Committee II
Theoretical Empiricism: A General Rationale for Scientific Model-Building

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by

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Discussion Paper

on

John L. Horn's and Jarl Risberg's

BLOOD FLOW IN THE BRAIN AND ADULTHOOD AGING OF COGNITIVE FUNCTIONS

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The study by John Horn and Jarl Risberg (1) relates adulthood aging and regional cerebral blood flow (rCBF) measured after inhalation of a mixture containing the radioactive tracer, 133-Xenon. As recently as 1980, only little and conflicting information was available on the effect of normal aging on rCBF, and an investigation using the inhalation technique with some 40 normal adults was noteworthy (2). The present study has data for almost 900 adults and it provides impressive evidence to corroborate other findings of a decline in rCBF with age (2,3 ,5,6). T e study does considerably more. It subjects the data to analysis using the partial least square (PLS) computer program. Models are distilled from analysis of data based on subsets of the study's population. Conclusions are drawn conce ning interrelationships among adult aging, blood flow for different regions of the brain, cortical functions, and fluid intelligence or the Gf factor, a concept to which Professor Horn has contributed greatly (7, 8). In line with Committee II's theme of theoretical empiricism, allow me to raise questions concerning the empirical and theoretical bases of the present study.

The summary paper does not give sufficient empirical data on the conditions under which the observations were made. Were the rCBF measures taken while the subjects were at rest, as is typical with the inhalation techniques (2,3,4), and, if so, were their eyes open or closed, their ears plugged or unplugged, etc? Or were the blood flow measurements made while the subjects were being tested, say, on mental abilities subsumed under fluid intelligence, or both at rest or while engaged in various mental or motor activities, and, if so, what tests were used. It is known that cortical blood flow may differ "whether the eyes are open or closed or whether there are repeated verbal instructions during the measurement [and] under different conditions of sensory input, cognitive processing, and motor activity" (5. p.144). If the blood flow measurements were made at rest, were the same subjects tested at another time in their mental abilities and did such data provide the basis for inferences concerning cortical functions and fluid intelligence. If not, what was the basis?

We know the subjects' ages: from the 20's to early 70's with most between 30 and 60 years of age. But we know little else about them. Were they normals? How many men and how may women were there? With the current interest in possible gender differences in cerebral blood flow and cortical functions (6,7,8) it would be pertinent to ask if there are sex differences in the present study's data.

The study draws parallels among declines with age in rCBR and in fluid intelligence but does not characterize or graph the declines. Over a time scale, say, from 20 to 70 years, how do the shapes of the two graphs compare and how comparable are the declines they portray?

The paper recognizes that the ISI (initial slope index) measures at the radiation sites on the head provide information about neurological functions in the surface sections of the cerebral cortex, not the innermost parts of the brain. Yet conclusions are drawn about the innermost parts, and, in particular, about the Ht area (to symbolize hypocampus-to-temporal lobe). Damage to this area is described as accompanied by declines in fluid intelligence (Gf) abilities. There is considerable discussion about the possible vulnerability of the Ht region to drops in blood pressure and what seems to be undue emphasis on such drops as causes during normal aging of brain damage or loss of neural tissue and the corresponding loss of the neurological basis for some intellectual capacities. If neural loss was involved, the paper reasons that the rCBF would decline in the affected areas.

The statistical model suggests that the observed negative correlation between age and the rCBF can be described mainly by two variables: SF (representing the brain's superior - frontal region) and MD (representing the midbrain region - but apparently not the anatomical midsection of the brain). One wonders why HT did not emerge as a significant factor. The authors note that correlations of the rCBF measure with a number of behavior variables suggests that MD measures an elementary form of attentiveness and SD a form that comes into play when the problem is more complex. The authors ask, "Could the aging declines of SF and MD be indicative of changes in the HT region of the brain"? (p. 10). They hypothesize that MD, perhaps because it is adjacent to Ht, is most directly affected by aging deficits developed in Ht, and that MD is an "arouser" of SF. They recognize that a problem with drawing such inferences is that the rCBF measures are not indicative of neural functioning in the areas where Ht is located. It is of interest to see if the study of blood flow in the innermost parts of the brain, made possible by the use of CT (computerized tomography) and PET (positron emission tomography) (8,9) will provide data to substantiate the provocative hypotheses raised in the paper under discussion.

Dr. Horn's and Dr. Risberg's paper suggests interrelations among certain mental abilities, their decline with age, and patterns of cortical structure and function. Radiation detectors, 16 on the right side and 16 on the left side of the head, recorded the rate of arrival of a radioactive isotope, with the ISI (initial slope index) used to measure rCBF (regional cerebral blood flow). The resulting data for 891 subjects were analyzed by means of a powerful computer program, PLS (partial least square methods). The present discussion focuses on the assumptions which seem to underlie the study and the factor analytic approach it used, while it leaves for another discussion consideration of the neurological assumptions.

The study is in the long line of attempts to characterize intelligence which go back at least to Charles Spearman's introduction in 1904 of "The two-factor theory of intelligence": the general or g factor, and a specific factor reflecting a particular ability. The two-factor theory, which led to a fierce debate between Spearman and E. L. Thorndike, was a milestone in the history of psychology. Spearman's attempt to use correlational data to support his theory has been described as the simplest possible factor analytic method. More complex factor analysis of intelligence has been undertaken by such scholars as L.L. Thurstone, J. P. Guilford, and R. B. Cattell. A factor analytic approach led Cattell (1963) distinguish two broad factors: fluid intelligence and crystallized intelligence. Perhaps because of modesty, John Horne doesn't even hint at the central role he has played in developing this distinction into what has come to be known as the Cattell-Horn Theory (Cattell, 1968, 1971, Horn,1967a, 1968, Horn and Cattell, 1966 Matarazzo, 1972.)

1. Not unexpectedly the paper under discussion accepts the Cattell-Horn Theory. Fluid intelligence (Gf) is regarded as a general relation-perceiving neural-physiological influence, which is relatively independent of education and experience. Crystallized intelligence (Gc) is considered highly sensitive to each person's unique cultural, educational and environmental experience. By restricting itself to these two factors, the study overlooks other factors and theories, e.g., as advanced by Hebb (1952) and Guilford (1971).

2. The paper accepts the related assumptions that fluid intelligence tends to drop off after early adulthood while crystallized intelligence changes little throughout most of adulthood (Cattell, 1979, 1980, Horn, 1970, 1978, Horn and Donaldson, 1980).

The issue of the relationship between intelligence and age is confounded. As Guilford observed (1967, p. 47): "Cross-sectional and longitudinal studies [tell] somewhat divergent stories. Whereas the former show almost universal decline in test performances among older groups, the latter more often than not show gains." The Cattell-Horn theory has been advanced to account for the empirical declines and non-declines as well as for the apparent decline in brain weight with age. But other theories have been advanced to account for the same data, e.g., the more sociopsychological theory offered by Riegel and Riegel (1972). Does the present study support one of these theories more than the other? My work on Einstellung effect and behavioral rigidity (or lack of flexibility or lack of fluidity) has found no simple relationship to age (Luchins, 1942, Luchins and Luchins, 1959).

3. The paper states, "We have a substantial amount of evidence indicating aging defects in a class of intellectual abilities that form what

is known as fluid intelligence (Gf)). The aging decline of these abilities is intimately linked to losses in capacities for achieving close concentration, maintaining undivided attention, demonstrating spontaneous alertness, and retaining the facility for encoding information" (p. 3). But it is not indicated how these capacities are tested in the present study. Aside from a hint on p. 9, we are not told what kinds of tasks or tests were used or even how many were used. Nor are the instructions described. Yet Thurstone (1947) has pointed out that the factorial structure of a test can be changed if the instructions are changed .

Were tests included of mental activities that involve crystallized intelligence? If so, did factor analysis show them clustering together or loading on particular factors differing for those found for the tests of activities pertaining to fluid intelligence? Or were no tests used? Were subjects perhaps tested while resting?

4. Humphreys (1967) gave an important methodological critique of some of the statistical methods and procedures which were employed by Cattell (1963). General criticisms of factor analytic approaches have been offered, among others, by Muenzinger (1955) and Luchins and Luchins (1959). Horn (1970), himself, has written about the subjectivity of factor analysis, pointing out that robust factors may emerge from factor analysis of fictitious data selected at random. Matarazzro (1972, p. 269) refers to the numerous, somewhat contradictory findings on the factorial structure of the Wechster Scales of Intelligence. Do appeals to physiological measures and an extensive computer program reduce subjectivity in factor analysis, or only seem to do so?

5. The paper notes that a model which provides a reasonable fit for different subsets of the available data requires 5 intercorrelated latent variables that involve the same configuration of manifest variables on both sides of the brain. What was there in the data which forced or favored such a model? With the present knowledge about differences in functioning of the two cortical hemispheres, it would have been of interest to consider a model that differed for the left and right hemispheres and possibly for the two sexes.

One wonders whether sex differences were monitored. Sex differences have been reported in the rate of change of various intellectual functions with age (e.g., Howell, 1955). It would be of interest to know if they can be found in the data collected in Professor Horn's study.

Brain damage in an area referred to as Ht (to symbolize hypocampus-to-temporal lobe) is described as accompanied by decline in fluid intelligence (Gf). In contrast, the abilities of crystallized intelligence (Gc) are little, or not at all affected by the same malfunctions in Ht that are associated with large declines in Gf.

The paper states that the evidence of many studies has now established that ISI (initial slope index) measures of rCBF (regional cerebral blood flow) are indicative of both traits and states of individuals (p. 2). But no evidence and no references are cited in the paper.

The ISI (initial slope index) measures are regarded as providing information about neural function in the surface section of the cerebral cortex, not the innermost parts of the brain. Yet conclusions are (cautiously) drawn for the innermost parts of the brain, such as the Ht region.

Two lalent variables were highlighted, labeled as SF and MD. It is not clear if they refer to mental function or to cortical structure or location. It is said:"...the neural functions represented by SF and MD are more susceptible to damage - perhaps not only damage associated with aging - than are other areas of the brain. Could the aging declines of SF and MD be indications of changes in the Ht region of the brain...MD is adjacent to the Ht region" (p. 10). Such examples of isomorphism between structure and function would be very important to psychology in general and Gestalt psychology in particular. But where is the evidence in the empirical data for such isomorphism?

7. Is blood flow the determinant of the cortical activity? If, for example, there is a way to increase the blood flow to a particular cortical activity, would mental activity improve correspondingly? Would blood flow or behavioral performance change, or would both change, if the tests were given in different ways, e.g., by testing the limits in diagnostic testing. If adequate oxygen supply is provided, what would be the consequence? It has been suggested that exercise of brain cells by virtue of continued education, formal and informal, may halt the decline in intellectual abilities with age, but this hypothesis needs much better experimental investigation (Guilford, 1967, p. 462). The methods of the present study may be fruitful approaches to testing the hypothesis.

In conclusion: Committee II is concerned with theoretical empiricism as a general rationale for scientific model-building. The paper under discussion does not reveal much about its empirical basis. It does not consider how theoretical approaches other than the model might account for the results. It provides a very interesting model as well as important corroborative cortical evidence for brain functioning and for factors resulting from factor-analysis. And one must view with awe a study which obtained thousands of cortical brain-flow readings and subjected them to a powerful computer analysis. But the model is such a subtle interplay of theory, data, and method that it leaves many unanswered questions.

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