

Cognition and affective style: Individual differences in brain electrical activity during spatial and verbal tasks[☆]

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Abstract

Relations between brain electrical activity and performance on two cognitive tasks were examined in a normal population selected to be high on self-reported measures of Positive or Negative Affectivity. Twenty-five right-handed women, from an original pool of 308 college undergraduates, were the participants. EEG was recorded during baseline and during psychometrically matched spatial and verbal tasks. As predicted, participants who were high in Positive Affectivity performed equally well on the verbal and spatial tasks, while participants who were high in Negative Affectivity had spatial scores that were lower than their verbal scores. There were no group differences in baseline EEG. Both groups exhibited left central activation (i.e., α suppression) during the verbal and spatial tasks. When EEG data were analyzed separately for the group high in Positive Affectivity, there was evidence of parietal activation for the spatial task relative to the verbal task. The EEG data for the group high in Negative Affectivity had comparable EEG power values during verbal and spatial tasks at parietal scalp locations. These data suggest that, within a selected normal population, differences in affective style may interact with cognitive performance and with the brain electrical activity associated with that performance.

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1. Introduction

Since the early 1960s, research on split-brain patients has led to a profusion of studies examining the lateralization of cognitive function in both clinical and normal populations. Once considered task specific (e.g., Gazzaniga, Bogen, & Sperry, 1962), the cerebral hemispheres are now determined to be more process-oriented. The left hemisphere appears to be specialized for information processing in a way conducive for analyzing verbal data; likewise, the right hemisphere is specialized for processing

spatial data (Banich & Heller, 1998; Beeman & Chiarello, 1998; Chabris & Kosslyn, 1998).

Clinical work with stroke patients has had a similar effect on research examining the lateralization of emotion expression and experience. Early work considered the two hemispheres to be differentially specialized for positive and negative emotions (e.g., Gainotti, 1972). More recently, the hemispheres are theorized to be more dynamic in their function. The left hemisphere appears to be associated with approach situations and positive emotions, while the right hemisphere with withdrawal situations and negative emotions (Davidson, 1988, 1995; Fox, 1991, 1994).

Although traditionally considered as separate systems, cognition and emotion are dynamically linked, working together to process information and execute action (Cacioppo & Berntson, 1999). Clinically, cognitive biases have been associated with the etiology/maintenance of certain emotional pathologies (e.g., Mogg, Bradley, Williams, & Matthews, 1993). It may be

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that cognition and emotion are likewise linked in non-clinical populations, but this link may not be as obvious because of the less extreme level of affective functioning. Likewise, the motivations associated with approach/withdrawal behaviors (e.g., Sutton & Davidson, 1997) may be linked to cognitive processing. Therefore, the purpose of this study was to examine cognitive performance and brain electrophysiology in a normal population selected to be high on positive affectivity or negative affectivity.

Evidence presented by Davidson and colleagues (Davidson, 1995; Davidson, Schaffer, & Saron, 1985) indicates that within a normal population differences in tonic EEG α (8–13 Hz) hemispheric activation are associated with affective style. EEG α values are inversely related to cortical involvement. Thus, lower power values in a hemisphere (or region) reflect greater cortical activation of that hemisphere (or region) relative to the other hemisphere (Lindsley & Wicke, 1974). Adults rating themselves high on the Beck Depression Inventory exhibit greater right frontal activation (i.e., lower EEG α values) during a resting baseline condition than adults rating themselves low on the inventory. Likewise, adults who are clinically depressed also exhibit right frontal activation or left frontal hypoactivation (Henriques & Davidson, 1991). Conversely, left frontal activation is associated with higher positive affect on self-report measures (Sutton & Davidson, 1997; Tomarken, Davidson, Wheeler, & Doss, 1992).

Developmental evidence seems to suggest that these electrophysiological differences in affective style may be evident as early as the first year of life. Fox and colleagues have shown that infants who cry at maternal separation are more likely to exhibit right frontal EEG activation during rest (Bell & Fox, 1994; Davidson & Fox, 1989; Fox, Calkins, & Bell, 1994; Fox & Davidson, 1987). In addition, infants who display negative affect and high motor activity at 4 months of age are reported to exhibit right frontal activation at 9 months and inhibited behavior at 14 months (Calkins, Fox, & Marshall, 1996). For many infants, these individual differences in affective style and EEG activation persist throughout the preschool years (Fox, Henderson, Rubin, Calkins, & Schmidt, 2001). Thus, the evidence from normal adults, clinical populations, and developmental studies points to a relation between individual differences in EEG hemispheric activation and certain aspects of affective style.

Likewise, there are studies of brain electrical activity during cognitive processing designed to engage either the left or right hemisphere. For example, there are reports of EEG activation in the hemisphere most engaged in the processing of either verbal or spatial information (e.g., Davidson, Chapman, Chapman, & Henriques, 1990; Furst, 1976; Galin & Ornstein, 1972; Roberts & Bell, 2002; Willis, Wheatley, & Mitchell, 1979). From an

individual differences perspective, increased hemispheric activation is related to better task performance and decreased activation is associated with poorer task performance (Davidson et al., 1990; Heller & Nitschke, 1997). These relations are similar to Levy's model (Levy, 1983) in which the role of tonic hemispheric arousal is related to performance involving hemispheric specialization. Levy found that performance on tasks requiring the left hemisphere is enhanced in individuals with tonic left hemisphere arousal. Performance is diminished in these same tasks for individuals with tonic right hemisphere arousal (Levy, Heller, Banich, & Burton, 1983).

Although many studies have examined the relations between verbal and/or spatial task performance and affective style (i.e., "personality"; e.g., Ackerman, Kanfer, & Goff, 1995; Crossman & Polich, 1989; Ozer, 1987; Schaie, Dutta, & Willis, 1991; Signorella, Jamison, & Krupa, 1989; Waggett & Lane, 1990), fewer studies have examined variations in affective style, cognitive performance, and hemispheric activation in a normal population. Using EEG values, Howard and colleagues (Howard, Fenwick, Brown, & Norton, 1992) reported that social extraversion was associated with left hemisphere activation during verbal and spatial tasks, while behavioral extraversion was related to left hemisphere activation only during the verbal task. Tucker and colleagues (Tucker, Hartry-Speiser, McDougal, Luu, & deGrandpre, 1999) reported decreased right hemisphere advantage (left visual field decrement) on a spatial memory task for participants high in self-reported negative affect. These negative affect participants also showed increased right hemisphere processing of point-awarding targets during the spatial memory task (i.e., lower α power values at the right posterior scalp locations) and increased left hemisphere processing of point-losing targets (i.e., lower α power values at the left posterior scalp locations). Thus, it is plausible that there are differences in affective style that interact with cognitive performance and the hemispheric activation associated with that performance.

The functional association of affect with hemisphere activation and cognitive processing may also be illuminated by the work done with clinical populations. Researchers working with depressed patients have reported tonic levels of right hemisphere activation among these patients (Baehr, Rosenfeld, Baehr, & Earnest, 1998; Matousek, Capone, & Okawa, 1981; Perris, von Knorring, Cumberbatch, & Murcizuno, 1981; Volavka, Abrams, Taylor, & Reker, 1981). Researchers have also reported that depressed patients display extreme right hemisphere activation during cognitive tasks thought to involve the right hemisphere (Flor-Henry & Koles, 1984; Flor-Henry, Koles, & Tucker, 1982). In addition, depressed patients tend to show cognitive deficiencies on certain right hemisphere tasks (Flor-Henry & Koles, 1984; Flor-Henry et al., 1982; Miller, Fujioka, Chap-

man, & Chapman, 1995). Thus, there may be an inverted U-shaped function with respect to the association between hemispheric activation and cognitive performance, with some “normal” level of tonic hemispheric arousal conducive to cognitive functioning and “extreme” arousal disadvantageous to cognition.

It may be that competition for resources induces interference in cognitive processing. Kinsbourne and Hissock (1983) proposed that this rivalry produces interference for the less important task because of decreases in processing capacity associated with a particular brain system. For the depressed individual with tonic right hemisphere activation, the increased demands of a right hemisphere task could diminish processing efficiency and result in diminished task performance.

Within a selected normal population there is the potential for differences in affective style to interact with cognitive performance and the hemispheric activation associated with that performance. It is possible that normal individuals exhibiting negative affective style will display greater right hemisphere activation during right hemisphere tasks than normal individuals displaying a more positive affective style. This greater degree of activation may interact with cognitive task performance in the normal population, as evidenced in clinical samples.

The purpose of this study was to examine brain electrical activity and cognitive task performance in a normal population selected to be high on positive or negative affectivity. The hypotheses are as follows:

Baseline EEG. Individuals high on self-reported negative affectivity would exhibit right frontal EEG activation and individuals high on positive affectivity would exhibit left frontal activation during the baseline condition.

Task performance. Individuals high on negative affectivity would perform more poorly on a right hemisphere spatial task than on a left hemisphere verbal task and individuals high on positive affectivity would perform equally well on right hemisphere and left hemisphere tasks.

Task EEG. Individuals high on negative affectivity would exhibit greater right hemisphere activation during spatial task performance than individuals high on positive affectivity. No group difference was hypothesized for the EEG during verbal task performance.

2. Method

2.1. Participant selection

Participants were 25 women selected from an initial pool of 308 undergraduate students in psychology and human development classes at a large suburban university. The pool of volunteers ranged in age from 18 to

51 (91% were between 18 and 22) and 78% of them were female. For class credit, the 308 volunteers completed the Multidimensional Personality Questionnaire (MPQ; Tellegen, 1982). This personality assessment factors into a hierarchical model with two second-order factor scales called “Positive Activation” and “Negative Activation” (Tellegen, Watson, & Clark, 1999a, 1999b; Watson & Tellegen, 1985). High Positive Activation (PA) reflects an alert person whose outlook is enthusiastic and joyful. High Negative Activation (NA) reflects a distressed person who displays nervousness, fear, and hostility (Watson & Tellegen, 1985). The PA and NA factors are not orthogonal; the questionnaire items corresponding to amazed, astonished, and surprised load on both the PA and NA factors, with weights of opposite signs (Tellegen et al., 1999b).

Because of the disproportionate number of women who completed the MPQ, the selection pool was restricted to women. The mean PA score for the selection pool of women in this study ($M = 156.9$, $SD = 12.2$) was comparable to that reported by Tellegen (1982) for women undergraduates ($M = 156.1$, $SD = 12.4$). However, the mean NA score for the selection pool of women in this study ($M = 134.1$, $SD = 13.5$) was higher than that noted by Tellegen (1982) for women undergraduates ($M = 128.8$, $SD = 11.8$).

Right-handed women between the ages of 18 and 22 who scored either one standard deviation above the group mean on the PA factor ($n = 21$) or one standard deviation above the group mean on the NA scale ($n = 23$) were invited to participate in the study. Those who were one standard deviation above the mean on both scales were excluded. Of the 44 women eligible for the study, five declined to participate, four agreed to participate but could not be scheduled for a laboratory visit because of school and work schedules, and nine could not be contacted (e.g., no phone number given, disconnected phone, and out of the country). Thus, 26 women participated in this study, with 14 being high on PA and 12 high on NA. One of the PA participants was later eliminated from data analysis because of equipment failure during EEG recordings, resulting in 25 participants with complete EEG data. The women were paid \$15 for their participation in the laboratory testing session. Length of time between initial completion of the MPQ and the laboratory EEG session ranged from 3 to 4.5 months.

2.2. Procedures

Each of the 25 participants was given a second copy of the MPQ and a copy of the Beck Depression Inventory (BDI) to complete prior to coming to the laboratory EEG session. The women were instructed to complete the MPQ and the BDI no earlier than the evening before their scheduled testing and to bring the

completed forms with them to the laboratory testing session.

The PA and the NA higher-order factors from the MPQ showed test–retest stability ($r = .817$ and $r = .820$, respectively, both p 's < .001) over the 3- to 4.5-month period from initial testing of the large pool of volunteers to the laboratory testing of the 25 participants. The 13 participants selected to be in the PA group had an initial mean PA score of 174.52 and continued to rate themselves as high on the PA factor just prior to laboratory testing, with a mean score of 171.89. This second PA score was above the original selection criterion. The 12 individuals initially selected to be in the NA group had a mean NA score of 159.37 and still scored themselves high on the NA factor immediately prior to the laboratory session. Their second NA score was 145.08, which was slightly below the original selection criterion of 147.60. One NA participant did not complete the set of questionnaires prior to the lab visit.

The PA ($M = 5.23$, $SD = .86$) and NA ($M = 9.36$, $SD = 3.10$) groups did not differ in their scores on the BDI completed immediately prior to the laboratory session ($F(1,22) = 1.91$, $p = .18$), although BDI and NA scores (completed prior to lab session) were positively correlated, $r = .51$, $p < .01$.

At the beginning of the testing session, participants were shown the EEG recording apparatus and given general instructions about the verbal and spatial tasks. After signing the informed consent form, electrodes were applied and EEG and EOG were recorded for a 1-min eyes opened baseline and during verbal and spatial tasks.

2.3. EEG recording

A stretch cap (Electro-Cap) with electrodes in the 10/20 electrode placement system was used for EEG collection. Because this study utilized the same verbal and spatial tasks used by Davidson et al. (1990) in their study of asymmetrical brain electrical activity, the EEG recording technique and frequency band selection mimicked one of the derivations of that previous study. Thus, recordings were made from F3, F4, C3, C4, P3, P4, referenced to Cz. Upon proper placement of the cap, recommended procedures regarding EEG data collection were followed (Pivik et al., 1993). Specifically, a small amount of abrasive was inserted into each electrode to allow gentle abrasion of the scalp with the blunt end of a Q-tip. Following this, conductive gel provided by the cap manufacturer was inserted into each electrode site. Electrode impedances were required to be below 5 k Ω . EOG, digitized along with the EEG channels and used for subsequent artifact editing, was recorded using Beckman miniature electrodes. Electrodes were placed on the external canthus and the super orbit of the right eye.

The electrical activity from each lead was amplified using separate Grass Model 7P11 amplifiers and band-passed from 1 to 100 Hz. Activity for each lead was displayed on a Grass Model 78 polygraph. Data were digitized on-line at 512 Hz using a Modular Instruments A/D board and acquisition software. The high sampling rate was used to ensure that the data were not affected by aliasing. Raw data were stored for later analysis.

Prior to the recording of each subject a 10 Hz, 50 μ V peak-to-peak (17.678 μ V rms) sine wave was input through each amplifier. This calibration signal was digitized for 30 s and stored for subsequent analysis.

2.4. EEG analysis

Spectral analysis of the calibration signal and computation of power at the 9–11 Hz frequency band was accomplished. The power figures were used to calibrate the power derived from the subsequent spectral analysis of the EEG.

The EEG data were examined and analyzed using software developed by James Long Company (Canoga Lake, NY). First, the data were re-filtered with a low pass filter set at 60 Hz and then artifact scored for eye movements and gross motor movements. Because these were adult data, artifact due to gross motor movements was very rare. These artifact-scored epochs were eliminated from all subsequent analyses. The data then were analyzed with a discrete Fourier transform (DFT) using a Hanning window of one-second width and 50% overlap. Power was computed for the 8–13 Hz α band.

2.5. Tasks

The Word Finding and Dot Localization tasks were used as the verbal and spatial measures. The two tasks have been matched psychometrically (Fujioka, 1986; Miller, 1986); therefore, direct comparisons of verbal and spatial abilities were possible. The two tasks have also been shown to measure hemispheric functioning, with the verbal Word Finding task engaging the left hemisphere and the spatial Dot Localization task engaging the right hemisphere (Davidson et al., 1990; Fujioka, 1986; Miller, 1986). An abbreviated 24-item form of each task (Davidson et al., 1990) was presented in slide format for this study. Participants were given practice slides for each task to ensure that they understood what they were expected to do during the task and how to initiate and terminate each trial.

The Word Finding task, patterned after the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1978), presented the participant with phrases that were the definitions for words. The participant was expected to write down the word being defined. Verbal score was the number of definitions correctly identified, with no errors resulting in a score of 24.

The Dot Localization task, modified from a measure by Hannay, Varney, and Benton (1976), presented the participant with two rectangles. The top rectangle contained two dots and the bottom rectangle, offset to either the right or the left of the top one, contained rows of digits in numerical order beginning with the number 1. The number of digits in the bottom rectangle varied from 18 to 50. The participant was expected to write down the two numbers that would be covered by the two dots if the rectangles were superimposed. Spatial score was the number of slides where *both* numbers were correctly identified. Again, no errors resulted in a score of 24.

Task order was randomized. Both tasks were self-paced and participants were given a button to press to initiate and terminate each trial. To initiate a trial for the first task, participants pressed the button and a slide appeared on the screen 80 cm in front of them. They were told to view each slide and then press the button again to terminate the trial after formulating an answer. Once the trial was terminated, participants were instructed to write their response on an answer sheet. The experimenter stressed the importance of writing answers only after the trial had been terminated. Participants were monitored to ensure that they complied with these instructions. The screen was blank during the writing period. When all trials for the first task were completed, the experimenter entered the room and gave the participant the answer sheet for the next task. Participants then proceeded at their own pace with the second task.

The button press functioned to change slides for each trial and to provide input to a Schmitt trigger on a Modular Instruments A/D board. EEG data were continuously digitized throughout each task. The pulses to the Schmitt trigger created an inter-trial interval file for each task. The data from the ITI file were used to determine the exact time period when the participant was attending to each of the slides. Only the EEG digitized while each trial slide was on the screen was used in the analyses.

Computation of verbal task EEG was accomplished by weighting the EEG power from each trial of the verbal task by the inverse of the number of DFT windows for each individual trial. Then EEG data from each trial of the verbal task were combined to compute a total verbal EEG value for each electrode site. Identical computations were made to obtain a total spatial EEG value for each electrode site. After the computation of the total verbal task EEG power and the total spatial task EEG power, these EEG values were transformed using the natural log to normalize distributions within each task.

2.6. Data analysis

MANOVA analysis was performed to examine the hypotheses concerning EEG power values. Individual

MANOVAs were used as a follow up to the hypothesis-testing MANOVA as a conservative test of effects. MANOVA is the test of choice with psychophysiological data because it does not have the sphericity assumptions associated with ANOVA procedures (Keselman, 1998) and is appropriate for psychophysiological data even when there is only one dependent variable (Picton et al., 2000).

3. Results

3.1. Affective style and baseline EEG

Prior to the examination of hypothesized group differences in baseline EEG, it was important to verify that the two affective style groups had equal amounts of artifact-free EEG (Pivik et al., 1993). The software program (James Long Company) for the Fourier analyses of the EEG used a window width of one second called a “DFT window.” Thus, *t* tests were performed on the number of DFT windows available for analysis. There were no group differences in the amount of baseline data ($t(23) = .63, p = .53$).

The hypothesis was that the NA group would exhibit right frontal EEG activation and the PA group left frontal activation during the baseline condition (i.e., a group by region by hemisphere interaction). The eyes open baseline data can be seen in Fig. 1. There was a main effect for region (Hotelling’s trace = .59, approx $F(2, 22) = 6.48, p = .006$), with the higher power values evident at parietal locations. There were no other effects or interactions involving the group variable (all *p*’s > .15).

3.2. Affective style and task performance

The hypothesis was that the NA individuals would perform more poorly on the right hemisphere spatial

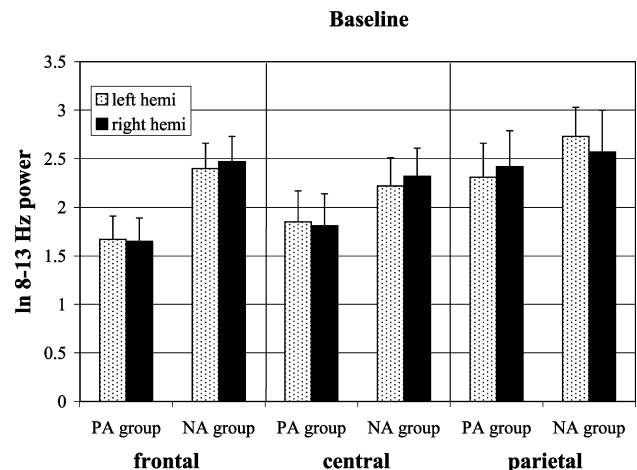


Fig. 1. Baseline EEG power values for the PA and NA groups.

task than on left hemisphere verbal task and that PA individuals would perform equally well on right hemisphere and left hemisphere tasks. Group scores on the verbal and spatial tasks can be seen in Table 1. The PA group had identical means on the verbal and spatial tasks ($t(12) = .00, p = 1.00$). The NA group, however, had a lower score on the spatial task relative to the verbal task ($t(11) = 2.16, p = .05$).

3.3. Affective style and task-related EEG

The hypothesis for EEG power was that the NA group would exhibit greater right hemisphere activation than the PA group during spatial task performance (i.e., a group by hemisphere interaction). No group difference was hypothesized for the EEG during verbal task performance. DFT windows were examined to verify that both affective style groups had equal amounts of EEG task data. There were no group differences in the amount of verbal ($t(23) = 1.48, p = .15$) or spatial ($t(23) = .50, p = .63$) data.

For the spatial task EEG power data (see Fig. 2), there was a main effect for region and a region by hemisphere interaction that were superceded by a group by region by hemisphere interaction (Hotelling's trace = .31, approx $F(2, 22) = 3.40, p = .05$). Follow-up analyses were accomplished on each region. For the parietal region, the group by hemisphere interaction approached significance ($F(1, 23) = 3.29, p = .08$). The NA group exhibited right parietal activation during the

spatial task, while the PA group exhibited parietal symmetry. For the central region, there was a main effect for hemisphere, with left hemisphere activation during the spatial task, $F(1, 23) = 14.22, p = .001$. For the frontal region, the group main effect approached significance, with the NA group exhibiting more EEG power during the spatial task, $F(1, 23) = 3.42, p = .08$.

For the verbal power data (see Fig. 3), there were main effects for region and hemisphere and a region by hemisphere interaction that were superceded by a group by region by hemisphere interaction (Hotelling's trace = .33, approx $F(2, 22) = 3.65, p = .04$). Follow-up analyses were accomplished on each region. For the parietal region, there was a group by hemisphere interaction, $F(1, 23) = 4.38, p = .05$. The NA group exhibited right parietal activation during the verbal task, while the PA group exhibited left parietal activation. For the central region, there was a main effect for hemisphere, with left hemisphere activation during the verbal task, $F(1, 23) = 17.94, p < .001$. For the frontal region, there also was a main effect for hemisphere, with left hemisphere activation during the verbal task, $F(1, 23) = 14.73, p = .001$.

3.4. Post-hoc analyses—no grouping variable

After hypothesis testing, post-hoc analysis of the task-related EEG was accomplished to determine whether the asymmetrical EEG activity findings of Davidson et al. (1990) using these same verbal and spatial tasks had been replicated with the current sample. The Davidson et al. (1990) sample consisted of 21 right-handed women who scored below 8 on the BDI prior to testing. As previously noted, the NA group in the current study had a BDI mean of 9.36, although this did not differ statistically from the mean of 5.23 shown by the PA group. The purpose of the Davidson et al. (1990) study was to compare the hemispheric activation

Table 1
Spatial and verbal task means (SE) for PA and NA groups

	Verbal task	Spatial task
PA group ($n = 13$)	19.69 (.70)	19.69 (1.17)
NA group ($n = 12$)	20.25 (.84)	16.83 (1.39)

Note. Maximum score = 24.

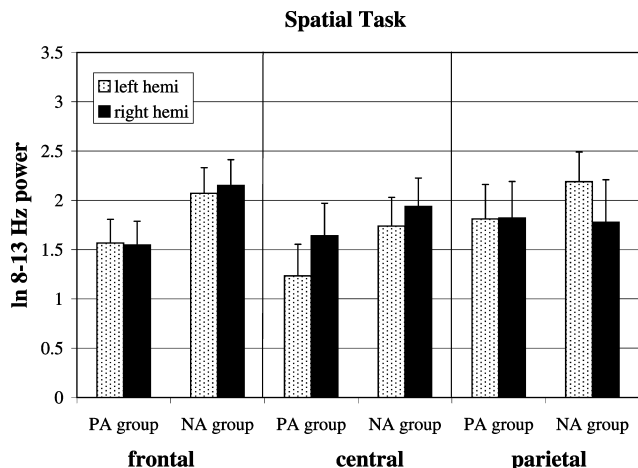


Fig. 2. Spatial task EEG power values for the PA and NA groups.

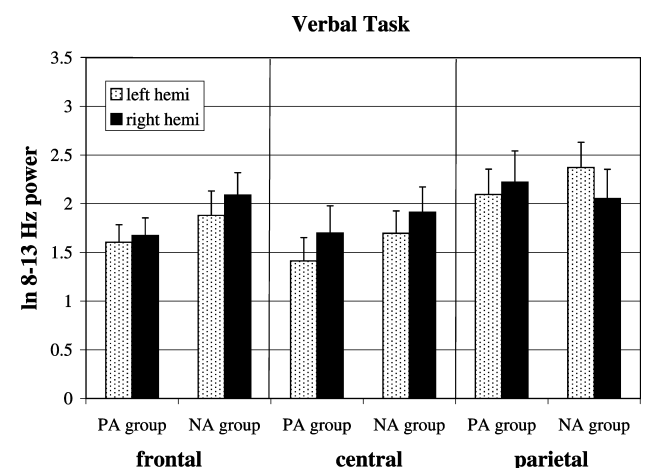


Fig. 3. Verbal task EEG power values for the PA and NA groups.

patterns of psychometrically matched verbal and spatial tasks at different frequency bands and with different reference derivations. The current study used one of those combinations: Cz-referenced data in the α (8–13 Hz) frequency band. Davidson et al. (1990) used multiple separate ANOVAs on the different band powers from two reference derivations for each region (frontal, central, and parietal). Task (verbal, spatial) and hemisphere (left, right) were the within-subjects variables. A task by hemisphere interaction signified a difference in asymmetrical EEG activity during verbal task performance compared to spatial task performance and they reported that there was a task by hemisphere interaction for all three regions. Thus, EEG power in the α frequency band at each region discriminated between the verbal and spatial tasks.

The EEG power values for the PA and NA groups were combined for these initial post-hoc analyses and the data can be seen in Fig. 4. Applying the Davidson et al. (1990) statistical analysis technique with the current data set, there was a main effect for task for the parietal EEG data, $F(1, 24) = 9.20, p = .006$. This was a function of greater suppression of EEG power during the spatial task relative to the verbal task in both hemispheres. Davidson et al. (1990) reported that their task by hemisphere interaction at parietal resulted from greater suppression of α power in the right hemisphere during the spatial task compared with the verbal task.

In the current data set, there was a main effect for hemisphere for the central region, $F(1, 24) = 23.63, p < .001$. This was a function of greater suppression of EEG power in the left hemisphere relative to the right hemisphere during both tasks. Davidson et al. (1990) reported that their task by hemisphere interaction at central resulted from greater suppression of α power in the left hemisphere during the verbal task compared with the spatial task.

Also in the current data set, there was a task by hemisphere interaction for the frontal region, $F(1, 24) = 6.19, p = .02$. This interaction was a function of greater suppression of EEG power in the left hemisphere relative to the right hemisphere during the verbal task, $t(24) = 3.58, p = .001$. Davidson et al. (1990) reported that their task by hemisphere interaction at frontal reflected greater suppression of α power in the right hemisphere during the spatial task compared with the verbal task.

To summarize the comparison, in the current data set there was a main effect for task for the parietal EEG data and a main effect for hemisphere for the central EEG data, whereas Davidson et al. (1990) reported a task by hemisphere interaction for both of these regions. Similarly, the task by hemisphere interaction for the frontal EEG data was manifested differently in the two data sets. It is the case, however, that the frontal and parietal EEG data in this sample discriminated between the verbal and spatial tasks as it did in Davidson et al. (1990) with an unselected sample.

3.5. Post-hoc analyses—PA and NA groups

The second level of post-hoc testing was accomplished to determine whether the EEG data discriminated between the verbal and spatial tasks at the group level. Thus, the preceding post-hoc analyses with no grouping variable were repeated separately for each group.

For the PA group (see Fig. 5), there was a main effect of task for the parietal region, with greater suppression of power in both hemispheres during the spatial task compared to the verbal task, $F(1, 12) = 5.38, p = .04$. There was a main effect for hemisphere for the central region, with greater suppression of power in the left hemisphere relative to the right for both tasks,

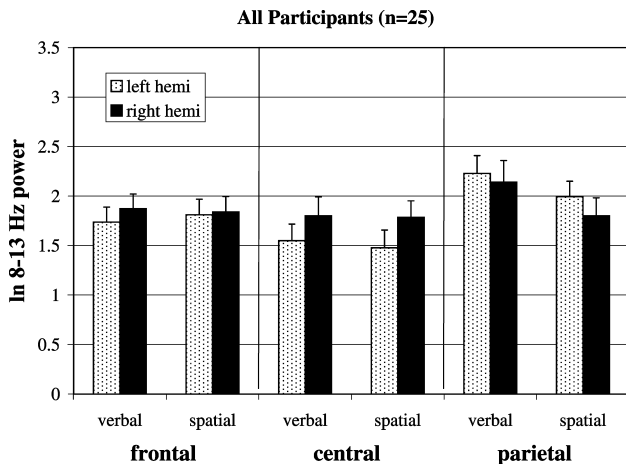


Fig. 4. Verbal and spatial task EEG power values for all participants.

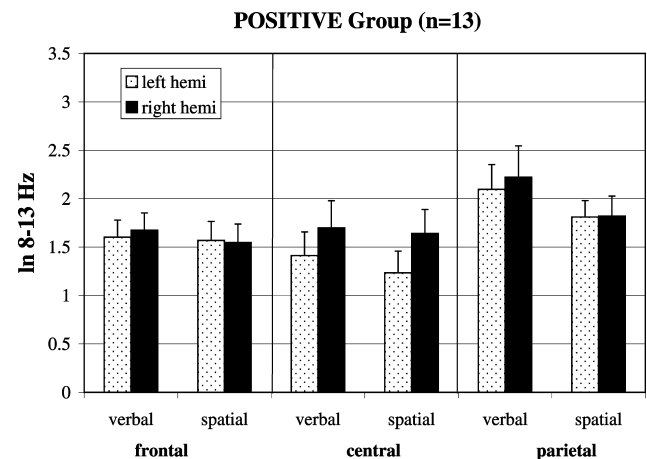


Fig. 5. Verbal and spatial task EEG power values for the PA group.

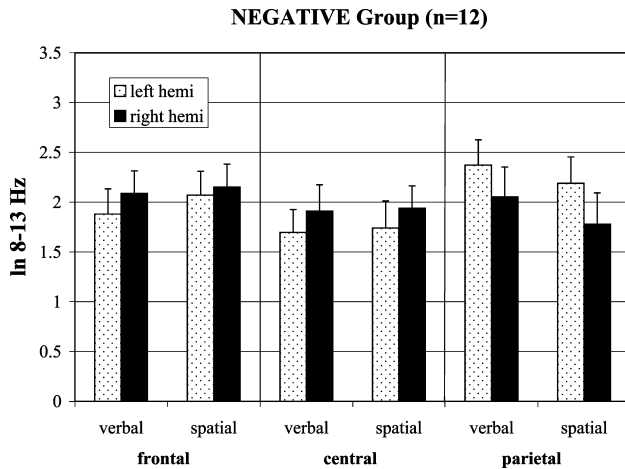


Fig. 6. Verbal and spatial task EEG power values for the NA group.

$F(1, 12) = 12.55, p = .004$. There were no effects or interactions for the frontal region, all p 's $> .12$.

For the NA group (see Fig. 6), there was a trend toward a main effect of hemisphere at parietal, with greater suppression of power in the right hemisphere relative to the left for both tasks, $F(1, 11) = 4.55, p = .06$. There was no effect for task and no task by hemisphere interaction at parietal, both p 's $> .09$. There was a main effect for hemisphere in the central region, with greater suppression of power in the left hemisphere relative to the right for both tasks, $F(1, 11) = 15.45, p = .002$. Finally, there was a main effect for hemisphere for the frontal region, with greater suppression of power in the left hemisphere relative to the right for both tasks, $F(1, 11) = 11.28, p = .006$.

When the data were analyzed separately by group, the parietal EEG discriminated between the verbal and spatial tasks for the PA group. The NA group had parietal EEG activation patterns that did not differ between verbal and spatial processing.

4. Discussion

Selecting respondents with elevated scores on the MPQ (Tellegen, 1982) higher-order factors of Positive Affectivity and Negative Affectivity yielded two groups of individuals who displayed no differences in frontal asymmetry during baseline EEG recordings. It had been predicted that the NA group would display right frontal activation and the PA group would display left frontal activation. Although right frontal activation is typically associated with greater Negative Affectivity (Davidson, 1995, 1998; however, see Hagemann, Naumann, Becker, Maier, & Bartussek, 1998; Reid, Duke, & Allen, 1998), not all types of "negative" affect are associated with greater relative right frontal activation. The most consistent frontal asymmetry findings are associated with

depression (Baehr et al., 1998; Davidson, 1998; Tomarken, Davidson, Wheeler, & Kinney, 1992). The selection instrument in this study, however, defines Negative affectivity as a higher-order factor incorporating not only depression, but also aggression, nervousness, and worry subfactors. Thus, selecting individuals on Negative Affectivity may include a range of individuals who are predisposed in different ways to negative affect. Not all of these variations in negative affect are necessarily associated with right frontal activation (Fox, 1994).

The NA group in this study did show a slight decrease in Negative Affectivity scores on the MPQ from initial selection to laboratory session. At initial selection, the NA group had a mean score on Negative Affectivity that was 25 points higher than the PA group scored on Negative Affectivity. At laboratory testing, the NA group mean had changed so that the Negative Affectivity difference between the groups was 15 points. The NA group in this study may exhibit a more changeable mood state or affective style than could be reflected in frontal EEG asymmetry. EEG recordings at the time of initial group selection may have been useful in disentangling these apparent discrepancies with some of the literature.

The NA and PA groups tended to show a difference in performance on a spatial task, previously demonstrated to engage the right hemisphere, relative to performance on a verbal task, previously demonstrated to engage the left hemisphere. The NA participants had a lower group mean score on the spatial task than they did on the verbal task. The PA group performed equally well on each of these two psychometrically matched tasks. Research with depressed patients has shown some impairment on right hemisphere tasks (Flor-Henry & Koles, 1984). Although the individuals in this study were not clinically depressed, they did rate themselves as high in Negative Affectivity.

The EEG data for the entire sample demonstrated evidence of left hemisphere frontal and central activation during a verbal task, thus confirming previous work with this verbal task (Davidson et al., 1990). There was little confirmation of right hemisphere activation during the spatial task; it was only evident when comparing the spatial task parietal power values of the NA group (right hemisphere activation) with those of the PA group (symmetry). This apparent right hemisphere activation for the NA group disappeared when comparing the spatial task parietal power values of the PA and NA groups with their own verbal task parietal power values. That comparison revealed greater α suppression at the parietal region during the spatial task relative to the verbal task; however, the suppression was observed in both hemispheres rather than in the right hemisphere only. Not all of the participants displayed greater parietal activation during the spatial task relative to the verbal task, however. This finding was specific to the PA

group. The NA group showed no differences in parietal activation between verbal and spatial tasks, although other researchers have reported right parietal activation during this type of task (e.g., Davidson et al., 1990; Galin & Ornstein, 1972). Perhaps the reason for the poor performance of the NA group on the spatial task relative to their performance on the verbal task was related to the lack of differentiation of the parietal EEG during the two tasks.

Group differences in right hemisphere activation during the spatial task had been predicted from a model specifying that poorer performance on the right hemisphere spatial task would be associated with extreme activation of the right hemisphere during task performance. Flor-Henry and colleagues (Flor-Henry & Koles, 1984; Flor-Henry et al., 1982) reported that depressed patients show elevated right hemisphere activation, and corresponding poorer performance, during right hemisphere tasks. The NA group in this study did not appear to exhibit “extreme” right activation, however. Examination of Fig. 2 shows that the EEG power values at the right parietal electrode sites are comparable for the NA and the PA groups. What appears to differ between the groups is the power at left parietal. Likewise, Fig. 6 shows that the NA group showed comparable activation at parietal during the verbal and spatial tasks. So, rather than extreme right parietal activation during the spatial task, the NA group appears to have experienced inconsequential parietal activation.

Similarly, Furst (1976) noted that in a group of normal participants, those with greater right hemisphere activation during spatial performance performed better on the task. Typically, increased activity during cognitive processing leads to better cognitive performance (Heller, Nitschke, & Miller, 1998). The increased activity can be experimentally induced. In a recent study using mood induction, Bartolic and colleagues (Bartolic, Basso, Schefft, Glauser, & Titanic-Schefft, 1999) reported that euphoria was associated with better verbal than figural performance, while dysphoria was associated with better figural than verbal performance. Perhaps the NA group in the study lacked the appropriate amount of right parietal activation sufficient for high levels of performance on the spatial task.

This study was limited by the selection criteria used for participant recruitment. The MPQ factors of Negative Affectivity and Positive Affectivity may not have been the best selection device. Studies with the most consistent findings for individual differences in frontal baseline hemispheric activation focus on depressed populations. Similarly, studies with the most consistent findings for poor performance on right hemisphere tasks utilize participants with clinical depression (e.g., Miller et al., 1995). Stronger support for the hypotheses of this study may be found with clinical populations. Nevertheless, there were group differences in spatial task

performance and group differences in parietal EEG activation patterns during the spatial task suggesting that the specific hemisphere may not be the determining factor in task proficiency. Perhaps overall parietal activation, regardless of the hemisphere, is more important.

In summary, interactions among affective style, cognitive task performance, and EEG power were found to be present in a normal population selected to be high on the self-reported characteristics of Positive and Negative Affectivity. These associations appeared to be limited to the spatial task, where participants rating themselves as high in NA performed more poorly on a task of spatial abilities as compared to a task of verbal abilities. Those high in NA also exhibited less parietal activation in both hemispheres during spatial performance than did those individuals high on PA. Thus, variations in affective style may have implications for brain electrical activity and cognitive functioning in a normal population.

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