and EET total.

A correlation matrix was developed from the correlations between performances on the social–cognitive tests in the HD gene expansion carriers, and stepwise regression analysis was performed with CAPs score as dependent variable and RME, EH total, SI-M total, and EET total as independent variables.

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[1] *The Awareness of Social Inference Test (TASIT)*: *Danish Translation* Copyright © (2008) by Skye McDonald, Sharon Flanagan and Jennifer Rollins, published by Pearson Assessment; Copyright © 2011 by Skye McDonald, Sharon Flanagan and Jennifer Rollins. Reproduced with permission from Pearson, Assessment. All rights reserved.

Results

Table 1 shows the background information for HD gene expansion carriers and healthy controls. Small but statistically significant differences were found for age and education, MoCA scores, and MMSE scores between the manifest HD gene expansion carriers and the premanifest HD gene expansion carriers and healthy controls. The former also had significantly lower DART scores than the healthy controls.

Table 2 shows the results from the social–cognitive tests before ANCOVA. The manifest HD gene expansion carriers scored significantly lower on all neuropsychological tests, except for the EH positive emotions, than healthy controls. Effect sizes in Table 2 show a substantial effect (>1) on most tests in manifest HD gene expansion relative to controls. After controlling for sex, education, age, DART score, and an Age $\times$ Status interaction effect by ANCOVAs (taking family-wise Type II risks into account), the group comparisons between healthy controls and the manifest HD gene expansion carriers remained significant on all tests, except for the EH positive emotions and the SI-M Paradoxical Sarcasm scores. There were no significant differences on any of the social–cognitive tests between the premanifest HD gene expansion carriers and healthy controls.

Figures 1–4 show the correlations between CAPs score and performances on the RME, EH total, SI-M total, and EET total for all HD gene expansion carriers. There was a significant negative correlation between CAPs score and performance on all tests ($p < .001$), indicating that performances on these four measures decrease when the cumulative toxicity of mutant huntingtin (disease burden) increases. The variance in test score explained by CAPs score was 27% for RME, 33% for EH total, 32% for SI-M total, and 27% for EET total.

For the premanifest HD gene expansion carriers alone, there was a significant negative correlation between CAPs score and RME ($p = .015$), EH total ($p = .006$), and SI-M total ($p = .007$); and for the manifest HD gene expansion carriers, there was a significant negative correlation between CAPs score and EH total ($p = .029$), EET total ($p = .029$), and SI-M total ($p = .048$).

Table 3 shows the correlation matrix of performances on the social–cognitive tests in the HD gene expansion carriers. Performances on all four tests correlated significantly to each other.

Table 4 shows the results from the stepwise linear regression model with CAPs score as dependent variable and the four social–cognitive tests as independent variables. We found that the significant negative association between CAPs scores and EH total and SI-M total remained whereas RME and EET were excluded from the model.

Discussion

Behavioral changes and cognitive decline can occur many years before the onset of motor symptoms in HD (Paulsen et al., 2013; Paulsen et al., 2014; Tabrizi et al., 2013; Vinther-Jensen et al., 2014; Bates et al., 2014). Social–cognitive functions are thought to be mediated in part by the ventromedial prefrontal cortex and could be expected to be impaired in HD due to dysfunctions of the frontostriatal circuits. Many studies have found impairments in emotion recognition to be among the earliest cognitive dysfunctions in HD (Dumas, van den Bogaard, Middelkoop, & Roos, 2013; Paulsen, 2011; Stout et al., 2011). Only a few studies have investigated more complex social–cognitive skills such as ToM and, to our knowledge, in manifest HD patients only (Allain et al., 2011; Brüne et al., 2011; Eddy et al., 2012; Eddy et al., 2014; Snowden et al., 2003). Social–cognitive impairments undoubtedly change a person's ability to enter into social situations on equal terms with others, and can lead to difficulties in social interactions and great frustration for both patients and caregivers. Therefore assessment of social–cognitive functions in HD gene expansion carriers is important to detect changes and to develop strategies for managing these changes.

We found significant differences in performances on all social–cognitive tests (except EH positive emotions and the SI-M Paradoxical Sarcasm scores) between manifest HD gene expansion carriers and healthy controls, and effect sizes showed a substantial effect (>1) on most tests in manifest HD gene expansion carriers relative to controls. We found no significant

Table 1

Background Information for HD Gene Expansion Carriers and Healthy Controls

Variable	Healthy controls ($n = 39$)	Premanifest HD gene expansion carriers ($n = 50$)	Manifest HD gene expansion carriers ($n = 50$)
Sex (male/female)	17/22	29/21	30/20
Age (years)	41 (20–68)	37 (20–54)[**]	51 (24–75)[*]
Education Index	14 (10–17)	14 (11–17)[**]	13 (8–17)[*]
DART score	27 (13–44)	24 (7–38)	23 (1–41)[*]
MMSE score	30 (27–30)	29 (26–30)[**]	28 (24–30)[*]
MoCA score	28 (25–30)	28 (20–30)[**]	26 (21–30)[*]
CAG repeat	19 (17–26)	42 (39–48)[*]	43 (40–53)[*]
UHDRS-Motor score	0 (0–4)	2 (0–5)[**]	20 (6–41)[*]
CAPs score	NA	0.7 (0.3–1.2)[**]	1.1 (0.5–1.7)

Note. Results are median (range) unless otherwise indicated. CAPs = CAG-Age Product Scaled; DART = Danish Adult Reading Test; HD = Huntington disease; MMSE = Mini-Mental State Examination; MoCA = Montreal Cognitive Assessment; NA = not applicable; UHDRS-Motor = Unified Huntington's Disease Rating Scale−Total Motor.
[*] Significant difference from healthy controls, $p < .05$ (corrected for multiple comparisons). [**] Significant difference from manifest HD gene expansion carriers, $p < .01$ (corrected for multiple comparisons).

Table 2
Test Performances for HD Gene Expansion Carriers and Healthy Controls

Social cognitive tests	Healthy controls ($n = 39$)	Premanifest HD gene expansion carriers ($n = 50$)	Manifest HD gene expansion carriers ($n = 50$)	Effect size (Cohen's d)[a]
RME test	24.3 (3.5)	25.1 (3.9)	19.2 (4.5)*	−1.2
EH total	18.6 (2.6)	18.8 (2.5)	15.0 (3.0)*	−1.3
EH positive emotions	7.4 (.9)	7.6 (.6)	7.0 (1.1)	−0.4
EH negative emotions	11.3 (2.4)	11.1 (2.3)	8.0 (2.6)*	−1.3
EET total	22.5 (3.6)	23.4 (2.6)	18.8 (3.7)*	−1.0
EET positive emotions	9.8 (1.7)	10.2 (1.2)	9.2 (1.4)*	−0.4
EET negative emotions	13.3 (2.5)	13.2 (1.9)	9.6 (2.9)*	−1.4
SI-M total	89.2 (6.7)	90.8 (5.0)	76.1 (11.7)*	−1.3
Sincere score	34.3 (4.2)	35.8 (3.3)	27.7 (8.7)*	−0.9
Paradoxical Sarcasm score	18.7 (2.0)	18.8 (1.1)	17.7 (2.0)*	−0.5
Simple Sarcasm score	36.5 (3.0)	36.0 (2.9)	30.7 (5.6)*	−1.3

Note. Results are mean (standard deviation). EET = Emotion Evaluation Task; EH = Emotional Hexagon; HD = Huntington disease; RME = Reading the Mind in the Eyes; SI-M = Social Inference−Minimal.
[a] Cohen's d values were calculated for manifest HD gene expansion carriers relative to healthy controls; negative numbers indicate worse performance relative to controls.
* Significant difference from healthy controls, $p < .05$ (corrected for multiple comparisons).

differences in performances on any of the social–cognitive measures in premanifest HD gene expansion carriers relative to healthy controls. Nevertheless, correlation analysis showed that worse performances on emotion recognition, ToM, and sarcasm detection tasks were associated with higher disease burden scores in premanifest as well as manifest HD gene expansion carriers, both singly and combined.

Social Cognition in Manifest HD Gene Expansion Carriers

A recent review concluded that recognition of facial expressions of all negative emotions is impaired in manifest HD gene expansion carriers (Henley et al., 2012). A few recent studies have investigated ToM using the RME (Allain et al., 2011; Eddy et al.,
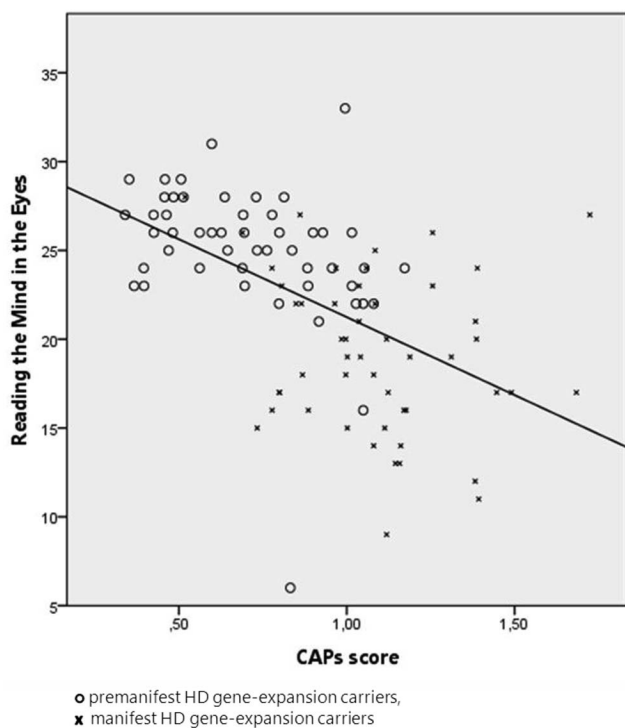

Figure 1. Correlation between the Reading the Mind in the Eyes test and CAG-Age Product Scaled (CAPs) score for the premanifest and manifest Huntington disease (HD) gene expansion carriers ($r = -.522$, $p < .001$).
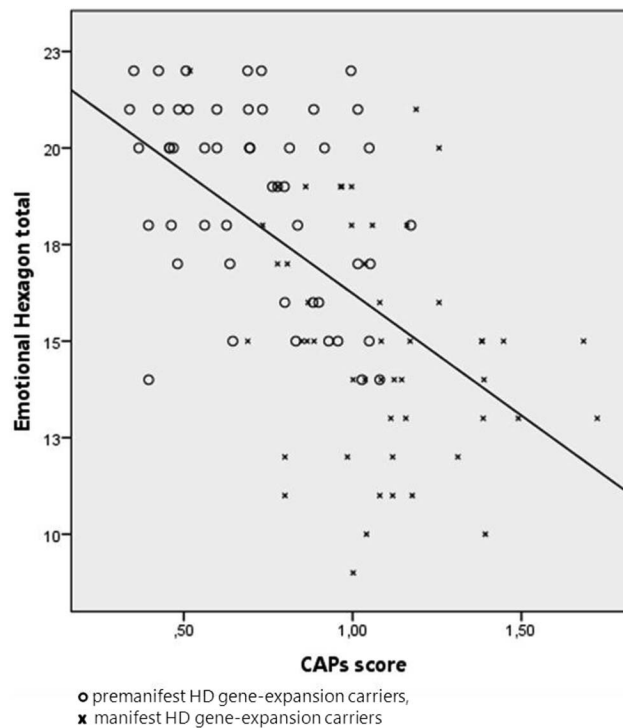

Figure 2. Correlation between the Emotional Hexagon and CAG-Age Product Scaled (CAPs) score for the premanifest and manifest Huntington disease (HD) gene expansion carriers ($r_s = -.598$, $p < .001$).
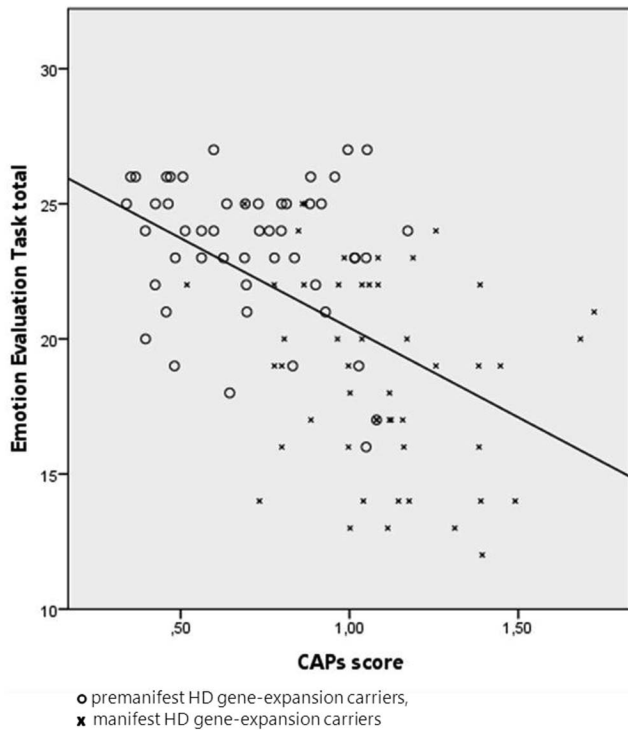
Figure 3. Correlation between the Emotion Evaluation Task and CAG-Age Product Scaled (CAPs) score for the premanifest and manifest Huntington disease (HD) gene expansion carriers ($r_s = -.545$, $p < .001$).

2012; Eddy et al., 2014) and all found impaired performances in manifest HD subjects. Our results (from a large group of manifest HD gene expansion carriers) are in accord with previous findings and support the contention that deficits in recognition of negative emotions and ToM appear early in HD.

To our knowledge, sarcasm detection has not previously been investigated in HD. Understanding sarcasm poses high demands on social interpretation skills, because one needs to understand both the facts and the underlying emotions and intentions of the speaker. The SI-M uses videos of method actors in everyday situations, and impairments on this test may resemble the everyday problems experienced by HD patients and their caregivers more closely than static images, cartoons, or stories.

The group of manifest subjects scored significantly worse than healthy controls on the simple sarcasm videos and the sincere videos, but not on the paradoxical sarcasm videos of the SI-M after ANCOVA. This differs from findings from other patient groups. Patients with schizophrenia, frontotemporal dementia, Alzheimer disease, and traumatic brain injury have been found to be impaired in detecting both simple and paradoxical sarcasm, but they perform at level with controls on the "sincere" videos (Bliksted et al., 2014; Buhl, Stokholm, & Gade, 2013; Kipps et al., 2009; McDonald et al., 2003). The exchanges of words in the paradoxical sarcastic videos are meaningless unless one understands that the speaker is being sarcastic. In this sense, they differ significantly from the simple sarcastic (and sincere) videos where the exchanges of words are instead ambiguous and it is necessary to interpret the emotional cues in order to understand what the speaker is trying to

convey. That the manifest HD gene expansion carriers show impairments on the sincere and the simple sarcastic videos but not on the paradoxical sarcasm videos indicates that the impairments seen in HD may relate to emotional situations that are ambiguous more than it relates to understanding sarcasm per se. At times it seemed that interpretations of ambiguous situations were quite unconventional. For example, the video portraying a male and a female talking about a movie (see example in the Method section). The conventional interpretation would be that he does not agree with her about the movie and that he did not like it. The comment "he has not even seen the movie, he is just pretending that he has seen it" suggests a completely different interpretation of the situation and the man's intentions. In a comparison of patients with HD and patients with frontotemporal dementia on interpretation of cartoons and story comprehension, it has been described that HD patients misconstrued the situations and made unconventional interpretations of the feelings and beliefs of the characters (Snowden et al., 2003). This indicates that there may be a specific social–cognitive impairment in HD related to misconstruing ambiguous social and emotional cues. Knowledge of such difficulties, if this observation proves valid, could help us better understand the problems with social interactions often associated with HD.

Social Cognition in Premanifest HD Gene Expansion Carriers

Cross-sectional studies of emotion recognition in premanifest HD gene expansion carriers have shown inconsistent results. We
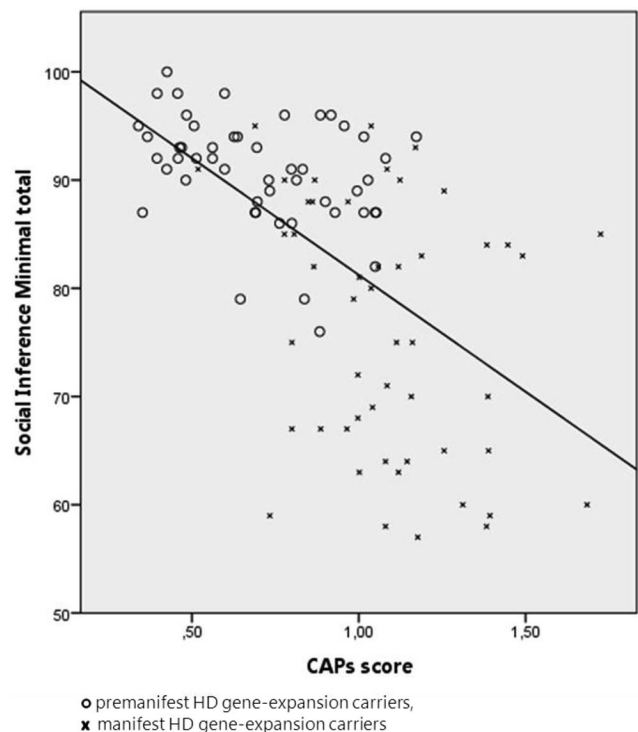

Figure 4. Correlation between the Social Inference−Minimal total and CAG-Age Product Scaled (CAPs) score for the premanifest and manifest Huntington disease (HD) gene expansion carriers ($r_s = -.569$, $p < .001$).

Table 3
Correlation Matrix of Social Cognitive Tests

Social cognitive tests	Emotion Hexagon total	Reading the Mind in the Eyes test	Emotion Evaluation Task total	Social Inference−Minimal total
Emotion Hexagon total	1			
Reading the Mind in the Eyes test	.68	1		
Emotion Evaluation Task total	.68	.72	1	
Social Inference−Minimal total	.57	.62	.65	1

Note. Results are Spearman's rho.

did not find impaired emotion recognition in premanifest HD gene expansion carriers. This is in line with other studies (Kipps, Duggins, McCusker, & Calder, 2007; Milders et al., 2003). We are unaware of any other studies investigating ToM or sarcasm detection in premanifest HD gene expansion carriers. We found no evidence of impaired ToM or sarcasm detection in the premanifest subjects, suggesting that either ToM and sarcasm detection are not significantly impaired in premanifest HD gene expansion carriers, or that the tests applied in this study are not sensitive enough to detect what may be small differences.

Disease Burden and Social Cognitive Functions

CAPs score is a disease burden score based on age and CAG repeat length, and it is most often used as a measure of the time to predicted motor onset. It can also be interpreted as a surrogate measure of the cumulative toxic effect of a person's exposure to mutant huntingtin, where a higher CAPs score means a larger and/or more prolonged exposure to mutant huntingtin (Zhang et al., 2011). We calculated a CAPs score for all HD gene expansion carriers to investigate the correlation between disease burden and cognitive performance irrespective of motor symptoms. Using disease burden scores instead of grouping subjects into premanifest and manifest HD gene expansion carriers may overcome some of the difficulties in comparing results between studies in HD. There is no consensus in the HD literature about the UHDRS-Motor score cutoff for inclusion in either group, and, even for large studies such as PREDICT-HD and TRACK-HD, the mean UHDRS-Motor scores in premanifest subjects are quite different (Stout et al., 2011; Tabrizi et al., 2011).

We found significant negative correlations between CAPs score and performances in both premanifest and manifest HD gene expansion carriers. The stepwise linear regression model showed that the significant negative association between CAPs score and EH total and SI-M total remained significant, whereas EET total and RME were excluded from the model. This indicates that performance on emotion recognition and sarcasm detection decreases with increasing disease burden. Therefore, even though we

found no significant mean differences between the premanifest subjects and the healthy controls, these correlational findings indicate that social–cognitive functions decrease over time in HD and that social–cognitive tests may be good measures of disease progression and potentially useful for follow-up assessments of individual patients in the clinic. This is in line with findings from emotion recognition tasks in PREDICT-HD and TRACK-HD, where longitudinal data have shown significant decrease in performance in premanifest subjects over time (Paulsen et al., 2014; Tabrizi et al., 2013).

Limitations

This study was cross-sectional, and to make firm conclusions about the utility of these tests for following patients in HD clinics, a longitudinal study would be preferable. Other limitations to the study relate to the tests used. The Danish version of TASIT was developed for research purposes and it has not been standardized and validated. This must, of course, lead to caution when interpreting results. Sarcasm as a part of everyday interaction is somewhat culture specific and thus generalization to all other cultures may be limited. The EET of the TASIT does not exist in a Danish version and thus was used without sound. Although our evaluation was that the test was still meaningful, the use of the test in a form different from the original requires caution when interpreting the results. Also the tests were administered in a fixed order rather than counterbalanced, which may have caused latter test performances to be influenced by the tests already administered.

Conclusion

We found that performance on social–cognitive measures decreases with increasing disease burden in HD, and our results indicate that, although social–cognitive deficits may not be among the earliest cognitive deficits in HD, such tests may be useful for tracking disease progression. Based on our results, it seems that simple emotion recognition tasks are just as sensitive for measuring social–cognitive deficits as more complex ToM and sarcasm

Table 4
Stepwise Linear Regression Results

Dependent variable	Model predictor variables	b_i	$SE(b_i)$	p	R^2
CAPs score	Emotion Hexagon total	−.033	.009	.000	.40
	Social Inference−Minimal total	−.009	.003	.001	

Note. CAPs = CAG-Age Product Scaled.

detection tasks, although the latter may contribute to a better understanding of the quality of social–cognitive impairments in HD. Our findings support a theory of impaired social–cognitive functions in the early stages of HD, which may be caused by dysfunction of the frontostriatal circuits. Knowledge of such difficulties can help us better understand the problems with social interactions often associated with HD and can, therefore, be of great importance to both patients and caregivers. Thus, assessment of social–cognitive impairments in HD gene expansion carriers is important in order to detect early changes, to track disease progression, and to counsel and support of HD patients and their caregivers.

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