Brain and Cognition **41,** 200–212 (1999)
Article ID brcg.1999.1118, available online at http://www.idealibrary.com on IDEAL®

Variations in EEG Coherence as an Index of the Affective Content of Dreams from REM Sleep: Relationships with Face Imagery

Tore A. Nielsen and Véronique Chénier

Dream and Nightmare Laboratory, Hôpital du Sacré-Coeur,
Montréal, Québec, Canada

EEG coherence was examined in relation to four measures of socioemotional dream content, including a new measure—the proportional representation of a character's face. Twenty-four healthy subjects, recorded for sleep stages and EEG activity, were awakened from REM sleep to report dream mentation and to rate it on these variables. Coherence scores were calculated for homologous interhemispheric electrode pairs (Fp1–Fp2, F3–F4, F7–F8, C3–C4, P3–P4, O1–O2, T3–T4, T5–T6) and for left and right intrahemispheric pairs for delta, theta, alpha, beta1, and beta2 frequencies. These were correlated with the mentation measures. Positive correlations were found between average interhemispheric coherence in most bands and the character face measure. A breakdown by gender revealed that this relationship was most evident for women, whereas for men positive correlations were observed between coherence and negative self-feeling. That similar relationships also obtained for both left and right intrahemispheric coherence is consistent with the hypothesis that dreamed socioemotional interactions reflect the integrative functioning of many brain regions in both hemispheres. © 1999 Academic Press

INTRODUCTION

EEG Correlates of Dream Mentation

Since the discovery of an association between EEG-defined sleep with rapid eye movements and the recall of vivid dreaming (Aserinsky & Kleitman, 1953; Dement & Kleitman, 1957), numerous investigators have attempted to identify more precise relationships between EEG parameters and dream mentation (see Pivik, 1994, for review). They have met with limited success in this endeavor. Most such studies have focused upon EEG power

Address reprint requests and correspondence to Tore A. Nielsen, Hôpital du Sacré-Coeur de Montréal, 5400, Boulevard Gouin Ouest, Montréal (Québec) H4J 1C5, Canada. Fax: (514) 338-2531. E-mail: Nielsen@ere.umontreal.ca.

0278-2626/99 $30.00

measures from a limited number of electrodes in relation to global measures of dreaming, such as the simple recall of having dreamed.

More recent PET imaging studies have found preliminary evidence of localized activity in affective centers during REM sleep dreaming. These include reports of elevated glucose metabolism in cingulate gyrus during REM sleep (Buchsbaum, Gillin, Wu, Hazlett, Sicotte, Dupont, & Bunney, 1989) and increased rCBF in amygdala, anterior cingulate cortex, pons, and thalamus during REM sleep with verified dreaming (Maquet, Péters, Aerts, Delfiore, Degueldre, Luxen, & Franck, 1996). Others have reported significant correlations between dreamed anxiety measures and glucose metabolism in various cortical regions (Gottschalk, Buchsbaum, Gillin, Wu, Reynolds, & Herrera, 1991). Although such studies have provided a tantalizing first glimpse at the emotional functions of the dreaming brain, they are less easily realized than EEG studies, primarily due to the practical difficulties of scanning subjects without disturbing their sleep.

There is thus an interest in reexamining the EEG as an index of emotional cognition during sleep. More recent, noninvasive, and less cost-intensive methods of EEG quantification, such as topographic spectral mapping and EEG coherence analysis, may be particularly valuable in quantifying correspondences between brain activity and emotion during sleep. For example, we recently demonstrated that topographic spectral analyses of the EEG distinguish both affectively intense nightmares from nonnightmare REM sleep episodes (Zadra & Nielsen, 1996) and the affectively neutral hallucinations of sleep onset from the more emotive dreams of REM sleep (Nielsen, Germain, & Ouellet, 1995).

The EEG coherence function has received much less attention than has EEG power in the investigation of dream mentation correlates. EEG coherence measures the similarity of activity between two electrode sites for a given frequency band and is theoretically independent of EEG amplitude. Research supporting the validity of the coherence function as a measure of affect is reviewed in the following section.

Validity of the EEG Coherence Function

Pioneering studies of EEG coherence are still pertinent to the question of affective processes during sleep, as these used coherence to study relationships between hippocampal cells and theta rhythms (Walter & Adey, 1963) and relationships between various limbic structures using indwelling electrodes in human subjects (Brazier, 1967). There were also early studies of coherence during various sleep stages (Dumermuth, Walz, Scollo-Lavizzari, & Kleiner, 1972; Johnson, 1972).

Although the recent explosion of interest in coherence has validated it as an index of functional brain organization under a wide variety of clinical and experimental situations (see Duffy, Jones, McAnulty, & Albert, 1995;

French & Beaumont, 1984, for reviews), its utility for measuring emotional processes also continues to advance. Some results have demonstrated changes in EEG coherence as a function of emotional states induced by films (e.g., Hinrichs & Machleidt, 1992; Schellberg, Besthorn, Klos, & Gasser, 1990) and affective illness (e.g., Armitage, Kowarch, Calhoun, Emstlie, Rush & Roffwarg, 1991) and in relation to normal and alexithymic emotional expression (Tenhouten, Walter, Hoppe, & Bogen, 1987). The latter study found that some interhemispheric coherence measures were associated with the ability to verbally express feelings, a task which presumably requires integration of emotional and verbal information between hemispheres. EEG coherence has also been found to index a variety of tasks involving marked gender differences (e.g., Duffy et al., 1995).

No studies have specifically studied EEG coherence in relation to dream emotion. However, negative emotions during REM sleep dreaming are extremely common (e.g., Nielsen, Deslauriers, & Baylor, 1991) and should be as prone to detection by sleep EEG coherence measures as by their waking state counterparts. In fact, in a pilot study aimed at determining the validity of EEG coherence as an index of emotional cognition during REM sleep (Nielsen, Ouellet, Cartier, & Montplaisir, 1994) we found evidence of a correlation between coherence and specific emotional features of dream experience. We examined whether three dream content variables varied with EEG coherence: emotions attributed to the self, to other characters, and to settings. These analyses revealed that emotions associated with the self and other characters, but not those associated with settings, were associated with different patterns interhemispheric EEG coherence. From these results, we suggested that elevated interhemispheric EEG coherence may index the integration of emotions which are associated with facial imagery in the right hemisphere with narrative-organizational processes (dream story organization) in the left hemisphere.

In the present article we describe an extension of this approach in which we examine relationships between EEG coherence and a new, and presumably more focused, measure of social–emotional interaction in dreams, specifically, *the explicit representation of a character's face during dreaming.* The rationale for examining facial imagery is that the face is one of the primary vehicles for identifying and communicating emotionally with other people (Ekman, 1982). Explicit facial representations in imagery may index one dimension of the socioemotional interactions which are generated virtually within the brain during REM sleep. Such interactions presumably involve the coordination of imagery processes by which the purported memory and adaptive functions of dreaming sleep are achieved, e.g., character imagery, motor imagery, self-representation, and settings.

Because numerous neuropsychological studies have shown that right hemisphere processes are more centrally implicated in the perception (Beeckmans & Michiels, 1996; Carlesimo & Caltagirone, 1995; Gur, Skolnick, & Gur, 1994; Lane, Kivley, Du Bois, Shamasundara, & Schwartz, 1995; Rapcsak, Polster, Comer, & Rubens, 1994; Rhodes, 1993) and expression (Blonder, Burns, Bowers, Moore, & Heilman, 1993) of facial communications, we predicted that right intrahemispheric EEG coherence would be more tightly associated with our measure of facial imagery, but not with other measures. Alternatively, based upon our pilot studies and on previous studies demonstrating that the emotional deficit of alexithymia involves a right–left hemisphere transfer of information (Tenhouten et al., 1987; Zeitlin, Lane, O'Leary, & Shrift, 1989) we predicted that interhemispheric coherence would be positively correlated with our socioemotional variables—and especially the facial imagery variable. Finally, consistent with the possibility that men's brains may be more functionally asymmetric than women's (McGlone, 1980) and with previous studies which have demonstrated gender differences in baseline waking cortical EEG coherence (e.g., Duffy et al., 1995; Kaiser & Gruzelier, 1996) we examined relationships between coherence and dream emotions separately for the two sexes.

METHODS

Fourteen women (22.1 ± 2.6 years) and 10 men (23.0 ± 2.8 years) with no history of psychiatric illness, no complaint of a sleep problem, and in good physical health slept for 2 consecutive nights in the sleep laboratory. All were right-handed. They were fitted with an electrode montage for recording sleep stages (EEG, EOG, EMG), ECG, and respiration, as well as a 19-channel 10–20 montage for topographic quantitative EEG analysis. On the first night they answered a battery of personality questionnaires before electrode placement, including one concerning important daytime events, the 16PF, the EPI (Eysenck Personality Inventory), BDI (Beck Depression Inventory), and the TAS (Toronto Alexithymia Scale). The 19-channel EEG montage was configured according to the International 10–20 system: Fp1, Fp2, F3, F4, F7, F8, C3, C4, P3, P4, O1, O2, T3, T4, T5, T6, Fz, Cz, and Pz and a linked-ear reference with a 10-kohm resistance.

For comparison purposes, 3 min of EEG was recorded during the waking state when the subject was seated, relaxed, and with eyes closed (3 min) and opened (3 min). Neither the personality questionnaire results nor the waking state EEG data were further analyzed in the present study.

REM Episode Awakenings

On both nights, subjects were awakened after each REM sleep episode of the night except for the first. They were allowed to sleep for 5 min before awakening in the second REM episode, for 10 min in the third, for 15 min in the fourth, and for 20 min in the fifth and sixth REM episodes. Subjects were awakened by calling their names over an intercom system.

Night 1 was considered a night for adaptation to the laboratory and was not further analyzed. Prior to sleep on Night 2 subjects viewed an emotionally troubling film about a woman caring for her father who is dying of cancer.

The Method of Time-Limited Dream Reporting

Immediately after being awakened from sleep, subjects were given a hand-held cassette recorder containing tape-recorded instructions about how to report and score their dream mentation. Subjects operated the cassette player manually and proceeded at their own pace. The instructions requested that subjects report their dream in two steps: (1) They were asked to report *only* the last 30 s of their dream and to provide details about only that 30-s sample. They were asked to rate this imagery on a number of yes/no and 5-point scales for presence/absence and intensity of emotions, characters, interactions with characters, faces of characters, self-imagery, and other attributes; (2) They were asked to report the dream mentation occurring *prior to* the last 30 s. Following recall of this mentation, they rated the content on the same yes/no and 5-point scales. Subsequent measures were based upon an average of these two sets of ratings.

Based on our previous pilot work, four key socioemotional measures were defined as follows: (1) %NEG-S, or the proportion of negative emotions attributed to the self; (2) %NEG-O, or the proportion of negative emotions attributed to other characters; (3) Nchar, or the number of nonself characters, and, most importantly, (4) %Face, or the proportion of characters for whom the face is explicitly represented. As proportions, variables 1, 2, and 4 all have the advantage of being relatively independent of the length of the mentation report.

Quantitative EEG Methods

From every REM episode for which an experimental awakening was conducted, two EEG samples were taken: one from the last and one from the second to last 60 s prior to awakening. Because all EEG samples were screened to be free of muscle and eye artifacts, the total duration of each of these samples could be less than 1 min. It was never less than 30 s, however. To reduce the quantity of electrophysiological data analyzed, only results from the last 60 s of preawakening EEG from one REM sleep episode per subject are reported here.

The EEG was sampled at 256 Hz by a Grass Model 12 acquisition system (cutoffs: 0.10–100 Hz), filtered with a Hanning window, and archived on optical disk. The raw data for all samples were subsequently resampled at 128 Hz to obtain a spectral resolution of 0.25 Hz for the 0- to 32-Hz spectrum. The fast Fourier transform was computed on successive 4-s epochs and resulting periodograms were averaged to obtain the amplitude power spectra.

From these, coherence spectra were calculated according to the algorithm described in Benignus (1969) (see Appendix 1). This included data normalization and the calculation of confidence limits. Averages were calculated for five separate frequency bands: delta (0.75–3.75), theta (4.00–7.75), alpha (8.00–11.75), beta1 (12.00–19.75), and beta2 (20.00–32.00). These were averaged over all electrodes and correlated with the four dream content measures using the Pearson correlation coefficient. As the purpose of the analysis was to identify point-to-point isomorphisms between EEG variables and dreaming variables, we examined correlations derived from individual REM sleep episodes, one episode per subject.

RESULTS

Three subjects (1 woman, 2 men) furnished mentation reports which contained no nonself characters. These were not included in the analyses. From the remaining 21 subjects, data from 1 late night REM sleep episode on Night 2 was selected for each subject for further analysis.

Interhemispheric Coherence

As shown in the first panel of Table 1, there were significant *positive* correlations between interhemispheric coherence in delta, alpha, and beta2 and the %Face variable (all $p < .05$). The correlations for theta and beta1 were only slightly lower (all $p < .10$). No other emotion variables were

TABLE 1
Pearson Correlations between EEG Inter- and Intrahemispheric Coherence Variables and Four Socioemotional Variables Scored for Dreams from REM Sleep

	Dream variable	Frequency band				
		delta	theta	alpha	beta1	beta2
Inter	1. %NEG-S	0.382	0.337	0.316	0.278	0.261
	2. %NEG-O	−0.135	−0.246	−0.192	−0.129	−0.147
	3. Nchar	−0.162	−0.075	−0.071	0.083	−0.014
	4. %Face	0.468*	0.390	0.485*	0.362	0.442*
Left intra	1. %NEG-S	0.451*	0.410	0.413	0.210	0.306
	2. %NEG-O	−0.152	−0.041	−0.130	−0.126	−0.171
	3. Nchar	0.004	0.022	0.056	−0.129	−0.046
	4. %Face	0.445*	0.479*	0.504**	0.411	0.384
Right intra	1. %NEG-S	0.302	0.302	0.333	0.288	0.306
	2. %NEG-O	−0.074	−0.018	−0.038	−0.210	−0.168
	3. Nchar	−0.177	−0.154	−0.039	0.023	−0.171
	4. %Face	0.567***	0.366	0.417	0.429	0.472*

* $p < .05$; **$p < .025$; ***$p < .01$.

correlated with coherence, although some trends were noted for delta and theta correlations with the self-feeling variable (%NEG-S).

Intrahemispheric Coherence

The patterns of correlations between coherence and %Face found for interhemispheric measures were also found for intrahemispheric measures. There were positive correlations between %Face and local coherence over the left hemisphere (delta, theta, alpha) and the right hemisphere (delta, beta2) (Table 1, bottom panels). All correlations with %Face were either statistically significant or showed strong trends. Right side delta coherence showed a particularly noteworthy correlation with the variable ($r = .567$, $p < .01$). The only other emotion variable to be correlated with coherence was again %NEG-S (delta) on the left side ($p < .05$), although strong trends were also noted for theta and alpha ($p < .10$). The direction of these relationships was in the same direction as that for %Face.

Gender Differences

When broken down by gender, the results clearly demonstrate that the EEG coherence correlations with %Face were apparent for women to a much greater degree than for men (Table 2). For women, of the 15 correlations calculated, 14 exceeded the $p < .05$ threshold and 1 was marginal, whereas for men none of the correlations even approached a trend. Conversely, correlations between EEG coherence and %NEG-S were clearly apparent for men but very weak for women (Table 3). For men, 6 of the 15 correlations be-

TABLE 2

Pearson Correlations between EEG Inter- and Intrahemispheric Coherence Variables and the Proportion of Character Faces (%Face) in Dreams from REM Sleep for Women and Men Separately

	%Face/EEG correlations	Frequency band				
		delta	theta	alpha	beta1	beta2
Women	Inter	0.562*	0.589*	0.574*	0.574*	0.637**
	Left intra	0.565*	0.645**	0.636**	0.644**	0.578*
	Right intra	0.643**	0.651**	0.567*	0.497	0.633**
Men	Inter	0.300	−0.098	0.304	−0.092	0.070
	Left intra	0.273	0.230	0.313	−0.070	0.058
	Right intra	0.434	−0.092	0.143	0.321	0.121

* $p < .05$; ** $p < .025$; *** $p < .01$.

tween coherence and %NEG-S were statistically significant and several more approached significance; for women none of the correlations approached significance. Despite these glaring gender differences, however, none of the comparable correlations for women and men were statistically different from one another.

On the other hand, some significant gender differences were noted for the %NEG-O variable: %NEG-O was negatively correlated with interhemispheric coherence (theta) for women (−.494) and positively correlated for men (.635; $p_{\text{dif}} = .030$); similar trends were noted for beta1 and beta2 (all $p_{\text{dif}} < .10$). A similar pattern of correlations was noted for left and right intrahemispheric coherence, but with significant differences for left beta1 and beta2 only (all $p_{\text{dif}} < .05$).

No other emotions variables were clearly associated with coherence. In

TABLE 3

Pearson Correlations between EEG Inter- and Intrahemispheric Coherence Variables and the Proportion of Negative Feeling Attributed to the Self (%NEG-S) in Dreams from REM Sleep for Women and Men Separately

	%NEG-S/EEG correlations	Frequency band				
		delta	theta	alpha	beta1	beta2
Women	Inter	0.198	0.307	0.192	0.178	0.148
	Left intra	0.303	0.176	0.291	0.204	0.201
	Right intra	0.159	0.314	0.201	0.211	0.219
Men	Inter	0.711*	0.405	0.634	0.576	0.642
	Left intra	0.659	0.770*	0.662	0.591	0.686
	Right intra	0.810**	0.420	0.728*	0.733*	0.746*

* $p < .05$; ** $p < .025$; *** $p < .01$.

particular, the number of characters variable (Nchar) showed no relationships or relationship trends in the analyses for either men or women.

DISCUSSION

Our previous studies showing that interhemispheric coherence decreases as a function of callosotomy (Montplaisir, Nielsen, Coté, Boivin, Rouleau, & Lapierre, 1990) and that it is low in subjects with agenesis of the corpus callosum relative to that of controls (Nielsen, Montplaisir, & Lassonde, 1993) have validated the use of this measure as an index of the functional connectivity of the two hemispheres. The present findings go further to demonstrate that, in general, coherence increases as the measure of character facial imagery becomes increasingly predominant in the mental experiences of subjects in REM sleep. Thus, it is possible that one of the sources of functional connectivity measured by coherence is a type of general cortical integration of affective character imagery processes which are associated preferentially with the right hemisphere (see Introduction) into narrative-organizational dreaming processes, which are associated preferentially with the left hemisphere (see Antrobus, 1987, and Greenberg & Farah, 1986, for reviews). If so, EEG coherence might serve as a useful tool for the exploration of how memories of socially relevant emotional experiences are processed during REM sleep. The latter is widely thought to comprise one of the essential functions of REM sleep (e.g., Breger, 1967; Koulack, 1993; Kramer, 1993; Perlis & Nielsen, 1993; see Moffitt, Hoffmann, & Kramer, 1993, for several review chapters).

That our results for the most part were generalized to both inter- and intrahemispheric channels fails to confirm our expectation that right hemisphere coherence would be preferentially associated with facial imagery. The largest correlation with %Face did obtain for right-side intrahemispheric coherence (delta band); however, more detailed analyses of specific electrode pairs may be necessary to determine whether such relationships are distinctive. Also, the fact that the correlations were observed for most of the five EEG frequency bands suggests that the facial imagery measure is not linked globally with any one particular band, such as theta (e.g., Winson, 1993). On the other hand, it should be noted that the correlation which showed the most marked divergence between men and women subjects (%NEG-O), i.e., negative for women ($-.494$) and positive for men (.635; $p < .03$), was interhemispheric coherence for the theta band. Clearly, more fine-grained topographic and regression analyses are required to clarify whether this effect for theta coherence reflects localized activity regions—e.g., temporal—which are closer to the hippocampal–amygdaloid structures in which the presumably integrative theta rhythms of REM sleep are detected (Fox, 1989).

Our results for gender differences suggest that changes in EEG coherence during sleep may be related to slightly different emotional processes in the dreams of the two sexes. In women, coherence is associated with increased predominance of character facial imagery and decreased predominance of negative affect attributed to these characters; in men coherence is associated less with facial imagery and more with increases in negative feelings attributed to the self (and, to a lesser extent, to others). One explanation of these differences is that they reflect differences in these subjects' emotional responses to the presleep film, which featured a female protagonist caring for a male victim of disease. If a major function of REM sleep is, indeed, to help the individual adapt to socially relevant emotional stressors, then one might expect men's and women's specific REM sleep processes—which are indexed, presumably, by EEG coherence—to respond differentially to such a heavily gender-biased stimulus. For example, if women were more emotionally involved in the film by virtue of identifying more with the protagonist, their adaptive mechanisms during REM sleep might have been relatively more engaged than those of the men. In fact, a posthoc *t* test did reveal a tendency for women to have more predominant negative self-feelings (%NEG-S) in their dreams ($M = 35\%$) than did the men ($M = 19\%$; $p < .12$).

Thus, we are not inclined to conclude that these gender differences reflect differences in brain asymmetry (McGlone, 1980). We previously failed to find gender differences in the REM sleep EEG coherence of normal men and women (Nielsen, Abel, Lorrain, & Montplaisir, 1990). Rather, they may reflect differences in the nature of the emotive stimuli presented to subjects on the day prior to sleep and the reaction of REM sleep processes attempting to facilitate adaptation to them. Further analyses of coherence in relation to a variety of emotional responses prior to and during sleep are clearly called for.

APPENDIX 1: CALCULATION OF UNBIASED FFT COHERENCE ESTIMATES

In the present study, estimation of coherence coefficients and their associated confidence intervals were calculated by the algorithm of Benignus (1969). This approach, which was developed using Monte Carlo procedures with empirical correction, is reproduced here in three steps: (1) calculation of coherence estimates from FFT spectra, (2) correction of bias in coherence estimates, and (3) computation of confidence interval bias estimates.

Calculation of Coherence from FFT Spectra

The cross power spectrum is derived from two separate power spectra following Tukey (1966) and Enochson and Goodman (1965) using

$$\hat{\gamma}^2(F) = \frac{\hat{G}^2_{xy}(F)}{\hat{G}_{xx}(F) \cdot \hat{G}_{yy}(F)},$$

where $\hat{G}_{xy}(F)$ is the cross power spectrum estimate, $\hat{G}_{xx}(F)$ is the power spectrum estimate of time series x, $\hat{G}_{yy}(F)$ is the power spectrum estimate of time series y, and F is the frequency index. Quantities with a caret indicate smoothed values, where smoothing is accomplished by averaging either over adjacent frequency bands or over spectra of segments into which the original time series is divided (Benignus, 1969, p. 145). It is assumed that the time series x and y possess Gaussian distributions and relatively flat spectra (Enochson & Goodman, 1965). The coherence value $\gamma^2(F)$ is subsequently transformed by a Fisher z for bias estimation.

Correction of Bias in Coherence Estimates

A least-squares procedure is used to calculate an estimate of coherence bias $\hat{B}(\hat{\gamma}^2)$ from a family of empirically derived bias correction curves. This formula (from Eq. 2 in Benignus, p. 146) is

$$\hat{B}(\gamma^2(F)) = \frac{1}{N}(1 - \gamma^2(F)),$$

where $\gamma^2(F)$ is the raw or biased FFT coherence estimate for any frequency band F. The calculated bias score $\hat{B}(\gamma^2(F))$ is subsequently subtracted from the raw coherence estimate producing the corrected coherence estimate $\tilde{\gamma}^2(F)$ or

$$\tilde{\gamma}^2(F) = \hat{\gamma}^2 - \hat{B}(\hat{\gamma}^2(F)).$$

Residual error following correction with $\tilde{\gamma}^2(F)$ is extremely small for samples of $N = 8$ or more.

Calculation of Confidence Interval Bias Estimates

Confidence intervals were calculated from z-transformed, biased coherence estimates, the limits converted back to coherence scores, and then bias estimates subtracted from each score as for step 2 above. The standard normal deviation ($\overline{\sigma}_{\hat{z}}$) for calculation of each confidence limit is

$$\overline{\sigma}_{\hat{z}} = \left(\sqrt{\frac{1}{2(N - 1.0)}}\right)(E(\sigma_{\hat{z}})) ,$$

where $E(\sigma_{\hat{z}})$ is an estimate of proportional error based upon the least-squares method, with the specific case adapted being $E(\sigma_{\hat{z}}) = 1 - 0.004^{(1.6\tilde{\gamma}^2+0.22)}$ (Benignus, 1969, p. 148). If, after subtraction, the lower confidence limit is negative, it is set to zero and a one-tailed upper limit is used.

REFERENCES

Antrobus, J. S. 1987. Cortical hemisphere asymmetry and sleep mentation. *Psychological Review,* **94,** 359–368.

Armitage, R., Kowatch, R. A., Calhoun, J. S., Emslie, G. J., Rush, A. J., & Roffwarg, H. P. 1991. A preliminary report of interhemispheric EEG coherence in depressed children, adolescents and normal controls. *Sleep Research,* **20,** 358.

Aserinsky, E., & Kleitman, N. 1953. Regularly occurring periods of eye motility, and concomitant phenomena during sleep. *Science,* **118,** 273–274.

Beeckmans, K., & Michiels, K. 1996. Personality, emotions and the temporolimbic system: A neuropsychological approach. *Acta Neurologica Belgica,* **96,** 35–42.

Benignus, V. A. 1969. Estimation of the coherence spectrum and its confidence interval using the Fast Fourier Transform, *IEEE Transactions on Audio and Electroacoustics,* **AU-17**(2), 145–150.

Blonder L. X., Burns A. F., Bowers D., Moore, R. W., & Heilman, K. M. 1993. Right hemisphere facial expressivity during natural conversation. *Brain and Cognition,* **21,** 44–56.

Brazier, M. A. B. 1967. Absence of dreaming or failure to recall? *Experimental Neurology,* Suppl. **4,** 91–98.

Breger, L. 1967. Function of dreams. *Journal of Abnormal Psychology Monograph 72 (No. 5, whole No.).*

Buchsbaum, M. S., Gillin, J. C., Wu, J., Hazlett, E., Sicotte, N., Dupont, R. M., & Bunney, W. E., Jr. 1989. Regional cerebral glucose metabolic rate in human sleep assessed by positron emission tomography. *Life Sciences,* **45,** 1349–1356.

Carlesimo, G. A., & Caltagirone, C. 1995. Components in the visual processing of known and unknown faces. *Journal of Clinical & Experimental Neuropsychology,* **17,** 691–705.

Dement, W., & Kleitman, N. 1957. Cyclic variations in EEG during sleep and their relation to eye movements, body motility, and dreaming. *Electroencephalography and Clinical Neurophysiology,* **9,** 673–690.

Duffy, F. H., Jones, K. J., McAnulty, G. B., & Albert, M. S. 1995. Spectral coherence in normal adults: Unrestricted principal components analysis: Relation of factors to age, gender, and neuropsychologic data. *Clinical Electroencephalography,* **26,** 30–46.

Dumermuth, G., Walz, W., Scollo-Lavizzari, G., & Kleiner, B. 1972. Spectral analysis of EEG activity in different sleep stages in normal adults. *European Neurology,* **7,** 265–296.

Ekman, P. 1982. *Emotion in the human face,* 2nd ed. Cambridge: Cambridge Univ. Press.

Enochson, L. D., & Goodman, N. R. 1965. Gaussian approximations to the distribution of sample coherence. *Bulletin AFFDL-TR-65-67.* Wright-Patterson AFB, Ohio: Air Force Flight Dynamics Lab, Research and Tech. Division, AF Systems Command.

Fox, S. E. 1989. Membrane potential and impedance changes in hippocampal pyramidal cells during theta rhythm. *Brain Research,* **77,** 283–294.

French, C. C., & Beaumont, J. G. 1984. A critical review of EEG coherence studies of hemisphere function. *International Journal of Psychophysiology,* **1,** 241–254.

Gottschalk, L. A., Buchsbaum, M. S., Gillin, J. C., Wu, J., Reynolds, C. A., Herrera, D. B. 1991. Positron-emission tomographic studies of the relationship of cerebral glucose metabolism and the magnitude of anxiety and hostility experienced during dreaming and waking. *Journal of Neuropsychiatry and Clinical Neurosciences,* **3,** 131–142.

Greenberg, M. S., & Farah, M. J. 1986. The laterality of dreaming. *Brain and Cognition,* **5,** 307–321.

Gur, R. C., Skolnick, B. E., & Gur, R. E. 1994. Effects of emotional discrimination tasks on cerebral blood flow: Regional activation and its relation to performance. *Brain and Cognition,* **25,** 271–286.

Hinrichs, H., & Machleidt, W. 1992. Basic emotions reflected in EEG-coherence. *International Journal of Psychophysiology,* **13,** 225–232.

Johnson, L. C. 1972. Computers in sleep research. In M. Chase (Ed.), *The sleeping brain,* Los Angeles: Brain Research Institute / Brain Information Services (UCLA). Pp. 277–321.

Kaiser, J., & Gruzelier, J. H. 1996. Timing of puberty and EEG coherence during photic stimulation. *International Journal of Psychophysiology,* **21,** 135–149.

Koulack, D. 1993. Dreams and adaptation to contemporary stress. In A. Moffitt, M. Kramer, & R. Hoffmann (Eds.), *The functions of dreaming.* Albany: State Univ. of New York Press. Pp. 321–340.

Kramer, M. 1993. The selective mood regulatory function of dreaming: An update and revision. In A. Moffitt, M. Kramer, & R. Hoffmann (Eds.), *The functions of dreaming.* Albany: State Univ. of New York Press. Pp. 139–196.

Lane, R. D., Kivley, L. S., Du Bois, M. A., Shamasundara, P., & Schwartz, G. E. 1995. Levels of emotional awareness and the degree of right hemispheric dominance in the perception of facial emotion. *Neuropsychologia,* **33,** 525–538.

Maquet, P., Péters, J.-M., Aerts, J., Delfiore, G., Degueldre, C., Luxen, A., & Franck, G. 1996. Functional neuroanatomy of human rapid-eye-movement sleep and dreaming. *Nature* **383,** 163–166.

McGlone, J. 1980. Sex differences in human brain organization: A critical survey. *The Behavioral and Brain Sciences,* **3,** 215–227.

Moffitt, A., Hoffmann, R., & Kramer, M. 1993. *The functions of dreaming.* Albany: State Univ. of New York Press.

Montplaisir, J., Nielsen, T. A., Côté, J., Boivin, D., Rouleau, I., and Lapierre, G. 1990. Interhemispheric EEG coherence before and after partial callosotomy. *Clinical Electroencephalography,* **21,** 42–47.

Nielsen, T. A., Abel, A., Lorrain, D., & Montplaisir, J. 1990. Interhemispheric EEG coherence during sleep and wakefulness in left- and right-handed subjects. *Brain and Cognition,* **14,** 113–125.

Nielsen, T. A., & Chénier, V. 1996. EEG coherence is associated with dreamed character faces and emotions. *Sleep Research,* **25,** 138.

Nielsen, T., Ouellet, L., Cartier, A., & Montplaisir, J. 1994. Association between interhemispheric EEG coherence and dreamed character imagery. 12th Congress of the European Sleep Research Society, Firenze, May 22–27.

Nielsen, T. A., & Ouellet, L. 1996. Character faces, actions and interactions differentiate the REM sleep dreams of women and men. Abstracts of the 13th International Conference of the Association for the Study of Dreams, Berkeley, California, July 1996.

Nielsen, T. A., Deslauriers, D., & Baylor, G. W. 1991. Emotions in dream and waking event reports. *Dreaming,* **1,** 287–300.

Nielsen, T. A., Germain, A., & Ouellet, L. 1995. Atonia-signalled hypnagogic imagery: Comparative EEG mapping of sleep onset transitions, REM sleep and wakefulness. *Sleep Research,* **24,** 133.

Nielsen, T. A., Montplaisir, J., & Lassonde, M. 1993. Decreased interhemispheric EEG coherence during sleep and wakefulness in agenesis of the corpus callosum. *European Neurology,* **33,** 174–177.

Perlis, M. L., & Nielsen, T. A. 1993. Mood regulation, dreaming and nightmares: Evaluation of a desensitization function for REM sleep. *Dreaming,* **3,** 243–257.

Pivik, R. T. 1994. The psychophysiology of sleep. In M. H. Kryger, T. Roth, & W. C. Dement (Eds.), *Principles and practice of sleep medicine,* 2nd ed. Philadelphia: Saunders. Pp. 384–393.

Rapcsak, S. Z., Polster M. R., Comer J. F., & Rubens A. B. 1994. False recognition and misidentification of faces following right hemisphere damage. *Cortex,* **30,** 565–583.

Rhodes, G. 1993. Configural coding, expertise, and the right hemisphere advantage for face recognition. *Brain and Cognition,* **22,** 19–41.

Schellberg, D., Besthorn, C., Klos, T., & Gasser, T. 1990. EEG power and coherence while male adults watch emotional video films. *International Journal of Psychophysiology* **9,** 279–291.

Tenhouten, W. D., Walter, D. O., Hoppe, K. D., & Bogen, J. E. 1987. Alexithymia and the split brain. V. EEG alpha-band interhemispheric coherence analysis. *Psychotherapy and Psychosomatics,* **47,** 1–10.

Tukey, J. W. In *Spectral Analysis of Time Series,* B. Harris, Ed. New York: Wiley, 1966.

Walter, D. O., & Adey, W. R. 1963. Spectral analysis of electroencephalograms recorded during learning in the cat. *Experimental Neurology,* **8,** 155–181.

Winson, J. 1993. The biology and function of rapid eye movement sleep. *Current Opinion in Neurobiology,* **3,** 243–248.

Zadra, A., & Nielsen, T. A. 1996. EEG spectral analyses of REM nightmares and anxiety dreams. Abstracts of the 13th International Conference of the Association for the Study of Dreams, Berkeley, California, July.

Zeitlin, S. B., Lane, R. D., O'Leary, D. S., & Schrift, M. J. 1989. Interhemispheric transfer deficit and alexithymia. *American Journal of Psychiatry,* **146,** 1434–1439.