Emotional Gaze in Frontotemporal Lobar Dementia

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Abstract

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Frontotemporal lobar dementia (FTLD) is a neurodegenerative disease that affects the frontal and temporal regions of the brain. Behavioral characteristics of FTLD include reduced reactivity to emotional stimuli and decreased ability to recognize emotional states in others. Though emotional deficits have been documented in FTLD, little is known about where the breakdown in emotional processing occurs. The present study assessed whether deficits occur at the level of attention deployment and whether attention to emotional cues can predict performance on tests of emotional reactivity and emotion recognition in a sample of 23 FTLD patients and 24 normal controls. Eye movements were tracked during viewing of emotional stimuli, as a proxy of visual attention to emotional cues. Latency of first fixation and percent tracked time were assessed. In a paired-faces task, where participants viewed emotional and neutral faces side-by-side, FTLD patients showed a lack of attentional preference for negative emotional information by gazing equally at negative and neutral faces. In an emotional faces task, where participants viewed a series of emotional faces, FTLD patients spent less time gazing at the eye region of negative faces than controls did. Latency of first fixation at
the eyes of a positive face predicted physiological reactivity to that face and time spent
gazing at the eyes of a positive face predicted caregiver ratings of positive emotional
reactivity in daily life. Time spent gazing at the eyes of negative faces predicted
physiological reactivity to negative film stimuli and recognition of negative emotions in
faces. Time spent gazing at negative faces in the paired faces task predicted caregiver
ratings of negative emotion recognition in daily life. Results of the present study show
deficits in emotional gaze in FTLD compared to controls and suggest that reduced
attention to emotional cues negatively impacts higher-order aspects of emotional
functioning, including emotional reactivity and emotion recognition.
Introduction

What is FTLD?

Frontotemporal Lobar Degeneration (FTLD) encompasses a group of neurodegenerative disorders that primarily affect the frontal and/or temporal regions of the brain. Prevalence of FTLD among older adults screened for dementia is estimated at 3-10% (Sjogren & Anderson, 2006), with mean age of onset between 45 and 65 years (Neary, 2005; Sjogren & Anderson, 2006). Sex distribution is thought to be equal (Neary, 2005), although some studies report greater occurrence in men than women (Harciarak & Jodzio, 2005). In contrast to Alzheimer’s disease, which is the most common form of dementia among people over 65, FTLD is thought to be the most common dementing disease under the age of 65 (Boxer & Miller, 2005; Ratnavalli et al, 2002). Studies also suggest that FTLD has a strong hereditary component, with a family history present in 40-50% of cases (Neary, 2005).

FTLD can be further divided into three subtypes: 1) frontotemporal dementia (FTD), 2) semantic dementia (SD), and 3) progressive non-fluent aphasia (PNFA) (Neary et al, 1998). FTD is characterized by prominent bilateral degeneration of the frontal lobes and changes in behavior and personality. SD is characterized by anterior temporal atrophy and the occurrence of fluent empty speech (i.e., effortless speech with frequent paraphasias). PNFA is characterized by predominantly left-sided frontotemporal loss and progressively reduced speech that is effortful and halting. The neuropathology underlying FTLD may involve argyrophilic inclusions (Pick bodies), positive for tau or ubiquitin (McKann, 2002; Davies, 2005). Mutation in genes (or “the gene”) that regulate tau have been found in 10-30% of patients with a family history of FTLD (Sjogren &
Andersen, 2006), suggesting that the tau gene plays an important role in familial transmission of the disease. Recent evidence also suggests that mutations in the progranulin gene are closely linked with tau-negative cases of FTLD (Baker et al, 2006).

Clinically, FTLD is thought to be distinguishable from other dementias (such as Alzheimer’s disease) based on the profound changes in personality and behavior toward others that occur in FTLD. For example, FTLD patients often show loss of empathy, lack of insight, increased self-centeredness and increased impulsiveness (Neary 2005; Boxer & Miller, 2005). By comparison, Alzheimer’s patients typically show preserved insight and social affiliation, though they may experience increases in depression (Grossman, 2002). FTLD patients can also display repetitive stereotyped behaviors and changes in appetite and food preference (Sjogren & Andersen, 2006). On tests of cognitive ability, FTLD patients show impaired executive functioning (e.g., planning, reasoning, set-shifting, and abstraction), but preserved memory and visuospatial skills (Neary, 2005, Boxer & Miller, 2005). Cognitive deficits associated with FTLD can often go undetected by tests of general mental status (Rascovsky et al, 2002). By contrast, Alzheimer’s patients show significant impairment on explicit learning, memory, and visuospatial tasks (Harciarak & Jodzio, 2005). The marked contrast between cognitive profiles of FTLD and Alzheimer’s disease may be attributable to the neuroanatomical differences between the disorders. In FTLD, deficits in executive functioning are likely mediated by degeneration of the frontal lobes. In Alzheimer’s disease, executive functions are initially spared, but damage cause by neuritic plaques and neurofibrillary tangles in medial temporal and parietal regions likely result in memory and visuospatial deficits (Maccioni et al, 2001; Braak & Braak 1995; Rascovsky et al, 2002).
Emotion & FTLD

Though changes in the social and emotional lives of patients appear to be what is most clinically compelling in FTLD, the nature and extent of these changes are not yet well understood. Only recently have studies begun characterizing the specific aspects of emotional functioning that are impacted in this disease. Because deficits in emotional functioning may be characteristic of FTLD, but not other neurodegenerative disorders (Lavenu et al, 1999, Fernandez-Duque & Black, 2005), testing for these deficits could aid in the process of differential diagnosis. Moreover, because areas of neural loss are fairly circumscribed (to the frontal and temporal lobes) in early stages of FTLD, it may be possible to link loss of specific emotional functions to tissue losses in specific brain areas. In this way, studies of dementia patients may also inform what is known about the general neural circuitry of emotion.

Broadly speaking, the skills and abilities that compromise emotional functioning can be parsed into three categories: emotional reactivity, emotion recognition, and emotion regulation. Emotional reactivity involves the ability to respond to emotionally evocative stimuli in appropriate ways (e.g., running away at the sight of a snake). Clinical observations of emotional bluntness and apathy suggest that emotional reactivity is impaired in FTLD patients. Through behavioral interviews and rating scales, caregivers report increases in interpersonal coldness (Rankin et al, 2003) and reduced expression of emotion among FTLD patients (Snowden et al, 2001). Laboratory studies that induce emotion through the presentation of evocative film clips have found that FTLD patients show intact reactivity to very simply themed happy, sad, and fear inducing films (Werner et al, 2007), but reduced reactivity to disgust films (Eckart et al, in prep).
In a study where participants were startled with a loud unexpected noise, FTLD patients showed a typical fear response to the noise, but a reduced secondary self-conscious response to the realization that they had been startled (Sturm et al, 2006). Also, in a study where participants performed a karaoke task known to elicit self-conscious emotion, FTLD patients showed diminished self-conscious behavior (i.e., embarrassment and amusement) and diminished physiological responding (Sturm et al, 2008). These clinical and laboratory data suggest that deficits in emotional reactivity may be nuanced and complex in FTLD. Though responses to simple stimuli evoking primitive emotions may remain intact, emotional responses involving greater cognitive processing may be compromised.

Another important aspect of emotional functioning is the ability to recognize emotional states in others. Emotion recognition requires both attention to relevant cues (e.g., facial expressions) and correct interpretation of these cues (e.g., down-turned lips indicate sadness). Thus far, the majority of research on emotion recognition in FTLD has centered on patients’ ability to identify specific emotions in photographed faces. Studies have consistently shown that, compared to controls (including neurologically normal and Alzheimer’s disease patients), FTLD patients have trouble recognizing negative emotional expressions, including anger, fear, sadness, and disgust (Lavenu et al, 1999; Keane, 2002; Rosen et al, 2004; Fernandez-Duque & Black 2005; Kessels et al, 2007; Diehl-Schmid et al, 2007). In a study where static neutral faces were morphed into emotional ones (mimicking the formation of an emotional expression), FTLD patients also showed impaired recognition of anger and disgust (Lough et al, 2006). Findings regarding FTLD patients’ ability to recognize positive emotion in faces are mixed. Some
studies report an intact ability to recognize happiness (Fernandez-Duque & Black, 2005, Rosen et al, 2006), whereas others report recognition deficits (Keane et al, 2002; Diehl-Schmid et al. 2007). Moreover, research has shown that impaired recognition of negative emotion in faces is correlated with specific areas of neural loss, including bilateral amgydala loss in a sample of SD patients (Rosen et al, 2004) and decreased tissue content in the lateral right inferior and middle temporal gyri in a combined sample of FTLD, Alzheimer’s, and control participants (Rosen et al, 2006). Thus, there is growing evidence to suggest that emotion recognition is impaired in FTLD, particularly in the case of negative emotions, and these impairments may be tied to specific areas of neural loss.

A third important aspect of emotional functioning is the ability to adjust or regulate one’s emotional response to meet the demands of the situation. For example, after spotting a snake in the grass, one might realize it would not be advantageous to emit a full-blown fear response (i.e., scream and run away), but rather it would be safer to suppress that response and slowly back away from the snake. Similarly, people use social cues to regulate their emotional responses. From an early age, we learn what emotions are appropriate and not appropriate to express in different social situations. In clinical observations, FTLD patients commonly exhibit disinhibited emotional behavior, including excessive talking and laughing and inappropriate sexual or aggressive behavior (Neary et al, 1998). There is also some empirical evidence to suggest that emotion regulation is disrupted in FTLD. In a study by Goodkind et al. (in press), FTLD patients and control participants were startled by a loud unexpected noise. When they heard this noise, patients and controls exhibited a similar degree of response. They were then warned they would hear the noise again and cued about when the noise was coming (but
not told what to do about it). In this condition, FTLD patients showed as large a startle response as they did in the first condition, whereas control subjects showed a decreased response. In a third condition, participants were instructed to suppress their reaction to the noise. This time, both patients and controls showed a decrease in startle response. These data suggest that FTLD patients do not “automatically” regulate their emotional responses, but when given explicit instructions, they are able to reduce the intensity of their emotional reactions.

**Emotional gaze**

An important component of both emotional reactivity and emotion recognition is attention to emotional stimuli in the environment. In other words, in order to react fearfully to the presence of a snake, one must be able to detect that a snake is in the vicinity. In order to recognize that another person is feeling happy, one must have access to emotional cues, such as a smiling face. Much of the information in everyday life (including emotional information) is communicated visually. Thus, there are many types of information competing for our visual attention. Previous research has shown that basic visual qualities of an object can influence our allocation of attention to that object. For example, images with high visual contrast, high spatial frequency, and the appearance of movement tend to have attentional priority over other stimuli in the environment (Franconeri, Hollingworth, & Simmons, 2005). Visual attention can also be influenced by more abstract qualities, such as novelty. Research shows that people devote more visual attention to novel than familiar objects (Yantis, 1993). In addition, studies suggest that emotional information can play an important role in the allocation of visual attention. Studies that have quantified eye movements have shown that when emotional (e.g.,
photograph of pointed gun) and non-emotional (e.g., photograph of an empty chair) images are presented side-by-side, people tend to look first and look longer the emotional image than the non-emotional image (Calvo & Lang, 2004; Rosler et al, 2005; Nummenenena et al, 2006). These data support the idea that emotional information holds special saliency in the environment and tends to attract visual attention.

There are many ways in which emotion can be communicated visually, ranging from the very subtle (e.g., hair raising on one’s skin) to the overt (e.g., clenching and shaking one’s fist). Moreover, humans (and some non-human primates) have developed a highly elaborate system of facial muscle movements that quickly and reliably communicate emotional states. In this system, coordinated contraction and relaxation of various muscle groups produce visible changes on the face that express a range of specific emotions. For example, contraction of the brow muscle (drawing the eye brows down and together) combined with contraction of muscles around the mouth (pressing the lips together) communicates a state of anger. In contrast, drawing the eyebrows up and together, in combination with pulling the lip corners down, communicates a state of sadness. Facial expressions provide an economical way of communicating information about internal states, as well as about threat and safety in the environment. There is evidence that agreement about the specific emotions communicated by facial displays is universal across gender, age, and cultural groups (Matsumoto & Willingham, 2006; Izard, 1994; Ekman & Friesen, 1971).

Though the ability to recognize emotion in faces is well-established, relatively little is know about how people visually process emotional facial expressions. Preliminary data suggest that people tend to scan emotional faces in a triangular pattern,
moving rapidly between the eyes and the mouth (Marsh & Williams, 2006; Adolphs et al, 2005). Indeed, many of the muscles involved in forming emotional expressions can be found in these regions of the face. Moreover, gazing at the eyes may be particularly important for identifying the specific emotion expressed in a face. In a study by Adolphs et al. (2005), a patient with bilateral amygdala damage was found to have difficulty recognizing fearful expressions in faces. Eye tracking data revealed that under free-viewing conditions, this patient tended to look less at the eye region, compared to controls. When the patient was instructed to look specifically at the eye region, her ability to recognize fear in faces reached normal levels. These data suggest that gaze patterns play an important role in collecting information necessary for making judgments about emotion. Furthermore, damage to specific neural structures may alter gaze patterns and subsequently disrupt the information collection process.

**Gaze & visual attention**

Gaze patterns are comprised of eye movements, which have also been studied as a proxy of visual attention. Under most circumstances, eye movements and shifts in visual attention are thought to occur in sync. When attending to a stimulus in the environment, we are motivated to gather more information about that stimulus. Eye movements help center the image of the stimulus on the fovea (the area of the retina with highest visual acuity), allowing for heightened perception of that stimulus and improved information gathering. Studies have also shown that eye movements and attention are associated with the same neural circuitry, comprised of connections between the frontal eye fields (FEFs) and posterior parietal cortex (PPC) (Corbetta et al, 1998; Moore & Fallah, 2001). In tasks where eye movements and shifts in attention were dissociated from one another, as
in the case of covert attention, both the FEFs and PPC showed increased activity (Corbetta et al, 1998). This close association between eye movements and visual attention suggests that the study of emotional gaze, or the pattern of eye movements exhibited during viewing of an emotional stimulus, might provide important information about how people process visual emotional stimuli. As a proxy of visual attention, eye movements might answer questions about the saliency of emotional cues in our environment (i.e., do emotional stimuli attract special attention?). Eye movements might also tell us more about what features of a stimulus (e.g., eye region of a face) are important for identifying emotion.

**Disturbances in emotional gaze**

Previous research suggests that emotional gaze provides important clues about how emotional information is processed. Thus, gaze patterns may provide additional insight into psychiatric disorders, for which disturbances in emotion processing are implicated. For example, Rinck et al. (2006) found that when a phobic stimulus (e.g., a picture of a spider) and a neutral stimulus are presented side-by-side, people with specific phobia are more likely to look first at the phobic stimulus, compared to controls. However, over the course of the trial, people with specific phobia spent less time looking at the phobic stimulus, in total, compared to controls. This type of gaze pattern reflects both the hypervigilant and avoidant information processing styles associated with specific phobia. Moreover, in a study where positive and negative emotional pictures were paired with neutral ones (Caseras et al, 2007), participants with dysphoria were found to look longer at negative pictures than controls, suggesting that people experiencing dysphoria have a selective bias for attending to negative emotional information. Given that our
behavior and affective states are shaped by the information we take in from the environment, over or under-attention to specific types of information may influence how we feel and function in the world. Using eye movement data, Nacewicz et al. (2006) found that under free-viewing conditions, adults diagnosed with autism spent less time looking at the eyes of faces, compared to controls. This tendency to avoid looking people in the eyes might contribute to social deficits associated with autism because engaging in eye contact is important for regulating social interactions (Emery, 2000) and gazing at the eyes may be critical for understanding the emotional states of others (Adolphs et al, 2005).

The integrity of the eye movement system can be disrupted by neurological damage and disease. For example, lesions in the frontal and parietal lobes can disrupt visual attention to novel stimuli (Knight, 1997; Daffner et al, 2003). Patients with certain neurodegenerative disorders, such as progressive supranuclear palsy (PSP) and Alzheimer’s disease, can develop impairments in eye movement abilities. Patients with PSP (a tau-protein disorder affecting subcortical regions of the brain) often lose the ability to make voluntary vertical eye movements and exhibit involuntary intrusive eye movements during steady gaze (Leigh & Zee, 2006). A subgroup of Alzheimer’s patients can develop symptoms of Balint’s syndrome (a neurodegenerative condition affecting the posterior parietal lobes), which include difficulty initiating eye movements and impaired visual scanning (Leigh & Zee, 2006). Damage to the temporal region of the brain may also produce changes in gaze patterns, particularly in the case of emotional gaze. There is evidence to suggest that subcortical structures (including the superior colliculus, pulvinar, and amygdala) play a significant role in processing visual emotional
information. Studies have found that patients who are cortically blind (lack conscious perception of visual stimuli due to damage to the primary visual cortex) can still detect and discriminate among emotional faces (Johnson, 2005; Morris et al, 2001). Moreover, damage to these subcortical structures may produce changes in emotional gaze, as evidenced by the previously mentioned study by Adolphs et al. (2005), which showed abnormal visual scanning of emotional faces in a patient with bilateral amygdala damage. It follows that focal damage to the temporal region of the brain due to neurodegenerative disease (as in the case of FTLD) may also impact visual scanning of emotional images.

**Emotional gaze & FTLD**

Emotional gaze remains largely unexplored in FTLD. Though selective deficits in emotional reactivity, emotion recognition, and emotion regulation have been found in these patients, little is known about their emotional gaze. However, the clinical presentation of FTLD provides grounds to suspect that patients will show disturbances in emotional gaze. Clinical observations of apathy and emotional blunting in FTLD patients (Neary et al, 1998) suggest that emotional cues become less salient as the disease progresses. Patients not only have difficulty recognizing emotional states in others, but also appear to be disinterested in how others are feeling (Neary 2005; Boxer & Miller, 2005; Rankin et al, 2003). Such lack of “interest” in emotion may be reflected by distribution of gaze during viewing of emotional and non-emotional stimuli. Previous studies using eye gaze as a proxy of visual attention have found that, for healthy adults, emotional images attract more attention than visually matched neutral images (Calvo & Lang, 2004; Rosler et al, 2005; Nummenena et al, 2006). If emotion is no longer salient
or interesting for FTLD patients, one would expect the distribution of gaze between emotional and non-emotional images to be equal.

Multiple studies have shown that FTLD patients have difficulty identifying specific emotions in faces (Lavenu et al, 1999; Keane, 2002; Rosen et al, 2004; Fernandez-Duque & Black 2005; Kessels et al, 2007; Diehl-Schmid et al, 2007). Given evidence that prototypical gaze patterns are associated with correct identification of emotion (Adolphs et al, 2005), one might expect FTLD patients to exhibit abnormal scanning of faces. There is some evidence to suggest that a subgroup of FTLD patients do, indeed, scan faces differently from control participants. In a study where patients and their caregivers were videotaped while discussing an area of disagreement, observer coding of the patients’ line of gaze (as either on or off the caregiver’s line of gaze) revealed that FTD patients made fewer attempts at eye contact with their caregivers than did Alzheimer’s patients (Sturm et al, under review). Failure to look their conversation partner in the eyes suggests reduced attention to what the partner is feeling, which in turn might lessen the ability to respond in emotionally congruent ways (e.g., expressing sympathy or validation).

Tracking emotional gaze may also provide important insight into patient deficits in emotional reactivity and emotion recognition. Caregiver reports of reduced emotional expression (Snowden et al, 2001) and laboratory findings of low reactivity to disgust (Eckart et al, in prep) and embarrassment stimuli (Sturm et al, 2006; Sturm et al, 2008) suggest that FTLD patients experience selective deficits in emotional responding. Because responding to an emotional stimulus requires attention to relevant cues (e.g., focus on the character’s facial expression in a film clip), it is important to assess whether
patients are attending to cues that trigger emotional arousal. By measuring eye gaze and emotional reactivity simultaneously, researchers may be better able to understand the relationship between gaze and emotional arousal in FTLD. FTLD patients have been shown to have difficulty recognizing emotional expressions (Lavenu et al, 1999; Keane, 2002; Rosen et al, 2004; Fernandez-Duque & Black 2005; Kessels et al, 2007; Diehl-Schmid et al, 2007). In order to better understand where the breakdown in emotion recognition occurs, it will be important to establish whether patients are collecting the visual information necessary for making judgments about emotion. If, for example, FTLD patients are not scanning the eye region of faces, they may be missing information that is critical for discriminating among emotional expressions. However, if patients show normal gaze patterns when scanning faces, it is likely that the breakdown occurs, not at the point of information collection, but at a higher level of information processing.

The clinical applications of studying emotional gaze in FTLD patients are yet to be determined. Previous research has shown that patterns of emotional gaze differ between psychiatric groups and controls. Differences in emotional gaze have been found between healthy controls and people with dysphoria (Caseras et al, 2007), specific phobia (Rinck et al, 2006), and autism (Nacewitz et al, 2007), suggesting that aberrant gaze patterns might serve as a marker of specific clinical conditions or disorders. Similarly, the study of emotional gaze might help differentiate FTLD patients from other neurological groups. Among FTLD patients, aberrant gaze could indicate a loss of interest in emotional information, evidenced by caregiver reports of apathy and interpersonal coldness. Aberrant emotional gaze might also indicate difficulty processing emotional information, resulting in impaired ability to navigate social situations. In order
to understand the clinical implications of emotional gaze in FTLD, it will be important to explore the relationship between measures of gaze and emotional and social functioning. As noted above, redirecting gaze may help alleviate deficits in emotion recognition (Adolphs, 2005). Thus, the study of emotional gaze in FTLD patients may have implications for clinical intervention. Patients’ processing of emotional information might be improved if they are prompted to attend to relevant cues.

The present study

The present study examined emotional gaze in FTLD patients and healthy control participants. My aims were to assess whether FTLD patients and controls scan emotional stimuli differently and whether differences in scan patterns are predictive of differences in emotional reactivity and emotion recognition, both in laboratory tasks and in daily life. Emotional gaze was assessed by tracking participants’ eye movements during viewing of photographed emotional faces. In one task, participants viewed a series of emotional faces under free-viewing and emotion recognition conditions. In a second task, participants viewed a series of emotional faces paired with neutral faces. Emotional reactivity was assessed with physiological measures in the emotional faces free-viewing task, with physiological, behavioral, and self-report measures in an emotional film viewing task, and with caregiver ratings of emotional reactivity in daily life. Emotion recognition was assessed in the emotional faces recognition task, in an emotional film recognition task, and with caregiver ratings of emotion recognition in daily life.

My hypotheses were as follows: 1) FTLD patients will show less attentional preference for emotional faces compared to controls. Caregiver reports of apathy and interpersonal coldness suggest that interest in emotional information is diminished in
FTLD. Thus, I predict that FTLD patients will gaze less at emotional faces (paired with neutral faces) compared to controls. 2) FTLD patients will scan emotional faces differently than controls. Previous research suggests that healthy adults tend to scan emotional faces in a triangular pattern, moving rapidly between the eyes and mouth. I predict that FTLD patients will deviate from this pattern, gazing less at the eye and mouth region compared to controls. 3) Emotional gaze will predict measures of emotional reactivity in FTLD patients and controls. Given that attention to emotional cues is necessary for eliciting an emotional response, I predict that gaze at emotional faces (paired with neutral faces) will predict measures of emotional reactivity. I also predict that gaze at the eye region of emotional faces will predict measures of emotional reactivity. 4) Emotional gaze will predict measures of emotion recognition in FTLD patients and controls. Given that recognition of emotional states in others depends on attention to emotional cues, I predict that gaze at emotional faces (paired with neutral faces) will predict measures of emotion recognition accuracy. Because previous research has shown that attention to the eye region is especially important for the correct identification of emotion in faces, I also predict that gaze at the eye region of emotional faces will predict measures of emotion recognition accuracy.

Methods

Participants

Participants consisted of 23 FTLD patients (12 FTD, 6 SD, and 5 PNFA) and 24 controls. The patient group ($M = 63.87$ years, $SD = 5.63$) was significantly younger than the control group ($M = 67.38$, $SD = 4.54$), $t(45) = 2.35, p < .05$. FTLD patients and control participants did not differ significantly in gender distribution (14 male patients, 9
male controls), \( \chi^2(1, N=47) = 2.57, \ NS \). FTLD patients participating in the study were recruited through the Memory and Aging Center at the University of California, San Francisco (UCSF). At UCSF, patients received comprehensive diagnostic testing, including neuropsychological assessment, neurological examination, genetics testing, and structural magnetic resonance imaging. These tests were administered by a multidisciplinary team of neurologists, psychiatrists, psychologists, and nurses. All patients included in the study met diagnostic criteria for FTLD, as defined by Neary, et al. (1998). Patient diagnoses were determined by a team of neurologists, after thorough review of the above test measures. Control participants were recruited from the Bay Area community through advertisements and word of mouth. All controls were screened with the Functional Activities Questionnaire (FAQ), Clinical Dementia Rating Scale (CDR), and Mini Mental State Exam (MMSE) and were determined to be free of cognitive and neurological disturbances. The eye tracking tasks were completed at the Berkeley Psychophysiology Laboratory at the University of California, Berkeley, as part of an extensive six-hour evaluation of social and emotional functioning (see Levenson et al, 2008). All participants were paid $30 for their participation in the Berkeley session.

**General procedure**

Upon arrival at the laboratory, participants signed consent forms (approved by the Committee for the Protection of Human Subjects at the University of California, Berkeley) that explained all tasks and measures. Participants were then seated in a well-lit 10 x 20 foot room equipped with a 20-inch Dell LCD computer monitor and a 21-inch color television monitor. Before the study tasks began, the experimenter applied sensors to the participant’s body to monitor physiological activity throughout the laboratory.
session. Data from three tasks were used for the present study. In the first task, participants watched emotionally evocative film clips and rated how they felt while watching the films. This task assessed reactivity to emotional stimuli. In the second task, they viewed a series of photographs with emotional content while their eye movements were monitored. This task assessed gaze patterns for emotional stimuli. In the third task, participants watched brief film clips with emotional content and reported how the main character in each film was feeling. This task assessed emotion recognition ability.

Participants also completed a number of other tasks (i.e., a startle probe, singing task, social interaction task, and structured interview), but data from these tasks were not included in the present study. Participants were asked to bring a caregiver (i.e., spouse, adult child, or close friend) to the lab session. While the participant was engaged in testing, the caregiver completed questionnaires about the participant’s emotional and social functioning.

**Study measures**

*Physiological responding.* Physiological measures were monitored continuously throughout the lab session using data acquisition software written by Robert W. Levenson. The software computed second-by-second averages for each of the following measures: (i) heart rate (Either Beckman miniature electrodes with Redux paste or Vermed SilveRest EKG pregelled electrodes were placed in a bipolar configuration on opposite sides of the participant’s chest, measuring the inter-beat interval calculated as the interval, in milliseconds, between successive R waves), (ii) finger pulse amplitude (a UFI photoplethysmograph recorded the amplitude of blood volume in the finger, using a photocell taped to the distal phalange of the index finger of the non-dominant hand), (iii)
finger pulse transmission time (the time interval, in milliseconds, measured between the R wave of the electrocardiogram (EKG) and the upstroke of the peripheral pulse at the finger site, recorded from the distal phalanx of the index finger of the non-dominant hand), (iv) ear pulse transmission time (a UFI photoplethysmograph attached to the right earlobe, recorded the volume of blood in the ear and the time interval, in milliseconds, measured between the R wave of the EKG and the upstroke of peripheral pulse at the ear site), (v) systolic blood pressure (a blood pressure cuff was placed on the distal phalanx of the non-dominant hand and continuously recorded the systolic blood pressure), (vi) diastolic blood pressure (a blood pressure cuff was placed on the distal phalanx of the non-dominant hand and continuously recorded the diastolic blood pressure), (vii) respiration period (a pneumatic bellows is stretched around the thoracic region and the inter-cycle interval was measured in milliseconds between successive inspirations), (viii) respiration depth (the point of the maximum inspiration minus the point of maximum expiration was determined from respiratory tracing), (ix) skin conductance (a constant-voltage device was used to pass a small voltage between either Beckman regular electrodes or BIOPAC electrodes [using an electrolyte of sodium chloride in unibase], attached to the palmar surface of the middle phalanges of the ring and index fingers of the non-dominant hand, (x) general somatic activity (an electromechanical transducer attached to the platform under the participant’s chair generated an electrical signal proportional to the amount of movement in any direction), and (xi) finger temperature (either a thermistor or BIOPAC surface temperature transducer attached to the distal phalange of the little finger of the non-dominant hand recorded temperature in degrees Fahrenheit). These eleven measures were selected to provide a broad index of activity in
the physiological systems important to emotional responding: cardiac, vascular, electrodermal, and striate muscle.

_Eye movements_. During the eye tracking tasks, eye movement patterns were recorded using an Applied Science Laboratories (ASL) H6 head-mounted monocular eye tracking system. This system consists of a camera, infrared light source, and “hot mirror” attached to a lightweight headband with adjustable mounts. The “hot mirror” is a lens coated with a translucent film that reflects infrared light directly into the pupil. Light reflecting off the retinal and corneal surface is, in turn, reflected off the mirror into the camera lens, creating an analyzable image of the eye. This reflective system allows direct observation of the eye without obstructing the participant’s line of gaze. Using contrast levels in the eye image, the ASL Eye-Trac software locates the center of the pupil and corneal reflection and uses these two points to determine the position of the eye. Recordings are always made from the participant’s left eye, following methodological convention. The system operates at a sampling rate of 60 Hz with an error margin of 0.5 degrees of visual angle. To account for shifts in eye position due to head movement, we used an Ascension Flock of Birds head tracker to monitor head motion. In the head tracker system, a sensor mounted on the eye tracker headband relays information about the head’s position to a stationary receiver. The ASL EyeHead Integration software merges the eye tracking and head tracking data so that eye position is recorded with respect to head position. The head tracker eliminates need for a head restraint and allows naturalistic head movement during stimulus viewing. The eye tracking stimuli were presented on the computer monitor using Eye Response’s Gaze Tracker software (Version 06.04.26). Participants were seated 24 inches away from the monitor. The eye
tracking software and stimulus presentation software ran on two Dell Optiplex GX620
desktops. Prior to presentation of the eye tracking stimuli, the system was calibrated by
recording eye position as the participant looked to each of nine calibration points
displayed on the monitor. The software uses this information to calculate point of gaze
anywhere on the computer screen. Participants were also questioned for any history of
eye problems that might impact the accuracy of eye tracking (e.g., cataracts, previous eye
surgery, poor vision etc.).

Facial behavior. During the reactivity films task, participants’ facial behavior was
recorded continuously using a remotely controlled high-resolution video camera, which
was partially concealed in the experimenter room. A team of undergraduate research
assistants then coded the participants’ videotaped facial behavior during the most intense
30 seconds of each reactivity film (as determined by a group of independent raters).
Behavioral codes were based on a modified version of the Emotional Expressive
Behavior coding system (Gross & Levenson, 1993), in which coders rate the extent to
which participants display nine specific emotional expressions (anger, disgust, happiness,
contempt, sadness, disgust, embarrassment, fear, and surprise) on a 0 to 3 scale (0 = none,
1 = mild, 2 = moderate, 3 = strong). Coders were trained by coding videotapes of
patients and controls obtained in another study until they reach 85% intercoder
agreement. Coding was done without sound, without information about which film was
being watched, and without knowing whether the participants were patients or controls.

Caregiver report. While the participant was engaged in other study tasks, the caregiver
completed a 44-item questionnaire (developed in the Berkeley Psychophysiological
Laboratory) about the participants’ social and emotional functioning in daily life. Each
item in the questionnaire describes a behavior or skill associated with social (e.g., “shows interest in interacting with friends or family”) or emotional (e.g., “expresses anger”) functioning. The caregiver rated on a 0 to 4 scale (0 = not at all, 2 = a little, 4 = a lot) the extent to which the participant exhibited each behavior/skill over the past month and before the onset of illness (in the case of FTLD patients) or ten years ago (in the case of control participants). Ten items pertained to emotional reactivity (e.g., “expresses amusement”) and ten items pertained to emotion recognition (e.g., “recognizes and understands when others are feeling amused”).

Study tasks

Emotional reactivity films. Participants watched three film clips, shown by extensive pilot testing to evoke amusement, sadness, and disgust in healthy controls. The amusement film (taken from an episode of *I Love Lucy*) is 1 min 51 sec long and shows a comic scene of two women wrapping chocolates. The sadness film (taken from the film *The Champ*) is 1 min 32 sec long and depicts a boy crying as his father dies. The disgust film (taken from an episode of *Fear Factor*) is 1 min 45 sec long and shows a man drinking fluid from a cow’s intestine. The films were shown on the television monitor positioned 4 feet in front of the participant. All task instructions were presented (in visual and audio form) on the television monitor. Each film was preceded by a 60 sec baseline period, during which participants were instructed to relax. After the baseline period, participants were told to “Please watch the film. Say STOP if you need the film stopped.” After each film ended, questions appeared on the monitor asking participants to rate how strongly they felt 11 specific emotions (affection, amusement, anger, calm, disgust, fear, embarrassment, enthusiasm, pride, sadness, and shame), using three response options
“no”, “a little,” or “a lot”). Responses were given verbally. Previous research (Werner et al, 2007) shows that FTLD patients are capable of making such judgments. After responding to the emotion reactivity questions, participants answered a multiple-choice question about the general plot of the film. This question was included to assure that group differences in emotional reactivity are not due to differences in comprehension of the film.

*Emotional faces.* Participants first viewed a series of color photographed faces, each expressing one of six emotions (happy, sad, afraid, disgusted, angry, and neutral) while their eye movements were monitored. All expressions were posed by the same young adult female actor and met Facial Action Coding System (FACS) criteria for the prototypical expression of each emotion. The photographs were displayed with a neutral gray background. Each photograph measured 6.5 (w) x 10 (h) inches, subtending a vertical visual angle of 11.8 degrees and a horizontal visual angle of 7.7 degrees when viewed from a distance of 24 inches. Presentation of each face was preceded by a fixation screen, consisting of a black letter X centered on a neutral gray background. In the free-viewing task, participants were verbally instructed to “look at the X and then the pictures.” For each of the six faces, participants first viewed the fixation screen for 15 seconds (allowing time to record baseline physiological activity) and then the emotional face for five seconds. In the repeated viewing task, participants were told they would see the faces again. This task was included to assess how repeated presentation of a face might alter gaze patterns. For each of the six faces, participants viewed the fixation screen (2 sec) and then the emotional face (5 sec). In the emotion recognition task, participants were told they would be asked to identify “how the woman is feeling” in
each of the pictures. For each of the six faces, participants viewed the fixation screen (2 sec), the emotional face (5 sec), and then a response screen (15 sec). During the response period, the emotional face was presented again alongside the prompt “How is the woman feeling?” and an alphabetical listing of emotion terms (i.e., afraid, angry, disgusted, happy, neutral, and sad). The prompt and response choices were also read out loud by the experimenter. The participants were instructed to give their responses verbally. The emotional faces were displayed during the response period to ensure that errors in emotion recognition are not due to an inability to remember the faces. In each task, the faces were presented in the same order (i.e., happy, sad, afraid, disgusted, angry, and neutral). Counterbalancing was not possible due to the fact that patient diagnoses are still pending when participants arrive for testing at UC Berkeley. At the end of each task, participants were shown the nine calibration dots again to verify the quality of the calibration. The system was recalibrated as needed.

Participants then viewed six face pairs, each consisting of an emotional face (happy, sad, or angry) and a neutral face, while their eye movements were monitored. All faces were taken from the Ekman & Friesen (1976) Pictures of Facial Affect database, which consisted of standardized black & white photographs of adult actors posing emotional expressions. The photographs measured 6.5 (w) x 10 (h) inches and were presented side by side on the computer monitor against a neutral gray background. The distance to the medial border of each photograph was 1.2 degrees of visual angle from the midline when viewed from a distance of 24 inches. The distance to the distal borders was 16.3 degrees. Participants viewed two happy-neutral pairs, two sad-neutral pairs, and two angry-neutral pairs. Because previous research (Rosler et al, 2005) has
shown a leftward-looking bias for paired stimuli in Indo-European-speaking participants, the position of the emotional and neutral face alternated between pairs. Within each face pair, the actor posing the emotional and neutral face was the same. Across face pairs, the actors varied, such that each face pair featured a different actor. All faces used in this task were those of male actors. In each trial, participants viewed the fixation screen (2 sec), the face pair (6 sec), and then a response screen (10 sec). During the response period, the prompt “Which picture do you find more interesting?” appeared above the faces. The left face was labeled “1” and the right face is face was labeled “2.” The prompt and response options were read out loud by the experimenter. The participants gave their responses verbally. At the end of the task, participants were shown the nine calibration dots again to verify the quality of the calibration.

A subset of FTLD patients and control participants completed an oculomotor control task to assess whether FTLD patients exhibit gaze deficits in non-emotional contexts. During the task, participants viewed a set of three dots (one red and two white) arranged in a triangular formation on a neutral gray background. Each of the dots measured 0.5 inches in diameter, subtending 1.0 degree of visual angle when viewed from a distance of 24 inches. Two of the dots were positioned where the eyes of emotional faces (in the emotional faces eye tracking task) fell on the screen. The third dot was positioned over the mouth region. Over the course of the trial, the position of the red dot changed every two seconds (first in a clock-wise direction, then counterclockwise) until it had been shown twice at each position. Participants were simply instructed to “follow the red dot” with their eyes.
Emotion Recognition films. Participants watched eleven 72 second-long film clips (all different from those used in the reactivity films task), shown by extensive pilot testing to convey a range of negative (anger, sadness, fear, and disgust), positive (enthusiasm, calm, affection, and amusement) and self-conscious (embarrassment, shame, and pride) emotions. The films and task instructions were shown on the same television monitor used in the reactivity films task. Each film was preceded by a 30 sec baseline period, during which participants were instructed to relax. After the baseline period, participants were told to “Please watch the film. Say STOP if you need the film stopped.” After each film ended, a question appeared on the monitor asking participants to identify which emotion the main character in the film felt most strongly. The eleven response options (affection, amusement, anger, calm, disgust, fear, embarrassment, enthusiasm, pride, sadness, and shame) were listed in alphabetical order (not in the order of film presentation) on the television monitor, alongside a still image of the film’s main character. Responses were given verbally. After responding to the emotion recognition questions, participants answered a multiple-choice question about the general plot of the film. This question was included to assure that group differences in emotion recognition were not due to differences in comprehension of the film.

Data Reduction

Physiological responding. Reactivity scores were computed for each physiological measure by subtracting the average level of activity during the pre-task baseline from the average level of activity during the study task. To provide a single, more reliable measure of overall physiological responding, a composite score was calculated across all physiological measures. To calculate this composite, a standardized score was computed.
for each measure and reverse scored as needed (i.e., for cardiac inter-beat interval, finger pulse amplitude, finger pulse transmission time, ear pulse transmission time, and respiratory inter-cycle interval) so that larger values reflect greater physiological arousal. The standardized scores were then averaged, resulting in a single physiological reactivity composite score for each study task. The composite score provided a broad measure of overall physiological activation. Physiological responding was assessed in the emotional faces free-viewing task and reactivity films task only.

Eye movements. Two types of eye movement measures were calculated using the Gaze Tracker software: (i) percent tracked time and (ii) latency of first fixation. Percent tracked time is the percentage of total tracked time spent within a particular region of an image (this includes fixations and gaze points with shorter durations). Latency of first fixation is the amount of time that lapses before the participant first fixates on a region of the image. Fixations are conceptualized as stops between eye movements, during which the eye pauses to take in visual information. In the present study, a fixation point was defined as a set of continuous gaze points measured within 1.0 degree of visual angle over a minimum of 0.1 seconds. For stimuli used in the emotional faces tasks, rectangular regions of interest (ROIs) were drawn around the eye (including the eye and brows), nose, and mouth region of each face. The sizes of these ROIs remained constant across facial expressions. For stimuli used in the paired faces task, same-sized rectangular ROIs were drawn around the emotional face and neutral face in each face pair. For stimuli used in the oculomotor control task, same-sized square ROIs were

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1 For the emotional faces free-viewing task, skin temperature, respiration period, and respiration depth were omitted from the physiological reactivity composite because these measures are unlikely to show meaningful change over the 5-sec presentation of each face.

2 Other eye movement measures (including number of fixations and percent fixation time) were also assessed. Because these measures correlated highly with percent tracked time and did not yield additional findings, they were omitted from the report to avoid redundancy.
drawn around the red dots. The two eye movement measures were calculated for each ROI\(^3\).

*Facial behavior.* For each reactivity film, intensity scores for the target emotion (i.e., happiness, sadness, or disgust) were summed across the most intense 30 seconds of the film clip and then averaged across coders. Inter-rater reliability among coders was high (\(\alpha = .87\))

*Interest self-reports.* For each trial in the paired faces task, participants’ responses were scored 1 if they endorsed the emotional (i.e., happy, sad, or angry) face as being “more interesting” and 0 if they endorsed the neutral face.

*Reactivity film self-reports.* For each reactivity film, participants’ responses indicating how much target emotion (i.e., amusement, sadness, or disgust) they felt were converted into scores on a 1 to 3 scale (1 = no, 2 = a little, 3 = a lot).

*Emotional faces recognition responses.* For each trial in the emotional faces recognition task, participants’ responses indicating which emotion the face expressed was scored 1 if the response matched the target emotion (e.g., “happy” for the happy face) and 0 if the response did not match.

*Recognition film responses.* For each reactivity film, participants’ responses indicating which emotion the main character felt most strongly were scored 1 if the response matched the target emotion (e.g., “amusement” for the amusement film) and 0 if the response did not match.

**Results**

\(^3\) In the case that a participant did not fixate at a particular ROI during a trial, the latency of first fixation for that ROI was recorded as the maximal viewing time in the trial (i.e., 6 sec in the paired faces task and 5 sec in the emotional faces tasks)
Participants. Because previous research suggests that FTLD patients have deficits in the realm of negative emotion, whereas positive emotions might be preserved, task performance for positively and negatively valenced stimuli were analyzed separately. Because patients and controls differed significantly in total MMSE score, t(45) = 4.22, p < .05, with patients scoring in the mildly impaired range (M = 26.26, SD = 3.77) and controls near ceiling (M = 29.55, SD = .57), total MMSE score was controlled for in all following analyses. Given that the patient group was significantly older than the control group, age was also controlled for in all subsequent analyses. In all within-subjects comparisons, age and MMSE total were centered on their grand means.

Oculomotor control task. Group differences in gaze at the red target dot in the oculomotor control task were assessed with univariate ANCOVAs. Dependent variables were average percent tracked time and average latency of first fixation over the six dot presentations. FTLD patients (EMM = 47.77, SE = 12.10) and controls (EMM = 69.58, SE = 9.36) spent equal time gazing at the target dot, F(1, 6) = 1.62, NS. Patients (EMM = .63, SE = .17) and controls (EMM = .52, SE = .13) also fixated equally quickly at the target dot, F(1, 6) = .23, NS. Thus, group differences in gaze measures in the emotional gaze tasks are not likely due to general differences in oculomotor functioning.

Hypothesis 1: FTLD patients will show less attentional preference for emotional faces compared to controls.

Positive face pairs. Group differences in attentional preference for positive (i.e., happy) faces in the paired faces task was assessed with 2 Group (FTLD, control) x 2 Region (positive face, neutral face) mixed model ANCOVAs. Dependent variables were

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4 Because the oculomotor control task was introduced part-way through data collection, only four FTLD patients and six controls completed the task.
average percent tracked time and average latency of first fixation across the two positive face trials. The ANCOVA for average percent tracked time yielded a significant main effect of group, $F(1, 42) = 14.84, p < .01$, and follow-up Bonferroni pairwise comparisons showed that FTLD patients spent less time gazing at the two target regions than controls did, $p < .01$ (see Table 1a for means). The main effect of region was also significant, $F(1, 42) = 4.84, p < .05$, and follow-up Bonferroni pairwise comparisons showed that across groups, participants spent significantly more time gazing at the positive face than at the neutral face, $p < .05$ (see Table 1a for means). The Group x Region interaction was not significant, $F(1, 42) = 1.01, NS$. The ANCOVA for average latency of first fixation yielded no significant main effect of group, $F(1, 42) = .16, NS$, no significant main effect of region, $F(1, 42) = .00, NS$, and no significant Group x Region interaction, $F(1, 42) = .75, NS$. FTLD patients and controls fixated equally quickly at positive and neutral faces.

**Negative face pairs.** To assess whether FTLD patients and controls attended to sad and angry faces differently in the paired faces task, gaze measures (average percent tracked time and average latency of first fixation) were submitted to a 2 Group (FTLD, control) x 2 Emotion (sad, angry) mixed model ANCOVA. The ANCOVA for average percent tracked time yielded a significant main effect of group, $F(1, 41) = 15.32, p < .01$, and follow-up Bonferroni pairwise comparisons showed that FTLD patients spent less time gazing at sad and angry faces than controls did, $p < .01$ (see Table 1b for means). There was no significant main effect of emotion, $F(1, 41) = 1.82, NS$, and no significant Group x Emotion interaction, $F(1, 41) = .30, NS$. The ANCOVA for latency of first fixation yielded no signification main effect of group, $F(1, 41) = 1.82, NS$, no significant main
effect of emotion, $F(1, 41) = .54$, NS, and no significant Group x Emotion interaction, $F(1, 41) = .13$, NS. Thus, gaze measures were averaged over sad and angry faces and their respective neutral face pairs to form composite gaze measures for negative faces.

Group differences in attentional preference for negative faces in the paired faces task was assessed with 2 Group (FTLD, control) x 2 Region (negative face, neutral face) mixed model ANCOVAs. Dependent variables were average percent tracked time and average latency of first fixation. The ANCOVA for average percent tracked time yielded a significant main effect of group, $F(1, 42) = 14.84$, $p < .01$, and a significant main effect of region, $F(1, 42) = 4.84$, $p < .05$, which were qualified by a significant Group x Region interaction, $F(1, 42) = 7.43$, $p < .01$. A follow-up univariate ANCOVA showed that FTLD patients spent significantly less time gazing at negative faces than controls did, $F(1, 42) = 16.91$, $p < .01$ (see Table 1a for means). However, patients and controls spent equal time gazing at neutral faces, $F(1, 42) = .18$, NS. In addition, follow-up repeated measures ANCOVAs showed that controls spent more time gazing at negative faces than neutral faces, $F(1, 20) = 14.1$, $p < .01$, whereas FTLD patients spent equal time gazing at negative and neutral faces, $F(1, 20) = .00$, NS (see Table 1a for means). The ANCOVA for average latency of first fixation yielded no significant main effect of group, $F(1, 42) = .20$, NS, no significant main effect of region, $F(1, 42) = 1.59$, NS, and no significant Group x Region interaction, $F(1, 42) = .14$, NS. FTLD patients and controls fixated equally quickly at negative and neutral faces.

**Self-reported interest.** A univariate ANCOVA showed that FTLD patients and controls reported equal interest in positive faces, $F(1, 39) = .49$, NS. To assess whether patients and controls reported different levels of interest in sad and angry faces, interest scores
were submitted to a 2 Group (FTLD, control) x 2 Emotion (sad, angry) mixed model ANCOVA. There was a significant main effect of emotion, $F(1, 38) = 4.83, p < .05$, and follow-up Bonferroni pairwise comparisons showed that across groups, participants reported less interest in angry faces than in sad faces, $p < .05$ (see Table 2 for means). The Group x Emotion interaction was also significant, $F(1, 38) = 13.75, p < .01$.

However, follow-up repeated measures ANCOVAs failed to show significant differences between sad and angry interest scores for FTLD patients, $F(1, 19) = 4.34, NS$, or controls $F(1, 19) = 1.74, NS$. Given the significant main effect of emotion in the preceding analyses, sad and angry interest scores were tested separately in subsequent analyses.

Univariate ANCOVAs showed that FTLD patients reported significantly less interest in sad faces than controls did, $F(1, 39) = 10.83, p < .01$, and equal interest in angry faces compared to controls, $F(1, 38) = .00, NS$ (see Table 2 for means).

**Gaze predicting self-reported interest.** The predictive power of gaze measures in the paired faces task was assessed. Linear regressions showed that across all participants, neither average percent tracked time, $b = .05, t(39) = .34, NS$, nor latency of first fixation, $b = .05, t(39) = .26, NS$, at positive faces significantly predicted interest scores for those positive faces. However, average percent tracked time spent gazing at negative faces did significantly predict interest scores for sad faces, $b = .41, t(39) = 3.30, p < .01$. A univariate ANCOVA yielded no significant Group x Percent Tracked Time interaction, $F(1, 37) = .12, NS$, suggesting that the relationship between gaze and interest held across groups. Average percent tracked time spent gazing at negative faces did not significantly predict interest scores for angry faces, $b = .23, t(38) = 1.51, NS$. Also, latency of first
fixation did not significantly predict interest scores for sad, \( b = -0.01, t(39) = -0.05, NS \), or angry faces, \( b = 0.11, t(38) = 0.70, NS \).

Summary: Hypothesis 1. Hypothesis 1 was supported insofar as FTLD patients showed less attentional preference for negative faces than controls did. In the paired faces task, FTLD patients spent equal time gazing at negative and neutral faces, whereas controls spent more time gazing at negative than neutral faces. Both FTLD patients and controls showed attentional preference for positive faces. In addition, time spent gazing at negative faces was predictive of self-reported interest in sad faces across the entire sample.

Hypothesis 2: FTLD patients will scan emotional faces differently than controls

Group differences in the scanning of emotional faces were assessed by examining gaze measures (percent tracked time and latency of first fixation) for the eye, nose, and mouth region of faces. Differences in the scanning of emotional faces across viewing conditions (free-view, repeat, and recognition) were also assessed.

Eye region

Positive face eyes. Group differences in scanning the eye region of a positive (i.e., happy) face were assessed with 2 Group (FTLD, control) x 3 Condition (free-view, repeat, recognition) ANCOVAs. Dependent variables were percent tracked time and latency of first fixation. The ANCOVA for percent tracked time yielded no significant main effect of group \( F(1, 38) = 2.46, NS \), no significant main effect of condition, \( F(1, 38) = 1.39, NS \), and no Group x Condition interaction, \( F(2, 38) = .47, NS \). Across conditions, FTLD patients and controls spent equal time gazing at the eye region of a positive face.

The ANCOVA for latency of first fixation yielded a significant main effect of Condition,
\( F(2, 38) = 4.05, p < .05, \) and follow-up Bonferroni pairwise comparisons showed that across groups, participants fixated at the eyes more quickly during the free-view than recognition condition, \( p < .05 \) (see Table 3a for means). The main effect of group, \( F(1, 38) = 1.53, NS, \) and Group x Condition interaction, \( F(2, 38) = 1.51, NS, \) were not significant.

**Negative face eyes.** To assess whether FTLD patients and controls scanned the eye region of sad, fearful, digusted, and angry faces differently in the three viewing conditions, gaze measures (percent tracked time and latency of first fixation) were submitted to a 2 Group (FTLD, control) x 4 Emotion (sad, fearful, disgusted, angry) mixed model ANCOVA for each viewing condition. The ANCOVA for percent tracked time in the free-viewing task yielded a main effect of group, \( F(1, 36) = 4.50, p < .05, \) and follow-up Bonferroni pairwise comparisons showed that across negative faces, FTLD patients spent less time gazing at the eye region than controls did, \( p < .05 \) (see Table 3b for means). The main effect of emotion was also significant, \( F(3, 36) = 3.30, p < .05, \) but closer examination with Bonferroni pairwise comparisons failed to show any significant differences in percent tracked time among sad, fearful, disgusted, and angry face trials. The Group x Emotion interaction was not significant, \( F(3, 36) = .87, NS. \) ANCOVAs for percent tracked time in the repeat and recognition conditions yielded no significant main effects of group \( F_{\text{repeat}}(1, 37) = 4.00, NS, F_{\text{recognition}}(1, 38) = 2.18, NS, \) no signification main effects of emotion, \( F_{\text{repeat}}(3, 37) = 1.97, NS, F_{\text{recognition}}(3, 38) = .66, NS, \) and no significant Group x Emotion interactions, \( F_{\text{repeat}}(3, 37) = 1.55, NS, F_{\text{recognition}}(3, 38) = .83, NS. \) ANCOVAs for latency of first fixation in the free-view, repeat, and recognition conditions yielded no significant main effects of group, \( F_{\text{free-view}}(1, 36) = 1.26, NS, \)
Group differences in scanning the eye region of negative faces were assessed with 2 Group (FTLD, control) x 3 Condition (free-view, repeat, recognition) ANCOVAs. Dependent variables were percent tracked time and latency of first fixation. The ANCOVA for percent tracked time yielded a significant main effect of group, $F(1, 38) = 6.17, p < .05$, and follow-up Bonferroni pairwise comparisons showed that across viewing conditions, FTLD patients spent less time gazing at the eye region of negative faces than controls did, $p < .05$ (see Table 3a for means). The main effect of condition, $F(2, 38) = .15, NS$, and Group x Condition interaction, $F(2, 38) = .31, NS$, were not significant. The ANCOVA for latency of first fixation yielded no significant main effect of group, $F(2, 38) = 1.04, NS$, no significant main effect of condition, $F(2, 38) = .50, NS$, and no significant Group x Condition, $F(2, 38) = 2.85, NS$. Across viewing conditions, FTLD patients and controls fixated equally quickly at the eye region of negative faces.

Neutral face eyes. Group differences in scanning the eye region of a neutral face were assessed with 2 Group (FTLD, control) x 3 Condition (free-view, repeat, recognition) ANCOVAs. Dependent variables were percent tracked time and latency of first fixation. The ANCOVA for percent tracked time yielded a significant main effect of group, $F(1, 34) = 4.81, p < .05$, and follow-up Bonferroni pairwise comparisons showed that across
viewing conditions, FTLD patients spent less time gazing at the eye region of a neutral face than controls did, $p < .05$ (see Table 3a for means). The main effect of condition, $F(2, 34) = .54$, $NS$, and Group x Condition interaction, $F(2, 34) = 1.18$, $NS$, were not significant. The ANCOVA for latency of first fixation yielded no significant main effect of group, $F(1, 34) = .69$, $NS$, no significant main effect of condition, $F(2, 34) = .60$, $NS$, and no significant Group x Condition, $F(2, 34) = 1.25$, $NS$. Across viewing conditions, FTLD patients and controls fixated equally quickly at the eye region of a neutral face.

**Nose region**

**Positive face nose region.** Group differences in scanning the nose region of a positive face were assessed with 2 Group (FTLD, control) x 3 Condition (free-view, repeat, recognition) ANCOVAs. Dependent variables were percent tracked time, and latency of first fixation. ANCOVAs for percent tracked time and latency of first fixation yielded no significant main effect of group, $F_{%Time}(1, 38) = .33$, $NS$, $F_{1stFix}(1, 38) = .02$, $NS$, no significant main effect of condition, $F_{%Time}(2, 38) = .59$, $NS$, $F_{1stFix}(2, 38) = .56$, $NS$, and no Group x Condition interactions, $F_{%Time}(2, 38) = 1.67$, $NS$, $F_{1stFix}(2, 38) = .44$, $NS$. Across conditions, FTLD patients and controls gazed equally at the nose region of a positive face. Means are presented in Table 4a.

**Negative face nose region.** To assess whether FTLD patients and controls scanned the nose region of sad, fearful, digusted, and angry faces differently in the three viewing conditions, gaze measures (percent tracked time and latency of first fixation) were submitted to a 2 Group (FTLD, control) x 4 Emotion (sad, fearful, disgusted, angry) mixed model ANCOVA for each viewing condition. ANCOVAs for percent tracked time in the free-view, repeat, and recognition conditions yielded no significant main
effects of group, $F_{\text{free-view}}(1, 36) = .40, \text{NS}$, $F_{\text{repeat}}(1, 37) = .07, \text{NS}$, $F_{\text{recognition}}(1, 38) = .52, \text{NS}$, no signification main effects of emotion, $F_{\text{free-view}}(3, 36) = 2.26, \text{NS}$, $F_{\text{repeat}}(3, 37) = 1.36, \text{NS}$, $F_{\text{recognition}}(3, 38) = 1.06, \text{NS}$, and no significant Group x Emotion interactions, $F_{\text{free-view}}(3, 36) = 2.74, \text{NS}$, $F_{\text{repeat}}(3, 37) = .29, \text{NS}$, $F_{\text{recognition}}(3, 38) = .43, \text{NS}$,. The ANCOVA for latency of first fixation in the free-view condition yielded a main effect of emotion, $F(3, 36) = 2.95, p < .05$, but closer examination with Bonferroni pairwise comparisons failed to show any significant differences in latency of first fixation among sad, fearful, disgusted, and angry face trials. The main effect of group, $F(1, 36) = .01, \text{NS}$, and Group x Emotion interaction, $F(3, 36) = .96, \text{NS}$, were not significant.

ANCOVAs for latency of first fixation in the repeat and recognition conditions yielded no significant main effects of group, $F_{\text{repeat}}(3, 37) = .34, \text{NS}$, $F_{\text{recognition}}(3, 38) = .12, \text{NS}$, no signification main effects of emotion $F_{\text{repeat}}(3, 37) = .80, \text{NS}$, $F_{\text{recognition}}(3, 38) = .80, \text{NS}$, and no significant Group x Emotion interactions, $F_{\text{repeat}}(3, 37) = .53, \text{NS}$, $F_{\text{recognition}}(3, 38) = .82, \text{NS}$. Thus, gaze measures were averaged over the four negative emotion trials to form composite gaze measures for negative faces in each viewing condition. Means are presented in Table 4b.

Group differences in scanning the nose region of negative faces were assessed with 2 Group (FTLD, control) x 3 Condition (free-view, repeat, recognition) ANCOVAs. Dependent variables were percent tracked time and latency of first fixation. ANCOVAs for percent tracked time and latency of first fixation yielded no significant main effect of group, $F_{\%\text{Time}}(1, 38) = .01, \text{NS}$, $F_{1st\text{Fix}}(1, 38) = .47, \text{NS}$, no significant main effect of condition, $F_{\%\text{Time}}(2, 38) = 1.35, \text{NS}$, $F_{1st\text{Fix}}(2, 38) = .37, \text{NS}$, and no Group x Condition interactions, $F_{\%\text{Time}}(2, 38) = 1.24, \text{NS}$, $F_{1st\text{Fix}}(2, 38) = 1.68, \text{NS}$. Across conditions, FTLD
patients and controls gazed equally at the nose region of negative faces. Means are presented in Table 4a.

**Neutral face nose region.** Group differences in scanning the nose region of a neutral face were assessed with 2 Group (FTLD, control) x 3 Condition (free-view, repeat, recognition) ANCOVAs. Dependent variables were percent tracked time and latency of first fixation. ANCOVAs for percent tracked time and latency of first fixation yielded no significant main effect of group, $F_{\%\text{Time}}(1, 34) = .24, NS$, $F_{1\text{stFix}}(1, 34) = .41, NS$, no significant main effect of condition, $F_{\%\text{Time}}(2, 34) = .79, NS$, $F_{1\text{stFix}}(2, 34) = 1.20, NS$, and no Group x Condition interactions, $F_{\%\text{Time}}(2, 34) = .17, NS$, $F_{1\text{stFix}}(2, 34) = 1.05, NS$. Across conditions, FTLD patients and controls gazed equally at the nose region of a neutral face. Means are presented in Table 4a.

**Mouth region**

**Positive face mouth region.** Group differences in scanning the mouth region of a positive face were assessed with 2 Group (FTLD, control) x 3 Condition (free-view, repeat, recognition) ANCOVAs. Dependent variables were percent tracked time and latency of first fixation. The ANCOVA for percent tracked time yielded a main effect of condition, $F(2, 38) = 3.78, p < .05$, and follow-up Bonferroni pairwise comparisons showed that across groups, participants spent less time gazing at the mouth in the repeat than free-view or recognition conditions $p < .05$ (see Table 5a for means). The main effect of Group, $F(1, 38) = .35, NS$, and Group x Condition interaction, $F(2, 38) = 2.67, NS$, were not significant. The ANCOVA for latency of first fixation yielded a main effect of Condition, $F(2, 28) = 4.78, p < .05$, and follow-up Bonferroni pairwise comparisons showed that across groups, participants fixated more quickly at the mouth in the free-
view than recognition condition, \( p < .05 \) (see Table 5a for means). The Group x Condition interaction was also significant, \( F(2, 38) = 5.73, p < .05 \), but closer examination with follow-up repeated measures ANCOVAs failed to show any significant differences in latency of first fixation among the three viewing conditions for FTLD patients, \( F(2, 17) = .91, \ NS \), or controls \( F(2, 19) = .23, \ NS \). The main effect of group was not significant, \( F(1, 38) = .12, \ NS \).

*Negative face mouth region.* To assess whether FTLD patients and controls scanned the mouth region of sad, fearful, disgusted, and angry faces differently in the three viewing conditions, gaze measures (percent tracked time and latency of first fixation) were submitted to a 2 Group (FTLD, control) x 4 Emotion (sad, fearful, disgusted, angry) mixed model ANCOVA for each viewing condition. ANCOVAs for percent tracked time in the free-view, repeat, and recognition conditions yielded no significant main effects of group, \( F_{\text{free-view}}(1, 36) = .66, \ NS, F_{\text{repeat}}(1, 37) = .62, \ NS, F_{\text{recognition}}(1, 38) = .13, \ NS \), no significant main effects of emotion, \( F_{\text{free-view}}(3, 36) = 1.53, \ NS, F_{\text{repeat}}(3, 37) = 1.03, \ NS, F_{\text{recognition}}(3, 38) = .44, \ NS \), and no significant Group x Emotion interactions, \( F_{\text{free-view}}(3, 36) = 1.18, \ NS, F_{\text{repeat}}(3, 37) = 1.65, \ NS, F_{\text{recognition}}(3, 38) = .66, \ NS \). The ANCOVA for latency of first fixation in the free-view condition yielded a main effect of emotion, \( F(3, 36) = 2.91, p < .05 \), but closer examination with Bonferroni pairwise comparisons failed to show significant differences in latency of first fixation among sad, fearful, disgusted, and angry face trials. The main effect of group, \( F(1, 36) = .47, \ NS \), and Group x Emotion interaction, \( F(2, 36) = 1.11, \ NS \), were not significant. ANCOVAs for latency of first fixation in the repeat and recognition trials yielded no significant main effects of group, \( F_{\text{repeat}}(1, 37) = .30, \ NS, F_{\text{recognition}}(1, 38) = .05, \ NS \), no significant main effects of
emotion, $F_{\text{repeat}}(3, 37) = .09, \ NS, F_{\text{recognition}}(3, 38) = .27, \ NS$, and no significant Group x Emotion interactions, $F_{\text{repeat}}(1, 37) = .50, \ NS, F_{\text{recognition}}(1, 38) = .82, \ NS$. Thus, gaze measures were averaged over the four negative emotion trials to form composite gaze measures for negative faces in each viewing condition. Means are presented in Table 5b.

Group differences in scanning the mouth region of negative faces were assessed with 2 Group (FTLD, control) x 3 Condition (free-view, repeat, recognition) ANCOVAs. Dependent variables were percent tracked time and latency of first fixation. ANCOVAs for percent tracked time and latency of first fixation yielded no significant main effects of group, $F_{\%\text{Time}}(1, 38) = .84, \ NS, F_{1st\text{Fix}}(1, 38) = .33, \ NS$, no significant main effects of condition, $F_{\%\text{Time}}(2, 38) = 1.81, \ NS, F_{1st\text{Fix}}(2, 38) = 1.90, \ NS$, and no significant Group x Condition interactions, $F_{\%\text{Time}}(2, 38) = .19, \ NS, F_{1st\text{Fix}}(2, 38) = .51, \ NS$. Across viewing conditions, FTLD patients and controls gazed equally at the mouths of negative faces. Means are presented in Table 5a.

Neutral face mouth region. Group differences in scanning the mouth region of a neutral face were assessed with 2 Group (FTLD, control) x 3 Condition (free-view, repeat, recognition) ANCOVAs. Dependent variables were percent tracked time and latency of first fixation. ANCOVAs for percent tracked time and latency of first fixation yielded no significant main effects of group, $F_{\%\text{Time}}(1, 34) = 2.14, \ NS, F_{1st\text{Fix}}(1, 34) = .40, \ NS$, no significant main effects of condition, $F_{\%\text{Time}}(2, 34) = .43, \ NS, F_{1st\text{Fix}}(2, 34) = 1.78, \ NS$, and no significant Group x Condition interactions, $F_{\%\text{Time}}(2, 34) = .44, \ NS, F_{1st\text{Fix}}(2, 34) = .24, \ NS$. Across viewing conditions, FTLD patients and controls gazed equally at the mouth of a neutral face. Means are presented in Table 5a.
Summary: Hypothesis 2. Hypothesis 2 was supported insofar as FTLD patients scanned the eye region of negative and neutral faces differently compared to controls. FTLD patients spent less time gazing at the eyes of negative and neutral faces than controls did. FTLD patients and controls did not differ in scanning the eyes of positive faces or in scanning the nose and mouth region of faces.

Hypothesis 3: Emotional gaze will predict measures of emotional reactivity in FTLD patients and controls

Physiological reactivity to faces. Physiological reactivity was assessed in the free-viewing condition of the emotional faces eye tracking task. A univariate ANCOVA showed that FTLD patients and controls were equally reactive to a positive face, $F(1, 37) = 1.26, NS$. To assess whether patients and controls exhibited different levels of physiological reactivity to sad, fearful, disgusted, and angry faces, reactivity scores were submitted to a 2 Group (FTLD, control) x 4 Emotion (sad, fearful, disgust, angry) mixed model ANCOVA. There was no significant main effect of group, $F(1, 37) = .18, NS$, no significant main effect of emotion, $F(1, 37) = .02, NS$, and no significant Group x Emotion interaction, $F(1, 37) = .51, NS$. Thus, physiological reactivity scores were averaged over sad, fearful, disgusted, and angry face trials to form a composite reactivity score for negative faces. A univariate ANCOVA showed that FTLD patients and controls were equally reactive to negative faces, $F(1, 37) = .17, NS$. Also, patients and controls were equally reactive to a neutral face, $F(1, 37) = .17, NS$. Mean reactivity scores are presented in Table 6.

Gaze predicting physiological reactivity to faces. The predictive power of gaze measures in the emotional faces free-viewing task was assessed. Linear regressions
showed that across all participants, percent tracked time spent gazing at the eyes of a positive face did not significantly predict physiological reactivity to the positive face, \( b = .04, t(36) = .24, \text{NS} \). However, latency of first fixation at the eyes of the positive face did significantly predict physiological reactivity to that face, \( b = .38, t(36) = 2.28, p < .05 \). Quicker fixation at the eyes was associated with lower physiological activation. A univariate ANCOVA yielded no significant Group x Latency of First Fixation interaction, \( F(1, 34) = .51, \text{NS} \), suggesting that the relationship between gaze and reactivity held across groups. Neither percent tracked time, \( b = -.17, t(36) = -1.06, \text{NS} \), nor latency of first fixation, \( b = .13, t(36) = .77, \text{NS} \), at the eyes of negative faces significantly predicted physiological reactivity to those negative faces. Similarly, neither percent tracked time, \( b = -.07, t(36) = -.40, \text{NS} \), nor latency of first fixation, \( b = .05, t(36) = .28, \text{NS} \), at the eyes of a neutral face significantly predicted physiological reactivity to the neutral face.

**Physiological reactivity to films.** Physiological reactivity was assessed in the reactivity films task. A univariate ANCOVA showed that FTLD patients and controls were equally reactive during the amusement film, \( F(1, 41) = .61, \text{NS} \). To assess whether patients and controls exhibited different levels of physiological reactivity during sadness and disgust films, reactivity scores were submitted to a 2 Group (FTLD, control) x 2 Emotion (sadness, disgust) mixed model ANCOVA. There was no significant main effect of group, \( F(1, 41) = .88, \text{NS} \), no significant main effect of emotion, \( F(1, 41) = .05, \text{NS} \), and no significant Group x Emotion interaction, \( F(1, 41) = .52, \text{NS} \). Thus, physiological reactivity scores were averaged over the sadness and disgust films to form a composite reactivity score for negative films. A univariate ANCOVA showed that FTLD patients
and controls were equally reactive to negative films, $F(1, 41) = .91, NS$. Mean physiological reactivity scores are presented in Table 7.

Gaze predicting physiological reactivity to films. The predictive power of gaze measures in the paired faces task and emotional faces free-viewing task was assessed. Linear regressions showed that neither percent tracked time, $b = .02, t(41) = .15, NS$, nor latency of first fixation, $b = .05, t(41) = .31, NS$, at a positive face in the paired faces task significantly predicted physiological reactivity to a positive (i.e., amusement) film. Also, neither percent tracked time, $b = .10, t(41) = .60, NS$, nor latency of first fixation, $b = .28, t(41) = 1.79, NS$, at a negative face in the paired faces task significantly predicted physiological reactivity to negative films. Linear regressions showed that across all participants, neither percent tracked time, $b = .00, t(37) = -.01, NS$, nor latency of first fixation, $b = .16, t(37) = .96, NS$, at the eyes of a positive face significantly predicted physiological reactivity to a positive film. However, percent tracked time spent gazing at the eyes of negative faces did significantly predict physiological reactivity to negative films, $b = .39, t(37) = 2.54, p < .05$. Increased gaze at the eyes was associated with increased physiological activation. A univariate ANCOVA yielded no significant Group x Percent Tracked Time interaction, $F(1, 36) = .93, NS$, suggesting that the relationship between gaze and reactivity held across groups. Latency of first fixation at the eyes of negative faces did not significantly predict physiological reactivity to negative films, $b = -.02, t(37) = -.12, NS$.

Behavioral reactivity to films. Behavioral reactivity was assessed in the reactivity films task. A univariate ANCOVA showed that FTLD patients and controls displayed equal amounts of positive emotion (i.e., happiness) during the amusement film, $F(1, 38) = 2.90,$
To assess whether patients and controls exhibited different levels of behavioral reactivity during sadness and disgust films, reactivity scores were submitted to a 2 Group (FTLD, control) x 2 Emotion (sadness, disgust) mixed model ANCOVA. There was a significant main effect of emotion, $F(1, 37) = 4.58, p < .05$, and Bonferroni pairwise comparisons showed that across groups, participants displayed more disgust during the disgust film than sadness during the sadness film, $p < .05$. The significant main effect of group, $F(1, 37) = 1.31, NS$, Group x Emotion interaction, $F(1, 38) = .36, NS$, were not significant. Given the significant main effect of emotion in the preceding analyses, sadness and disgust behavioral reactivity scores were tested separately in subsequent analyses. Univariate ANCOVAs showed that FTLD patients and controls displayed equal amounts of sadness during the sadness film, $F(1, 37) = 1.95, NS$, and equal amounts of disgust during the disgust film, $F(1, 40) = .20, NS$. Mean behavioral reactivity scores are presented in Table 7.

*Gaze predicting behavioral reactivity to films.* The predictive power of gaze measures in the paired faces task and emotional faces free-viewing task was assessed. Linear regressions showed that neither percent tracked time, $b = .09, t(38) = .51, NS$, nor latency of first fixation, $b = .29, t(38) = 1.86, NS$, at a positive face in the paired faces task significantly predicted behavioral reactivity to a positive film. Also, neither percent tracked time, $b = .09, t(40) = .58, NS$, nor latency of first fixation, $b = .20, t(40) = 1.35, NS$, at negatives face in the paired faces task significantly predicted behavioral reactivity to negative films. Linear regressions showed that neither percent tracked time, $b = .15, t(34) = .86, NS$, nor latency of first fixation, $b = -.02, t(34) = -.10, NS$, at the eyes of a positive face significantly predicted behavioral reactivity to a positive film. Similarly,
neither percent tracked time, $b = -.19$, $t(36) = -1.20, NS$, nor latency of first fixation, $b = .23$, $t(36) = 1.42, NS$, at the eyes of negative faces significantly predicted behavioral reactivity to sadness or disgust films.

Self-reported reactivity to films. Self-reported reactivity was assessed in the reactivity films task. A univariate ANCOVA showed that FTLD patients and controls reported feeling equal amusement during the amusement film, $F(1, 41) = 3.40, NS$. To assess whether patients and controls reported different levels of reactivity during sadness and disgust films, reactivity scores were submitted to a 2 Group (FTLD, control) x 2 Emotion (sadness, disgust) mixed model ANCOVA. There was a significant main effect of group, $F(1, 40) = 6.28, p < .05$, and follow-up Bonferroni pairwise comparisons showed that across negative emotions, FTLD patients reported less reactivity than controls did, $p < .05$ (see Table 7 for means). The main effect of emotion was also significant, $F(1, 40) = 13.16, p < .01$, and follow-up Bonferroni pairwise comparisons showed that across groups, participants reported feeling more disgust during the disgust film than sadness during the sadness film, $p < .01$ (see Table 7 for means). The Group x Emotion interaction was not significant, $F(1, 40) = .29, NS$. Given the significant main effect of emotion in the preceding analyses, sadness and disgust self-report scores were tested separately in subsequent analyses. A univariate ANCOVA showed that FTLD patients and controls reported feeling equal sadness during the sadness film, $F(1, 40) = 2.96, NS$. However, FTLD patients reported feeling less disgust during the disgust film than controls did, $F(1, 40) = 7.00, p < .05$ (see Table 7 for means).

Gaze predicting self-reported reactivity to films. The predictive power of gaze measures in the paired faces task and emotional faces free-viewing task was assessed. Linear
regressions showed that neither percent tracked time, $b = -.04$, $t(41) = -.26$, NS, nor latency of first fixation, $b = -.22$, $t(41) = -1.22$, NS, at a positive face in the paired faces task significantly predicted self-reported reactivity to a positive film. Similarly, neither percent tracked time nor latency of first fixation at negative faces in the paired faces task significantly predicted self-reported reactivity to sadness, $b_{\%Time} = .02$, $t_{\%Time}(40) = .10$, NS, $b_{1stFix} = -.08$, $t_{1stFix}(40) = -.47$, NS, or disgust films, $b_{\%Time} = .00$, $t_{\%Time}(41) = .02$, NS, $b_{1stFix} = -.08$, $t_{1stFix}(41) = -.74$, NS. Linear regressions also showed that neither percent tracked time, $b = -.05$, $t(37) = -.32$, NS, nor latency of first fixation, $b = .08$, $t(37) = .51$, NS, at the eyes of a positive face significantly predicted self-reported reactivity to a positive film. Neither percent tracked time nor latency of first fixation at the eyes of negative faces significantly predicted self-reported reactivity to sadness, $b_{\%Time} = -.04$, $t_{\%Time}(36) = -.26$, NS, $b_{1stFix} = .00$, $t_{1stFix}(36) = .01$, NS, or disgust films, $b_{\%Time} = -.14$, $t_{\%Time}(37) = -.91$, NS, $b_{1stFix} = -.06$, $t_{1stFix}(40) = -.38$, NS.

*Caregiver report on emotional reactivity*. To assess whether caregivers reported on joy and amusement reactivity differently, reactivity ratings were submitted to a 2 Group (FTLD, control) x 2 Emotion (joy, amusement) mixed model ANCOVA. The main effect of Group was significant, $F(1, 25) = 18.62$, $p < .01$, and follow-up Bonferroni pairwise comparisons showed that across positive emotions, caregivers ratings of emotional reactivity were lower for FTLD patients than for controls, $p < .01$ (see Table 8b for means). The main effect of emotion, $F(1, 25) = 1.01$, NS, and Group x Emotion interaction, $F(1, 25) = .00$, NS, were not significant. Thus, caregiver ratings were averaged over joy and amusement to form a composite reactivity rating for positive

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5 Because the caregiver report measures were not available at the start of data collection, only 13 FTLD patients 17 controls have caregiver report data.
emotion. A univariate ANCOVA showed that caregiver ratings of positive emotional reactivity were lower for FTLD patients than for controls, $F(1, 25) = 18.62, p < .01$ (see Table 8a for means). This effect also held after controlling for caregiver ratings of premorbid positive emotional reactivity, $F(1, 21) = 15.37, p < .01$. To assess whether caregivers reported on sadness, fear, disgust, and anger reactivity differently, reactivity ratings were submitted to a 2 Group (FTLD, control) x 4 Emotion (sadness, fear, disgust, anger) mixed model ANCOVA. There was no significant main effect of group, $F(1, 23) = .02, NS$, no significant main effect of emotion, $F(3, 23) = 1.97, NS$, and no significant Group x Emotion interaction, $F(3, 23) = .95, NS$. Thus, caregiver ratings were averaged over sadness, fear, disgust, and anger to form a composite reactivity rating for negative emotion. A univariate ANCOVA showed that caregiver ratings of negative emotional reactivity were equal for FTLD patients and controls, $F(1, 26) = .00, NS$. Mean caregiver ratings presented in Table 8a.

*Gaze predicting caregiver report on emotional reactivity.* The predictive power of gaze measures in the paired faces task and emotional faces free-viewing task was assessed. Linear regressions showed that across participants, neither percent tracked time, $b = .03, t(25) = .14, NS$, nor latency of first fixation, $b = .34, t(25) = 1.89, NS$, at positive faces in the paired faces task significantly predicted caregiver ratings of positive emotional reactivity. Similarly, neither percent tracked time, $b = .14, t(26) = .77, NS$, nor latency of first fixation, $b = .04, t(26) = .22, NS$, at negative faces in the paired faces task significantly predicted caregiver ratings of negative emotional reactivity. However, linear regression showed that across participants, percent tracked time spent gazing at the eyes of a positive face significantly predicted caregiver ratings of positive emotional
reactivity, $b = .48$, $t(23) = 2.79, p < .05$. Increased gaze at the eyes was associated with increased reactivity ratings. A univariate ANCOVA yielded no significant Group x Percent Tracked Time interaction, $F(1, 21) = .12, NS$, suggesting that the relationship between gaze and reactivity ratings held across groups. Latency of first fixation at the eyes of a positive face was not predictive of caregiver positive emotion reactivity ratings, $b = .00$, $t(23) = .01, NS$. Also, neither percent tracked time, $b = .00$, $t(24) = .02, NS$, nor latency of first fixation, $b = -.39$, $t(24) = .70, NS$, at the eyes of negative faces significantly predicted caregiver ratings of negative emotional reactivity.

**Summary:** Hypothesis 3. Hypothesis 3 was supported insofar as gaze measures predicted certain measures of emotional reactivity across FTLD patients and controls. Latency of first fixation at the eyes of a positive face predicted physiological reactivity to that face. Time spent gazing at the eyes of negative faces predicted physiological reactivity to negative films. Time spent gazing at the eyes of a positive face predicted caregiver ratings of positive emotional reactivity in daily life.

Hypothesis 4: Emotional gaze will predict measures of emotion recognition in FTLD patients and controls

**Recognition of emotional faces.** Recognition of emotion in faces was assessed in the recognition condition of the emotional faces eye tracking task. A univariate ANCOVA showed that FTLD patients and controls were equally accurate at recognizing a positive (i.e., happy) face, $F(1, 37) = .12, NS$. To assess whether patients and controls exhibited different levels of recognition accuracy for sad, fearful, disgusted, and angry faces, recognition scores were submitted to a 2 Group (FTLD, control) x 4 Emotion (sad, fearful, disgust, angry) mixed model ANCOVA. There was a significant main effect of
group, $F(3, 36) = 11.48, p < .01$, and follow-up Bonferroni pairwise comparisons
showed that across negative emotions, FTLD patients were less accurate at recognizing
ewmotional faces than controls were, $p < .01$ (see Table 9 for means). The main effect of
emotion, $F(3, 36) = 1.11, NS$, and Group x Emotion interaction, $F(3, 36) = .45, NS$, were
not significant. Thus, recognition scores were averaged over sad, fearful, disgusted, and
angry face trials to form a composite recognition score for negative faces. A univariate
ANCOVA showed that FTLD patients were less accurate at recognizing negative faces
than controls were, $F(1, 37) = 11.52, p < .01$ (see Table 9 for means). Patients and
controls were equally accurate at recognizing a neutral face, $F(1, 37) = .00, NS$.

*Gaze predicting recognition of emotional faces.* The predictive power of gaze measures
in the emotional faces recognition task was assessed. Linear regressions showed that
across all participants, neither percent tracked time, $b = .15, t(37) = .92, NS$, nor latency
of first fixation, $b = -.09, t(37) = -.53, NS$, at the eyes of a positive face significantly
predicted recognition of the positive face. However, across all participants, percent
tracked time spent gazing at the eyes of negative faces significantly predicted recognition
of those negative faces, $b = .32, t(37) = 2.06, p < .05$. Increased gaze at the eyes was
associated with increased recognition accuracy. A univariate ANCOVA yielded no
significant Group x Percent Tracked Time interaction, $F(1, 35) = .26, NS$, suggesting that
the relationship between gaze and recognition held across groups. Latency of first
fixation to the eyes of negative faces did not significantly predict recognition of those
negative faces, $b = -.08, t(37) = -.48, NS$. Also, across all participants, neither percent
tracked time, $b = .14, t(36) = .89, NS$, nor latency of first fixation, $b = .07, t(36) = .46,
NS$, at the eyes of a neutral face significantly predicted recognition of the neutral face.
Recognition of emotional films. Recognition of emotion in films was assessed in the recognition film task. To assess whether patients and controls exhibited different levels of recognition accuracy for enthusiasm, calm, affection, and amusement films, recognition scores were submitted to a 2 Group (FTLD, Control) x 4 Emotion (enthusiasm, calm, affection, amusement) mixed model ANCOVA. There was a main effect of group, $F(1, 40) = 7.88, p < .01$, and follow-up Bonferroni pairwise comparisons showed that across positive emotions, FTLD patients were less accurate at recognizing emotional films than controls were, $p < .01$ (see Table 10b for means). The main effect of emotion, $F(3, 40) = 1.22, NS$, and Group x Emotion interaction, $F(3, 40) = .52, NS$, were not significant. Thus, recognition scores were averaged over enthusiasm, calm, affection, and amusement trials to form a composite recognition score for positive films. A univariate ANCOVA showed that FTLD patients were less accurate at recognizing positive films than controls were, $F(1, 41) = 8.19, p < .01$ (see Table 10a for means). To assess whether patients and controls exhibited different levels of recognition accuracy for sadness, fear, disgust, and anger films, recognition scores were submitted to a 2 Group (FTLD, Control) x 4 Emotion (sadness, fear, disgust, anger) mixed model ANCOVA. There was no main effect of group, $F(1, 38) = 1.68, NS$, no main effect of emotion, $F(3, 38) = .94, NS$, and no significant Group x Emotion interaction, $F(3, 38) = 1.73, NS$. Mean recognition scores presented in Table 10b. Thus, recognition scores were averaged over sadness, fear, disgust, and anger trials to form a composite recognition score for negative films. A univariate ANCOVA showed that FTLD patients and controls were equally accurate at recognizing negative emotional films, $F(1, 41) = .1.42, NS$. 

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**Gaze predicting recognition of emotional films.** The predictive power of gaze measures in the paired faces task and emotional faces recognition task were assessed. Linear regressions showed that across all participants, neither percent tracked time, \( b = .08, t(41) = 55, NS \), nor latency of first fixation, \( b = .20, t(41) = 1.21, NS \), at positive faces in the paired faces task significantly predicted recognition of positive films. Similarly, neither percent tracked time, \( b = -.09, t(41) = -.62, NS \), nor latency of first fixation at negative faces, \( b = -.12, t(41) = -.08, NS \), in the paired faces task significantly predicted recognition of negative films. Linear regressions also showed that neither percent tracked time, \( b = .23, t(38) = 1.62, NS \), nor latency of first fixation, \( b = -.18, t(38) = -1.24, NS \), at the eyes of a positive face significantly predicted recognition of positive films. Neither percent tracked time, \( b = -.06, t(38) = -.43, NS \), nor latency of first fixation, \( b = -.03, t(38) = -.17, NS \), at the eyes of negative faces significantly predicted recognition of negative films.

**Caregiver report on emotion recognition.** To assess whether caregivers reported on joy and amusement recognition differently, recognition ratings were submitted to a 2 Group (FTLD, control) x 2 Emotion (joy, amusement) mixed model ANCOVA. There was a main effect of group, \( F(1, 23) = 20.64, p < .01 \), and follow-up Bonferroni pairwise comparisons showed that across positive emotions, caregiver ratings of emotion recognition were lower for FTLD patients than for controls, \( p < .01 \) (see Table 8c for means). The main effect of emotion, \( F(1, 23) = .90, NS \), and Group x Emotion interaction, \( F(3, 23) = .21 \), were not significant. Thus, caregiver ratings were averaged over joy and amusement to form a composite recognition rating for positive emotion. A univariate ANCOVA showed that caregiver ratings of positive emotion recognition were
lower FTLD patients than for controls, $F(1, 24) = 24.22, p < .01$ (see Table 8a for means). This effect also held after controlling for caregiver ratings of premorbid positive emotion recognition accuracy, $F(1, 21) = 35.74, p < .01$. To assess whether caregivers reported on sadness, fear, disgust, and anger recognition differently, recognition ratings were submitted to a 2 Group (FTLD, control) x 4 Emotion (sadness, fear, disgust, anger) mixed model ANCOVA. The main effect of group was significant, $F(1, 21) = 23.81, p < .01$, and follow-up Bonferroni pairwise comparisons showed that across negative emotions, caregiver ratings of emotion recognition were lower for FTLD patients than for controls, $p < .01$ (see Table 8c for means). The main effect of emotion was also significant, $F(3, 21) = 3.37, p < .05$, but closer examination with Bonferroni pairwise comparisons failed to show any significant differences among sadness, fear, disgust, and anger recognition ratings. The Group x Emotion interaction was not significant, $F(3, 21) = .06$. Thus, caregiver ratings were averaged over sadness, fear, disgust, and anger to form a composite recognition rating for negative emotion. A univariate ANCOVA showed that caregiver ratings of negative emotion recognition were lower FTLD patients than for controls, $F(1, 25) = 31.54, p < .01$ (see Table 8a for means). This effect also held after controlling for caregiver ratings of premorbid negative emotion recognition accuracy, $F(1, 21) = 36.42, p < .01$.

_Gaze predicting caregiver report on emotion recognition_. The predictive power of gaze measures in the paired faces task and emotional faces recognition task were assessed. Linear regressions showed that across all participants, neither percent tracked time, $b = .11, t(24) = .56, \text{NS}$, nor latency of first fixation, $b = .07, t(24) = .35, \text{NS}$, at positive faces in the paired faces task significantly predicted caregiver ratings of positive emotion.
recognition. However, percent tracked time spent gazing at negative faces in the paired faces task significantly predicted caregiver ratings of negative emotion recognition, $b=.38, t(25)=2.33, p<.05$. Increased gaze at negative faces was associated with increased recognition ratings. A univariate ANCOVA yielded no significant Group x Percent Tracked Time interaction, $F(1, 23) = .39, NS$, suggesting that the relationship between gaze and recognition held across groups. Latency of first fixation at negative faces in the paired faces task did not significantly predict caregiver ratings of negative emotion recognition, $b = -.13, t(25) = -.68, NS$. Linear regressions also showed that neither percent tracked time, $b = -.01, t(22) = -.06, NS$, nor latency of first fixation, $b = -.06, t(22) = -.29, NS$, at the eyes of a positive face significantly predicted caregiver ratings of positive emotion recognition. Similarly, neither percent tracked time, $b = .20, t(23) = 1.10, NS$, nor latency of first fixation, $b = -.03, t(23) = -.15, NS$, at the eyes of negative faces significantly predicted caregiver ratings of negative emotion recognition.

**Summary: Hypothesis 4.** Hypothesis 4 was supported insofar as gaze measures predicted certain measures of emotion recognition across FTLD patients and controls. Time spent gazing at the eyes of negative faces predicted recognition of specific negative emotion in those faces. Time spent gazing at negative faces in the paired faces task predicted caregiver ratings of negative emotion recognition in daily life.

**Discussion**

Previous research has shown that FTLD patients exhibit deficits in the realm of emotional functioning. Studies of caregiver reports and laboratory tasks have found reduced emotional expressiveness in patients (Rankin et al, 2003; Snowden et al, 2001) and reduced reactivity to negative emotional stimuli (Sturm et al, 2006; Werner et al,
Moreover, research has shown that FTLD patients have difficulty recognizing emotional states in others. Patients show reduced ability to recognize emotional expressions in faces, particularly negative emotional faces (Lavenu et al., 1999; Keane, 2002; Rosen et al., 2004; Fernandez-Duque & Black, 2005; Lough et al., 2006; Kessels et al., 2007; Diehl-Schmid et al., 2007). Although deficits in the processing of emotional information in FTLD have been documented in a number of ways, little is known about where the breakdown in information processing occurs. The present study examined whether impairment occurs early in the process, at the stage of visual attention deployment and information gathering. If FTLD patients do not visually attend to emotionally salient cues in the environment, they are not likely to gather the information necessary for eliciting an emotional response or making a correct judgment about emotional states in others. In the present study, eye movements were used as a proxy of visual attention. As in prior research (Adolphs et al., 2005; Calvo & Lang, 2004; Rosler et al., 2005; Marsh & Williams, 2006; Nummenenena et al., 2006), time spent gazing at emotional cues and latency of first fixation at those cues served as indicators of attention to emotional information. In addition, the relationship between gaze and emotional functioning was assessed by examining whether gaze patterns predicted measures of emotional reactivity and emotion recognition.

Group differences in emotional gaze

Results supported the hypothesis that FTLD patients and control participants differ in attentional preference for emotional information. In the paired faces task, where participants viewed a series of emotional faces paired with matched neutral faces, FTLD participants spent less time gazing at negative faces than controls did. Consistent with
previous research (Calvo & Lang, 2004; Rosler et al, 2005; Nummenena et al, 2006) control participants showed an attentional bias for negative emotional information by gazing longer at the negative faces than the matched neutral faces. In contrast, FTLD patients gazed equally long at the negative and neutral faces. This suggests that for controls, negative faces hold some special salience or additional information (beyond what is conveyed by a neutral face) that attracts visual attention. However, for FTLD patients (for whom emotional information may no longer be meaningful or particularly salient), gaze time was evenly distributed between negative and neutral faces, showing a lack of visual attentional preference for negative emotional information. In the positive-neutral face pairs, both FTLD patients and control participants spent more time gazing at the positive faces than the matched neutral faces. Thus, it appears that visual attentional preference for positive emotional information might remain intact in FTLD. Moreover, there was some evidence that distribution of gaze is predictive of self-reports of “interest” in emotional information; across all participants, increased time spent gazing at negative faces in the paired faces task was predictive of greater self-reported interest in sad faces. However, time spent gazing at positive faces and time spent gazing at negative faces were not predictive of self-reported interest in positive or angry faces. The discrepancy in findings could be due, in part, to the imprecision of the self-report measure. For example, it is possible that participants interpreted the term “interest” to mean “liking,” which would not necessarily correspond to measures of attentional bias. One might “like” an angry face less than a neutral face because the angry face is threatening, but still gaze more at the angry face because it is adaptive to pay attention to threatening cues in the environment.
Results also supported the hypothesis that FTLD patients scan emotional faces differently compared to control participants. In the emotional faces task, FTLD patients spent less time gazing at the eyes of negative faces than controls did. This is consistent with the finding that FTD patients engage in less eye contact with their caregivers during a discussion of relationship of conflict, in comparison to controls (Sturm et al, under review). Previous research has shown that gaze at the eyes is particularly important for recognizing negative emotion in faces (Adolphs et al, 2005). However, if FTLD patients’ motivation to understand how others are feeling is diminished, as clinical reports of apathy and interpersonal coldness suggest (Rankin et al, 2003), the time they spend gazing at the eyes of negative faces might also be diminished. In contrast, FTLD patients and controls spent equal time gazing at the eyes of a positive face. Prior research suggests that though negative emotional functioning is widely impacted in FTLD, some aspects of positive emotional functioning might be preserved (Werner et al, 2007; Fernandex-Duque & Black, 2005, Rosen et al, 2006). It might be that cues signaling positive emotion remain salient, and thus, continue to drawn visual attention. Moreover, FTLD patients spent less time gazing at the eyes of a neutral face than controls did. It appears that in the absence of emotional expression, patients will still gaze less at the eye region of faces compared to controls.

Interestingly, FTLD patients and controls did not differ in time spent gazing at the nose or mouth region of positive, negative, and neutral faces. Given that the eyes are especially important for communicating information in social contexts (Emery, 2000), it is not surprising that gaze differences between FTLD patients and control participants would be concentrated in this region. Moreover, decreased gaze at the eyes in FTLD
patients cannot be explained by increased gaze at the nose or mouth. Rather, time spent not gazing at the eyes can only be attributed to increased gaze at the outer region of faces, where less emotional information is available. It is also interesting to note that there were no group differences in latency of first fixation for any of the regions in any of the faces. This shows that the eyes attracted attention equally quickly in FTLD patients and controls, but sustained that attention for a shorter duration in FTLD patients than in controls. Furthermore, the few differences in gaze measures among the three viewing conditions (free-view, repeat, and recognition) suggests that both FTLD patients and controls scan emotional faces in ways that are consistent across repeated presentations of faces and different viewing conditions. Also, equal performance on the oculomotor control task by a subset of FTLD patients and controls suggests that group differences in gaze in the paired faces and emotional faces tasks are not indicative of a more general (or non-emotional) gaze deficit in FTLD patients.

Gaze & emotional reactivity

Results of the eye tracking tasks support differences in emotional gaze between FTLD patients and control participants. They also suggest that in FTLD, impairment occurs at a very early point in emotion processing, i.e., at the level of attention deployment and information gathering. Moreover, if FTLD patients are not selectively attending to emotional cues in the environment, they might be missing information that is crucial for the experience of emotion and/or the recognition of emotion in others. This suggestion that gaze deficits play an important role in higher level emotional functioning was supported in subsequent analyses. Across subjects, latency of first fixation at the eyes of a positive face predicted physiological reactivity to that face, such that quicker
fixations were associated with lower physiological activation. The finding is consistent with previous research showing that positive emotional stimuli have de-arousing or soothing effects on the autonomic nervous system (Fredrickson & Levenson, 1998; Yuan et al, under review). However, gaze at the eyes of negative faces did not predict physiological reactivity to those faces. Unlike positive emotional cues, negative emotional cues are expected to increase physiological activation, helping prepare the organism to deal with threat and danger. The brief presentation of static negative emotional faces on a computer screen may not have been sufficient for eliciting such a response. For the reactivity films task (a stronger elicitor of emotional response), time spent gazing at the eyes of negative faces did predict physiological reactivity to negative films, such that increased gaze was associated with higher physiological activation. This suggests that attention to the eyes in negative emotionally evocative situations contributes to increases in physiological arousal. Moreover, the relationships between gaze and physiological activity were not specific to FTLD patients or controls, but rather were found across groups. Also, groups did not differ in physiological reactivity in either the emotional faces or reactivity films tasks. Thus, the association between gaze and physiological activity appears to be independent of FTLD diagnosis.

Results indicated that gaze measures did not predict behavioral or self-report measures of emotional reactivity in the reactivity films task. Consistent with past research (Eckart et al, in prep), FTLD patients reported feeling less disgusted during the disgust film, but as sad during the sad film and as amused during the amusement film, as controls did. There were no group differences in facial expressions of target emotion for any of the reactivity films. Although gaze behavior might play a role in eliciting
physiological response in laboratory tasks, it may not be as influential in other domains of emotional reactivity that require specific facial muscle movement and additional cognitive processing.

Results also suggest that emotional gaze, as assessed by laboratory tasks, has relevance for emotional reactivity in daily life. Time spent gazing at the eyes of a positive face was predictive of caregiver ratings of positive emotional reactivity in daily life, in that increased gaze was associated with increased reactivity. This suggests that attention to cues indicating another person is feeling positively towards you will, in turn, increase your experience of positive emotion. Or, it could be that attention to positive emotional cues in others increases one’s empathic or vicarious experience of positive emotion. The relationship between gaze and caregiver ratings was not specific to FTLD patients or controls, but rather held across groups. However, group comparisons showed that caregiver ratings of positive emotional reactivity were lower for FTLD patients than for control participants. Thus, gaze at the eyes of a positive face might predict decline in positive emotional reactivity associated with FTLD. Gaze at the eyes of negative faces did not predict caregiver ratings of negative emotional reactivity. Though attending to negative facial expressions might elicit a negative emotional response, there are numerous other factors (e.g., concerns about health and finances) that contribute to the experience of negative emotion in daily life. Thus, attention to emotional cues in faces may have relatively little influence on overall levels of negative emotional reactivity, as rated by caregivers. Caregiver ratings of negative emotional reactivity were equivalent for FTLD patients and control participants.

Gaze & emotion recognition
Results of the present study also indicate that deficits in emotional gaze have implications for emotion recognition. Time spent gazing at the eyes of negative faces predicted recognition of emotion in those faces, such that increased gazed was associated with increased recognition accuracy. This finding is consistent with previous research showing that attention to the eye region is critical for recognition of negative emotion in faces (Adolphs et al, 2005). The relationship between gaze and emotion recognition in faces was not specific to FTLD patients or control participants, but rather held across groups. However, consistent with prior studies (Lavenu et al, 1999; Keane, 2002; Rosen et al, 2004; Fernandez-Duque & Black 2005; Kessels et al, 2007; Diehl-Schmid et al, 2007), FTLD patients were less accurate at recognizing specific negative emotions in faces compared to controls. This suggests that gaze at the eyes of negative faces could help predict decline in negative emotion recognition associated with FTLD. Gaze at the eyes of a positive face did not predict recognition of emotion in that face. It may be that attention to the eyes is less critical for the recognition of positive emotion than negative emotion in faces or that the recognition threshold for gaze at the eyes is lower for positive faces than it is for negative faces. Consistent with prior studies (Fernandez-Duque & Black, 2005, Rosen et al, 2006), FTLD patients and controls were equally accurate at recognizing emotion in the positive face. This finding supports the idea that some aspects of positive emotional functioning may be preserved in FTLD.

Interestingly, gaze measures did not predict recognition of positive or negative emotion in films. Compared to control participants, FTLD patients were less accurate at recognizing both positive and negative emotions in the recognition films task. The recognition films task differed from the emotional faces task, in that participants could
draw from vocalizations, background music, body gestures, and situational context (in addition to facial expressions) to decipher how characters in the films were feeling. The presence of so many other emotional cues may have diluted the impact of emotional gaze on emotion recognition accuracy.

Furthermore, time spent gazing at negative faces in the paired faces task was predictive of caregiver ratings of negative emotion recognition in daily life, in that increased gaze was associated with increased recognition accuracy. This suggests that recognition of negative emotion in others improves with selective attention to emotional cues in the environment. The relationship between gaze and caregiver ratings was not specific to FTLD patients or controls, but rather held across groups. However, caregiver ratings of negative emotion recognition were lower for FTLD patients than for control participants. This suggests that gaze at negative faces (paired with neutral faces) might predict decline in negative emotion recognition associated with FTLD. Gaze at positive faces in the paired faces task did not predict caregiver ratings of positive emotion recognition. In the paired faces task, FTLD patients gazed at positive faces as much as controls did. However, caregiver ratings for positive emotion recognition were lower for FTLD patients than for controls. Perhaps, selective attention to positive faces alone is insufficient for recognizing positive emotion in daily life. It may be that attention to speech content or body gestures is also necessary for consistent detection of positive emotional states in others.

Limitations

There are a number of limitations in the present study worthy of note. First, gaze findings were based on a limited number of trials. In the emotional faces task,
participants viewed one set of happy, sad, fearful, disgusted, angry, and neutral faces, which were all posed by the same actor. To assure that findings are not specific to this particular set of stimuli, the results would need to be replicated with a variety of stimuli sets. Similarly, the paired faces task consisted of happy, sad, and angry face-pairs only. Generalizability would be increased by replicating results with more trials and other specific emotions. Second, the relationships found between gaze and emotional functioning were essentially correlational in nature. To test whether deficits in emotional functioning are caused by deficits in emotional gaze, one would need to conduct a study in which gaze is experimentally manipulated (either by occluding parts of the emotional stimuli or by training participants to alter their gaze behavior). Third, the present study examined gaze at static faces only. To make broader conclusions about attention to emotional information in FTLD, it would be important to assess gaze at other types of emotional stimuli. Because emotional cues can consist of non-visual information (e.g., tone of voice), it would also be important to assess attention to emotion in other sensory modalities (e.g., auditory).

Another major limitation of the present work is the inclusion of only one dementia group. Thus, it is not known whether group differences in emotional gaze should be attributed to FTLD specifically or to clinical dementia more broadly. Including patients with other forms of dementia (such as Alzheimer’s disease) in future testing would help answer this question. Moreover, the nature the relationship between emotional gaze and emotional functioning might be further explained with formal mediational analyses. Such analyses would elucidate whether diagnostic group
differences in emotional reactivity and emotion recognition can be explained by group differences in emotional gaze.

Future Directions

Determining the anatomical basis of deficits in emotional gaze would be extremely important for future research. Prior research has shown that visual attention to emotional cues is subserved by both cortical (i.e., frontal eye fields and posterior parietal lobe) and subcortical (i.e., superior colliculus, pulvinar, and amygdala) structures in the brain. Thus, deficits in emotional gaze may be indicative of damage or loss in these areas. Future studies combining neuroimaging and eye tracking might further our understanding of the neural circuitry of emotional gaze. Studying FTLD patients could be particularly informative, as these patients show early loss in frontal and temporal areas. The assessment of emotional gaze might also have utility in the diagnosis of neurological patients. Previous research has shown that deficits in emotional functioning can distinguish FTLD patients from those with other neurodegenerative disorders, such as Alzheimer’s disease. Thus, identifying differences in emotional gaze among various neurological groups might aid in the process of differential diagnosis. The assessment of emotional gaze might also translate into clinical interventions for FTLD patients.

Adolphs et al. (2005) found that a bilateral amygdalectomy patient (who showed reduced gaze at the eyes of fearful faces and reduced ability to recognize fear in faces) could be trained to increase gaze at the eye region, and subsequently improve emotion recognition accuracy. In a similar way, it might be that FTLD patients could be coached into increasing attention to emotional cues, which might in turn improve emotion recognition and emotional responding.
Conclusion

Results of the present study showed deficits in emotional gaze in FTLD patients. Specifically, FTLD patients showed less attentional preference for negative emotional faces over neutral faces and attended less to the eyes of negative faces, compared to control participants. There was also evidence that reduced attention to emotional cues is predictive of reduced emotional reactivity and reduced emotion recognition. This exploration of emotional gaze in FTLD shows that deficits in low-level attentional processes are highly relevant to higher-order aspects of emotional functioning and suggests that there is more to be learned through future research using these methods and patient populations.
References


Neuroanatomical correlates of impaired recognition of emotion in dementia.

*Neuropsychologia*, 44, 365-373.


### Table 1a
Positive & Negative Paired Faces Percent Tracked Time & Latency of First Fixation estimated Marginal Means (SE)

<table>
<thead>
<tr>
<th>Group</th>
<th>Positive-Neutral Pairs</th>
<th>Negative-Neutral Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive Faces</td>
<td>Neutral Faces</td>
</tr>
<tr>
<td></td>
<td>% Time</td>
<td>1st Fix</td>
</tr>
<tr>
<td>FTLD (n = 23)</td>
<td>45.49 (2.08)</td>
<td>.63 (.10)</td>
</tr>
<tr>
<td>Ctrl (n = 24)</td>
<td>48.82 (2.08)</td>
<td>.60 (.10)</td>
</tr>
</tbody>
</table>

1Latency of first fixation measured in seconds

### Table 1b
Sad & Angry Paired Faces Percent Tracked Time & Latency of First Fixation estimated Marginal Means (SE)

<table>
<thead>
<tr>
<th>Group</th>
<th>Sad Faces</th>
<th>Angry Faces</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Time</td>
<td>1st Fix</td>
</tr>
<tr>
<td>FTLD (n = 23)</td>
<td>42.73 (2.29)</td>
<td>.62 (.08)</td>
</tr>
<tr>
<td>Ctrl (n = 24)</td>
<td>51.21 (2.23)</td>
<td>.65 (.08)</td>
</tr>
</tbody>
</table>

1Latency of first fixation measured in seconds

### Table 2
Estimated Marginal Means (SE) for Paired Faces Self-Report Interest Scores

<table>
<thead>
<tr>
<th>Group</th>
<th>Positive-Neutral Pairs</th>
<th>Negative-Neutral Pairs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive Faces</td>
<td>Sad Faces</td>
</tr>
<tr>
<td>FTLD (n = 23)</td>
<td>.87 (08)</td>
<td>.28 (.10)</td>
</tr>
<tr>
<td>Ctrl (n = 24)</td>
<td>.78 (08)</td>
<td>.78 (.09)</td>
</tr>
<tr>
<td>Condition</td>
<td>Positive Face</td>
<td>Negative Faces</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td>% Time</td>
<td>1st Fix</td>
</tr>
<tr>
<td>FTLD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free-view</td>
<td>31.96 (4.87)</td>
<td>.84 (.21)</td>
</tr>
<tr>
<td>Repeat</td>
<td>38.48 (6.45)</td>
<td>1.60 (.30)</td>
</tr>
<tr>
<td>Recognition</td>
<td>34.49 (5.85)</td>
<td>1.72 (.46)</td>
</tr>
<tr>
<td>Ctrl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free-view</td>
<td>47.80 (4.59)</td>
<td>.80 (.20)</td>
</tr>
<tr>
<td>Repeat</td>
<td>49.16 (6.08)</td>
<td>.67 (.28)</td>
</tr>
<tr>
<td>Recognition</td>
<td>41.87 (5.51)</td>
<td>1.10 (.43)</td>
</tr>
</tbody>
</table>

Latency of first fixation measured in seconds.

Table 3b

<table>
<thead>
<tr>
<th>Condition</th>
<th>Sad Face</th>
<th>Fear Face</th>
<th>Disgust Face</th>
<th>Angry Face</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Time</td>
<td>1st Fix</td>
<td>% Time</td>
<td>1st Fix</td>
</tr>
<tr>
<td>FTLD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free-view</td>
<td>28.91 (5.11)</td>
<td>1.00 (.29)</td>
<td>30.51 (5.10)</td>
<td>1.55 (.34)</td>
</tr>
<tr>
<td>Repeat</td>
<td>27.67 (5.88)</td>
<td>1.70 (.37)</td>
<td>24.11 (4.98)</td>
<td>1.42 (.37)</td>
</tr>
<tr>
<td>Recognition</td>
<td>31.28 (4.63)</td>
<td>1.08 (.31)</td>
<td>32.71 (5.09)</td>
<td>1.01 (.34)</td>
</tr>
<tr>
<td>Ctrl</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free-view</td>
<td>44.21 (5.11)</td>
<td>.84 (.28)</td>
<td>40.94 (5.10)</td>
<td>1.17 (.34)</td>
</tr>
<tr>
<td>Repeat</td>
<td>46.79 (5.37)</td>
<td>.73 (.34)</td>
<td>43.10 (4.54)</td>
<td>.96 (.34)</td>
</tr>
<tr>
<td>Recognition</td>
<td>44.58 (4.11)</td>
<td>.99 (.28)</td>
<td>37.43 (4.52)</td>
<td>1.17 (.30)</td>
</tr>
</tbody>
</table>

Latency of first fixation measured in seconds.
### Table 4a
Nose Region Percent Tracked Time & Latency of First Fixation\(^1\) Estimated Marginal Means (SE) for Positive, Negative, and Neutral Faces in Free-View, Repeat, and Recognition Viewing Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Positive Face</th>
<th></th>
<th>Negative Faces</th>
<th></th>
<th>Neutral Face</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Time 1(^{st}) Fix</td>
<td>% Time 1(^{st}) Fix</td>
<td>% Time 1(^{st}) Fix</td>
<td>% Time 1(^{st}) Fix</td>
<td>% Time 1(^{st}) Fix</td>
<td>% Time 1(^{st}) Fix</td>
</tr>
<tr>
<td>FTLD ((n = 20))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free-view</td>
<td>26.07 (.38)</td>
<td>.79 (.37)</td>
<td>21.53 (.16)</td>
<td>1.05 (.30)</td>
<td>15.55 (.83)</td>
<td>.99 (.48)</td>
</tr>
<tr>
<td>Repeat</td>
<td>21.42 (.45)</td>
<td>1.26 (.41)</td>
<td>22.71 (.06)</td>
<td>1.17 (.29)</td>
<td>15.85 (.49)</td>
<td>1.75 (.50)</td>
</tr>
<tr>
<td>Recognition</td>
<td>25.30 (.94)</td>
<td>1.31 (.39)</td>
<td>18.38 (.35)</td>
<td>1.70 (.31)</td>
<td>19.41 (.94)</td>
<td>1.08 (.40)</td>
</tr>
<tr>
<td>Ctrl ((n = 23))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free-view</td>
<td>15.97 (.36)</td>
<td>1.08 (.34)</td>
<td>18.00 (.29)</td>
<td>1.29 (.36)</td>
<td>16.97 (.60)</td>
<td>1.97 (.45)</td>
</tr>
<tr>
<td>Repeat</td>
<td>24.60 (.42)</td>
<td>1.12 (.38)</td>
<td>23.05 (.34)</td>
<td>1.12 (.28)</td>
<td>20.71 (.66)</td>
<td>1.61 (.46)</td>
</tr>
<tr>
<td>Recognition</td>
<td>23.08 (.65)</td>
<td>.99 (.37)</td>
<td>22.50 (.16)</td>
<td>.91 (.29)</td>
<td>20.43 (.70)</td>
<td>1.23 (.37)</td>
</tr>
</tbody>
</table>

\(^1\)Latency of first fixation measured in seconds

### Table 4b
Nose Region Percent Tracked Time & Latency of First Fixation\(^1\) Estimated Marginal Means (SE) for Sad, Fearful, Disgusted, and Angry Faces in Free-View, Repeat, and Recognition Viewing Conditions

| Condition  | Sad Face |  | Fear Face |  | Disgust Face |  | Angry Face |  |
|------------|----------|-----------------|-----------------|-----------------|-----------------|-----------------|
|            | % Time 1\(^{st}\) Fix | % Time 1\(^{st}\) Fix | % Time 1\(^{st}\) Fix | % Time 1\(^{st}\) Fix | % Time 1\(^{st}\) Fix | % Time 1\(^{st}\) Fix |
| FTLD \((n = 20)\) |  |  |  |  |  |  |
| Free-view  | 19.63 (4.08) | .87 (3.38) | 17.82 (3.21) | .30 (2.29) | 30.38 (4.11) | 1.10 (4.40) |
| Repeat     | 24.15 (5.98) | 1.24 (4.46) | 21.35 (4.75) | 1.45 (4.41) | 26.56 (5.50) | 1.30 (4.42) |
| Recognition| 19.22 (3.75) | 1.20 (4.40) | 15.26 (3.94) | 1.90 (4.47) | 20.29 (4.42) | 1.39 (4.41) |
| Ctrl \((n = 23)\) |  |  |  |  |  |  |
| Free-view  | 20.85 (4.08) | .82 (3.38) | 19.28 (3.21) | 1.11 (2.29) | 16.59 (4.11) | .84 (4.40) |
| Repeat     | 23.97 (5.46) | 1.31 (4.42) | 23.68 (4.34) | .81 (3.38) | 25.83 (5.03) | .79 (3.42) |
| Recognition| 21.89 (3.33) | 1.00 (3.46) | 22.17 (3.50) | .68 (3.42) | 24.89 (3.92) | .84 (3.92) |

\(^1\)Latency of first fixation measured in seconds
### Table 5a
Mouth Region Percent Tracked Time & Latency of First Fixation Estimated Marginal Means (SE) for Positive, Negative, and Neutral Faces in Free-View, Repeat, and Recognition Viewing Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Positive Face</th>
<th>Negative Faces</th>
<th>Neutral Face</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Time</td>
<td>1st Fix</td>
<td>% Time</td>
</tr>
<tr>
<td>Free-view</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FTLD (n = 20)</td>
<td>14.36 (3.00)</td>
<td>2.64 (0.50)</td>
<td>16.45 (3.59)</td>
</tr>
<tr>
<td>Repeat</td>
<td>15.38 (3.14)</td>
<td>2.64 (0.53)</td>
<td>12.92 (2.69)</td>
</tr>
<tr>
<td>Recognition</td>
<td>15.38 (4.98)</td>
<td>3.14 (0.52)</td>
<td>14.28 (2.92)</td>
</tr>
<tr>
<td>Ctrl (n = 23)</td>
<td>14.19 (2.83)</td>
<td>2.08 (0.47)</td>
<td>11.55 (3.38)</td>
</tr>
<tr>
<td>Repeat</td>
<td>5.40 (2.96)</td>
<td>3.74 (0.50)</td>
<td>9.02 (2.53)</td>
</tr>
<tr>
<td>Recognition</td>
<td>16.69 (4.69)</td>
<td>1.88 (0.49)</td>
<td>11.89 (2.75)</td>
</tr>
</tbody>
</table>

Latency of first fixation measured in seconds

### Table 5b
Mouth Region Percent Tracked Time & Latency of First Fixation Estimated Marginal Means (SE) for Sad, Fearful, Disgusted, and Angry Faces in Free-View, Repeat, and Recognition Viewing Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Sad Face</th>
<th>Fear Face</th>
<th>Disgust Face</th>
<th>Angry Face</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Time</td>
<td>1st Fix</td>
<td>% Time</td>
<td>1st Fix</td>
</tr>
<tr>
<td>Free-view</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FTLD (n = 20)</td>
<td>14.00 (3.59)</td>
<td>3.43 (0.44)</td>
<td>16.84 (4.16)</td>
<td>2.71 (0.55)</td>
</tr>
<tr>
<td>Repeat</td>
<td>11.62 (2.89)</td>
<td>2.88 (0.53)</td>
<td>9.85 (3.46)</td>
<td>3.28 (0.55)</td>
</tr>
<tr>
<td>Recognition</td>
<td>13.87 (3.32)</td>
<td>3.26 (0.53)</td>
<td>13.88 (3.56)</td>
<td>2.65 (0.51)</td>
</tr>
<tr>
<td>Ctrl (n = 23)</td>
<td>9.91 (3.59)</td>
<td>3.29 (0.44)</td>
<td>13.00 (4.16)</td>
<td>2.81 (0.55)</td>
</tr>
<tr>
<td>Repeat</td>
<td>7.47 (2.63)</td>
<td>3.37 (0.48)</td>
<td>11.65 (3.16)</td>
<td>3.15 (0.50)</td>
</tr>
<tr>
<td>Recognition</td>
<td>10.49 (2.95)</td>
<td>2.51 (0.47)</td>
<td>14.73 (3.16)</td>
<td>2.76 (0.45)</td>
</tr>
</tbody>
</table>

Latency of first fixation measured in seconds
Table 6
Estimated Marginal Means (SE) for Emotional Faces Physiological Reactivity Scores

<table>
<thead>
<tr>
<th></th>
<th>Positive Face</th>
<th>Sad Face</th>
<th>Fearful Face</th>
<th>Disgusted Face</th>
<th>Angry Face</th>
<th>Negative Faces</th>
<th>Neutral Face</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FTLD</strong></td>
<td>-.06 (.10)</td>
<td>.01 (.11)</td>
<td>.03 (.11)</td>
<td>.06 (.11)</td>
<td>-.06 (.10)</td>
<td>.01 (.04)</td>
<td>-.01 (.10)</td>
</tr>
<tr>
<td>(n = 23)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ctrl</strong></td>
<td>.10 (.09)</td>
<td>-.03 (.10)</td>
<td>-.05 (.10)</td>
<td>-.09 (.10)</td>
<td>.08 (.10)</td>
<td>-.02 (.04)</td>
<td>.05 (.09)</td>
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<tr>
<td>(n = 24)</td>
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</tbody>
</table>

Table 7
Estimated Marginal Means (SE) for Reactivity Film Physiological, Behavioral, and Self-Report Reactivity Scores

<table>
<thead>
<tr>
<th></th>
<th>Physiological Reactivity</th>
<th>Behavioral Reactivity</th>
<th>Self-Reported Reactivity</th>
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<tbody>
<tr>
<td></td>
<td>Amuse Film</td>
<td>Sad Film</td>
<td>Disgust Film</td>
</tr>
<tr>
<td><strong>FTLD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n = 23)</td>
<td>-.06 (.09)</td>
<td>-.10 (.10)</td>
<td>-.03 (.08)</td>
</tr>
<tr>
<td><strong>Ctrl</strong></td>
<td>.05 (.08)</td>
<td>.07 (.10)</td>
<td>.02 (.08)</td>
</tr>
<tr>
<td>(n = 24)</td>
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</table>

Table 8a
Estimated Marginal Means (SE) for Caregiver Positive and Negative Emotional Reactivity and Emotion Recognition Ratings

<table>
<thead>
<tr>
<th></th>
<th>Reactivity Ratings</th>
<th>Recognition Ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive Emotion</td>
<td>Negative Emotion</td>
</tr>
<tr>
<td></td>
<td>Positive Emotion</td>
<td>Negative Emotion</td>
</tr>
<tr>
<td><strong>FTLD</strong> (n = 13)</td>
<td>3.92 (.46)</td>
<td>5.27 (1.08)</td>
</tr>
<tr>
<td><strong>Ctrl</strong> (n = 17)</td>
<td>6.82 (.41)</td>
<td>5.32 (.92)</td>
</tr>
</tbody>
</table>
Table 8b
Estimated Marginal Means (SE) for Caregiver Joy, Amusement, Sadness, Fear, Disgust, and Anger Reactivity Ratings

<table>
<thead>
<tr>
<th></th>
<th>Joy</th>
<th>Amusement</th>
<th>Sadness</th>
<th>Fear</th>
<th>Disgust</th>
<th>Anger</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTLD</td>
<td>1.90 (.25)</td>
<td>2.03 (.28)</td>
<td>1.42 (.26)</td>
<td>1.59 (.37)</td>
<td>.83 (.31)</td>
<td>1.73 (.42)</td>
</tr>
<tr>
<td>(n = 13)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ctrl</td>
<td>3.34 (.22)</td>
<td>3.48 (.24)</td>
<td>1.66 (.23)</td>
<td>1.39 (.32)</td>
<td>1.27 (.27)</td>
<td>1.48 (.37)</td>
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<tr>
<td>(n = 17)</td>
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</tr>
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</table>

Table 8c
Estimated Marginal Means (SE) for Caregiver Joy, Amusement, Sadness, Fear, Disgust, and Anger Recognition Ratings

<table>
<thead>
<tr>
<th></th>
<th>Joy</th>
<th>Amusement</th>
<th>Sadness</th>
<th>Fear</th>
<th>Disgust</th>
<th>Anger</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTLD</td>
<td>2.10 (.25)</td>
<td>2.31 (.21)</td>
<td>1.52 (.24)</td>
<td>1.50 (.28)</td>
<td>1.29 (.29)</td>
<td>1.66 (.28)</td>
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<td>(n = 13)</td>
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</tr>
<tr>
<td>Ctrl</td>
<td>3.71 (.23)</td>
<td>3.80 (.19)</td>
<td>3.36 (.25)</td>
<td>3.46 (.29)</td>
<td>3.19 (.31)</td>
<td>3.54 (.29)</td>
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<td>(n = 17)</td>
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Table 9
Estimated Marginal Means (SE) for Emotional Faces Recognition Scores

<table>
<thead>
<tr>
<th></th>
<th>Positive Face</th>
<th>Sad Face</th>
<th>Fearful Face</th>
<th>Disgust Face</th>
<th>Angry Face</th>
<th>Negative Face</th>
<th>Neutral Face</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTLD</td>
<td>.97 (.06)</td>
<td>.67 (.08)</td>
<td>.69 (.11)</td>
<td>.74 (.07)</td>
<td>.70 (.11)</td>
<td>.68 (.06)</td>
<td>.98 (.05)</td>
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<td>(n = 20)</td>
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<tr>
<td>Ctrl</td>
<td>.94 (.06)</td>
<td>1.07 (.07)</td>
<td>.67 (.08)</td>
<td>1.07 (.06)</td>
<td>.92 (.09)</td>
<td>1.00 (.05)</td>
<td>.98 (.04)</td>
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<td>(n = 23)</td>
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Table 10a
Estimated Marginal Means (SE) for Recognition Film Positive and Negative Recognition Scores

<table>
<thead>
<tr>
<th></th>
<th>Positive Films</th>
<th>Negative Films</th>
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<tbody>
<tr>
<td>FTLD</td>
<td>.73 (.05)</td>
<td>.94 (.05)</td>
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<tr>
<td>(n = 23)</td>
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<td></td>
</tr>
<tr>
<td>Ctrl</td>
<td>.96 (.05)</td>
<td>.85 (.05)</td>
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<tr>
<td>(n = 24)</td>
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</table>
Table 10b
Estimated Marginal Means (SE) for Recognition Film Enthusiasm, Calm, Affection, Amusement, Sadness, Fear, Disgust, and Angry Recognition Scores

<table>
<thead>
<tr>
<th></th>
<th>Enthus Film</th>
<th>Calm Film</th>
<th>Affect Film</th>
<th>Amuse Film</th>
<th>Sad Film</th>
<th>Fear Film</th>
<th>Disgust Film</th>
<th>Angry Film</th>
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</thead>
<tbody>
<tr>
<td>FTLD</td>
<td>.59 (.10)</td>
<td>.83 (.07)</td>
<td>.74 (.09)</td>
<td>.77 (.08)</td>
<td>.91 (.08)</td>
<td>.95 (.06)</td>
<td>.73 (.09)</td>
<td>.75 (.09)</td>
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<tr>
<td>Ctrl</td>
<td>.95 (.10)</td>
<td>.99 (.07)</td>
<td>.94 (.09)</td>
<td>.95 (.08)</td>
<td>.85 (.08)</td>
<td>.95 (.06)</td>
<td>.99 (.09)</td>
<td>.96 (.09)</td>
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<td>(n=24)</td>
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