Frontal lobe injuries, violence, and aggression:

A report of the Vietnam Head Injury Study

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Article abstract—Knowledge stored in the human prefrontal cortex may exert control over more primitive behavioral reactions to environmental provocation. Therefore, following frontal lobe lesions, patients are more likely to use physical intimidation or verbal threats in potential or actual confrontational situations. To test this hypothesis, we examined the relationship between frontal lobe lesions and the presence of aggressive and violent behavior. Fifty-seven normal controls and 279 veterans, matched for age, education, and time in Vietnam, who had suffered penetrating head injuries during their service in Vietnam, were studied. Family observations and self-reports were collected using scales and questionnaires that assessed a range of aggressive and violent attitudes and behavior. Two Aggression/Violence Scale scores, based on observer ratings, were constructed. The results indicated that patients with frontal ventromedial lesions consistently demonstrated Aggression/Violence Scale scores significantly higher than controls and patients with lesions in other brain areas. Higher Aggression/Violence Scale scores were generally associated with verbal confrontations rather than physical assaults, which were less frequently reported. The presence of aggressive and violent behaviors was not associated with the total size of the lesion nor whether the patient had seizures, but was associated with a disruption of family activities. These findings support the hypothesis that ventromedial frontal lobe lesions increase the risk of aggressive and violent behavior.

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Aggression and violent behavior are pervasive problems in the United States as we near the end of the 20th century[1,2] and are currently perceived as both a social *and* public health problem.[1,3] Prevention, assessment, and management of aggressive and violent behavior are important goals of health practitioners.[4-7] Among the purported contributors to aggressive and violent behavior are a history of brain damage and, more specifically, impaired ventromedial frontal lobe functioning.[8] The neuropsychological rationale for this inference is as follows: When schema-like knowledge (which would include rules of social behavior), stored in the frontal lobes, is activated, it leads to an inhibition of more primitive reactions (e.g., violent or aggressive behavior) to environmental provocation. If social schema knowledge is less accessible (e.g., in the case of frontal lobe damage or dysfunction), then generally inappropriate social forms of behavior, such as physical threats and intimidation, may more easily emerge in potential or actual confrontational situations.[9-12]

Some researchers discount the limited evidence for an association between a dysfunctional prefrontal cortex and an increased tendency for aggressive and violent behavior and stress the importance of genetic, environmental, and social factors.[13-16] Others dispute an association between frontal lobe dysfunction and aggression and violence because the methods and subjects used in previous studies were problematic (e.g., subject selection bias, small number of subjects, and so on).[8,17-19] The Vietnam Head Injury Study (VHIS) provides a unique opportunity to test the hypothesis that normally functioning frontal lobes are critical to the maintenance of appropriate social behavior, and in particular, to the modulation of potentially aggressive and violent expressions of behavior.[20-26] In the VHIS, a large cohort of previously healthy young men who suffered a penetrating brain injury during their service in Vietnam and normal controls, matched for time in Vietnam, age, and education, were examined 10 to 15 years post-injury at Walter Reed Army Medical Center (WRAMC) in Washington, D.C., with a comprehensive neuropsychological, neurologic, and psychosocial battery of tests. Subsequent to their WRAMC visit, a family member or close friend designated by the patients and controls was sent several personality questionnaires, including the Katz Adjustment Scale (KAS) (an inventory that indicates the behavioral adjustment of the subject to home life), that instructed them to judge the subject's current daily interpersonal behavior. By comparing how a family member

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views the behavior of normal controls or patients on items from these and other questionnaires, designed to reflect the frequency and severity of aggressive and violent behavior, we were able to test the hypothesis that a dysfunctional frontal lobe leads to aggression and violence.

Subjects. Subjects were drawn from the W.F. Caveness Vietnam Head Injury Study registry, which includes 1,221 survivors of penetrating brain wounds suffered between 1967 and 1970 in Vietnam on whom the attending neurosurgeon had completed a registry form and on whom military and Veterans Administration (VA) follow-up records were available. Approximately 15 years later, the 1,118 veterans still alive were invited to participate in an extensive follow-up clinical study. The VA, the three branches of the Armed Services, and the American Red Cross coordinated efforts to recruit, transport, and study these veterans. Of the 1,118 survivors, 520 participated in the study at WRAMC between August 1981 and August 1984. Injury and preinjury characteristics of the soldiers on the original registry were available from military and VA records. When we compared characteristics of the 520 head injured who came to WRAMC for study with those who did not, we found no evidence of bias.[27] Controls (N = 85) were recruited from VA files of non–head-injured soldiers who had served in Vietnam the same years and were within the same age range as soldiers on the Caveness registry. Those controls and the head-injured subjects had the same average age at examination at WRAMC (36 years) and had similar scores on the Armed Forces Qualification Test (AFQT)[28,29] taken prior to service in Vietnam (mean percentile score on the AFQT = 54 for head-injured subjects, 57 for controls).

The subjects selected for the present study were a *subset* of the VHIS sample (head-injured [N = 279] and control subjects [N = 57]) whose families completed and returned a set of inventories, including the KAS, that were mailed to them after the inpatient phase of the VHIS. There was no bias that we could identify (e.g., based on age, education, pre-injury AFQT score, or pre-injury history of aggression and violence) between subjects whose families or friends returned the mailed questionnaires and those who didn't other than a higher likelihood of the forms being returned if the subject was married (χ^2 [1] = 5.91, $p < 0.01$). Characteristics of the subjects by group and subgroup are presented in the table.

Methods. *Multidisciplinary clinical evaluation.* The clinical evaluation at WRAMC consisted of comprehensive standard assessments, including a neurologic history and examination, neuropsychological testing, rehabilitation assessment, speech and language testing, EEGs, evoked potentials, and CT. The entire clinical evaluation of each patient required, on average, 40 hours, divided among the 5 days of the patients' stay at WRAMC. In addition, an extensive standardized interview was conducted in the home by trained Red Cross volunteers, and a separate set of psychosocial questionnaires was mailed to relatives or friends of the patients and controls subsequent to their WRAMC inpatient evaluation. Seventy-nine percent of these family members and friends had known the participants for over 10 years. Seventy percent of persons answering the mail questionnaire were wives. The remainder were close relatives (20%), or friends (5%), or those who had another type of relationship (5%) with the subject (e.g., social worker). Responses were obtained on a total of 279 patients and 57 controls. They resemble the total VHIS population in terms of age, education, pre- and post-injury AFQT score, total brain volume loss, test behavior, and mood state. We were unable to determine any bias in subjects who returned our questionnaires and those who did not.

CT coding. Both lesion location and brain volume loss were determined from standardized CTs done on a GE 8800 scanner in 0.5-cm slices at 25 degrees from the orbital-meatal line, yielding about 23 standard slices per patient. A light pen was used to outline the affected area in each slice, and total lesion volume was calculated by adding these areas on relevant slices. The median brain volume loss was 26 cc (range, 0 to 310 cc). In addition, a brain atlas template system created for the VHIS was used to identify brain structures involved in each lesion across slices. These volume loss and lesion location measures have been used in other VHIS studies investigating structure-function relationships in this cohort.[28-35]

The aggression and violence evaluation. In this study, we analyzed a subset of scales, questions, and tests that were directly administered either to subjects or a family member/close friend during the inpatient WRAMC evaluation or to family members or friends by mail subsequent to the subject's WRAMC inpatient evaluation. The total aggression and violence evaluation included the following:

(1) A *single inpatient question* about violence that was asked of the subject by the study neurologist (A.M.S.) during his inpatient WRAMC examination ("Have you ever had any violent behavior against persons or things? We all lose our temper now and then, but have you ever beat someone up or torn up a room?").
(2) Pre- and post-injury *Armed Forces Qualification Test* scores (a measure of intelligence). The pre-injury AFQT was administered to the subjects before the beginning of their military service. The post-injury AFQT was administered during the WRAMC examination 10 to 15 years after their service (or injury) in Vietnam.[28,29]
(3) *Beck Depression Inventory* (self-report of depression) total score.[36]
(4) *Neurobehavioral Rating Scale (NBRS)* (an inventory sensitive to aberrant subject behavior that was completed by the test examiner[37]).
(5) *Katz Adjustment Scale* (a 205-item inventory completed by a family member or friend that reveals his or her judgment of the subject's competency across a variety of social and behavioral domains[38]). We identified all the items on the KAS that would reflect a range of aggressive and violent attitudes and behavior. These items were combined into a scale from which two kinds of scores were derived (see below).
(6) *VHIS Family Questionnaire* (an inventory that asked specific questions about the family's or friend's ability to cope with the subject's current behavior).

The NBRS and the questionnaires and inventories contained in the mailings indicate the views of an *observer* regarding the tendencies of the patients and controls toward aggressive and violent behavior. The neurologist's

Table *Characteristics of the subjects by group and subgroup*

Group	N	Age	Education	Pre-injury AFQT score	Post-injury AFQT score	Beck Depression Inventory	Behavioral Rating Scale	Total brain volume loss
Controls	57	36.10 (1.55)	13.37 (2.04)	59.38 (23.87)	68.85 (22.63)	8.52 (7.76)	3.66 (4.8)	00.00
All head injured	279	36.16 (3.44)	13.22 (2.43)	54.11 (25.15)	53.57 (26.97)	10.65 (8.51)	5.41 (6.43)	39.07 (43.69)
Mediofrontal only	20	37.05 (4.82)	13.70 (2.25)	60.31 (22.27)	67.31 (25.23)	8.40 (6.75)	4.85 (4.77)	22.48 (15.13)
Other head injured (MFO)	240	36.15 (3.10)	13.27 (2.55)	55.01 (25.97)	54.67 (27.21)	10.23 (7.69)	5.46 (6.56)	40.52 (40.81)
Orbitofrontal only	14	36.14 (1.79)	14.14 (1.79)	57.64 (24.02)	65.00 (24.97)	8.46 (7.40)	8.21 (15.53)	29.95 (23.44)
Other head injured (OFO)	246	36.22 (3.33)	13.26 (2.55)	55.28 (25.84)	55.15 (27.30)	10.17 (7.65)	5.25 (5.53)	39.83 (40.52)
Anterior temporal only	13	36.07 (2.81)	13.61 (2.46)	51.72 (27.52)	63.76 (24.23)	12.92 (8.55)	3.69 (3.85)	15.54 (11.40)
Other head injured (ATO)	247	36.22 (3.29)	13.29 (2.53)	55.58 (25.67)	55.17 (27.36)	9.93 (7.57)	5.50 (6.53)	40.46 (40.40)
Mediofrontal involvement	42	36.35 (4.31)	13.30 (2.22)	58.63 (21.67)	59.56 (26.32)	10.38 (7.89)	5.81 (5.75)	50.16 (47.14)
Other head injured (MFI)	218	36.19 (3.04)	13.31 (2.58)	54.79 (26.42)	54.90 (27.39)	10.03 (7.59)	5.33 (6.57)	37.31 (38.15)
Orbitofrontal involvement	28	35.96 (1.79)	13.25 (2.08)	55.62 (25.16)	59.16 (26.06)	9.55 (6.94)	7.89 (11.78)	46.60 (40.38)
Other head injured (OFI)	232	36.25 (3.40)	13.31 (2.58)	55.39 (25.83)	55.23 (27.38)	10.15 (7.72)	5.10 (5.38)	38.49 (39.83)
Anterior temporal involvement	60	35.50 (2.77)	12.96 (2.26)	53.40 (25.28)	54.73 (27.42)	10.81 (7.59)	6.21 (6.91)	52.23 (48.60)
Other head injured (ATI)	202	36.42 (3.37)	13.41 (2.60)	56.00 (25.86)	55.87 (27.24)	9.87 (7.65)	5.17 (6.28)	35.64 (36.60)

AFQT scores are percentiles. A Beck Depression Inventory total score of 15 or greater is suggestive that the subject is experiencing at least a mild depression. The Neurobehavioral Rating Scale scores ranged between 0 and 27, with a higher score indicating greater neurobehavioral symptomatology. Total brain volume loss is in cubic centimeters. Means and standard deviations are shown.

question about violence queried self-assessment by the patient or control. Although the main emphasis of this study is whether family and friends viewed the patients or controls as having aggressive or violent tendencies, we also considered whether subject self-report and observer report of aggression and violence were consistent.

The main dependent variables we used to determine whether the subject was viewed as aggressive or violent were the "Any Violence" and "Extreme Violence" Scale scores that were solely based on items from the KAS.

(1) *Any Violence Scale (AVS).* Fifteen items on the KAS dealing with aggressive and violent tendencies or feelings (e.g., threatening, irritated, annoyed, and so on) were scored (see figure 1 for a listing of the items). Each time a family member reported the subject as *sometimes, often,* or *almost always* exhibiting aggressiveness or violent behavior as reflected in a particular item, the subject was given a score of 1 for that item. If the family member reported that the subject "almost never" exhibited the aggressive or violent behavior as reflected in a particular item, the subject was given a score of 0 for that item. Scores on this scale ranged from 0 to 15.

(2) *Extreme Violence Scale (EVS).* The same 15 items were scored. Each time a family member or friend reported the subject as *almost always* exhibiting aggressive or violent behavior as reflected in a particular item, the subject was given a score of 1 (all other responses were coded as 0). Scores on this scale also ranged from 0 to 15. Subjects receiving a score on this scale represented the most extreme cases of aggression and violence among our sample.

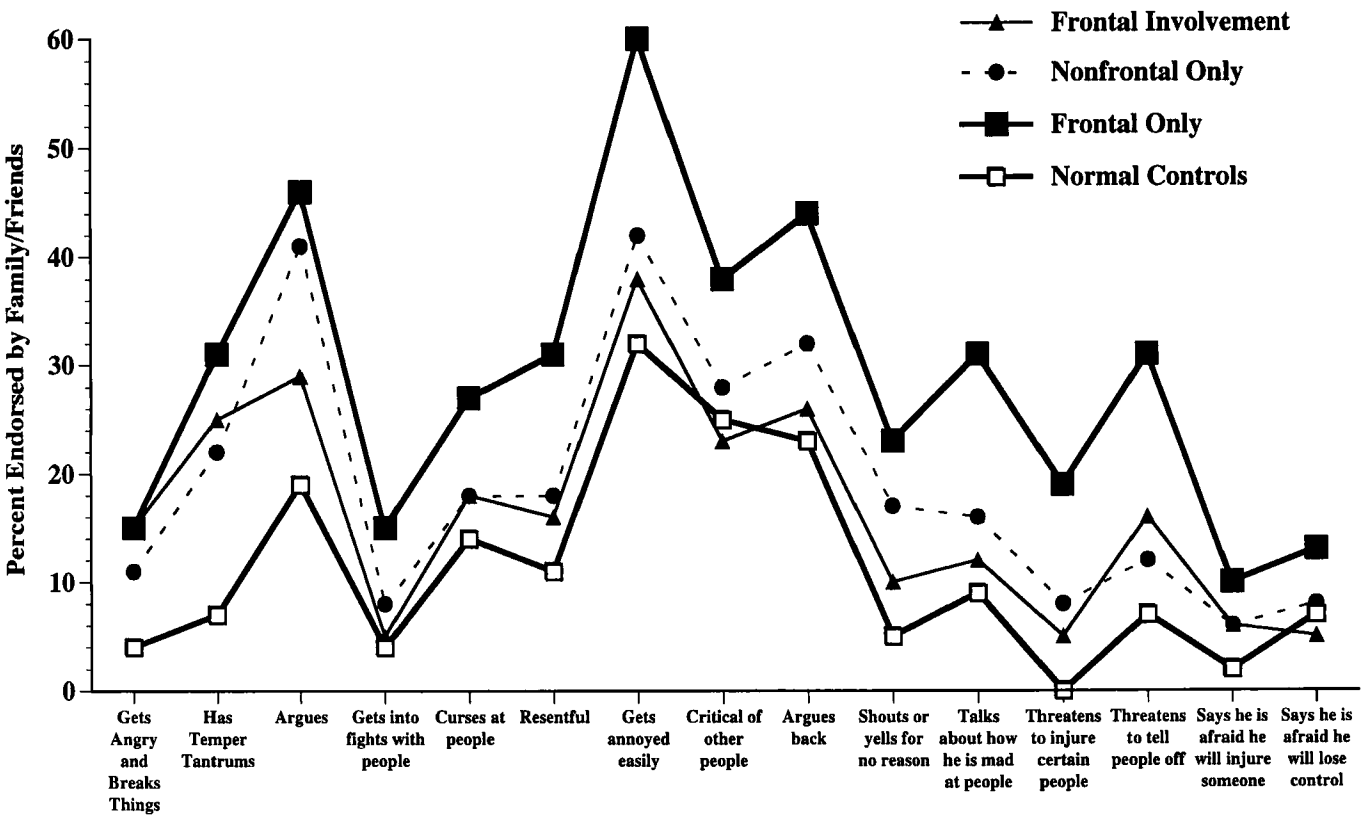

Figure 1. Percentage of items on aggression and violence from the KAS endorsed by friends and family members of controls and patients whose lesions included or were restricted to the frontal lobes or to nonfrontal regions.

Study design and statistical analysis. AVS and EVS scores were compared between various patient groups or controls. We predicted that the following patient groups would have abnormal scores on the AVS and EVS compared with controls or other patient groups: frontal (any involvement), orbitofrontal, mediofrontal, and anterior temporal (because of possible amygdalar damage[39,40]). We always analyzed AVS and EVS scores separately and made the following planned comparisons:

(1) *Controls* versus all head injured.
(2) *Controls* versus patient groups whose lesion was limited to *only* the cortical area of interest (e.g., mediofrontal only).
(3) *Controls* versus patient groups whose lesion *involved,* but was not limited to, the cortical area of interest (e.g., mediofrontal involved).
(4) Patient groups whose lesion was limited to *only* the cortical area of interest versus patients whose lesion *excluded* the cortical area of interest.
(5) Patient groups whose lesion *involved,* but was not limited to, the cortical area of interest versus patients whose lesion *excluded* the cortical area of interest.

In addition, we considered the relationship of AVS scores to open-ended and questionnaire comments about the subjects' behavior by the family or friend, subject self-reports, and to their performance on the neurologic examination, cognitive tasks, and mood-state inventories. We selected the AVS because it had a wider distribution of scores than the EVS.

We used chi-squares, Pearson's product-moment correlations, and ANOVAs (with Tukey post-hoc tests) to examine the effects of lesion location and size on observers' views of the patients' aggressive and violent behavior.

Results. The percentage of family members or friends who endorsed each of the aggression and violence items from the KAS is shown in figure 1. Family members or friends of patients whose lesion was limited to the frontal lobes (frontal-only group) tended to endorse aggression and violence items more often than family members or friends of other patient groups or controls. Some items indicating a less virulent form of aggression (e.g., gets annoyed easily) were endorsed by friends and relatives of up to 60% of the patients. Other items representing more overt aggression (e.g., curses at people) were endorsed by friends and relatives of at least 20% of the patients. Items representing actual physical violence (e.g., gets into fights with people) were endorsed by up to 14% of the friends and relatives of the patient with a lesion restricted to the frontal lobes.

Despite these qualitative differences in observations of the subjects' aggressive and violent behavior, there were no significant differences between the performance of the controls and frontal-only group on any of the following variables that could explain the KAS item endorsement differences: age, education level achieved, pre-injury AFQT test scores, post-injury Wechsler Adult Intelligence Test–Revised Full Scale IQ scores,[41] or Beck Depression Inventory scores.

Since no single item from the KAS best exemplifies aggression and violence, we focused our formal statistical analyses on the *total scores* obtained from the 15-item scale we devised.

Any Violence Scale. The head-injured group, as a whole, had a significantly higher AVS score compared with controls ($F(1, 317) = 7.19, p < 0.007$).

Both mediofrontal-only lesion ($F[1, 92] = 13.98, p < 0.0003$) and orbitofrontal-only lesion ($F[1, 78] = 12.60, p < 0.0007$) groups had significantly higher AVS scores compared with the control group. There was no difference, however, in AVS scores between patients with anterior temporal lobe lesions and controls.

In a succeeding ANOVA analysis, we enlarged our sample sizes by including subjects whose lesion *involved,* but was not limited to, a specific brain region. Once again we found that patients whose lesion involved the mediofrontal ($F[1, 159] = 8.05, p < 0.005$) and, in particular, orbitofrontal ($F[1, 107] = 11.68, p < 0.0009$) regions of the frontal lobes had higher AVS scores than controls. Anterior temporal lobe-lesion patients had scores that were not different from controls.

Patients with mediofrontal-only ($F[1, 192] = 5.65, p < 0.01$) and orbitofrontal-only ($F[1, 230] = 5.81, p < 0.01$) lesions also had higher AVS scores than patients with lesions in other cortical areas. Patients with anterior temporal lobe lesions had scores similar to other patients.

Finally, patients whose lesion involved other cortical areas with orbitofrontal ($F[1, 259] = 4.51, p < 0.03$) (but not mediofrontal) involvement had a higher AVS score than patients whose lesion did not include the orbitofrontal cortex. On the other hand, patients with anterior temporal lobe ($F[1, 259] = 3.98, p < 0.04$) lesions had a *lower* AVS score than patients whose lesion did not include that region.

Extreme Violence Scale. As a group, the head-injured patients had a significantly higher EVS score than the normal controls ($F[1, 317] = 4.09, p < 0.04$).

Patients with *restricted* mediofrontal ($F[1, 92] = 4.42, p < 0.03$) or orbitofrontal ($F[1, 78] = 6.72, p < 0.01$) lesions also had a higher EVS score than controls, whereas those with anterior temporal lobe lesions did not differ from controls.

Among patients whose lesions *involved,* but were not restricted to, either mediofrontal, orbitofrontal, or anterior temporal lobe regions, only those patients whose lesion included the orbitofrontal cortex had a higher EVS score than controls ($F[1, 107] = 5.61, p < 0.01$).

Unlike the AVS, for the EVS, there were no differences between patients with mediofrontal, orbitofrontal, or anterior temporal lobe lesions, regardless of whether the lesion was restricted to, or merely included, those regions *when they were compared with patients with lesions that did not include those areas.*

Other analyses. There were also no significant relationships across groups between AVS or EVS scores and total brain volume loss or the presence or absence of seizures.

We next compared the Profile of Mood States (POMS) Anger-Hostility Scale scores of the normal controls and patients.[42] Head-injured patients, as a group, had higher (indicating more anger/hostility) scores than the normal controls ($F[1, 312] = 7.41, p < 0.006$). Patients with mediofrontal *only* ($F[1, 92] = 5.08, p < 0.02$) and anterior temporal *only* ($F[1, 70] = 4.68, p < 0.03$) lesions also had higher POMS Anger-Hostility scores than controls as did patients with mediofrontal *involvement* ($F[1, 158] = 8.27, p < 0.004$), anterior temporal *involvement* ($F[1, 118] = 8.51, p < 0.004$), and orbitofrontal *involvement* ($F[1, 106] = 3.81, p < 0.05$). No between-patient group comparisons on this scale reached significance.

Validity analysis of AVS scores. Open-ended questions in the VHIS Family Questionnaire were also coded for any expression of aggressive or violent behavior. For example, comments such as "he gets mad easily," "has temper flare-ups," "is short-tempered," "can be violent," "demonstrates sudden, unprovoked anger," or "is hostile at times" were occasionally noted in response to the question, "Which behavioral changes, if any, have been the most disturbing to you?" These responses were spontaneous and should have reflected those aspects of the subject's behavior that were most problematic and critical to the family. Fifty-one percent of the questionnaires noted a behavioral change. Of these, 18% contained a response indicating the family's perception that the patient had a problem with aggressive and/or violent behaviors.

Of the subjects who, during the neurologic examination, denied having violent episodes against persons or things, 18% had family members or close friends who disagreed and claimed they were aggressive and violent. Of the subjects who reported to the neurologist violent behavior, only 32% had family members who also mentioned such behavior on the VHIS Family Questionnaire. Nearly all family members or friends who reported violent behavior on the VHIS Family Questionnaire open-ended question also reported that the subject was aggressive or violent on the AVS. On the other hand, only about 25% of family members or friends indicating a problem with aggression and violence on the AVS also reported a problem on the VHIS Family Questionnaire open-ended question. Perhaps family members may have under-reported aggression and violence on the VHIS Family Questionnaire because the subject may have been present when that questionnaire was being completed, or alternatively, the anger and hostility in the patients reported on the AVS by family members and friends may not have been the foremost difficulty perceived by them and therefore received less priority in an open-ended question format.

Relationship of the AVS score to family routine. In the VHIS Family Questionnaire that accompanied the KAS, the family member or close friend completing the survey for either controls or head-injured patients was also asked whether the subject's current behavior had affected him or her in *specific* ways (figure 2). We computed chi-squares to assess the relationship between scoring at least 1 point on the AVS and endorsement of the items on the family questionnaire. There was a significant relationship between obtaining an AVS score and endorsing the following statements: "needs help in coping with his behavior" (χ^2 [1] = 13.46, $p < 0.001$), "his personality has changed since injury" (χ^2 [1] = 51.94, $p < 0.001$), "his personality has changed since I knew him" (χ^2 [1] = 33.96, $p < 0.001$), "there is distress in the family due to changes in the veteran post-injury" (χ^2 [1] = 45.49, $p < 0.001$), "some of the changes have been disturbing" (χ^2 [1] = 28.06, $p < 0.001$), "his behavior has upset household routine" (χ^2 [1] = 34.77, $p < 0.001$), "the family has changed their household or leisure habits because of the veteran's behavior" (χ^2 [1] = 18.30, $p < 0.001$), "his children have taken over some of the veteran's tasks" (χ^2 [1] = 5.80, $p < 0.01$), "his children

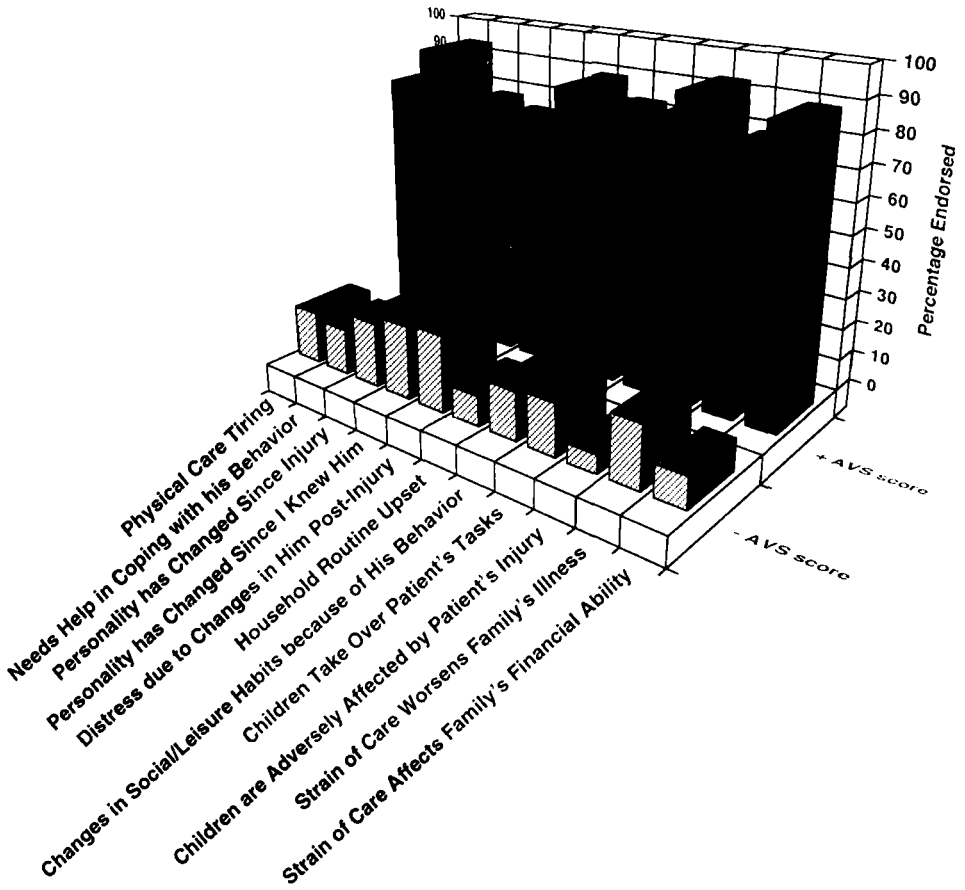

Figure 2. Endorsements of friends and family members of specific items from the VHIS Family Questionnaire. See text for details.

have been adversely affected by the veteran's injury" (χ^2 [1] = 25.73, $p < 0.001$), "strain of care worsens family member's illness" (χ^2 [1] = 5.00, $p < 0.02$), and "his behavioral change has strained the family and their financial security" (χ^2 [1] = 45.02, $p < 0.001$).

There was no relationship between the AVS score and the following statements: "able to look after himself," "veteran has improved since his injury," "household member has to stay away from school or work to look after him," "family member's health has suffered from caring for the veteran," "frequency of contact with a medical professional," "prior experience in caring for a brain-injured patient," "frequency of contact with a mental health professional," and "how long you have known the veteran."

This profile of AVS-family complaint associations suggests that the subjects' aggressive and violent behaviors strikingly affect the fabric of the family or close friends' daily life, frequently upsetting both children and adults. However, despite this disturbance of daily life, the family or close friend of the aggressive and violent subject is not more likely than family or friends of the nonaggressive subject to seek medical or mental health professional support. In fact, there were no between-group differences for whether a subject (or his family) had sought psychiatric counseling. Rather, given the subject's relatively independent home life, family and friends seem resigned to cope with the disturbances the best they can without seeking psychiatric intervention.

Correlation of AVS scores to performance on selected neuropsychological variables. Wisconsin Card Sorting Test (WCST).[43] A significant association between the number of WCST categories completed and the AVS score was found in the right mediofrontal-only group, but this was not so for the other lesion groups.

Continuous Performance Test (CPT).[44] Most measures from the CPT were significantly associated with the AVS score in the right mediofrontal-only and right orbitofrontal-only groups. Other correlations were scattered and inconsistent.

Neurobehavioral Rating Scale.[37] Higher scores on the NBRS were modestly correlated with AVS scores across groups but no interesting patterns were observed. The NBRS was completed on the basis of the subject's behavior at WRAMC and may not be a good indicator of routine interpersonal aggression and violence.

Discussion. Our results indicated that head-injured veterans, as a group, were reported by their family or friends to be more aggressive/violent than non–head-injured veterans.[45-48] Patients with focal ventromedial frontal lobe lesions, in particular, had a significantly higher frequency of aggressive and violent behavior than controls or than patients with lesions elsewhere in the brain. Not all patients who exhibit aggression and violence will recognize such behavior in themselves, nor will all relatives report such behavior unless specifically questioned. In our sample, aggression and violent behavior appeared unrelated to certain other variables such as epilepsy, total brain volume loss, level of intelligence, or depression. The results of some other studies are inconsistent with this finding.[49-51] Although family members and close friends do their best to cope with the

aggression and violent behavior exhibited by both patients and controls, they nevertheless report that it takes a significant toll on them and their children. Unfortunately, many of these families are either not seeking help to manage these behaviors or the help is not available in their local community.

Patients with anterior temporal lobe lesions were likely to report more anger or hostility than was noticed by friends or relatives. Patients with mediofrontal lesions both reported, and were reported to have, an increased frequency of aggression and violence; however, patients with orbitofrontal-only lesions were reported to be more violent and aggressive even though they tended not to be as aware of this behavior.

Some of the effects of frontal lobe lesions previously reported in the neurobehavioral literature, such as disinhibition and lack of insight, might contribute to an increased expression of environmentally reactive behavior that would include aggression and violence.[9-12] In turn, providing greater environmental control should reduce the frequency of aggressive and violent behavior in patients with frontal lobe lesions. Moreover, certain medications may also prove useful in managing aggressive and violent behaviors. Unfortunately, our data set didn't allow us to address either of those suggestions.

We previously found that patients with right orbitofrontal lesions had increased anxiety levels compared with patients with lesions elsewhere in the brain.[30,52] Increased anxiety levels are consistent with a tendency to engage in aggressive and violent behavior. In that same study,[30] we also reported that patients with lesions to the left dorsolateral prefrontal cortex claimed more aggressive behavior. However, the current study indicated that friends or family members of patients with left dorsolateral frontal lesions reported fewer examples of aggression and violence than friends or family members of patients with ventromedial lesions. This discrepancy between self-report of the patient and observers' ratings of aggression and violence requires further study.

Knowledge *stored* in the human prefrontal cortex plays a managerial role in the control of behavior and takes the form of mental models, thematic understanding, plans, and social rules.[9-12] These forms of knowledge enable humans to engage in an extended series of behaviors that have an overall theme or goal, rather than simply reacting to the moment-by-moment provocations or demands of the environment by expressing their internal raw emotion. Within this framework, we would expect that lesions to the prefrontal cortex would impair the ability to access and sustain such managerial knowledge. This impairment would bias the regulation and expression of behavior away from plans, social rules, and mental schemas towards environmental hyperresponsiveness, making spontaneously appearing or reactive aggressive and violent behavior more likely.

Although lesions in the ventromedial prefrontal cortex may be more likely to result in aggressive and violent behavior, not all patients with these lesions had such behavior, and some patients with lesions elsewhere in the brain, and even normal controls, can show an increased tendency towards aggressive and violent behavior.[8,25,53]

In summary, patients in our cohort with ventromedial prefrontal lobe lesions were more likely than patients with lesions in other locations in the brain to exhibit aggressive and violent behavior (but see Tonkonogy[54]). This was more weighted towards verbally aggressive than physically violent behavior. Developing intervention techniques to reduce aggressive and violent behavior in patients with ventromedial prefrontal lobe lesions should be a priority of rehabilitation programs since such behaviors are disruptive at work and to the family, are often kept within the family, and result in a significant burden to society.

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