cause it can be represented as a point in m-dimensional space; and there exists a likelihood ratio, or a unique set if the number of stimulus intensities is greater than two, for each such point. (iii) The observer responds with a decision or hypothesis about the physical state of the world. This decision arises from some strategy, that is, a decision rule, which partitions the set of possible observations into a number of response classes; in the present instance, "nothing" through "warm" and "hot" to "painful." (iv) In accepting or rejecting various hypotheses about the state of the world, the observer makes use of a posteriori probabilities. (v) The likelihood ratio is a single real number that expresses the strength of evidence associated with each observation. The dimensionality of the observation or event in no way influences the calculation of the likelihood ratio by the observer. It is assumed that observers can compare various sensory events with an ordinal scale that is monotonic with the likelihood ratio.

Green and Swets (*1*, p. 123) state: "It is important to note that the objectivity of detection theory methods does not require that the experimenter be able to score the subject as right or wrong; he need only know which value of the signal he presented on each trial. The experimenter cannot score the subject as right or wrong when he is measuring a transition from hot to cold, from not painful to pain, from beats to roughness, or from achromaticity to chromaticity. He can, however, determine the reliability with which an observer can discriminate between any two (or more) signals on one of these continua by determining an ROC curve . . ." Furthermore, it is not necessary to obtain pain reports; d's can be based on intensity reports (high or low) or on confidence ratings (*17*).

McBurney's other objection is that absolute sensitivity and differential sensitivity are not two aspects of a single sensory capability, since, for example, manipulation of sensory adaptation may cause the two types of sensitivity to move in opposite directions. This is certainly true. However, in the study of visual contrast thresholds as a function of stimulus duration, one would never attempt to plot a point from the absolute sensitivity function (scotopic threshold) in the midst of a relative sensitivity (photopic) curve. Confusion arises here because McBurney, and indeed many of the handbooks, use but two terms to describe the four situations portrayed in Table 1. Thus, it is not always clear whether absolute and differential sensitivity refer to the intensity of the stimulus background or to the intensity of the blank. (In signal detection theory "blank" refers to the zero or lower intensity stimulus.) In his second paragraph, McBurney's definition of absolute sensitivity is that of type A, and his differential sensitivity refers to type B and perhaps type D measurements. It is perfectly legitimate to compare type A measurements with type B, since both are absolute sensitivity with respect to background; similarly, types C and D measurements may be compared. It is improper, as McBurney points out, to compare type A, absolute surround sensitivity, with either type C or D. This we did not do. Since the thermal stimuli were applied to warm skin of a constant intensity (single adaptation level), we were only concerned with type C and D measurements, that is, with differential sensitivity with respect to background, and with both absolute (0 versus 120 mcal sec^{-1} cm^{-2}) and differential sensitivity (120 versus 240 to 425 mcal sec^{-1} cm^{-2}) with respect to discrimination. Clark (*18*) obtained 17 d' values at intervals of 25 mcal sec^{-1} cm^{-2} from 0 to 425 mcal sec^{-1} cm^{-2}. The "absolute sensitivity point" at 0 to 25 mcal sec^{-1} cm^{-2} was not unique and fitted the d' versus thermal intensity function. Defined in terms of discrimination, but not in terms of surround, absolute and differential sensitivity are, indeed, related aspects of a single sensory capability.

Let us recapitulate our argument. Values of d', independent of the quality of the subjective report ("warm," "pain," "high," or "yes"), measure the capacity of the nervous system to transmit information about the amounts of thermal radiation reaching the skin. Conceivably, transmission in fibers mediating pain could be blocked without affecting d'. This seems unlikely in principle, since d' depends upon total information transmitted, nor has it been found in practice. Recognized anesthetics (*15*) and analgesics decrease d', acupuncture did not; thus, we conclude that acupuncture is not an effective analgesic. For what it is worth, and forgetting signal detection theory entirely, both during and following acupuncture, our subjects felt that a skin incision would inflict the usual amount of pain.

W. CRAWFORD CLARK

Department of Research Psychology, New York State Psychiatric Institute, New York 10032

J. C. YANG

Department of Anesthesiology, Columbia University College of Physicians and Surgeons, New York 10032

WAYNE HALL

Department of Psychology, University of New South Wales, Kensington, Australia, 2033

References and Notes

1. D. M. Green and J. A. Swets, *Signal Detection Theory and Psychophysics* (Wiley, New York, 1966); W. C. Clark, *Anesthesiology* **40**, 272 (1974).
2. C. R. Chapman, J. D. Gehrig, M. E. Wilson, *Science* **189**, 64 (1975).
3. Board of Acupuncture Anesthesia, *Acupuncture Anesthesia* (in Chinese) (People's Publishing Society, Shanghai, ed. 1, 1972), pp. 214–215.
4. W. C. Clark and J. C. Yang, *Science* **184**, 1096 (1974).
5. Research Group of Acupuncture Anesthesia, Peking College, *Chin. Med. J.* **3**, 151 (1973).
6. P. H. Jenerick, Ed., *Proceedings NIH Acupuncture Research Conference* (Publication No. NIH-74-165, Department of Health, Education, and Welfare, Washington, D.C., 1973).
7. Durations of acupuncture treatment were reported as follows: 8 minutes, P. L. Man (*6*, p. 69); 15 minutes, G. Smith (*6*, p. 69); 20 minutes, R. W. Brennan (*6*, p. 46) and P. C. Tang (*6*, p. 65); and 30 minutes, D. E. Bresler (*6*, p. 68).
8. S. C. Man and F. D. Baragar, *Can. Med. Assoc. J.* **109**, 609 (1973).
9. H. T. Chang, *Sci. Sin.* **16**, 25 (1973).
10. For example, analgesia was reported to persist 40 minutes by P. C. Tang (*6*, p. 65), 12 hours by D. E. Bresler (*6*, p. 68), but only 30 seconds by M. H. M. Lee (*6*, p. 77).
11. A. Taub, *Science* **178**, 9 (1972).
12. W. C. Clark, *J. Abnorm. Psychol.* **74**, 363 (1969).
13. ——— and J. S. Goodman, *ibid.* **83**, 364 (1974).
14. R. L. Hayes, G. J. Bennett, D. J. Mayer, *Science* **189**, 64 (1975).
15. C. R. Chapman, T. M. Murphy, S. H. Butler, *ibid.* **179**, 1246 (1973).
16. D. H. McBurney, *ibid.* **189**, 65 (1975).
17. W. C. Clark and L. Mehl, *J. Exp. Psychol.* **97**, 148 (1973); W. C. Clark and D. J. Dillon, *Percept. Psychophys.* **13**, 491 (1973).
18. W. C. Clark, paper presented to the annual meeting of the Psychonomic Society, St. Louis, 1971.

10 March 1975

Hemispheric Asymmetry and Musical Performance

Bever and Chiarello (*1*) described an unexpected right ear superiority (putatively a left hemisphere dominance) for musicians in a melody recognition task. The usual observation (*2*) that recognition of melodic stimuli produces left ear superiority (right hemisphere dominance) was seen in a second group of listeners who were musically "naive." The counterindication was interpreted to be a result of musical training in which specialized left hemisphere analysis had been developed. The trained ("sophisticated") musicians apparently had learned to analyze the tonal sequence according to what Bever and Chiarello called "internal relationships of its components," an aspect of the serial or sequential (analytic) process of the left hemisphere (*3*). In contrast, musically naive listeners lacking specialized training had processed melodic passages according to the more holistic or unit mode of cognition in the right hemisphere (*4*).

To support the effect of musical training, Bever and Chiarello cited my report (*5*) of college musicians who also failed to show the usual left ear dominance for melodies. But my results did not demonstrate right ear superiority, whereas they did show left ear dominance for musical

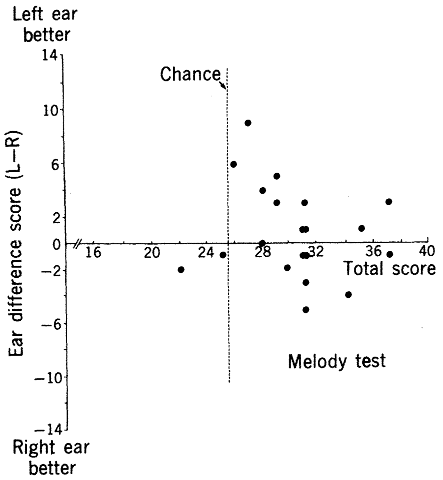

Fig. 1. Melodies. Ear difference scores are plotted against total scores (maximum = 40) for each of 20 subjects. Positive differences (plotted above the abscissa) indicate that the left ear was better; negative ones, that the right ear was better. Scores to the left of the *Chance* line were not significantly different from chance guessing. Note that there are equal numbers of subjects with left ear and right ear superiority.

chords. However, musical experience of my subjects was not controlled, so that it is possible that the population consisted of both naive and sophisticated listeners whose results taken together would neutralize any ear superiority.

Resolution of this problem can be achieved by using Bever and Chiarello's observation that "sophistication" was reflected in higher performance scores. That is, if sophistication and superior performance are related, then a gradient from left ear dominance to right ear dominance ought to be correlated with increasing skill of performance. The poorer performers would have the higher left ear scores and the better performers the higher right ear scores. The significance of such a correlation can be tested statistically.

Figure 1 is a scatter diagram of ear difference score (score with left ear minus score with right ear) versus total score for each subject in the melody test. As predicted, those with lower overall scores tend to have higher left ear scores, and those with higher overall scores tend to have higher right ear scores. Since the trend is not true of the extremes, neither the Pearson correlation coefficient nor the Spearman rank correlation reach significance ($r_P = -.203$, $r_S = -.269$; d.f. = 18; $P > .1$). The high extreme data cannot be excluded from analysis in spite of the fact that near-perfect scores contribute less to the question of ear bias than do scores of subjects who find the test moderately difficult. At the lower extreme, however, total scores less than 26 are not statistically different from scores expected from chance guessing ($P > .1$, two-tailed binomial test). It is reasonable to assume, therefore, that neither of the two scores that fell below chance contribute meaningful information to the data pool.

When the chance scores are eliminated, the correlations become significant ($r_P = -.451$, $r_S = -.521$; d.f. = 16; $P < .05$, two-tailed). The rank correlation was significant in spite of corrections necessary for the numerous ties at the median. Furthermore, this correlation occurred in a dichotic listening test of melodies even though the usual left ear superiority was absent.

The correlative effect is in clear contrast to the results of a similar analysis of ear dominance versus total performance in the chords test. The scatter diagram in Fig. 2 shows that in spite of a significant number of left ear scores, virtually no gradient, much less a correlation, exists for the data. In other words, musical sophistication, as measured by superior performance, will predict right ear superiority (left hemisphere dominance) for melodic but not for chordal stimuli.

Apparently melodies can be recognized either by the holistic method of the right hemisphere or by the time-ordering method of the left hemisphere. Bever and Chiarello claim that musical training draws more and more on left hemisphere functioning, which causes the observed right ear superiority and a greater overall performance. Conversely, it might be argued that good performance alone, independent of training, is a measure of increased left hemisphere participation in melody recognition, although this was clearly not the case for chordal stimuli. The data did not give an independent measure of hemispheric participation.

The present analyses support the idea that there are people who are more capable of using the left hemisphere, either "naturally" or through training, and thus perform well on time-ordering, sequential analysis tasks. Conversely, "right-brained" people would be expected to dominate on tasks which require unitary,

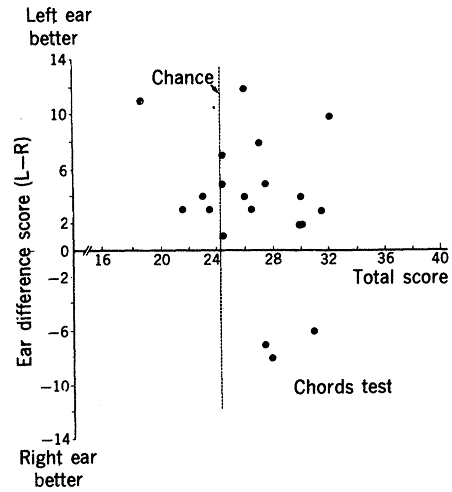

Fig. 2. Chords. The graph is similar to that in Fig. 1. There were twice as many stimuli in the chords test, so the total scores were scaled to match the range of the melodies test (maximum = 80/2 = 40). Note that there are significantly more subjects with left ear superiority.

holistic cognition. Thus, studies which center on left-right hemispheric differences may either use techniques that compare performances of the left and right hemispheres in subjects of the same population, or select right- and left-brained populations and compare the performances between the two groups.

HAROLD W. GORDON

Technion-Aba Khoushy School of Medicine, Department of Behavioral Biology, Technion City, Haifa, Israel

References and Notes

1. T. G. Bever and R. Chiarello, *Science* **185**, 537 (1974).
2. D. Kimura, *Q. J. Exp. Psychol.* **16**, 355 (19 D. Shankweiler, *J. Comp. Physiol Psychol.* **62**, 115 (19 O. Spreen, F. Spellacy, J. Reid, *Neuropsychologia* **8**, 243 (1970).
R. Efron, *Brain* **86**, 403 (1963); A. Carmon and I. Nachshon, *Cortex* **7**, 410 (19 Y. Halperin, I. Nachshon. A. Carmon, *J. Acoust. Soc. Am.* **53**, 46 (19 G. Cohen, *J. Exp. Psychol.* **97**, 349 (1973).
J. Levy-Agresti and R. W. Sperry, *Proc. Natl. Acad. Sci. U.S.A.* **61**, 1151 (1968); J. Levy, *Nature (Lond.)* **244**, 615 (1969); J. E. Bogen, *Bull. Los Ang. Neurol. Soc.* **34**, 135 (1969); R. D. Nebes, *Cortex* **7**, 333 (19 *Brain* **95**, 633 (19 J. Levy, C. Trevarthen, R. W. Sperry, *ibid.*, p. 61; H. W. Gordon, thesis, California Institute of Technology (1973); R. W. Sperry, in *The Psychophysiology of Thinking*, F. J. McGuigan and R. A. Schoonover, Eds. (Academic Press, New York, 1973), chap. 6; H. W. Gordon and J. E. Bogen, *J. Neurol. Neurosurg. Psychiat.* **37**, 727 (1974).
5. H. W. Gordon, *Cortex* **6**, 387 (1970).

6. I thank J. E. Bogen and A. Carmon for their advice and criticism in preparation of this manuscript. Supported by a grant from the Israel Center for Psychobiology, Charles E. Smith Family Foundation.

9 May 1974