Frontal Asymmetry, Dispositional Affect, and Physical Activity in Older Adults

Eric E. Hall and Steven J. Petruzzello

Physical activity has been consistently linked to better mental health—greater positive affect and life satisfaction, less negative affect, anxiety, and depression (Petruzzello et al., 1991; McAuley & Rudolph, 1995). Brain activation patterns have been linked to dispositional affect: greater relative left anterior hemisphere activation relates to positive affect, and greater relative right anterior activation relates to negative affect (Davidson, 1992). In this study, measures of resting EEG frontal asymmetry, dispositional affect, and physical activity were obtained from 41 older adults. Frontal asymmetry significantly predicted positive affect. In the high active group (n = 21), frontal asymmetry significantly predicted affective valence and satisfaction with life; in the low active group (n = 20), it significantly predicted negative affect. Physical activity was also significantly related to better dispositional affect. These findings suggest that the relationship between frontal brain activity and dispositional affect is influenced by physical activity in older adults.

Key Words: brain activation, EEG, exercise, aging

It is well known that regular physical activity participation has numerous physical and mental health benefits (U.S. Department of Health and Human Services, 1996). The benefits that accrue due to physical activity participation may be most significant in older adults because of declines in structure and function of the body, including the brain, that take place with aging (Dustman, Emmerson, & Shearer, 1994; Holloszy & Kohrt, 1995). Unfortunately, with increasing age there is a general trend towards declining physical activity participation (Stephens & Caspersen, 1994). Caspersen and Merritt (1995), using data from the Behavioral Risk Factor Surveillance System (BRFSS), reported that for adults aged 65 and older, 35.6% of males and 42.0% of females engaged in no leisure time physical activity while only 16.1% and 11.4% of males and females, respectively, engaged in regular intense activity (more than 3 times per week, 20 min or more per session, at 60% of maximal cardiorespiratory capacity at least). Stephens and Craig (1990) showed that the percentage of men and women engaging in aerobic activities like swimming and cycling dropped 55-67% between the ages of 25 and 44 to 65 years and older.

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In addition to the lack of physical activity, affective disorders are a significant problem in the older adult population. Data from community samples have been reported specifically for depression and anxiety, two common categories of affective disorders. Blazer, Hughes, and George (1987) found that 27% of community adults 60 years of age and older reported depressive symptoms, with 8% suffering from major depressive episodes. The Epidemiologic Catchment Area survey reported slightly lower percentages, with approximately 15% of adults 65 years and older having depressive symptoms (Regier et al., 1984). Kessler, Foster, Webster, and House (1992) have shown, using data from two large national surveys, that depressive symptoms and the associated psychological distress varies over the lifespan, with increases occurring for both men and women after age 60. Although depressive symptomology affects a sizable portion of the older adult population, the prevalence of major depression among the elderly living in the community has been found to be less than 3% (Regier et al., 1988). Similar percentages have been reported for anxiety disorders. Himmelfarb and Murrell (1984) estimated that 17.1% of males and 21.5% of females over 55 years of age experienced anxiety symptoms sufficient enough to require some intervention. Regier et al. (1988) found that 3.6% of men and 6.8% of women 65 years and older could be classified as having anxiety disorders.

Various mental health variables have been shown to be influenced by physical activity in older populations. Typically, physically active older persons report greater psychological well-being and less depression than their sedentary counterparts (McAuley & Rudolph, 1995; O’Connor, Aenchtbacher, & Dishman, 1993). Unfortunately, most of the previous research has been characterized by a reliance on singular measures of dispositional affect and has been done using a singular level of analysis. A much greater understanding of the influence of physical activity on mental health can be obtained if a multilevel analytic approach is pursued (Cacioppo & Berntson, 1992). To this end, the present study addressed relevant affective components from multiple levels.

In younger adult populations, previous research has shown that resting regional brain activation, measured via scalp-recorded electroencephalography (EEG), can act as a biological marker for dispositional affect and affective reactivity to emotion-eliciting stimuli (Davidson, 1992, 1993, 1994). Davidson (1992, 1993) has proposed that anterior brain asymmetries, as assessed via EEG, reflect a basic neuro-anatomical asymmetry in the control of approach- and withdrawal-related behaviors. Davidson (1993) has suggested that the frontal regions may act as an emotion convergence zone that integrates emotional input and output. The frontal lobes of the brain are thought to be responsible for approach and withdrawal systems and their subsequent affective responses (Davidson, 1992). To approach or withdraw from a situation is a fundamental adaptive response, with approach behavior being associated with positive affect while withdrawal behavior being related to negative affect (Davidson, 1993). Greater activation of the left frontal lobe relative to the right is associated with the approach system and positive affect. On the other hand, greater activation of the right frontal lobe relative to the left is associated with the withdrawal system and negative affect (Davidson, 1993). Differential activation of these anterior portions of the left and right hemispheres has been associated with positive affect (e.g., happiness) and negative affect (e.g., sadness, depression, and anxiety), respectively (Henriques & Davidson, 1990, 1991; Schaffer, Davidson,
Saron, 1983; Tomarken, Davidson, Wheeler, & Doss, 1992). Such individual differences in hemispheric activation can thus serve both as a neurobehavioral substrate of affect, that is, predisposing an individual to have generally positive or negative affect (Henriques & Davidson, 1990; Tomarken, Davidson, Wheeler, & Doss, 1992), or as a “neural threshold” for reactivity to affective stimuli (Tomarken, Davidson, & Henriques, 1990; Tomarken, Davidson, Wheeler, & Doss, 1992).

In one of the few studies examining the relationship between exercise, affect, and brain asymmetry, Petruzzello and Landers (1994) found that greater left frontal activation, relative to right frontal activation, was related to lower trait anxiety ($r = - .61$). This resting EEG asymmetry was also predictive of post-exercise anxiety levels. Unfortunately, it cannot be determined from these data the extent to which this relationship was influenced by physical activity history, as all of the subjects were relatively active and physically fit.

The purpose of the present study was to examine the relationship between physical activity, frontal asymmetry, and dispositional affect in older adults. It was hypothesized that frontal asymmetry would be able to predict dispositional affect, with greater relative left activation being related to indices of positive affect (positive affect, affective valence, and satisfaction with life), and greater relative right activation being related to indices of global negative affect (negative affect, anxiety, and depression). Secondly, individuals who were highly active were hypothesized to have more positive affect and less negative affect than low active older adults. Thirdly, differences were examined in frontal asymmetry that might have been due to physical activity participation.

**Methods**

**PARTICIPANTS**

A total of 41 (15 males, 26 females, $M$ age = 68.7 ± 5.8 years) right-handed participants (Edinburgh Handedness Inventory; Oldfield, 1971) were solicited by newspaper and other advertisements in the local community to participate in this study. All participants were screened for the presence of intellectual impairment using the Short Portable Mental Status Questionnaire (SPMSQ; Pfeiffer, 1975). There were no significant differences in the number of chronic diseases and medication usage reported between the high and low active groups; however, there was a significantly greater number of women in the low active group (see Table 1). Because of this gender imbalance, gender was used as a categorical variable in subsequent analyses. Participants completed a statement of informed consent and were paid $10.00 for their participation in the study.

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1 The SPMSQ consists of general memory type questions (e.g., “What day of the week is it?” and “Who is the President of the United States?”) Answering at least three of these questions incorrectly is considered standard exclusionary criteria as established by researchers of the Establishment of Populations for Epidemiologic Studies of the Elderly (National Institute on Aging, 1990).
Table 1  Subject Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>High active</th>
<th>Low active</th>
<th>p value</th>
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</thead>
<tbody>
<tr>
<td>n</td>
<td>21</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Males/females</td>
<td>11/10</td>
<td>4/16</td>
<td>.031</td>
</tr>
<tr>
<td>Age (years); M ± SD</td>
<td>68.1 ± 5.44</td>
<td>69.4 ± 6.22</td>
<td>ns</td>
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<tr>
<td>Age range (years)</td>
<td>60–78</td>
<td>61–85</td>
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<tr>
<td>Medication usage</td>
<td>1.9 ± 1.3</td>
<td>2.5 ± 1.8</td>
<td>ns</td>
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<tr>
<td>Chronic diseases</td>
<td></td>
<td></td>
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<tr>
<td>Cancer</td>
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<td>1</td>
<td></td>
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<tr>
<td>Heart conditions</td>
<td>2</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>0</td>
<td>1</td>
<td></td>
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<tr>
<td>Multiple sclerosis</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Self-reported frequency (days · week⁻¹); M ± SD</td>
<td>3.6 ± 1.51</td>
<td>0.9 ± 1.36</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Self-reported duration (min · session⁻¹); M ± SD</td>
<td>65.7 ± 35.77</td>
<td>15.8 ± 24.08</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Self-reported intensity; M ± SD</td>
<td>4.4 ± 2.16</td>
<td>1.2 ± 1.97</td>
<td>&lt; .0001</td>
</tr>
<tr>
<td>Self-reported length (months); M ± SD</td>
<td>141.42 ± 172.29</td>
<td>18.65 ± 43.93</td>
<td>.004</td>
</tr>
<tr>
<td>PASE; M ± SD</td>
<td>127.7 ± 50.41</td>
<td>81.4 ± 48.22</td>
<td>.005</td>
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<tr>
<td>Exercise subscale of PASE; M ± SD</td>
<td>37.5 ± 16.61</td>
<td>6.1 ± 4.79</td>
<td>&lt; .0001</td>
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*Based on self-reported intensity using Borg’s (1982) CR-10 RPE scale; 0.5 = very, very light, 5 = hard, 10 = very, very hard. *Chi-square Test.

MEASURES

Physical Activity. The Physical Activity Scale for the Elderly (PASE; New England Research Institutes, 1991) was used to assess physical activity level. In addition, self-reported frequency, intensity, duration, and length of regular exercise involvement were obtained. The PASE has been shown to be a reliable and valid measure of general physical activity level in the elderly (Washburn, Smith, Jette, & Janney, 1993). The PASE is a 10-item scale that assesses leisure time, household, and occupational physical activity. Upon examination, it appeared that the PASE score and the self-reported indices of exercise involvement were dissociated. The PASE was significantly related to length of regular exercise involvement (r = .42, p = .004), but not related to self-reported frequency (r = .17, p = .151), duration (r = .17, p = .151), or intensity of exercise (r = .24, p = .061). Thus, an exercise-specific subscale of this questionnaire was devised by scoring only those items relating to exercise (Questions 2-6). Exercise was defined as “planned, structured, and repetitive bodily movement done to improve or maintain one or more components
of physical fitness” (p. 21, U.S. Department of Health and Human Services, 1996). The exercise subscale of the PASE was significantly related to self-reported frequency \( (r = .61, p < .0001) \), duration \( (r = .49, p = .001) \), intensity of exercise \( (r = .61, p < .0001) \), and length of regular exercise involvement \( (r = .54, p < .0001) \). Because participants were recruited with the intention of obtaining a high active and a low active group distinction, subjects were placed into high or low active categories based on a median split of the exercise subscale.  

**Dispositional Affect.** Because no single measure can adequately tap the various dimensions of affect, dispositional affect was assessed with a variety of measures. The trait form (TAI; Form Y-2) of the State Trait Anxiety Inventory (STAI; Spielberger, 1983) was used to measure trait anxiety. This is a 20-item scale using a 4-point Likert response format ranging from 1 (Not at all) to 4 (Very much so), with possible total scores ranging from 20 to 80. The TAI assesses the predisposition to interpret stressful situations as threatening. The TAI has been shown to have acceptable reliability and validity when used with older subjects (50–69 years old); reliability exceeds .85 (Spielberger, 1983). 

Positive and negative affective dispositions were assessed with the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). This 20-item scale has been shown to be a reliable and valid measure of positive and negative affect. There are 10 items each for positive and negative affect, using a 5-point Likert response format ranging from 1 (Not at all) to 5 (Extremely), with possible total scores ranging from 10 to 50. The difference between positive and negative affect, termed affective valence, was also examined (Tomarken, Davidson, Wheeler, & Doss, 1992). Affective valence (PA-NA) is thought to reflect the pleasantness-unpleasantness dimension of the circumplex model of affect (Russell, 1980, 1983). The PANAS displays trait-like stability when the long-term response set is used (i.e., “How you feel on average”), with coefficient alphas of .88 and .87 for positive and negative affect, respectively. Test-retest reliabilities have also been reported to be .68 and .71 for positive and negative affect, respectively (Watson, Clark, & Tellegen, 1988). 

The Geriatric Depression Scale (GDS; Yesavage, Brink, Rose, & Adey, 1983) was used to assess depression. This 30-item instrument was designed for use with older adult samples. As opposed to more traditional self-report measures of depression (e.g., the Beck Depression Inventory), the GDS uses a simpler format (Yes/No as opposed to Likert scales) and does not deal with sexuality or somatic symptoms, which are typically less valid signs of depression in the elderly. Possible scores on the GDS range from 0 to 30. This scale shows favorable psychometric properties, with test-retest reliabilities over a 1-week timeframe of .85, and internal consistency coefficients of .94 (Yesavage et al., 1983).

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2An example of this occurred with a 63-year-old male who was relatively physically inactive, but since he was still working full-time (40 hr/week), his PASE score was 218. Using the exercise subscale of the PASE, his score became 2. Additionally, the PASE asks for activity levels over the past 7 days, and this may not always be reflective of an individual’s general activity level. For example, because of difficulties recruiting nonactive or very low active participants, most of the high active participants were recruited and tested during the winter, and the low active participants being were recruited the following spring. A seasonal effect may have taken place whereby people in the spring were able to do more house/lawn work compared to the people in the winter. The spring is also more conducive to participating in outdoor activities such as walking and gardening.
The Satisfaction with Life Scale (SWLS; Diener, Emmons, Larsen, & Griffin, 1985) was used to measure global life satisfaction. This is a 5-item scale that uses a 7-point Likert response format ranging from 1 (strongly disagree) to 7 (strongly agree), with possible scores ranging from 5 (low satisfaction) to 35 (high satisfaction). This scale has been shown to have favorable psychometric properties, with a test-retest reliability of .82 after 2 months and an internal consistency coefficient of .87. Additionally, this scale has been validated in a geriatric population (Diener et al., 1985).

BRAIN ACTIVATION

Resting brain activity (i.e., EEG) was recorded from nine scalp sites (3 homologous pairs and 3 midline sites) of the International 10-20 electrode placement system. These included left, right, and midline recordings from the midfrontal, central, and parietal regions. Raw EEG data were subjected to spectral analysis to decompose the complex EEG waveforms into their component sine wave frequencies. Because of its extensive use in the activation-affect literatures, activity in the alpha frequency band (8–13 Hz) was of primary interest; however, theta and beta frequencies were also examined to determine if the effect was specific to the alpha frequency. Activity in this band is thought to reflect activation of the underlying cortex, such that greater alpha activity is related to less activation, while less alpha activity is associated with greater activation (Andreassi, 1989). Resting EEG has been shown to be a reliable and valid index of regional brain activation (Tomarken, Davidson, Wheeler, & Kinney, 1992).

PROCEDURES

Participants began by reading and signing an informed consent document approved by the University’s Institutional Review Board. Following completion of the consent form, participants completed a packet of questionnaires and underwent EEG assessment in counterbalanced order during the same session. Average time for the session was approximately 1.5 hr. An experimenter was present to answer any questions subjects may have had concerning the questionnaires while they were being completed.

While seated in a comfortable chair, the subjects were prepped for EEG recording (see below). After signal integrity had been confirmed and recorded via impedance checks, subjects were asked to sit quietly while baseline measures of EEG were collected. Resting EEG measures were obtained during eight 60-s baseline periods (four with eyes open and four with eyes closed). Using the same protocol as Tomarken, Davidson, Wheeler, and Kinney (1992), subjects were randomly assigned to one of two counterbalanced sequences to determine eyes-open (O) and eyes-closed (C) trials of resting baselines (O-C-C-O-C-O-C or C-O-C-O-C-O-C-C-O). A short break (45–60 s) was given between baseline periods, along with a 3-min break between the fourth and fifth baseline assessments. During the recording of these baselines, participants were instructed to be as “restful” as possible.
EEG RECORDING

A stretchable lycra electrode cap (Electro-Cap, Inc.) was fitted on the subject's head for electrode application and assessment of regional brain activity (i.e., EEG). Placement of the cap utilized anatomical landmarks, the inion and nasion, on the subject's head to insure proper location. Using this procedure, electrode placements have been shown to deviate negligibly from the International 10-20 System locations (Blom & Anneveldt, 1982). EEG activity was recorded from the left, right, and midline of the midfrontal (F3, F4, Fz), central (C3, C4, Cz), and parietal (P3, P4, Pz) regions. All leads were referenced to linked earlobes, and all electrode impedances were below 5 KΩ. Impedances for homologous (e.g., F3, F4) sites were within 500Ω of each other. Ocular artifact was assessed by electro-oculogram (EOG) recording from electrodes placed laterally to both eyes, as well as above and below one eye to record eye movements.

EEG data were acquired using a Grass Model 12 Neurodata acquisition system equipped with Model 12AS amplifiers. All bioelectric signals were amplified 20,000x, and high and low pass filters were set at 1 and 100 Hz, respectively (roll-off = 6 dB/octave; 60 Hz notch filter in). The amplified and filtered signal was digitized at a sampling rate of 256 points per second and stored on a Gateway 486/DX2 computer for later analysis using EEGSYS software (Version 5.5, Friends Medical Science Research Center, Baltimore, MD).

DATA REDUCTION AND ANALYSIS

Offline, EEG waveforms were visually inspected for artifact by comparing activity at the scalp leads with the EOG. EEG containing artifact was marked and excluded from each EEG trial prior to further analysis of the data. All artifact-free data that were 2 s in duration were subjected to a fast Fourier transform (FFT) for decomposition of the EEG waveform into sine wave components. These components were used to derive spectral power estimates (in µV²), which were then converted to a power density function (in µV²/Hz). Power density was determined in three bands: theta (4–7 Hz), alpha (8–13 Hz), and beta (13–20 Hz). A natural log transformation was applied to all power density values to normalize distributions (Gasser, Bacher, & Mocks, 1982; Pollock, Schneider, & Lyness, 1990). All analyses were done with the four "eyes-closed" trials, because each subject had more than 10 artifact-free EEG segments (minimum of 20 s) for each given baseline (Gasser, Bacher, & Steinberg, 1985; Mocks & Gasser, 1984). The "eyes-open" conditions were not used for analysis, because nine of the subjects did not have at least four baselines with a minimum of 10 artifact-free EEG segments per baseline. Overall, the "eyes-open" condition averaged 19, 2-s EEG segments per 1 min baseline (63% of data was artifact-free), while the "eyes-closed" conditions averaged 26, 2-s EEG segments per 1 min baseline (87% of data was artifact-free).

Analyses of power density were conducted for the alpha (8-13 Hz) frequency band. The alpha band was of primary interest due to its inverse relationship with activation (Andreatta, 1989) and its more consistent association with affective processes (Davidson, 1992; Pollock & Schneider, 1989, 1990). An EEG asymmetry index was also derived (Pivik et al., 1993). This index reflects the log alpha power density difference in corresponding regions of the two hemispheres.
(i.e., log R – log L alpha power). Thus, higher asymmetry scores represent lower amounts of alpha activity and relatively greater activation in the left hemisphere for a particular region. This asymmetry score has been demonstrated to have acceptable psychometric properties, with test-retest correlation equaling .68 over 3 weeks time (Tomarken, Davidson, Wheeler, & Kinney, 1992).

STATISTICAL ANALYSES

MANOVAs, ANOVAs, and regression analyses were used to examine the relationship between physical activity, EEG, and dispositional affect variables in this older population. Effect sizes (ES) were calculated by subtracting mean scores of low active subjects from high active subjects and dividing the result by the pooled standard deviation to determine the magnitude of difference in the dispositional affective variables between high active and low active groups.

Results

PHYSICAL ACTIVITY

The mean scores (± SD) for the entire group on the PASE and exercise subscale of the PASE were 105.2 ± 54.08 and 22.2 ± 20.04, respectively. The entire sample (N = 41) was divided into high active (n = 21) and low active (n = 20) groups based on a median split of the exercise subscale of the PASE (median = 18.25). As discussed earlier (see Physical Activity under Measures), the exercise subscale of the PASE was used because of its much stronger relationship to self-reported exercise behavior than the total PASE score (see footnote 2). Physical activity characteristics for the two groups are shown in Table 1. One-way ANOVAs between the two groups showed significant differences between the groups on both the total PASE score, F(1, 39) = 9.01, p = .005, and the exercise subscale of the PASE, F(1, 39) = 66.23, p < .0001.

PHYSICAL ACTIVITY, DISPOSITIONAL AFFECT, AND GENDER

The mean scores (± SD) for the various affective measures are shown in Table 2. All mean differences are in the direction hypothesized based on physical activity level, with high active persons having more life satisfaction and positive affect, and less depression, negative affect, and trait anxiety compared to their low active counterparts. A one-way MANOVA using the dispositional affect variables as the dependent variables and the activity group (high/low) as the independent variable showed a significant difference between the two groups: F(5, 35) = 3.84, p = .007. Follow-up univariate F tests showed significant differences for positive affect, F(1, 39) = 11.44, p = .002, ES = 1.06; satisfaction with life, F(1,39) = 9.89, p = .003, ES = .98; depression, F(1, 39) = 6.95, p = .012, ES = –.83; and trait anxiety, F(1, 39) = 5.46, p = .025, ES = –.73. No significant differences were evident for negative affect, F(1, 39) = 1.02, p = .319, ES = –.31.

Regression analyses were used to determine the ability of the total score PASE and the exercise subscale of the PASE to predict dispositional affect. The
interaction of Gender with Physical Activity was also examined to see if it was a significant predictor (Pedhazur, 1997). Positive affect was the only variable that the total PASE score was able to significantly explain, $R^2 = .114$, $\beta = .337$, $F(1, 39) = 5.011$, $p = .031$. However, the exercise subscale of the PASE was able to significantly explain positive affect, $R^2 = .236$, $\beta = .486$, $F(1, 39) = 12.044$, $p = .001$; satisfaction with life, $R^2 = .232$, $\beta = .482$, $F(1, 39) = 11.809$, $p = .001$; affective valence, $R^2 = .184$, $\beta = .429$, $F(1, 39) = 8.80$, $p = .005$; trait anxiety, $R^2 = .116$, $\beta = -.340$, $F(1, 39) = 5.101$, $p = .030$; and depression, $R^2 = .095$, $\beta = -.308$, $F(1, 39) = 4.091$, $p = .050$. Gender had no significant interaction with Physical Activity in these regression analyses.

**TOPOGRAPHICAL EEG ALPHA ACTIVITY**

There were no significant differences ($ps > .05$) between the high and low active groups in either mean alpha power at individual sites or asymmetry scores (log R - log L) across the regions (frontal, central, and parietal).

**EEG, DISPOSITIONAL AFFECT, AND PHYSICAL ACTIVITY**

Regression analyses were used to determine the ability of frontal alpha asymmetry (log F4 - log F3) to predict dispositional affect. The interaction of activity level (high active vs. low active) and frontal alpha asymmetry was examined to determine whether it was a significant predictor (Pedhazur, 1997). Because of the exploratory
nature of this research and the fact that we were predicting the direction of the relationship based on a theoretical model, tests of significance were based on a one-tailed t-test of the beta coefficient. Positive affect was the only variable that frontal alpha asymmetry was able to significantly explain: $R^2 = .098$, $\beta = .313$, $t = 2.061$, $p = .023$. However, significant Activity Group interactions were found for negative affect, $R^2_{\text{change}} = .138$, $\beta = -.404$, $t = -2.476$, $p = .009$; affective valence, $R^2_{\text{change}} = .067$, $\beta = .282$, $t = 1.915$, $p = .037$; and satisfaction with life, $R^2_{\text{change}} = .066$, $\beta = .280$, $t = 1.827$, $p = .038$; therefore, separate regression analyses were done by activity group on these two variables. Frontal asymmetry predicted negative affect in the low active group, $R^2 = .149$, $\beta = .386$, $t = 1.775$, $p = .047$, and had a trend for the high active group, $R^2 = .129$, $\beta = -.359$, $t = -1.677$, $p = .055$. It must be noted that the relationship of frontal asymmetry and negative affect is in the predicted direction for the high active group, but in the opposite direction for the low active group. Frontal alpha asymmetry also predicted affective valence, $R^2 = .274$, $\beta = .523$, $t = 2.377$, $p = .008$, and satisfaction with life, $R^2 = .156$, $\beta = .395$, $t = 1.873$, $p = .038$, but only for the high active group. No significant relationships between any other frontal asymmetry score (i.e., theta or beta) and dispositional affect were found.

**Discussion**

The present study addressed the relationships among physical activity, brain activation, and dispositional affect in older adults. It was possible to differentiate dispositional affect on the basis of physical activity levels (high/low active), with significant differences between high and low active groups for positive affect, satisfaction with life, depression, and trait anxiety. These relationships between physical activity and dispositional affect are consistent with what would be expected from people who are more physically active (Petruzzello et al., 1991; McAuley & Rudolph, 1995; O'Connor et al., 1993; Plante & Rodin, 1990).

Additionally, it was hypothesized that resting anterior brain asymmetry would reflect dispositional affect. Specifically, it was predicted that greater relative left activation of the frontal sites (F3 compared to F4) would be associated with more positive affect and satisfaction with life, and less negative affect, anxiety, and depression. Partial support was obtained for this hypothesis in that frontal asymmetry was able to explain significant variance in positive affect. This is consistent with previous findings (Ahern & Schwartz, 1985; Jacobs & Snyder, 1996; Tomarken, Davidson, Wheeler, & Doss, 1992). For example, Ahern and Schwartz (1985) showed a differential lateralization for positive and negative emotion, with greater relative left frontal hemisphere activation for positive emotions, and greater relative right frontal hemisphere activation for negative emotions. Positive and negative emotions were elicited by a researcher asking questions in which subjects were to imagine positively or negatively laden situations (i.e., happiness, sadness), or by simply responding to a question (i.e., Give a synonym for the word happy). Jacobs and Snyder (1996) and Tomarken, Davidson, Wheeler, and Doss (1992) showed positive and negative affect (measured by the PANAS) to be significantly correlated with relative left frontal activation and relative right frontal activation, respectively.

Although frontal alpha asymmetry did not differ by activity group, significant interactions with Activity were shown in the ability of frontal alpha asymmetry to
explain affective variables. Frontal alpha asymmetry predicted affective valence and satisfaction with life in the high active group with a strong trend for negative affect. In the low active group, however, it was able to predict negative affect, but in the opposite direction of what was hypothesized. Frontal alpha asymmetry in the high active group was able to better distinguish dispositional affect in relation to Davidson’s approach/withdrawal framework than in the low active group. The only significant relationship in the low active group was with negative affect, and it was in the opposite direction of what was hypothesized and previously shown in younger adults (Ahern & Schwartz, 1985; Jacobs & Snyder, 1996; Tomarken, Davidson, Wheeler, & Doss, 1992). While these data may not fit in the approach/withdrawal framework, they do appear to be consistent with what would be expected under the hemi-aging hypothesis (Elias, 1979). This hypothesis proposes that the right hemisphere ages more rapidly and may influence cognitive/affective processing. The right hemisphere is thought to be important in the processing of negative affect (Davidson, 1992; Sackeim & Gur, 1978; Suberi & McKeever, 1977). McDowell, Harrison, and DeMaree (1994) found that elderly subjects were less accurate at identifying negative and neutral affective facial tone than younger subjects. Due to the findings in the present study, it may be reasonable to propose that physical activity influences the relationship between brain asymmetry and affect because of the more consistent findings in the high active group. However, because this is a cross-sectional study, such interpretations should be made cautiously.

Another possible explanation for the enhanced ability of frontal alpha asymmetry to predict dispositional affect in high active older adults may be that physically active older adults may be able to maintain brain function better than low active older adults. In the brain, neurotransmitters can have two effects on the postsynaptic neuron: (a) excitation that lowers the neuron’s membrane threshold so that it is more likely to fire, or (b) inhibition that raises the threshold and decreases the probability of neuronal firing. The probability of cell discharge depends on the summation of many inhibitory and excitatory influences. With aging, inhibitory strength weakens and is expected to adversely affect physical and cognitive functioning (Dustman, Emmerson, & Shearer, 1994; Dustman & Shearer, 1987). Additionally, the EEG of older adults is more homogenous in waveforms across electrode sites than is the case in younger adults (Dustman, LaMarche, Cohn, Shearer, & Talone, 1985). These results “suggest that aging is associated with a loss of functional autonomy of brain areas such that the older brain responds in a more homogenous or global manner” (Dustman, Emmerson, & Shearer, 1994, p. 146). However, physically fit elderly subjects have been shown to be similar to young adults on measures of such functional autonomy (e.g., cortical coupling values), suggesting that aerobic exercise may modulate excitation/inhibition relationships (Dustman, Emmerson, Ruhling et al., 1990; Dustman, Emmerson, & Shearer, 1994). Future EEG research in the elderly should address EEG coherence between physical activity groups. EEG coherence measures the similarity between two EEG signals at different brain regions, similar to cortical coupling, and is thought to be reflective of structural and functional coupling of those brain regions (Hudgahl, 1995; Thatcher, Krause, & Hrybyk, 1986; Tucker, Roth, & Blair, 1986). The current study addressed EEG coherence in high and low active older adults. While no significant differences were seen between the two groups, there appears to be a trend with high active older adults having less EEG coherence, which is thought to reflect
Table 3  EEG Alpha Coherence

<table>
<thead>
<tr>
<th>Site</th>
<th>High active $M$</th>
<th>High active $SD$</th>
<th>Low active $M$</th>
<th>Low active $SD$</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interhemisphere</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F3-F4</td>
<td>.700</td>
<td>.11</td>
<td>.744</td>
<td>.09</td>
<td>.425</td>
</tr>
<tr>
<td>C3-C4</td>
<td>.422</td>
<td>.19</td>
<td>.480</td>
<td>.10</td>
<td>.375</td>
</tr>
<tr>
<td>Intraheemisphere</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F3-C3</td>
<td>.651</td>
<td>.14</td>
<td>.738</td>
<td>.10</td>
<td>.701</td>
</tr>
<tr>
<td>F4-C4</td>
<td>.610</td>
<td>.20</td>
<td>.725</td>
<td>.09</td>
<td>.741</td>
</tr>
</tbody>
</table>

a decrease in coupling in these brain regions and possibly increased functional autonomy (see Table 3). This decreased EEG coherence may be a possible explanation for an increased ability of frontal alpha asymmetry to predict dispositional affect in older adults.

In summary, the present findings indicate that resting frontal alpha asymmetry is related to positive affect in older adults. The ability of frontal brain activation to explain dispositional affect appears to be influenced by physical activity levels. Physical activity levels were strongly related to positive affect, satisfaction with life, depression, and trait anxiety. These results support the use of EEG measurement as an important tool in examining dispositional affect and suggest that physical activity may be one way in which dispositional affect can be maintained or improved with advancing age. However, the relationship between brain activation, physical activity, and dispositional affect in older adults needs to be studied more extensively.

References


Acknowledgments

This work was partially supported by a grant from the University of Illinois Office of Gerontology and Aging Studies. The authors would also like to thank Panteleimon Ekkekakis for his technical support and comments on early drafts of this manuscript.