frequency spectra since the assumption that the EEG moves to a higher frequency band when the spectral intensity of the α band is attenuated during active tasks may not always be legitimate. The data of Gevins *et al.* should encourage further studies of the multiple dimensions along which cognitive tasks may vary and the relations of these tasks to changes in particular features of the EEG spectral signature.

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References and Notes

1. A. S. Gevins, G. M. Zeitlin, J. C. Doyle, C. D. Yingling, R. E. Schaffer, E. Callaway, C. L. Yeager, *Science* **203**, 665 (1979).
2. L. R. Warren, L. Peltz, E. S. Haueter, *Brain Language* **3**, 283 (1976); J. G. Beaumont, A. R. Mayes, M. D. Rugg, *Electroencephalogr. Clin. Neurophysiol.* **45**, 393 (1978).
3. J. C. Doyle, R. Ornstein, D. Galin, *Psychophysiology* **11**, 567 (1974); S. R. Butler and A. Glass, *Electroencephalogr. Clin. Neurophysiol.* **36**, 481 (1974); K. Osborne and A. Gale, *Biol. Psychol.* **4**, 185 (1976); J. E. Bennett and J. Trinder, *Psychophysiology* **14**, 293 (1977); S. S. McLeod and L. J. Peacock, *ibid.*, p. 308; M. Hirshkowitz, J. Earle, B. Paley, *Neuropsychologia* **16**, 125 (1978); R. J. Davidson and A. Marshak, *Psychophysiology* **15**, 269 (1978).
4. R. J. Davidson and G. E. Schwartz, *Psychophysiology* **14**, 58 (1977).
5. G. McKee, B. Humphrey, D. W. McAdam, *ibid.* **10**, 441 (1973); W. Rapaczynski and H. Ehrlichman, in preparation.
6. K. I. Robbins and D. W. McAdam, *Brain Language* **1**, 189 (1974).
7. H. Ehrlichman and M. S. Wiener, *Psychophysiology*, in press.
8. R. Ornstein, J. Johnstone, J. Herron, C. Swencionis, *Neuropsychologia*, in press.

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In two experiments we found many spatial EEG patterns, including interhemispheric ones, which distinguished uncontrolled tasks (experiment 1), but none that distinguished controlled tasks (experiment 2) (*1*). We concluded that the existence of spontaneous EEG patterns specifically correlated with the mental components of tasks had not been demonstrated (*2*).

Davidson and Ehrlichman make three points: (i) Many previous studies have found "left-right" EEG differences related to "cognitive set" under supposedly controlled conditions; (ii) the random occurrence of "short" duration (10 to 15 seconds) tasks in our experiment 2 precluded the formation of a cognitive set; and (iii) the mental rotation task (*3*) used in our experiment 2 is not a "right hemisphere" task.

We do not think that these points are substantive:

Controlled studies (see Table 1). None of the studies cited by Davidson and Ehrlichman meet all the minimum criteria necessary to rule out extraneous, other-than-mental influences on the EEG patterns recorded (see Table 1). In order to study possible EEG signs of mental operations, it is necessary that all of the following criteria be met (*4*).

Table 1. Methodological shortcomings of studies cited by Davidson and Ehrlichman. The criteria for experiments on EEG correlates of mental activities [1, 2, 4, 5 from Donchin *et al.* and 3 and 6 from Gevins and Schaffer, see (*4*)] described in the text.

Study	Fails to meet criteria*
Beaumont *et al.* (*18*)	3, 4
Bennett and Trinder (*19*)	1, 2, 3, 4, 5
Butler and Glass (*20*)	3, 4, 6
Davidson and Marshak (*21*)	2, 3, 5, 6?
Davidson and Schwartz (*22*)	1?, 2?, 3?, 4?, 5, 6?
Doyle *et al.* (*23*)	1, 2, 3, 4, 5
Ehrlichman and Wiener (*24*)	1, 2, 3, 4, 5, 6?
Hirshkowitz *et al.* (*25*)	3, 4, 5, 6
McKee (*26*)†	3, 4?, 5, 6
McLeod and Peacock (*27*)	1, 3, 4, 5
Ornstein *et al.* (*28*)	1, 3, 4, 6
Osborne and Gale (*29*)	1, 3, 4, 6
Robbins and McAdam (*30*)	3, 4, 6
Schwartz *et al.* (*31*)	3, 5, 6
Warren *et al.* (*32*)	3, 4, 6

*Items with question mark (?) denote insufficient data in report to evaluate. †Sample size was four.

1) There should be minimal or no differences between tasks in stimulus properties.

2) There should be no differences in efferent activities between tasks.

3) In order to minimize EEG differences associated with effort and task difficulty, there should be minimal or no differences in performance-related factors between tasks.

4) There should be behavioral validation that the tasks were correctly performed during the time corresponding to those segments of EEG recording selected for analysis (*5*).

5) The EEG patterns from the left and right hemispheres should be presented separately.

6) All extracerebral artifacts from the EEG should be rejected prior to analysis.

Cognitive set. EEG correlates of "cognitive set" have previously been reported for uncontrolled tasks 9 seconds in duration (*6*). Two results in our experiments tended to contradict the requirement of a cognitive set that takes longer than 15 seconds to establish. (i) In our experiment 1, EEG patterns associated with uncontrolled tasks were more consistently discriminable during the first 15 seconds than during any other portion of the 1 minute of task performance. (ii) In our experiment 2, when two or three mental rotation problems (each lasting 6 to 15 seconds) happened to occur in a row, there were no significant differences in any spectral EEG measure from any electrode placement between the first and subsequent problems.

Right hemisphere tasks. It is reasonable to suppose that the mental rotation task (*3*) used in our experiment 2 requires different cognitive operations from the addition and letter substitution tasks and that this task was associated with a spatial EEG pattern. These suppositions follow from three lines of evidence not involving the EEG. (i) The isolation of a spatial rotation factor, distinct from a number facility factor in factor-analytic evaluations of psychometric test batteries (*7, 8*). (ii) Shepard and his colleagues (*9*) found that practiced persons solve such tasks by constructing and rotating some sort of mental image. (iii) Neuropsychological evidence of deficits in spatial rotation abilities from patients showing right posterior cortical lesions (*10*) or from commissurotomy patients whose left hemisphere only was used during task performance (*11*). Although patients with left parietal lesions also display deficits in spatial rotation ability (*12*), the relative loss in ability seems greater for right hemisphere damage (*13*).

Thus, using equal or more rigorous criteria for the selection of cognitively and cortically differentiated tasks than those customarily employed in previous EEG research, we expected the mental rotation task to be more right hemisphere oriented than the arithmetic and letter substitution tasks. We did not find any EEG spectral differences between tasks. Since our analytic methodology is demonstrably more powerful than that used in previous EEG studies on this topic (*14*), the negative result may not be attributed to weakness of the analysis. We therefore do not accept the conclusions of non "right hemisphericity" by others who have used the mental rotation task without meeting all criteria 1 through 6 (*15*). Additionally, some studies not meeting criteria 1 through 6 have shown relative right hemisphere activation for this same mental rotation task (*16*).

Thus, it is unreasonable to dismiss a posteriori as not "right hemisphere" a task that fails to show a desired effect in the EEG. To do so would imply that the EEG is an accurate measure of higher cortical functions, but this is exactly the hypothesis being tested.

Over the last 50 years, researchers have frequently thought they had evidence relating EEG patterns to mental activities, only to find that their conclusions were unwarranted because of inadequate controls or insufficiently sensitive analysis (*17*). Our negative results pin down the inadequacies of the current research paradigm that attempts to correlate abstract psychological constructs with simple measures of the mass electrical activity of the nervous system.

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References and Notes

1. A. S. Gevins, G. M. Zeitlin, J. C. Doyle, C. D. Yingling, R. E. Schaffer, E. Callaway, C. L. Yeager, *Science* **203**, 665 (1979).
2. The term spontaneous EEG does not include event-related (time-locked) brain potentials (ERP's).
3. R. N. Shepard and J. Metzler, *Science* **171**, 701 (1971).
4. These criteria were discussed by E. Donchin, M. Kutas, and G. McCarthy [in *Lateralization in the Nervous System*, S. Harnad, R. Doty, L. Goldstein, J. Jaynes, G. Krauthamer, Eds. (Academic Press, New York, 1977), p. 339] and A. S. Gevins and R. E. Schaffer (*17*).
5. This includes eliminating tasks that by common sense can be expected to be beyond the abilities of the participants such as mentation for up to 40 seconds without internal vocalization.
6. K. Osborne and A. Gale, *Biol. Psychol.* **4**, 185 (1976).
7. L. Thurstone, *Multiple Factor Analysis, a Development and Expansion of "The Vectors of Mind"* (Univ. of Chicago Press, Chicago, 1947).
8. J. French, R. Ekstrom, L. Price, *Kit of Reference Tests for Cognitive Factors* (Educational Testing Service, Princeton, N.J., 1963); J. Carroll, in *The Nature of Intelligence*, L. Resnick, Ed. (Erlbaum, Hillsdale, N.J., 1976).
9. L. Cooper and R. Shepard, in *Handbook of Perception*, vol. 8, *Space and Object Perception*, E. Carterette and M. Friedman, Eds. (Academic Press, New York, 1978); M. Just and P. Carpenter, *Cognitive Psychol.* **8**, 441 (1976).
10. H. Hecaen, in *Interhemispheric Relations and Cerebral Dominance*, V. Mountcastle, Ed. (Johns Hopkins Press, Baltimore, 1962); J. Bogen, *Bull. L.A. Neurol. Soc.* **34**, 135 (1969).
11. J. Levy-Agresti and R. Sperry, *Proc. Natl. Acad. Sci. U.S.A.* **61**, 1151 (1968); B. Milner and L. Taylor, *Neuropsychologia* **10**, 1 (1972).
12. N. Butters and M. Barton, *Neuropsychologia* **8**, 205 (1970); D. Benson and M. Barton, *Cortex* **6**, 19 (1970).
13. M. Piercy, H. Hecaen, J. De Ajuriaguerra, *Brain* **83**, 225 (1960); E. DeRenzi, in *Asymmetrical Function of the Brain*, M. Kinsbourne, Ed. (Cambridge Univ. Press, Cambridge, 1978), p. 49; R. Nebes, in *ibid.*, p. 99.
14. This was evident in the results of experiment 1, in which we were able to predict the behavioral task from independent EEG samples [A. S. Gevins, G. M. Zeitlin, C. D. Yingling, J. C. Doyle, M. F. Dedon, J. H. Henderson, R. E. Schaffer, J. T. Roumasset, C. L. Yeager, *Electroencephalogr. Clin. Neurophysiol.* **47** (No. 5), 693 (1979); A. S. Gevins, *IEEE Trans. Pattern Anal. Machine Intell.*, in press.
15. In a recent study, R. Ornstein *et al.* (*Neuropsychologia*, in press) included a modified version of the mental rotation task and produced results consistent with our negative finding. However, their study did not meet methodological criteria 1, 3, 4, and 6 outlined above. In particular, their EEG and behavioral evidence indicated that participants made relatively less effort for this task.
16. C. Furst, *Nature (London)* **260**, 254 (1976); C. Rebert and D. Low, *Electroencephalogr. Clin. Neurophysiol.* **44**, 724 (1978).
17. A. S. Gevins and R. E. Schaffer, *CRC Crit. Rev. Bioeng.*, in press.
18. J. G. Beaumont, A. R. Mayes, M. D. Rugg, *Electroencephalogr. Clin. Neurophysiol.* **45**, 393 (1978).
19. J. E. Bennett and J. Trinder, *Psychophysiology* **14**, 293 (1977).
20. S. R. Butler and A. Glass, *Electroencephalogr. Clin. Neurophysiol.* **36**, 481 (1974).
21. R. J. Davidson and A. Marshak, *Psychophysiology* **15**, 269 (1978).
22. R. J. Davidson and G. Schwartz, *ibid.* **14**, 58 (1977).
23. J. C. Doyle, R. Ornstein, D. Galin, *ibid.* **11**, 567 (1974).
24. H. Erlichman and M. Wiener, *ibid.* **16**, 247 (1979).
25. M. Hirshkowitz, J. Earle, B. Paley, *Neuropsychologia* **16**, 125 (1978).
26. G. McKee, B. Humphrey, D. W. McAdam, *Psychophysiology* **10**, 441 (1973).
27. S. S. McLeod and L. J. Peacock, *ibid.* **14**, 308 (1977).
28. R. Ornstein *et al.*, *Neuropsychologia*, in press.
29. K. Osborne and A. Gale, *Biol. Psychol.* **4**, 185 (1976).
30. K. I. Robbins and D. W. McAdam, *Brain Language* **1**, 189 (1974).
31. G. Schwartz, R. Davidson, E. Pugash, *Psychophysiology* **13**, 498 (1976).
32. L. R. Warren, L. Peltz, E. S. Haueter, *Brain Language* **3**, 283 (1976).

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Differential Killing of Normal and Cystic Fibrosis Fibroblasts by Dexamethasone

Kurz *et al.* (*1*) claimed that neither dexamethasone nor dibutyryl adenosine 3′,5′-monophosphate (cyclic AMP) kills normal human diploid fibroblasts. This contradicts our previous finding that the two drugs reduce the plating efficiency of normal human diploid fibroblasts but are less toxic to fibroblasts from individuals with cystic fibrosis (CF) (*2–6*). Although Kurz *et al.* claimed to have reproduced our methods, there were serious differences which render their results invalid.

In our studies, we distinguished between normal and CF fibroblasts through the use of a cell survival assay. This assay requires that each cell, in order to be scored as a survivor, express its reproductive capacity by doubling at least six times after exposure to cytotoxic agents. The correct use of this method requires that stringent standards be adhered to in order to ensure that cells scored as survivors (in the form of colonies) are indeed capable of prolonged proliferation after exposure to a cytotoxic agent. In our earlier reports, we had stated that cells must form colonies of at least 50 cells (*2*), but that figure was later increased to 65 to 75 cells (*6*). To ensure that only true colonies were counted, cells in all our dishes are counted visually and then scanned under the microscope. Colonies found not to contain the minimum number of cells are excluded from the count.

When appropriate minimum standards are not adhered to in scoring colonies, invalid results are obtained since many cells are able to perform four or five divisions after exposure to a cytotoxic agent before reproduction ceases. When colonies of less than a certain number of cells are counted as survivors, the result is that the actual toxicity of a particular agent is underestimated. (Control dishes have few or no abortive colonies, whereas dishes exposed to cytotoxic agents, especially at high doses, have many abortive colonies. Therfore, when survival is corrected for plating efficiency, the result is falsely elevated.) Kurz *et al.*'s claim that 78 to 134 percent of normal fibroblasts survived in $10^{-5}M$ dexamethasone phosphate was based on counts of colonies that contained "about 30 or more cells." This would require only five cell doublings and thus would include a fair number of abortive colonies. We have seen many cells divide up to five times after drug exposure and then cease dividing as determined by daily microscopic observation. To illustrate the consequences of including abortive colonies in the analysis, we are providing data from an experiment with human cells that were exposed to ethylmethane sulfonate (EMS), a potent cytotoxic mutagen (Table 1). The effect of including small colonies is to make EMS seem less toxic than it actually is.

Another issue raised by Kurz *et al.* is the effect of cell number on the plating

Table 1. Cell survival after exposure to ethylmethane sulfonate.

Drug concentration	Cells plated per 100-mm dish	Colonies with ≥ 75 cells*	Survival† (%)	Colonies with ≥ 30 cells*	Survival† (%)
None	1500	54	100	57	100
50 μg/ml	2000	42	59	67	88
100 μg/ml	3000	46	43	97	85

*Numbers are averages. †Corrected for plating efficiency.

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Lateralized Cognitive Processes and the Electroencephalogram

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