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Quantitative Electroencephalographic Correlates of Post-Stroke Depression

Fred Ulam Ph.D.^a, Paul Thomlinson Ph.D.^b, Rodney Quinn M.D.^c, Todd Smith Psy.D.^d & Teresa Tempelmeyer Ph.D.^e

^a Cox Health Systems, Inc. In , Springfield, MO, USA

^b division of Cox Health Systems, in , Springfield, MO, USA

^c Ferrell-Duncan Clinic in , Springfield, MO, USA

^d Cox Health systems in Springfield , MO, USA

^e Adult Inpatient Psychiatry Unit of Cox Health Systems , Springfield, MO, USA

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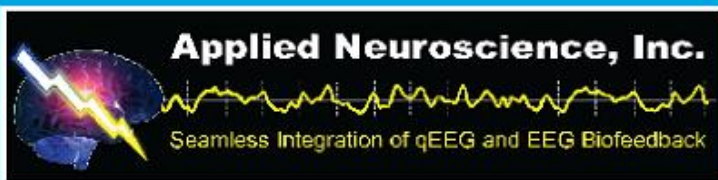
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Fred Ulam, Ph.D., Paul Thomlinson, Ph.D., Rodney Quinn, M.D., Todd Smith, Psy.D. and Teresa Tempelmeyer, Ph.D.

Cox Health Systems and Burrell Behavioral Health
Springfield, Missouri

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Post stroke depression (PSD) is widely recognized as a complication in the rehabilitation process, and numerous studies have shown a relationship between depression and compromised outcome following stroke (e.g., Parikh, et al., 1990). Several studies have examined specific anatomic and physiological correlates of PSD. One of the more recent of these is the work of Astrom, Adolfsson, and Asplund (1993), in which the researchers found left anterior lesions to be among the most significant predictors of PSD in the acute stage of recovery. Quantitative electroencephalography (QEEG) has emerged as a useful, non-invasive, functional method of evaluating both neurological and psychiatric disorders. Using QEEG, Davidson and associates (e.g., Davidson & Tomarken, 1989) have consistently found greater left frontal alpha power to be associated with depression, and with tendency toward depression. Given the robustness of the relationship between QEEG patterns and depressive symptomatology, and given that the approach has not been used among PSD patients for such a purpose, the present study was conducted to compare qEEG patterns between CVA patients with and without depression. Twenty one patients with cortical or subcortical CVAs were recruited as volunteer participants, and upon proper consent were administered the Beck Depression Inventory (BDI) and the Yesavage Geriatric Depression Scale (GDS). Participants underwent QEEG testing with the Cadwell Spectrum 32 digital EEG apparatus, and analyses were based on the NYU database (John, 1994). Interhemispheric power asymmetries, averaged across traditional frequency bandwidths and measured in homologous pairs from prefrontal to occipital sites, were correlated with global depression scores on both indices. Significant correlations were found between frontal QEEG asymmetries and both the BDI and GDS, and in every case the asymmetry is indicative of greater left frontal power. Correlations of the highest magnitude were found in the prefrontal and superior frontal areas, which is consistent with Davidson and associates' findings with non-neurologically involved depressives. None of the posterior asymmetry measures showed significant correlations with subjective depression indices. These results, taken from a larger, ongoing study, are consistent with previous research implicating dysfunction of the left anterior quadrant in depressive symptoms, but go beyond those findings by extending them to the PSD population.

Lesion localization in post-stroke depression (PSD) has been the subject of extensive research for over a decade. A large number of studies have implicated left anterior lesions in association with PSD (Morris, P.L.P, Robinson, R.G., Raphael, B., Hopwood, M.J., 1996).

Independent investigations of physiological correlates of depression and mood, primarily using quantified electroencephalographic methods have also frequently identified left frontal hypoactivation as a correlate of depression (Davidson, R.J., 1994). As of the present writing,

we have not identified any studies in which quantitative electroencephalographic (QEEG) methods have been used to investigate PSD. The present study attempts to bridge the gap in the literatures on PSD and the QEEG correlates of depression by using QEEG methods to investigate depression among stroke victims.

A majority of studies examining structural imaging measures among post cerebrovascular accident depressives have identified the left hemisphere as being important in the regulation of mood, such that anterior left hemisphere lesions are associated with increased likelihood of depression (Robinson, R.G., Kubos, K.L., Starr, L.B., and Price, T.R., 1984; Morris, P.L.P., Robinson, R.G., Carvalho, M.L. et al., 1996; Morris, P.L.P., Robinson, R.G., Raphael, B. and Hopwood, M.J., 1996; Herrmann, M., Bartels, C., Schumaker, M. and Wallesch, C.W., 1995; Astrom, M., Adolfsson, R. and Asplund, K., 1993;). Several studies have failed to find an association between post-stroke depression and lesion location (Agrell, B. and Dehlin, O., 1994; House, A., 1996; Dam, H., Pedersen, H.E., Ahlgren, P., 1989.) As is usually the case, differences in methodology often make it difficult to explain such discrepant findings.

A series of investigations have shown differences in brain electrical activity between depressed and nondepressed individuals (Shaffer, C.E., Davidson, R.J. and Saron, C., 1983; Henriques, J.B. and Davidson, R.J., 1991.). The specific pattern of brain electrical activity associated with depression found by this group involves left frontal hypoactivation as indicated by an alpha power asymmetry in which there is greater alpha activity over the left midfrontal area relative to the homologous area on the right. It is well known that alpha attenuation is associated with cortical activation and therefore greater alpha power over a region likely represents hypoactivation of that area.

In light of the quantitative electroencephalographic findings associated with depression, which have been found to be quite

reliable, stable measures among normal individuals and non-neurologically involved depressives (Davidson, R.J., Wheeler, R.E. and Kinney, L., 1992), we hypothesized that frontal power asymmetries might be sensitive to depression among post CVA individuals. We reasoned that discrepancies in the neuroanatomical literature regarding lesion location and depression might be partly explained by the fact that anatomical measures fail to measure *functional* changes in brain activity that could be remote from the vicinity of the lesion, yet still meaningfully related to the production of depressive symptoms. QEEG methods therefore offered a reliable, sensitive, yet noninvasive way of addressing the question of regional brain dysfunction associated with post-stroke depression.

The dependent measure chosen in this study was the sum of EEG power asymmetries across all four of the traditional frequency bands (i.e., delta = 0.5 - 3.9 Hz., theta = 4.0 - 7.9 Hz., alpha = 8.0 - 12.9 Hz., beta = 13.0 - 25.0 Hz.). Although previous research with non-neurologically involved populations has identified activity within the alpha band to be reflective of hypoactivation, it was reasoned that the shift to the slower frequencies that typically accompanies structural damage to the brain would in many instances obliterate changes in alpha activity that might otherwise be present. Therefore, in the presence of structural damage, it was hypothesized that a shift toward the slower end of the EEG frequency spectrum would be a better measure of hypoactivation, and that this shift in the frequency composition of the brain electrical signal could be sensitively measured by summing across all four of the traditional frequencies.

It was hypothesized that a meaningful relationship would be found between the summed power asymmetry over the midfrontal regions and depressive symptoms reported by stroke victims during the post-acute stages of recovery, in the first three months following their cerebrovascular accidents. Specifically, we hypothesized that the greater the left frontal power relative to homologous right frontal sites, the greater the

depressive symptoms that would be endorsed by the post-CVA patients. The report that follows details preliminary findings among a relatively small initial sample of patients.

Method

Participants

Participants were 21 patients, referred for neuropsychological assessment through Cox Health Systems, all of whom had experienced either a cortical or subcortical cerebrovascular accident (CVA) within the previous three months of the time of their participation in this study. The ages of the participants ranged from 41 to 89 years, with a mean age of 70.7 years (SD=11.92). Sixty-nine percent of participants were male.

Apparatus and Instrumentation

Electroencephalograms were recorded using the 10-20 International System of electrode placement. Gold-silver chloride disc electrodes were filled with electroconductive gel, all impedances were at or below 5K ohms, and the electrodes were referenced to linked ears. Activity was recorded with a Cadwell Spectrum 32 Digital EEG. Activity was sampled at a rate of 200 hertz (Hz) with filters set at .5 Hz for the low frequency filter and 70 Hz for the high frequency filter. The activity was digitized on-line and stored to the hard drive of the computer for later analysis.

Most QEEG features are significantly non-Gaussian in their distributions. For this reason, all neurometric calculations for individual patients were transformed for Gaussianity before z transformation. Scores from this study were referenced to normative data collected at the New York University Brain Research Laboratories (John, Prichep, & Easton, 1987).

Two psychometric measures of depressive symptomatology were administered to participants. The Beck Depression Inventory (BDI) was utilized because it is characterized by a long history of research and clinical use, ease of administration, brevity, and excellent psychometric characteristics (Beck & Steer, 1993). The Yesavage Geriatric

Depression Scale (GDS) was included to add breadth to the assessment of depressive symptomatology, and because it was anticipated that many of the participants would be of advanced age. The GDS also possesses ample evidence of psychometric soundness (Yesavage, et al., 1983).

Procedures

All participants, after proper informed consent to take part in the study, were administered the BDI and GDS as part of a larger psychometric battery which included various neuropsychological measures. Quantitative EEG measures were then taken on all participants.

QEEG activity was recorded while participants were resting with eyes closed in a quiet dimly lit room. Drowsiness was minimized by technicians gently alerting participants whenever there was slowing of the posterior alpha and/or presence of increased slowing of the vertex, both of which are indications of early onset drowsiness. This is in accordance with the standardized procedures used at the New York University Brain Research Laboratories, where the quantitative EEG database was developed. Approximately 20 minutes of data was recorded in this manner.

Electrooculogram channels were used to assist in identifying eye movement artifact. In a similar manner, electromyographic artifact was minimized by instructing participants to relax frontalis, temporalis, and masseter muscles as needed. EEG activity was inspected off-line for selection of artifact-free epochs to be used for quantitative analysis.

Spectral analysis was performed on the artifact-free data for the four conventional frequencies (i.e., delta = 0.5 - 3.9 Hz., theta = 4.0 - 7.9 Hz., alpha = 8.0 - 12.9 Hz., beta = 13.0 - 25.0 Hz.). This was computed for each of 48 2.5 second epochs that were then averaged together for a total of 2 minutes of EEG activity. The resulting mean microvolt values for each electrode and each frequency were then squared, giving mean power

values (power= uv^2) for each frequency band and electrode location. Each value was then z-transformed.

For this study, interhemispheric power asymmetries were computed for each frequency band and were then summed across those bands. The rationale for summing across bands warrants some explanation. Prior literature in which frontal EEG asymmetries have shown meaningful relationships to measures of depression among neurologically intact individuals have involved the alpha frequency band. The most consistent finding has been that of increased alpha activity over the left midfrontal location relative to the homologous location in the right hemisphere as a correlate of depression. This increased left frontal alpha has been understood as representing *hypoactivation* of the left frontal area, given the widely known association between alpha synchronization and cortical idling, and the converse finding of alpha attenuation and cortical activation among awake individuals (Davidson, 1994).

Interhemispheric power asymmetries, derived from a sum of absolute power across frequencies for homologous electrode locations from left and right hemispheres, were used as correlates of the depression indices. The assumption of increased alpha activity as an index of hypoactivation is questionable among victims of CVA. A substantial body of literature exists which confirms that increased slow activity in the delta and theta frequency bands is the most common QEEG correlate of stroke induced brain dysfunction (Faught, 1993). Furthermore, the literature shows that often there is a loss or reduction of faster frequencies (i.e., both alpha and beta activity) in regions of the cortex that are dysfunctional secondary to a CVA (Nagata, et al., 1982). For this reason, it seemed very possible that neurologically based dysfunction secondary to CVA that could conceivably have a meaningful relationship to depressive symptomatology, would be unlikely to be restricted to the alpha frequency. Furthermore, it was apparent that CVA related slowing can often obliterate alpha activity, therefore making it unlikely that meaningful

Table 1
Descriptive Statistics and Correlation Coefficients for QEEG Power Asymmetries and Depression Measures (BDI and GDS)

Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10
1. GDS	10.57	5.79	-	60*	68*	65*	57*	57*	13	02	09	35
2. BDI	13.70	12.88		-	50*	51*	54*	49*	18	01	19	26
3. FP1-2	-2.86	3.95			-	80*	76*	63*	09	00	29	20
4. F3-4	-2.83	3.52				-	67*	68*	28	25	39	40
5. F7-8	-1.82	3.19					-	61*	52*	24	43	43
6. C3-4	-2.23	5.03						-	57*	35	61*	52*
7. T3-4	-0.33	1.93							-	74*	63*	61*
8. T5-6	-1.03	3.69								-	52*	42
9. P3-4	-2.06	3.58									-	69*
10. O1-2	1.30	3.61										-

* $p < .05$; one-tailed test. Note: Decimal points have been omitted from the correlation coefficients

Figure 1
Correlations Between QEEG Power Asymmetries and the BDI

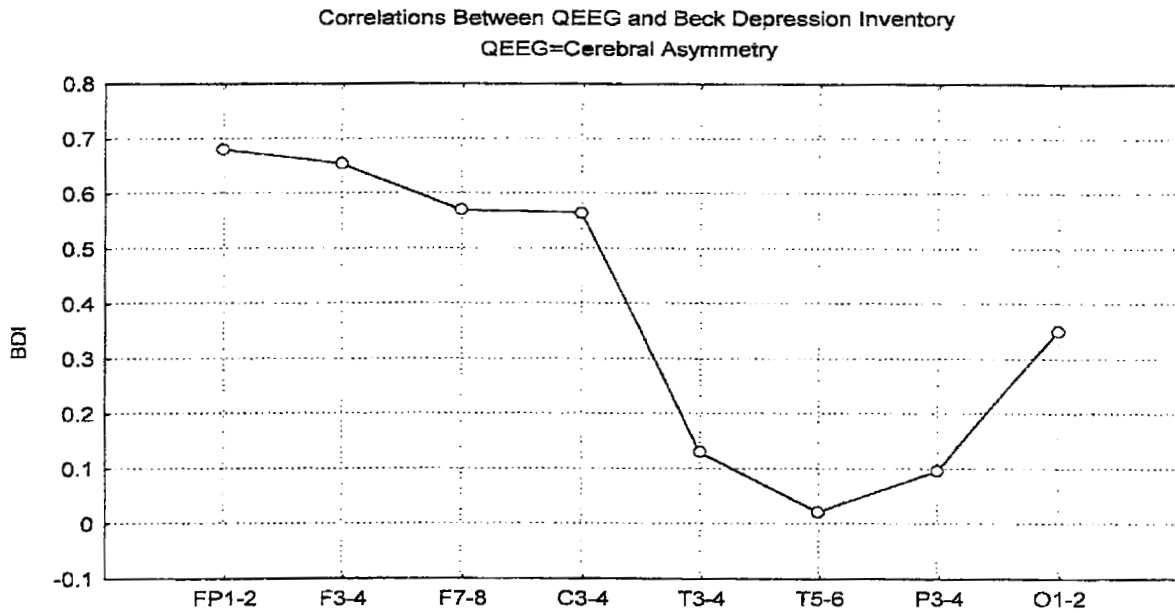
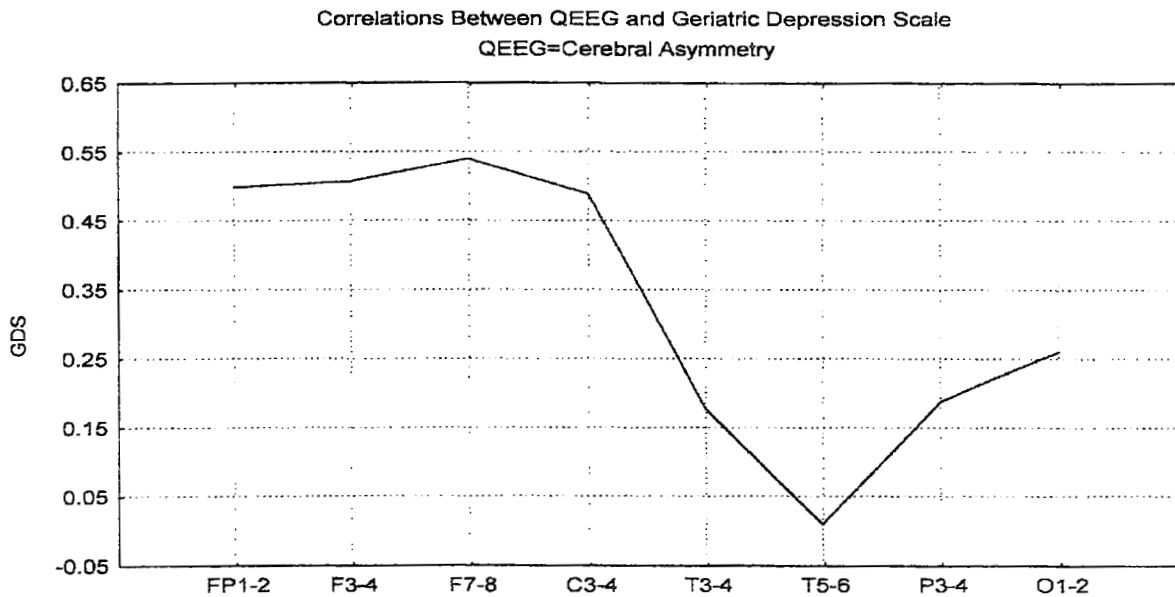


Figure 2
Correlations Between QEEG Power Asymmetries and the GDS



associations between depressive symptoms and alterations in alpha asymmetries would be found. On the other hand, the consistent association between increased slow activity and cortical dysfunction following stroke suggested that there might be regional asymmetries of slow activity (delta and theta) that might be an index of hypoactivation among this population. Generally, the slower components in the frequency spectrum account for a greater percentage of the total power than do the faster components. This is due to their higher amplitude, and is particularly true of pathological slowing. It was therefore reasoned that summing across all four frequency bands would provide a sensitive measure of a shift of the overall frequency composition of the EEG spectrum. Further, it was reasoned that a shift toward the slower frequencies would serve as a meaningful index of hypoactivation of a given brain region among CVA victims.

Results

Data analysis consisted of transforming the QEEG data for Gaussianity, summing across the frequency bands, and correlating the interhemispheric power asymmetries with the results from the BDI and GDS. Descriptive statistics and Pearson product moment correlation coefficients are presented in Table 1.

The patterns of correlations between the QEEG power asymmetries and the depression measures, moving posteriorly from FP1-2 through O1-2, are graphically displayed in Figures 1 and 2.

Discussion

As hypothesized, the preliminary findings with a small sample of post-CVA patients show statistically significant, moderately strong relationships between measures of frontal EEG asymmetry and reports of symptoms of depression. The association is such that the greater the asymmetry of QEEG power to the left frontal region, the greater the depressive symptoms reported by patients. None of the posterior asymmetry measures show a meaningful

relationship with depression, although the occipital asymmetry shows a trend toward significance.

Although these preliminary findings must be regarded as very tentative, they are consistent with both the majority of neuroanatomical studies of post-stroke depression and the QEEG studies of non-neurologically involved depressed individuals. The neuroanatomical evidence suggests that lesion location is an important factor in post-stroke depression such that there is a greater likelihood of depression associated with lesions in the left anterior frontal region. Our results support this notion, but also suggest that functional changes remote from the anatomical lesion may be important in the etiology of depression following a cerebrovascular accident. Examination of individual cases within our patient sample shows individuals with structural lesions in the left hemisphere who are *not depressed* and who have a frontal asymmetry in the *opposite* direction, that is greater power over the right frontal area relative to the left. This suggests that functional measures, such as QEEG, PET, SPECT and fMRI may be more important in elucidating the physiological correlates of mood states following brain damage owing to their sensitivity to *remote effects* in areas distant from but connected to the area of anatomical damage. This may help to explain some of the inconsistencies and discrepancies in post-stroke depression studies that have relied on neuroanatomical measures. These tentative conclusions, of course, must await confirmation with the larger patient sample. Data collection for this project is ongoing at our center and includes data from a matched control population.

Future research using QEEG correlates of depression, among CVA victims and other neurologically involved individuals should emphasize measures of observed depressive symptoms in addition to questionnaires eliciting subjective symptoms. This may be particularly important to assess the utility of QEEG as an adjunctive assessment of depression with individuals whose neuropsychological deficits preclude them from giving accurate subjective report regarding their own affective status.

Conditions such as aphasia and agnosagnosia are particularly relevant in this regard, in that both of these syndromes are known to interfere with patient's ability to tell us if they are depressed or not. A fruitful direction of future research would be to use QEEG measures in assessing affective reactivity to various emotionally charged types of stimulation among post-stroke patients. Previous research (Wheeler, RE, Davidson, R.J. and Tomarken, A.J., 1993.) has already demonstrated that changes in the frontal EEG alpha asymmetry are sensitive to different types of emotional stimulation among normal individuals. It is conceivable that such emotional reactivity, or perhaps the lack thereof, could be of value in predicting which patients are in need of pharmacological treatment versus psychotherapy or both.

Although there has been vast improvement in the side-effect profiles of antidepressant medications, as the SSRI compounds have been developed, it would still be desirable to have a rational, relatively objective way of determining which of these medically fragile post-CVA patients are mostly likely to need the addition of one more medication to their usually complex regimen. Additionally, while supportive psychotherapy is usually indicated to assist patients with their adjustment to CVA, the possibility of a meaningful, functional yet physiologically based measure to assess the reactivity of mood and therefore the prognosis of a given patient as a candidate for psychotherapy would be helpful.

References

Agrell, B., and Dehlin, O. (1994). Depression in stroke patients with left and right hemisphere lesions: A study in geriatric rehabilitation in-patients. *Aging: Clin. and Exper. Research*, 6, 49-56.

Astrom, M., Adolfsson, R., and Asplund, K. (1993). Major depression in stroke patients: A 3-year longitudinal study. *Stroke*, 24, 976-982.

Beck, A., and Steer, R. (1993). *Beck Depression Inventory manual*. San Antonio, TX: Harcourt-Brace.

Dam, H., Pedersen, H.E., and Ahlgren, P. (1989). Depression among patients with stroke. *Acta Psychiatrica Scandinavica*, 80, 188-124.

Davidson, R.J., Wheeler, R.F. and Kinney, L. (1992). Psychometric properties of resting anterior EEG asymmetry: Temporal stability and internal consistency. *Psychophysiology*, 29, 576-592.

Davidson, R.J. (1994). Temperament, affective style and frontal lobe asymmetry (pp. 518-536). In Dawson, G. and Fischer, K.W., Eds., *Human Behavior and The Developing Brain*. New York: Guilford Press.

Faught, E. (1993). Current role of electroencephalography in cerebral ischemia. *Stroke*, 24, 609-613.

Henriques, J.B. and Davidson, R.J. (1990). Regional brain electrical asymmetries discriminate between previously depressed and healthy control subjects. *Journal of Abnormal Psychology*, 99, 22-31.

Herrmann, M., Bartels, C., Schumaker, M., and Wallesch, C.W. (1995). Poststroke depression: Is there a pathoanatomic correlate for depression in the postacute stage of stroke? *Stroke*, 26, 850-856.

House, A. (1996). Depression associated with stroke. *The Journal of Neuropsychiatry*, 8, 453-457.

John, E. R., Pritchep, L. S., & Easton, P. (1987). Normative data banks and neurometrics: Basic concepts, methods and results of norms constructions (pp. 449-495). In A. Remond (Ed.), *Handbook of Electroencephalography and Clinical Neurophysiology: Vol. 3. Computer Analysis of the EEG and Other Neurophysiological Signals*. Amsterdam: Elsevier.

Morris, P.L., Robinson, R.G., Raphael, B., and Hopwood, M., (1996). Lesion location and post-stroke depression. *The Journal of Neuropsychiatry and Clinical Neurosciences*, 8, 399-403.

Morris, P.L.P., Robinson, R.G., Carvalho, M.L., Albert, P., Wells, J.C., Samuels, J.F., Eden-

- Fetzer, D., and Price, T.R. (1996). Lesion characteristics and depressed mood in the stroke data bank study. *The Journal of Neuropsychiatry and Clinical Neurosciences*, 8, 153-159.
- Nagata, K., et al. (1982). Topographic electroencephalographic study of cerebral infarction using computed mapping of EEG. *Journal of Cerebral Blood Flow and Metabolism*, 2, 79-88.
- Robinson, R.G., Kubos, K.L., Starr, L.B., Rao, K. and Price, T.R. (1984) Mood disorders in stroke patients: Importance of location of lesion. *Brain*, 107, 81-93.
- Schaffer, C.E., Davidson, R.J. and Saron, C. (1983) Frontal and parietal electroencephalogram asymmetry in depressed and nondepressed subjects. *Biological Psychiatry*, 18, 753-762.
- Yesavage, J., et al. (1983). Development and validation of the Geriatric Depression Scale: A preliminary report. *Journal of Psychiatric Research*, 17, 37-49.

Frederick A. Ulam, Ph.D. is a neuropsychologist with Cox Health Systems, Inc. in Springfield, MO. He is engaged in full-time outpatient neuropsychology practice, and also is on the staff at the Sleep Disorder Center. He performs quantitative EEG evaluations in the neurophysiology lab at Cox Health Systems. Research interests primarily involve the interface between neuropsychology and neurophysiology.

R. Paul Thomlinson, Ph.D. is a licenced psychologist and is Director of Research at Burrell Behavioral Health, a division of Cox Health Systems, in Springfield, MO. Dr. Thomlinson is currently involved with other research projects dealing with the interface of behavioral health and medical care. He is on the adjunct faculty at Southwest Baptist University and Central Michigan University.

Rodney Quinn, M.D., is the chairman of Neurology at the Ferrell-Duncan Clinic in Springfield, MO. Dr. Quinn is also the medical director of the Neurophysiology Lab at Cox Health Systems in Springfield, MO. His fellowship in EEG and residency in neurology were at the University of Iowa Hospital and Clinics. He is a fellow of the American Clinical Neurophysiology Society.

Todd Smith, Psy.D. is a neuropsychologist employed full-time by Cox Health systems in Springfield, MO, where he provides consultation and assessment in the inpatient rehabilitation unit as well as house-wide neuropsychology consultations. He also is engaged in part-time private practice in Springfield. Dr. Smith is interested in the early detection of dementia, with particular emphasis in utilizing verbal learning and verbal fluency paradigms.

Teresa Tempelmeyer, Ph.D. is a licenced clinical psychologist with the Adult Inpatient Psychiatry Unit of Cox Health Systems, Springfield, MO. Dr. Tempelmeyer's clinical responsibilities include conducting individual and group psychotherapy and psychological evaluations of adults on the inpatient psychiatry unit. Her prior research interests dealt with the use of the Rey 15 Item Test among clinical psychiatric inpatients. She is a member of the APA.