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ABSTRACT

This report describes some current research which links selected aspects of brain research to selected issues in education. These issue areas include: (1) the relationship between neurophysiology and cognition; (2) the implications of cerebral lateralization for creativity, imagery, and art education; (3) sex differences in brain functioning; (4) nutrition and learning; (5) new methods in analyzing learning disabilities; and (6) implications for a newly emerging concept of holistic education. (Author/DS)

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TOWARDS MORE EFFECTIVE TEACHING AND LEARNING: WHAT CAN RESEARCH IN THE BRAIN SCIENCES CONTRIBUTE?

A Survey of Some Recent Research Efforts
and Their Implications for Education

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Towards More Effective Teaching and Learning: What Can Research in the Brain Sciences Contribute?

I. SUMMARY:

Recent advances in research in the brain sciences -- the study of the human brain -- have been dramatic. At the same time, speculation in the popular literature has often been overly-dramatic. Many educators, seeking implications of brain research for educational policy, are understandably confused.

On the one hand, there is renewed interest among educators, policy makers, teachers and parents in what brain research, or "neurophysiology", has to say about such diverse issues as learning disabilities, creativity, the impact of improper nutrition on behavior and learning, differences in learning modes between males and females, the use of imagery in teaching, and improvements in the teaching of art. These latter areas have received widespread attention through research work known as "cerebral lateralization" or more popularly, "left/right brain" studies.

On the other hand, many of those intimately familiar with neurophysiology are warning caution. There is general disagreement on the strengths and weaknesses of the linkages between brain research and educational policy. Some claim that a strong causal link between "brain and mind" will never be established. Others find the correlations strong enough to warrant new policy decisions, especially regarding nutrition in schools. Most agree, however, that rigorous, well-designed experiments that clarify linkages between brain research and education warrant further attention and increased support.

Probably the most important conclusion: more educators need to become cognizant at least of the fundamentals of the brain sciences to better assess which, if any, implications for educational policy are justified.

II. Overview:

Linking Brain Research to Educational Policy: Pitfalls or Promise?

There is a growing sentiment among those responsible for educational policy that the vast number of studies of the neurophysiology of the brain -- or research in the brain sciences -- may hold far-reaching implications for educators in the 1980s and beyond. At stake is the intriguing possibility that properly formulated interrelationships between brain sciences and educational sciences (especially cognitive psychology) might allow us, in Howard Gardner's phrase, "to grasp the brass-ring secret" of learning. The more this possibility is questioned by many researchers, (also by Gardner himself), the more intrigued many policy makers seem to become.

Several recent works by authoritative researchers are linking brain research to education. The book entitled The Brain and Education (1978) edited by Jeanne Chall (Harvard) and Allan Mirsky (Boston University, now NIH) is one example. Merlin Wittrock's work at UCLA, The Brain and Psychology (1980) and "Learning and the Brain" (1980), is another. Equally significant work by people such as Marcel Kinsbourne, Joseph Bogen -- and John Eccles, a Nobel Laureate -- lend weight and substance to the importance of brain research for education and especially for educational policy. At the same time, many doubts and unanswered questions remain.

Most educational policy makers have difficulty in sorting out just what is important and relevant for them in the brain sciences. To many who have had no prior experience with neurophysiology -- and this includes the vast majority in education -- brain research may give a deceptively unified appearance of being a field with a single, apparently straight forward aim: to describe the organization of the brain. To those familiar with the field, however, the competing schools, aims, and divergent hypotheses add levels of complexity that render the notion of linking brain sciences to education too broad and general to be meaningful. Which aspect of brain sciences, and which sectors of education?

In this report, we describe some current research that links selected aspects of brain research to selected issues in education. These issue areas include the relationship between neurophysiology and cognition; the implications of cerebral lateralization for creativity, imagery, and art education; sex differences in brain functioning; nutrition and learning; new methods in analyzing learning disabilities; and implications for a newly emerging concept of "holistic education ".

In all of these selected areas, there are at least three questions that educational policy makers should explore:

- What are those who understand neurophysiology actually saying that is relevant to cognitive psychology and education?
- Are the linkages between brain research and education strong enough yet as a basis for influencing educational policy, or
- Are they at least promising enough that anyone concerned with educational policy should be cognizant of their potential impact and stimulated by their far-reaching implications?

III. Who's Doing What? Some Selected Research Projects

In the pages that follow, we describe the work of selected researchers who, in our opinion, are dealing with key issues in this field. Most of these people are well-known; some are younger scholars at the beginning of their careers. While we cannot endorse every implication for educational practice that these particular researchers draw from their research work, all of them are carefully addressing issues that have the potential to exert significant influence on American educational policy in the 1980s and beyond.

Because the literature and research on neurophysiology and cognition has become so vast -- over 500,000 articles in medical and educational journals -- the present report must necessarily omit description of many excellent efforts. However, throughout the report and in its appendix, readers are referred to other sources that may be consulted for additional particulars.

The Teaching of Art and the Study of Left/Right Brain Differentiation

Work of: Betty Edwards
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Betty Edwards, author of the book entitled Drawing on the Right Side of the Brain,* teaches drawing at the California State University, Long Beach. Her book is being widely used in the teaching of art and is undoubtedly the best known work having to do with left/right hemispheric differentiation of the brain. Her techniques are successful, according to many art teachers.

What Edwards has done is to use left/right hemispheric differentiation to explain her highly successful educational techniques as a teacher of art. Marilyn Ferguson offers a concise summary of Edwards' methods and rationale as follows:

> "Although some of these techniques were stumbled upon by artists over the years, no one was sure how and why they worked. Other methods in this book were discovered or devised by Edwards, first as she explored the 'shift' she experienced when drawing and later when she learned about split-brain research demonstrating the brain's capacity for dual consciousness. When she learned that the left hemisphere was verbal and analytical, the right spatial and holistic, she realized why she was essentially unable to speak while doing demonstration drawings before classes.
>
> Her techniques, developed over the past decade, serve to turn off the over-active left hemisphere. The left brain interferes with perception because of its simplistic certainty that if it can name and categorize something, it need not look carefully.
>
> The ability to draw depends upon the right hemisphere's ability to see relationships: angles, lines, curves, patterns of light and darkness.

---

*Betty Edwards, Drawing on the Right Side of the Brain, Los Angeles, J.P. Tarcher, 1979.

Among the techniques to confound the left hemisphere:

• Drawing upside-down. This keeps the novice artist from identifying the parts being copied and therefore perception is more direct. (Forgers often copy signatures upside-down so their own bias does not interfere with the actual form of the original letters.)

• Drawing edges and contours. These are too diffuse or complex to interest the left hemisphere. They are un-nameable.

• Drawing negative space -- that is, looking at the area around objects and drawing that shape rather than focusing on the objects themselves."*

A close reading of Edwards' book yields a subtle and important point. She developed her methods out of her own empirical practice -- led by her own intuitions about what might work and her own critical observation about what does work. This is the way most fine teachers develop their personal methods. Only later did she become cognizant of work in brain research and discover that the left/right model provided a clarifying rationale for her methods. Most reviews of her work miss this point, although Edwards herself makes it. This may lead some readers to assume that Edwards developed her techniques as an application of the left/right model, which is not the case.

This distinction is important because it implies that, in this case, research played more of a secondary rationalizing role than a primary one of initiating or stimulating new practices. Until other learning strategies as brilliant as Edwards' are developed by starting with the left/right model and applying it to practice, one lesson to be drawn is that the creativity of teachers does more to inspire new curricular developments than does the work of researchers.

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*Marilyn Ferguson, "Tricks for Drawing on the Right Side of the Brain", The Brain/Mind Bulletin, Los Angeles, Ca., Vol. 4, no. 16, July 2, 1979.

Nevertheless, what is most important about Edwards' work lies in her making the connection between what works in the classroom and why, according to neurophysiological research. In making this connection she has provided us with a clear example of the relevance of neurophysiological theory to educational practice in the teaching of drawing.

Linking Brain Growth and Mental Development

Work of: Professor Herman Epstein
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Tel: 617-647-2750

Epstein, a biologist and neurophysiologist at Brandeis who has studied the implications of his work for education, has found that the human brain undergoes spurts in growth and complexity during five age periods: 3-10 months, and 2-4, 6-8, 10-12, and 14-16 years. About 85% of all children fit this pattern.

While the first growth spurt is an increase in size, the other four manifest themselves as a substantial increase in the complexity of the neural networks. Functionally, this should correspond to an increased ability for complex thinking processes. Experimental data exist to support these biological inferences, according to Epstein.

What adds promise to Epstein's findings is his claim that his brain growth stages correspond to Piaget's data on intelligence development. Piaget postulated four main stages of development:* 0-1 (motor stage), age 2 (sensorimotor), 6-7 (concrete operations), and 10-11 (formal operations stage). Dr. Pat Arlin, an educational psychologist from Vancouver, has gathered evidence of significant additional development during ages 14-16 - a finding which corrresponds to Epstein's data. The Department of Education sponsored a seminar in August, 1979, that allowed Epstein, Arlin and others to

*These ages represent the earliest ages that some individuals begin to move from one stage to the next. A substantial portion of adults never reach the final steps.

explore these relationships.

Thus brain growth periods may turn out to be a biological basis of the Piaget stages. What implications can one derive by using this knowledge of the existence of correlated spurts in brain growth with mental functioning? Epstein has some intriguing hypotheses:

The matching of instruction to the thinking levels of children would seem to be the first task of any educational strategy, especially at the junior high school level. This is because children around ages 12-14 show a hiatus in brain growth. The data reveal that only a small minority of children can experience any change in cognitive level during this period -- indeed that some 75% of children will sit through three consecutive years unable to handle material presented at the level of formal reasoning. Since most junior high school material uses this level, nearly three-fourths of the children are probably "turned off" by it.

What Epstein recommends is to concentrate during this period on affective and psychomotor skills rather than on introduction of novel intellectual processes. This would necessitate schools developing instructional materials that depart from most commercially published programs that invariably introduce new cognitive information. Thus Epstein argues that middle school programs should

> "a) discontinue the mass introduction of novel cognitive skills to middle grades students who do not have such readiness; b) present new cognitive material at the existing skill level of students; and c) work to mature existing cognitive skills of middle grades learners."

Further, Epstein recommends that "the middle school programs must be restructured to include a large component of experience and practice of skills within opportunities for interaction with nature, society, and people. This will require transposing a substantial portion of the middle school experience outside the walls of the school." This could be done through community service projects, nursing homes, day care centers, and natural resource reclamation projects.

Epstein's work also leads him to consider implications for programs like Head Start (which he feels occurs at the wrong age period) and for gifted children, 30% of whom do not manifest formal operations at age 14. According to Epstein, "This is not surprising, since IQ is related mainly to speed of learning, while cognitive level is related to style of learning. Thus we are led to predict that close to 30% of high IQ children should be subject to the 'turn-off' phenomenon."

Epstein and his associates have carried out several test programs, initially in some Poughkeepsie schools, and most recently in Lexington, Mass., where he and Dr. Arlin have developed and administered courses to teachers to sensitize them to different cognitive levels and to show them how to apply these concepts to match curricular materials to a child's state of development.

Some References: Herman T. Epstein and Conrad F. Toepfer, Jr., "Basis for Reorganizing Middle Grades Education" Educational Leadership, May, 1978.

"Summary Report of Seminar on Cognitive Levels", conference held in Washington, August 9-11, 1979

"Brain Growth and Cognitive Functioning", Colorado Journal of Educational Research, Vol 19, 3-4, 1979

Guided Imagery and the Teaching of Foreign Languages

Work of: Dr. Beverly Galyean
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Beverly Galyean, an education consultant specializing in confluent/ holistic learning models, with particular emphasis on their application to foreign language instruction, has developed viable teacher training and curriculum models that are now being piloted in Los Angeles City Schools. Teachers are trained to use a variety of affective, emotive, intuitive, and nonlinear learning activities such as guided imagery, visualization, meditation, body movement, psychokinetic art, music, drama, and fantasy/ dream/ESP activities to help children master basic skills and traditional subject matter. Empirical results from these projects show that the children (elementary to high school, "gifted" to "low achieving") taught via these affective nonlinear methods tend to score higher on tests of basic skills than do students taught primarily through linear verbal/analytical modes.

According to Galyean, the students achieve more not only cognitively but show impressive gains in behavioral norms as well. High school students decrease negative classroom behaviors when they meditate and engage in guided imagery activities on a daily basis with their teacher. Elementary children demonstrate a more rapid readiness to begin working on basic skill material after experiencing meditative and guided imagery activities. Hyperactive children calm quickly when exposed to guided body movement and centering/ breathing/meditative activities. And in several instances teachers report accelerated learning of computational skills and reading material following imagery activities.

Galyean's work is influenced by the background of her doctoral studies in Confluent Education, during which time she was prepared in the following counselling strategies: Gestalt, encounter group, human relations, psychosynthesis, values awareness, transpersonal identification and Rogerian counseling. She also links this to brain/mind theory and neurophysiological research, including hemispheric lateralization. It should be noted that, unlike Betty Edwards, the connection she draws between lateralization and her work is not clearly demonstrable. Rather it has to do with employment of mental imagery as a powerful learning tool and respect for a diversity of cognitive styles in individual learners.

Galyean's work has generated important empirical results which show the desirability of using a mix of traditional and non-traditional approaches in one conjoint learning procedure.

For example, in a recent foreign language teaching experiment which she conceived and directed in Los Angeles, students benefitted dramatically from this conjoint learning procedure. As reported by the Brain/Mind Bulletin, this program for seventh to eleventh graders

> "included guided imagery, movement and art therapy, fantasy, poetry, drama, music, values clarification and healing arts.
>
> A related project improved the English and Spanish of Chicano children, kindergarten through third grade.
>
> Using a variety of introspective conversational activities, students generated their own study programs. They established what they wanted to learn and practice, Beverly Galyean, project developer, told Brain/Mind Bulletin. "The teachers apply a self-awareness type of language activity to the regular text lesson. For example, when students practice the past/imperfect tense, they close their eyes, breathe deeply and take an

imaginary journey to some significant event in the past. Then they open their eyes, draw and write in the foreign language about what they experienced."

Another example of the use of emotions in heightening a lesson: When learning to use the French verb aimer (to love) in clauses beginning with 'because,' students close their eyes and imagine themselves in the presence of five persons they love. The students are asked to tell these people why they love them. Finally, they draw the loved ones and write captions in the foreign language."

What makes this work most impressive is that students performed, on the whole, almost twice as well as comparison groups on speaking and writing tests. In addition "many of the junior and senior high students reported positive changes in their personal lives as well as their ability to concentrate in school."*

*"Confluent Teaching Doubles Language Test Scores", Brain/Mind Bulletin, Los Angeles, Ca., Vol. 5, no. 10, April 7, 1980.

Aphasia, Use of Symbols, and Implications for Art Education

Work of: Dr. Howard Gardner
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It is perhaps paradoxical that those who can say little -- patients suffering from "aphasia", or the loss of certain language abilities -- may tell us more than most about brain and mind, according to Howard Gardner who studies brain functions of aphasic patients at Veterans Hospital in Boston and who also conducts research at Harvard on art education and the development of artistic skills.

After years of working with patients who have suffered damage to right and left hemispheres of their brain,* Gardner is skeptical of oversimplified dichotomies that assign, for example, linguistic skills to the left side of the brain and aesthetic abilities to the right. In a recent test of 74 right-handed, brain-damaged subjects, he concluded with a "double dissociation": that is, "an intact left hemisphere does not of itself ensure adequate comprehension of all linguistic messages" and "an intact right hemisphere does not guarantee adequate aesthetic sensitivity."** These conclusions resulted from giving a series of tests requiring subjects to relate metaphoric sentences with a picture that "went best" with a particular sentence.

While Gardner uses rigorous methods in such research, even he notes

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*Work conducted at Boston Veterans Administration Hospital, Aphasia Research center, Jamaica Plain; and Department of Neurology, Boston University, School of Medicine, Boston, Mass.

**"The Comprehension of Metaphor in Brain-Damaged Patients" in Brain, 1977.

the extreme difficulty of accounting for the large number of variables involved. In the research cited above, for example, he separated subjects into groups of patients with lesions on the right hemisphere, left hemisphere, left anterior, and left posterior plus a demented and a control group. Other factors such as precise site or size of lesion could not be taken into account. Experimental limitations such as these and others have led Gardner to remark that one explanation as plausible as many in today's popular literature is that the left brain handles "the familiar" while the right brain deals with "the unfamiliar". His article on "What We Know (and Don't Know) About the Two Halves of the Brain" is an excellent statement of caution in this field.

Gardner's work at Harvard as director of Project Zero* focuses on the systematic study of art education and reflects a growing sophistication in relating brain and mind to language and other forms of expression. In longitudinal studies of nine children starting at age one, Gardner follows the development of seven different "families" of symbol use: language, symbolic play, numbers, music, dance and movement, two-dimensional representation (drawing and mapping), and three-dimensional representation (clay and block building). He critiques Piaget's work as giving "scant consideration to the thought processes used by artists, writers, musicians, athletes, [and] equally little information about processes of intuition, creativity, or novel thinking".**

The work at Project Zero is nearing a phase of attempting to apply the

*The name refers to the amount of knowledge considered available about art education when the project began.

**"Developmental Psychology After Piaget", Human Development, 1979.

insights gained from its new frameworks and experimental results to ongoing problems in art education by working with schools, museums, children's televisions, and other agencies. Implications for present-day art education are far-reaching and have already had "considerable impact on American thinking about artistic education", according to The Washington Post (April 27, 1980). For example, Gardner feels it is wrong for schools to isolate artistic skills from linguistic ones and to label the arts nonbasic to education. The creation and appreciation of art can be aided by good teaching, without which the whole world of art will remain beyond the reach of most children. Gardner also takes a controversial position that there is a qualitative and quantitative decline in children's drawing abilities around age 7, a fact ignored in classroom practice.

Howard Gardner's provocative, systematic research is being further amplified via a new project that seeks to provoke new thinking about "human potential". Sponsored by the Van Leer Foundation with a grant to Harvard and directed by Dr. Harold Lasker, the "human potentials project" is likely to provide a test for some of Gardner's hypotheses during the coming 3-4 years.

Some References: The Shattered Mind: The Person After Brain Damage, Knopf, New York, 1975

The Arts and Human Development, Wiley, New York, 1973

"What We Know (and Don't Know) About the Two Halves of the Brain", Harvard Magazine, Cambridge, April, 1978

with Suzanne Hamby, "The Role of the Right Hemisphere in the Apprehension of Complex Linguistic Materials" forthcoming

Cerebral Lateralization and Cognitive Development

Work of: Marcel Kinsbourne, M.D.
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Kinsbourne is most notable for his interest in left/right laterialization as it affects learning disabilities. His article with Merrill Hiscock entitled "Cerebral Lateralization and Cognitive Development"* provides an excellent and comprehensive review of the literature on this subject. Kinsbourne's interest in the multidimensional relationships among child development, cognitive growth and development, neurology and learning disabilities reflects his training as a pediatrician and child psychologist who has developed expertise in neurology for the purpose of clarifying issues in children's learning and psychology.

His particular research interests reflect this interdisciplinary orientation. His work focuses on language disabilities in children (he has written a book entitled Language Development and Neurological Theory**) and on attentional problems and autism (both of which may have important neurological connections).

Recently he has turned his attention to the role nutrition plays in this mix of issues. For example, in the March 1980 issue of Science, he coauthored

*From Jeanne Chall and Allan Mirsky (eds.) Education and the Brain, University of Chicago Press, 1978.

**Marcel Kinsbourne Language Development and Neurological Theory, 1977 Academic Press.

an article on the relationships of food dyes to hyperactivity.*

His work on left/right lateralization is contained in his book entitled Asymetrical Functioning of the Brain.**

*James M. Swanson and Marcel Kinsbourne, "Food Dyes Impair Performance of Hyperactive Children on a Laboratory Learning Test", Science, Vol. 207, no. 28, March 1980

**Cambridge University Press, 1978.

Sex Differences in Hemispheric Asymmetry

Work of: Susan Leigh Star
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Susan Star is a young feminist scholar whose work on sex differences in hemispheric asymmetry has been published in several books edited by Ruth Hubbard, Professor of Biology at Harvard. Hubbard, who is foremost among feminist scholars concerned with the ways in which science views women, considers Star to be the most articulate and accurate feminist critic of the left/right brain research in particular, and sexist biases in the literature on the psychology of consciousness in general.*

With care and balance in her research, Star shows the difficulties inherent in broad claims that males are more closely associated with left brain functioning and females with right brain functioning. Such claims, for example would imply that men are more verbally skilled than women, which is contrary to the results of standardized tests.

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*Susan Leigh Star, "Feminism and the Psychology of Consciousness," Science/Technology and the Humanities, Fall 1979, Vol. 2, no. 3, pp. 303-308.

Her articles, "The Politics of Left and Right: Sex Differences in Hemispheric Asymmetry",* and Sex Differences and the Dichotomization of the Brain: Methods, Limits, and Problems in Research on Consciousness,"** provide a clear critique of key problems associated with left/right brain research valuable not only for the feminist issues they raise but also for the more general issues in the brain sciences. These include methodological difficulties, conflicting data and interpretations, the extent to which social values and ideology influence the interpretation of scientific data, and the misconceptions promoted by writers who too often mistake conjecture for fact when relating the neurosciences to human nature.

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*In an anthology about women and biology, Women Look at Biology Looking at Women, Ruth Hubbard et al. (eds.), Cambridge, Mass.: Schenkman, 1979.

**In Genes and Gender: Pitfalls in Research on Sex and Gender, ed. M. Lowe and R. Hubbard. (N.Y.: Gordian Press, 1979). A third article, "Right Brain Epistemology" will appear in a book of essays for the Modern Language Association Commission on the Status of Women, J.P. Stanley and S. Hoogland, (eds.).

Creativity, Creativity Testing, and Cerebral Hemisphericity

Work of: Professor E. Paul Torrance
with J. Pansy Torrance
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E. Paul Torrance is one of the most prolific investigators in the field of creative behavior. Since 1958, he has been nurturing a quiet revolution to make elementary, secondary, higher, and career education more creative. His long history of teaching creativity and of developing creativity tests combines with his recent interest in left/right brain research. The implications of his work for schooling are far-reaching and include: fundamental reorientation of teacher training towards more creativity; creativity tests as a counterpoint to IQ testing; development of new interdisciplinary curricular materials and reform of statewide school purchasing programs; new programs to study the future that go beyond the walls of the classroom, even for elementary school pupils; and so on.

Some of the highlights of his work are encapsulated below:

- The creative education revolution: Education today is more creative than 20 years ago. In 1976, all 108 sixth graders of a stable representative Georgia school were administered the same creativity tests given to their 91 counterparts in 1967: the greatest gains were in originality and elaboration, two characteristics of creativity. These results were confirmed by Flanagan, who recorded increases in creativity at the same time as noting decreases in grammar and computation skills.

Objective studies administered in 1962 showed that prospective teachers had attitudes that would not reward and even would suppress development of creative abilities. By 1978, 96% of a test sample of 508 teachers-in-training thought more class time should be used for teaching creative thinking.

o Testing: In 1959, Torrance pointed out that if one identified as gifted the upper 20% of a school population based on an intelligence test, 70% of the most creative would be missed. The most widely used test for creativity is the TTCT (Torrance Tests of Creative Thinking). It has been translated into 30 languages. In the US, over 100,000 students take the test annually. Over 1000 research studies have examined its utility -- to all age groups, with minorities, and for its long-run predictability which is now being validated through a 20-year follow-up study (in progress).

o Left/Right Hemisphericity: Torrance believes that the accumulated research on the specialized functions of cerebral hemispheres "has given additional theoretical and empirical support" to his work. Therefore he has developed tests for right hemisphere (nonverbal) thinking, such as "Sounds and Images" published in 1973. He also developed "Your Style of Learning and Thinking" (fourth revision) for use with normally functioning adults and adolescents.

As reported in Brain/Mind Bulletin (1979), Torrance has shown that people can change their preferred styles of learning through training, that those having a left-hemisphere style of processing information score lower on tests of creative thinking ability, and that gifted students with a predominantly left-brain style have greater difficulty in seeing implications of new knowledge.

o Combining futurism and creative education: Two extraordinary programs were developed by Torrance et al. to encourage children (starting from age 2-3) and adults to think creatively about the future. These are the "Future Problem Solving Sociodrama" and the "Future Problem Solving Bowl". Breakthroughs are achieved in both techniques when participants are able to use "states of consciousness other than the ordinary, fully rational states", i.e. emotional factors are equally important to intellectual ones in imaging the future. Both techniques also are commonly used outside the classroom walls, in one case at the Goddard Space Center where students were "taken to another planet" and asked to design a new way of life.

Torrance feels it is especially important that gifted/talented children be exposed to such future-oriented techniques. By 1978, the Future Problem Solving Bowl had expanded from the initial 23 high schools in northeastern Georgia to over 300 schools and 6000 students in 24 states. In 1980, the University of Nebraska administered the program, supported in part by the Nebraska Association for the Gifted, to an estimated 30,000 people.

- International aspects: Torrance cites work from 25 different countries showing that creativity can be studied cross-culturally. He has examined styles of learning and thinking in the USA, Japan, Israel, India, and Mexico. Some conclusions: Japanese students score higher on intuition, verbal instruction, and precision while US students are higher, respectively, in logic, demonstration, and looseness (lack of structure).

- Summary: Torrance has conducted work along the lines described above with pre-school children, with students in career education, and with the elderly -- as well as in elementary, secondary, and higher education -- and has developed well-researched tests for nearly all of them. These are listed and described in "Highlights: Georgia Studies of Creative Behavior, 1970-1979", available from the University of Georgia. The extensiveness and originality of Torrance's work makes him a most provocative and substantial figure, the importance of whose work has been underestimated in our opinion.

Some References: "Creativity and Futurism in Education: Retooling", Education, Vol. 100, summer, 1980

"Role of Hemisphericity in Performance on Selected Creativity Measures", Gifted Child Quarterly, 1979, Vol. 13 (with S.A. Mourad)

"Perceived Changes in Styles of Learning and Thinking (Hemisphericity) Through Direct and Indirect Training", Journal of Creative Behavior, Vol. 12, 1978 (with C. Reynolds)

"Torrance Tests of Creative Thinking: Norms-Technical Manual (Research Edition)", Personnel Press, Lexington, Mass., 1966

Gifted Children in the Classroom, Macmillian, 1965

Is Creativity Teachable?, Phi Delta Kappan Education Foundation, 1973

"Evaluating the Elusive Aspects of Career Education", Journal of Research and Development in Education, 1979, Vol. 12

Learning and the Brain

Work of: Professor Merlin C. Wittrock
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Wittrock's interests center on the relationships between cognitive psychology and classroom instruction. He has taught courses in both these areas at U.C.L.A. In the interest of further illuminating those relationships, Wittrock has recently turned his attention to exploring the interface of cognitive psychology and neurophysiology. The fruits of this exploration are contained in a series of articles which, taken together, provide the most complete and useful review of the literature that relates brain functioning to cognitive processes in learning. Wittrock's work in articles such as "Learning and the Brain"* and "Education and the Cognitive Processes of the Brain"** is careful, even-handed, well-researched, and insightful.

Wittrock's own research in the area of learning and the brain is highlighted by his work in generative processes in learning and memory, particularly as these processes relate to the acquisition of language and reading skills.

By "generative cognitive processes", Wittrock means those processes by which children and adults generate meanings for written language by relating

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*"Learning and the Brain" from M.C. Wittrock, ed. The Brain and Psychology, Academic Press, 1980.

**"Education and the Cognitive Processes of the Brain" from Jeanne Chall and Alan Mirsky, (eds.) Education and the Brain, University of Chicago Press, 1978.

it to their knowledge and memories of experience. By this constructive process they make sense out of prose and connected discourse. In constructing his theory of generative cognitive processes, Wittrock makes reference to two essential learning processes which have been studied both in neurosciences and in cognitive psychology: attention and encoding.*

Wittrock's theoretical work has been supplemented by empirical studies such as those he describes in "Learning and the Brain".

> "In a number of studies, my students and I have studied the effects of the generation of imagery and verbal elaborations upon learning in school. Bull and Wittrock (1973) found that when elementary school children drew simple pictures of the definitions of vocabulary words they remembered more of the meaning of the words than when they wrote and studied the definitions.
>
> In another study (Wittrock et al., 1975), a familiar story facilitated the generation of meaning for new and undefined vocabulary words. Doctorow et al. (1978) found that instructions given to junior high school students to generate a summary sentence after each paragraph of a story sizeably increased their retention and comprehension of the stories.
>
> In a recently completed study (Wittrock & Lutz, in preparation), college students reading a chapter from Rachel Carson's book, The Sea Around Us, increased their memory of the information in the chapter by constructing a verbal analogy for the main idea of each paragraph or by constructing a summary sentence after reading each paragraph. In these studies, self-generated verbal or imaginal representations of the information to be learned facilitated learning."**

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*Encoding has to do with the constructing and storing (in memory) of abstract and concrete representations and interpretations of events from experience.

**Bull, B.L. and Wittrock, M.C. "Imagery in the Learning of Verbal Definitions", British Journal of Educational Psychology, 1973, 43, pp. 289-293. Wittrock, M.C. et al. "Reading as a Generative Process", Journal of Educational Psychology, 1975, 67, pp. 484-489. Doctorow, M.J., et al. "Generative Process in Reading Comprehension", Journal of Educational Psychology, 1978, 70, pp. 109-118. Wittrock, M.C. and Lutz, K. "Reading Comprehension and the Generation of Verbal Analogies and Summaries," in preparation.

Wittrock's importance, then, rests both on his integrative skills as a reviewer of the field of learning and the brain sciences as well as on his own integrative research and theory building as a cognitive psychologist.

Considering his solid, systematic, multidisciplinary work, Wittrock deserves to be regarded as a leader among those who are attempting to reach a useful and balanced understanding of a variety of implications in the relationship of brain functioning to cognitive psychology and of both these areas to classroom instruction.

III. WHO'S DOING WHAT? ADDITIONAL NAMES AND RESEARCH WORK

Many more names and research projects were suggested to us during the course of our inquiry. Given the constraints on time and resources, not all could be followed up and investigated. These include

Dr. Joseph E. Bogen, M.D.
Roos Loos Medical Group
1711 West Temple Street
Los Angeles, CA. 90026
Tel: 213-413-1313

A neurosurgeon who has participated in the disconnection of cerebral hemispheres in severe epileptics. He has related left-right lateralization to parallel ways of knowing in several articles. Readers are referred to his article "Some Educational Implications of Hemispheric Specialization" in Chall and Mirsky.

Professor Jeanne Chall
Harvard Graduate School of Education
Cambridge, Mass. 02138
Tel: 617-495-3521

Widely recognized professor of reading. Editor, with Allen Mirsky, of Education and the Brain, 1978.

Dr.Eric Courchesne
Medical School
University of California
San Diego, Ca. 92037

Engaged in research on learning disabilities and EEGs.

Dr. Joaquin Cravioto, Chairman
Division of Scientific Research
Hospital del Nino Iman
Insurgentes dur 3700
Mexico city 22, D.F., Mexico

Malnutrition and education. Has data on 200 village children in Mexico, from their birth to age 7, on effects of malnutrition.

Dr. Peter Fuller
Child Development and
Mental Retardation Center
University of Washington
Seattle, Washington 98105
Tel: 206-543-0124

Engaged in research on learning disabilities and EEGs.

Dr. David Galin
[San Francisco]

He studied left/right brain in young children.

Carlton Gajdusek
National Institute of Health
Washington, D.C.

Works in the field of neuro-physiological pathology.

Dr. Norman Geschwind
Harvard Medical School
Boston, Mass.

Considered one of the foremost researchers on the relationship between neurophysiology and behavior.

Dr. Michael Gazzaniga
Department of Neurology
Division of Cognitive Neuroscience
Cornell Medical School
1300 York Avenue
New York, New York
Tel: 212-472-8296

Significant work in left/right brain studies and handedness.

Dr. Muriel Lezak
Clinical Psychologist
Veteran's Hospital
Health Services Center
3710 Southwest Veterans Road
Portland, Oregon 97210
Tel: 503-222-9221

Author of <u>Neuropsychological Assessment</u>, 1976. Work in child psychology, integration of left/right brian, and reading.

Mr. Joseph Psotka
National Institute of Education
Department of Learning and Development
1200 19th Street N.W.
Washingoton, D.C. 20208
Tel: 202-254-6572

Helped to organize conference on neurphysiology at U.C.L.A. in mid-1970s. Continued interest in the field.

Ms. Julia Sherman, Director
Women's Research Institute of Wisconsin
3917 Plymouth Circle
Madison, Wisconsin 5705
Tel: 608-233-0255

Work on sex differences in brain functioning.

<u>A Symposium on Recent Research on the Human Brain and Implications for Education, July 15-19, 1980</u>

Organizer: Ms. Mary Leighton
College of Education
University of Oregon
Eugene, Oregon
Tel: 503-686-3407

From July 15-19, 1980, over 900 educators (mainly teachers) gathered to hear eight speakers discuss research on the human brain as a possible new significant frontier for educators. The topics and speakers were as follows:

<u>The Challenge of Brain Research</u>
Herman Epstein, Professor of Biology,
Brandeis University

<u>Biological Time: The Clock Within Us</u>
Michael Menaker, Professor of Biology and
Director of Neuroscience Training and
Research, University of Oregon

<u>Development of the Human Brain</u>
Marcus Jacobson, Professor of Anatomy,
University of Utah, College of Medicine

<u>Specialization in the Cerebral Hemispheres</u>
Murial Lezak, Clinical Neuropsychologist,
Veterans Hospital, Portland, Oregon

<u>Sex Differences in Brain Function</u>
Julia Sherman, Director, Women's Resesarch
Institute of Wisconsin

<u>Language Processing in the Brain</u>
D. Frank Benson, Professor of Neurology,
The Center for Health Sciences,
Los Angeles

<u>Endorphins: The Body's Own Opiates</u>
Avram Goldstein, Professor of
Pharmacology, Stanford University

<u>Biofeedback: A Challenge to the Priorities of Brain Research</u>
Barbara Brown, former Chief of Experiential
Physiology, Veterans Hospital, Sepulveda,
California

Ms. Leighton concluded that the conference was successful in informing the participants and provoking their thinking. However, the presentations were less germaine to educational practice than had been hoped. Many felt that this research would become more relevant further into the future -- some said as far as 25-50 years into the future. The experience of this very good symposium indicates at least two things relevant to the Horace Mann Learning Center.

First, small workshops would probably be more productive at this stage than large symposia. What is needed now, and what few agencies seem to be sponsoring, are opportunities for brain researchers to think about the educational implications of their work, together with and aided by cognitive psychologists. This process requires small group interaction with sufficient time to develop researchable propositions.

Second, even though brain research may be years away from much of educational policy, it is very close at hand in at least one important respect, which is the ethical dimension. Just as the purposes of research in genetic engineering recently sparked constructive controversy, it is quite possible that brain research may provoke similar debate. Properly formulated, such discussion could benefit neurophysiology by indicating new priorities and it could help educators understand the strong and weak points of brain research. In order for such debates to be properly formulated, educational policy makers will have to become better informed about the present state-of-the-art of brain research.

IV. TOPICS FOR DISCUSSION: ISSUES AND IMPLICATIONS

The work described in the foregoing pages can be summarized as follows:

A growing collection of evidence indicates that left and right sides of the human brain process information differently. While there is general agreement about the existence of these differences, their precise nature and significance are the subject of considerable disagreement. The increase in scientific experimentation has been matched -- if not exceeded -- by popular speculation: it has become fashionable to relate many behavioral dichotomies to specializations of either the left or right hemisphere. Distinguishing scientific hypothesis from unsubstantiated speculation thus has become difficult for educators seeking implications of the brain sciences for educational policy.

In this section, we begin by describing some methodological problems that make it difficult to link neurophysiology and cognition. Then we identify several key issues of importance to educators, noting areas of agreement and disagreement among researchers.

Methods in Neurophysiology and the "Brain/Mind" Problem

Educators should be cognizant of a number of fundamental methodological problems.

- None of the present research methodologies can determine with certainty how the brain functions.

What we know about how the brain functions comes from research that is limited by our ability to get physically inside the living brains of fully functional, normal human beings. Research strategies have included

1) observations of the interior of the brain by neurosurgeons working on live animals, dead humans, or on human beings afflicted by pathology or injury;

2) researchers' observations of behavioral distortions in human subjects known to have certain brain dysfunctions;

3) electroencephelograms (EEG's) which through external monitoring distinguish between different kinds of brain wave patterns present in different regions of the brain, correlated with externally observed modes of mental functioning or responses to behavioral tasks;

4) a host of other externally exhibited and monitored behaviors such as eye movements, listening patterns, and performance on a variety of kinds of tests.*

It should be pointed out that the major contemporary impetus for left/right brain studies derives from early work on abnormal adults by Roger Sperry. Years later, doubts still persist as to how much explanation abnormal brains can provide about normally-functioning, intact brains.

Another methodological problem is the difficulty in pinpointing locations for brain functions. As Gardner has pointed out, it cannot be proved that a function is housed in a particular location just because that function is impaired by damage to that location. His famous analogy is that the functioning of a radio can be terminated by cutting off the plug, but no one would conclude that the sound was "housed" in the plug.

As Merlin Wittrock explains:

> "Cognitive functions cannot be reduced to neural structures and psychological processes..." (1978) "... the precise neurological mechanisms involved in different types of learning are not known." (1980)

Hence, those interested in connecting neurological functioning with learning must rely on findings which are always limited by being unable to

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*This list is not necessarily exhaustive.

"get inside" the live, fully functioning, healthy human brain.

- Relating brain function to cognition or behavior requires constructing a hypothetical model of the mind. Such models are built by postulating assumptions and "filling in" where evidence is incomplete. As useful as such models may be, they are experimental hypotheses, not hard fact as is sometimes implied.

Generating models of the mind is an age-old occupation of philosophers, more recently of psychologists and most recently of neurophysiologists. Sperry and his associates constructed such hypothetical models in generating the notion of two brains from research in patients whose hemispheres had been severed. This procedure is invariably used by everyone who relates a model of complex neurological functioning to human cognition, thought, perception, learning, memory, and so on.

The difficulty in verifying relationships between neurological structures and cognition is sometimes referred to as "the brain/mind problem". A recent book on the subject includes a dialogue of great interest between philosopher Karl Popper and Nobel Lauriate neurophysiologist John C. Eccles. Its title, The Self and Its Brain,* reflects the recurrent notion that the brain and mind are indeed different entities. Whether or not it is the case that the mind is greater than the sum of the brain's parts, the problem of the difference between the nature of mental processes and the nature of neurophysiological functioning is at least one of two separate levels of analyses that may be correlated but not easily linked in any direct causal manner.

Many of the problems in the research arise when causal relations are posited across levels such as these. And there are many levels, ranging

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*Karl R. Popper and John C. Eccles, The Self and Its Brain. New York: Springer International, 1977.

upward in elaboration from synapses and electro-chemical functions, through neurological regions of the brain, to mental functions at the psychological level, to complex human behaviors at the level of the social sciences and humanities.*

The construction of hypothetical models of the mind seems both inevitable and promising. One virtue of relating neurophysiology to cognition is that neurophysiological research may stimulate the development of new models of the mind that more adequately portray mental functioning. Caution, however, is in order: since the distinctions between empirically verifiable data and the hypotheses drawn from that data are often disregarded by many popularizers and overly minimized by some researchers, there is a tendency for the hypothetical models of mental functioning to be interpreted as facts about how the brain works.

Susan Leigh Star summarizes these problems cogently, showing how literally hundreds of "models of the mind" have been derived from Sperry's original work on no more than 20 adults:

> The current strong wave of interest in hemispheric asymmetry began with the work of Roger Sperry, who studied persons with severe epilepsy who had had their corpora callosa (the nerves and other tissue connecting the two halves of the brain) surgically severed in an attempt to control seizures. As a result, these people had two separately functioning brain systems--their right hand literally did not know what their left was doing (unless they had a chance to look and see!). Sperry presented the two sides of the brain in such people with a variety of stimuli--verbal, tactile, and visual. On the basis of his subjects' responses, he was able to generalize about the types of functions that the two hemispheres perform separately He concluded that the left half of the brain determines logical thought, most speech, mathematical ability and "executive" decisions, while the right half rules visuo-spatial

*For further discussion of the levels of analysis problem, see Steven Rose, The Conscious Brain, Vintage Books, New York, 1973.

ability, emotions, and intuitions. His hypothesis about the left hemisphere controlling verbal functions was supported by observations on brain-damaged people with lesions in their left hemispheres, many of whom have more and severer speech impairments than those with right hemisphere lesions.

The strict equation of spatial ability with right hemisphere functions, and of verbal ability with the left, combined with the tenet that it is most natural to use one side of the brain at a time, formed the basis for subsequent theories about sex differences in asymmetry. Sperry's hypothesis, based on his observations of fewer than twenty patients, became a "fact" that was subsequently used to build new theories.*

Since we are in a period of intense interest in neurophysiology, it is not surprising that a number of brain-based models of the mind are currently in use. In addition to the many models reflecting the left/right brain differentiation, there are also models stimulated by research in artifical intelligence (M.A. Arbib's Metaphorical Mind, for example), models based on theories of brain evolution (P.D. MacLean's Triune brain) and a model based on the image of a holograph (Karl Pribram's Holographic Theory of Consciousness).

Perhaps the most important point for educators is to proceed with great care when relating learning to the neurosciences. This warning, repeated by many in the field, is well summed up by Jeanne Chall and Allen Mirsky who conclude their book Education and the Brain with the following statement:

"Every chapter author acknowledges the great complexity of the brain and the theoretical disagreements that arise from this complexity. If this brings confusion and uncertainty to the

*Susan Leigh Star, "Sex Differences and the Dichotomization of the Brain: Methods, Limits and Problems in Research on Consciousness, Program in Human Development and Aging," University of California, San Francisco, in Genes and Gender: Pitfalls in Research on Sex and Gender, Ruth Hubbard and Marian Lowe (editors), Gordian Press, New York, 1979.

different neuroscientists, it brings an even greater sense of insecurity to the non-specialist. In the search for certainty, there may be a tendency to hold one simple theory. It is important for the non-specialist to know that the various brain theories are being constantly refined and modified."*

Creativity, Imagery, and Art Education

The most practical implications of cerebral lateralization to classroom practice concern the areas of creativity, imagery, and art education. The popular success of Betty Edwards and others in teaching drawing, the research of Howard Gardner in art education, and the creativity enhancements and testing by E. Paul Torrance all deserve further explorations. Despite some obvious commonalities among the work these people represent, there are profound and unresolved areas of disagreement. Gardner, for example, would not view the brain as two halves in the way Betty Edwards does; rather he would describe "seven brains", or seven brain functions that correspond to the seven symbol systems he studies.

Both Gardner and Edwards seek to enhance nonverbal skills. In contrast, Torrance and ~~also~~ Wittrock would "draw on the right side of the brain" to develop linguistic capacities. Wittrock, for example, uses imagery to increase vocabulary skills. Torrance seeks ways to enhance written expression.

Thus in the promising areas of creativity, imagery, and art education, "educating for both halves of the brain" means very different things to different people. For policy-makers, this implies a need for more experimentation and for further dissemination of a variety of information and ideas.

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*Jeanne Chall and Allen Mirsky (eds.) Education and the Brain, University of Chicago Press, 1978, page 376.

This could perhaps best be done through small workshops that involve not only researchers but practitioners as well. It should be noted that the 1980 conference of the American Association for the Study of Mental Imagery has held such workshops. More information on their program can be obtained from Ms. Anne Dickason, Program Director, Mental Imagery Conference, 219 Nolte Center, 315 Pillsbury Drive S.E., Minneapolis, Minn. 55455. For further discussions in this area, see Joseph Khatena, "Creative Imagination Imagery: Where is It Going?", Journal of Creative Behavior, Vol. 10, no. 3, 1976, pp. 159-192.

Sex Differences in Left/Right Brain Research: Fact or Fantasy?

- In the popular literature, the left side of the brain is often associated with male consciousness while the right side is associated with female consciousness. To what extent are such claims born out by research?

Claims of this sort are not well supported by present neurophysiological research. They seem to be based on early speculations of writers like Robert Ornstein* and others who were extrapolating from research-based hypotheses which have since come to be seriously questioned, even by Ornstein himself. Susan Leigh Star sums it up well:

> "In the years since Ornstein's book was written, many psychophysiologists have revised their initial conceptions of brain asymmetry, and most, including Ornstein, now realize that there is no duality of consciousness in the brain."**

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*Robert Ornstein, The Psychology of Consciousness, New York, W.H. Freeman and company, 1972.

**Susan Leigh Star, "Sex Differences and the Dichotomization of the Brain: Methods, Limits and Problems in Research on Consciousness, Program in Human Development and Aging," University of California, San Francisco, in Genes and Gender: Pitfalls in Research on Sex and Gender, Ruth Hubbard and Marian Lowe (editors), Gordian Press, New York, 1979.

Nonetheless, Ornstein's The Psychology of Consciousness remains very influential and many voices continue to echo conceptions now out-dated.

What differences in left brain/right brain functioning are now thought to exist between males and females, and what sense can one make of any such differences? The research findings and even the hypotheses are conflicting and contradictory. Three examples of such hypotheses are provided on the following pages. These examples are excerpted and described in some detail, reflecting the importance and complexity of this issue. Readers who prefer to do so may skip or skim to the next topic for discussion that begins on page 50.

EXAMPLE 1:*

Two Competing Hypotheses about Right Brain/Left Brain Functions

The following two hypotheses have been among the most widely discussed and believed theories about sex differences in brain asymmetry. They are both based on alleged sex differences on spatial and verbal tasks, and represent two entirely different reasonings from basically the same set of "facts;" Levy and Sperry say that women are inferior on spatial tasks because of a *lesser degree of lateralization;* Buffery and Gray say that they are superior on verbal tasks because women's brains are *more lateralized.*[15]

The Levy-Sperry Hypothesis

Levy and Sperry begin their reasoning by noting that females perform poorly on certain tests for spatial abilities, and that left-handed men perform poorly on the same tests. Left-handers, they state, perform poorly on these tests because of "cross-talk" from their left hemispheres while performing the tasks: they are said to be less lateralized. The authors argue that the superiority of right-handed males in such spatial tasks is due to a *greater* lateralization of the brain: Levy states that "it might be that female brains are similar to those of left-handers in having less hemispheric specialization than male right-hander's brains."[16] She and Sperry also draw a furtner analogy between females and left-handers: they state that in left-handers language is mediated by both sides of the brain (whereas in right-handers it is a left brain function) and that the language component in the right hemisphere of the left-handers (alleged to be absent in right handers for the most part) is what interferes with "pure" right-hemisphere performance on spatial tasks. (In fact, it is *not* true that left-handers usually have bilateral language representation![17]) From this Levy and Sperry generalize to females who, they assume, also have bilateral representation for language, and they conclude that this is why females as a group perform more poorly than males on spatial tasks.

A number of researchers have already begun to accept their hypothesis as fact, and are using it to interpret further findings, although the problems with it are legion. Levy and Sperry do not address training and socialization as possible factors in performance of spatial tasks. They do not verify their assumption that the tests measure the degree of hemispheric specialization. And they do not address the critical fact that females consistently perform better than males on tests of *verbal* ability, a fact which would seem to contradict their assumption that females have bilateral language representation (which, by their reasoning, should make their verbal abilities *poorer*). Rather, they seem more interested in explaining male superiority on spatial tasks, whatever contortions of logic this might demand.

* excerpted from Susan Leigh Star, op.cit.

EXAMPLE 2

The Buffery-Gray Hypothesis

Buffery and Gray examine the same test scores as Levy and Sperry, which show that males perform better at certain spatial tasks; but unlike Levy and Sperry, they also take into account female verbal superiority.

To explain how both apparent superiorities can co-exist, Buffery and Gray construct the following hypothesis. They postulate that in males, linguistic and visuo-spatial abilities are represented in both hemispheres, whereas in females they are separated into the left and right hemispheres respectively. (Thus for Buffery and Gray, females are *more* lateralized than males, exactly opposite to Levy and Sperry's conclusion.) Buffery and Gray then assert that bilateral representation is most efficient for visuo-spatial tasks — a direct contradiction of most theories — because these tasks require a global, holistic perception. Hence males, with less lateralization than females, perform better on visuo-spatial tests. Then, with a confounding leap in logic, they assert that verbal tasks "require *more* lateralization," since they are more "specific" and "delicate" and "localized" than spatial tasks. Hence women, with greater lateralization than men, perform better at verbal tasks.

There are at least three serious problems with their hypothesis. The first is that deriving a more global or Gestalt perception from superior performance on the spatial tasks that have been used in these tests requires a bit of imagination. For instance, one task is the rod and frame test, which gauges the ability, in a darkened room, to adjust a movable glowing rod within a tilted frame to a vertical position. Another tests the ability to distinguish pictures of familiar objects that are concealed within a camouflaging background. The ability to take a figure out of its background context is called "field independence" and is used as an example of "spatial ability."

In these sorts of tests females, on the average, are less able to separate a figure from its context, and are therefore said to be more field dependent than males. From this it would appear that *females* are the ones who exhibit Gestalt perception (right hemisphere), yet this is attributed to *men* in the attempt to explain their supposedly superior spatial ability.

But a more blatant contradiction emerges from the Buffery-Gray theorizing. They casually mention that

> male superiority on visual tasks only appears when manipulation of spatial relationships is involved. On tasks which depend for their execution principally on the discrimination and/or comparison of fine visual detail, the direction of the sex differences is reversed. Thus women are better than men on . . . a *number* of other tests of visual matching and visual search. . . [emphasis mine][15]

EXAMPLE 2 (continued) *

Thus, the *only* tasks that show men are more able are tests of manipulation of the environment or some part of it. The equation of this with spatial ability, not to mention its high valuing, reflects the respect accorded male skills in this society.

Buffery and Gray end the above quote with: "Thus women are better than men on ... a number of other tests of visual matching and visual search which are predictive of good performance on clerical tasks."[18]

Finally, Buffery and Gray, like Levy and Sperry, never identify by means of physiological tests the hemisphere whose presumed activity they associate with a particular task. They *postulate* that men are less lateralized than women; they *postulate* that verbal skills require greater lateralization, and visuo-spatial skills less lateralization. But they never *measure* the brain activity of males or females during the performance of any of these tasks.

* excerpted from Susan Leigh Star, op.cit.

EXAMPLE 3*

WITTROCK: SEX DIFFERENCES IN COGNITIVE PROCESSES

In a thorough review of the psychological literature on sex differences, Maccoby and Jacklin (1974) reported that the verbal abilities of boys and girls are quite similar until early adolescence.[98] At about age eleven and beyond the verbal abilities of females are superior, by about .25 of a standard deviation, to the verbal abilities of males. In adolescence and adulthood, males are superior by about .4 of a standard deviation to females on visual-spatial tasks, and after about age twelve or thirteen on mathematical tasks also. No sex difference was found in analytic ability, except for a male superiority when spatial ability was involved in disembedding complex figures.

The recent research on the cognitive processes of the brain complements the above findings in several interesting ways. For over a decade a mild controversy has existed over the difference between the sexes in hemispheric distribution of language and spatial processes. Levy and Sperry argue that, compared with women, men have a greater degree of lateralization, with verbal processes in the left hemisphere and spatial functions in the right hemisphere, while women tend to have both verbal and spatial processes represented to a slightly greater degree in each hemisphere. Buffery and Gray argue nearly the opposite, believing that speech perception and consequently other verbal processes of girls develop earlier and become more strongly lateralized than those of boys, who have spatial processes more equally represented in both hemispheres.[99] Why a strong lateralization increases language ability in females, while its opposite, bilateral cerebral representation of nonlanguage skills, facilitates spatial ability in males is not made clear.

In the recent literature, Ray et al. report that males were lateralized for so-called right hemispheric or left hemispheric tasks, while no statistically significant differences between the same tasks were found for females.[100] Hannay and Malone found that males, but not females, showed a right visual field superiority for recognizing nonsense words, indicating less lateralization of linguistic functions in females than in males.[101] Witelson found spatial functions well lateralized in boys at about age six, but not in girls until about age thirteen.[102] On the other hand, Wolff and Hurwitz found earlier and greater left hemispheric specialization in girls for serial regulation of motor behavior, that is, keeping in time with a metronome and tapping a steady rhythm.[103] With biofeedback information about heart rate, females shifted to a greater right hemisphere activation than did males in an attempt to influence their heart rates.[104] Both sexes were equally effective at self-regulation of heart rate, although they used somewhat different strategies in attaining the equivalent outcomes.

* excerpted from M.C. Wittrock, "Education and the Cognitive Processes of the Brain", in Education and the Brain, Jeanne Chall and Allan Mirsky, (editors), University of Chicago Press, 1978.

EXAMPLE 3 (continued)*

Tucker studied analytic-spatial and synthetic-spatial tasks and found that males used their left hemispheres predominantly in the analytic task and their right hemispheres predominantly in the synthetic task.[105] Females used their right and left hemispheres in the analytic task, but showed a greater EEG difference between rostral and caudal (front and back) regions within the same cortical hemisphere. Bogen et al. found that black or white urban women do as well as men on the Street Gestalt Completion Test.[106]

In sum, sex differences in mean cognitive proficiency in different intellectual tasks are either nonexistent in most areas, or remarkably small in the remaining areas. They do not emerge until adolescence, suggesting an influence of culturally determined roles.

There is no educationally relevant empirical support in the studies reviewed here for the belief that one sex is more or less intellectually qualified than the other to pursue academic learning. The observed differences in hemispheric lateralization, which are still controversial, reflect a richness and diversity in the use of cognitive processes to attain equivalent outcomes and equal proficiency.

* excerpted from M.C. Wittrock, "Education and the Cognitive Processes of the Brain", in Education and the Brain, Jeanne Chall and Allan Mirsky, (editors), University of Chicago Press, 1978.

Wittrock, in a later article, expands upon this conclusion: **

> Although as groups, men, women, left-handers and right-handers sometimes differ in cognitive proficiency and in the ways they process information, the groups also overlap substantially in cognitive proficiency and in methods of processing information. One educational implication of these findings is that although some individuals will be more proficient than others at academic learning, students should not, by reason of sex or handedness, be discouraged from the pursuit of any academic subject matter taught in schools.

** M.C. Wittrock, "Learning and the Brain", The Brain and Psychology, Academic Press, 1980.

Sometimes, these unclear and conflicting interpretations of research results are not adequately reflected in the popular literature. Many otherwise worthy causes may do themselves more harm than good by seeking support on such a weak base. For example, Susan Leigh Star presents a feminist critique of this problem as it occurs in feminist literature:

> Feminists utilizing the research on hemispheric asymmetry should be careful to avoid similar pitfalls and not take right and left brain dichotomies literally when analyzing women's oppression, or at least not use them in the simple literal fashion in which they are popularly represented. There is a strong metaphoric relationship between the popular dichotomizations for "right brain" and "left brain" functions/perceptions and some of the ideological/material differences between feminists and sexists. Some feminist values that have recently been articulated[21] include holistic perceptions, nondualistic thought, and a validation of intuition. Patriarchal values are associated with linear thought, propositionality that "objectifies," and dualism. However, the linkage of male dominance on a social level with "the left brain" is too simplistic.
>
> An example of this kind of oversimplification occurs in an article by gina:
>
> > So dualism resides in the very brain. The ways of perceiving that came to be grouped in the left hemisphere are the tools men used to take control of the planet. Linear thinking, focused narrowly enough to squeeze out human or emotional considerations, enabled men to kill ... with free consciences. Propositional thinking enables men to ignore the principles of morality inherent in all the earth's systems, and to set up instead their own version of right and wrong which they could believe as long as its logic was internally consistent ... All ways of perceiving that threatened the logical ways with other realities were grouped together on the other (right) side of the brain and labeled "bad."
> >
> > The separation of "good" and "bad" qualities into left and right sides of the brain, and the universally constant valuation of qualities, can be seen in every patriarchal culture through its attitudes toward left and right-handedness ...[22]

> Gina here introduces a dualism that *rejects* as male our ability to use the tools of intellectual reasoning and logic; and this, too, is dangerous for it perpetuates stereotypic masculine/feminine dualities, and even more subtly so if they occur in the same person. Our left hemispheres are not precarious, "male" places to be visited but not dwelt in. We need to utilize both halves of our brains in a flexible and adaptive manner, based, as gina suggests, in a moral society which respects the activities of both.
>
> For feminists, our central concerns must be to eliminate patriarchal mechanisms that have blocked the expression and *validation* of language and spatial/intuitive/environmental skills in women, and to encourage the development of these skills in the holistic manner of which we seem to be capable.

Another perplexing issue that confounds the question of sex differences is the nature-nurture controversy. Even where there are differences that show up on EEGs between males and females, it remains unclear whether such differences are due to differences in innate neurophysiological structures or whether they are socially induced. Some assume that because the research is neurophysiologically based, any differences can be attributed to differences in human nautre. Others, however, point out that differences even in the physical development of the brain can be due to factors such as social environment, nutrition, etc.

An alternative and intriguing approach is offered by the work of Herman Epstein:*

> It was pointed out above that the brain growth spurt of girls at age eleven years is about twice that of boys, while something like the converse is true of the brain growth spurt that occurs around age fifteen years. If we connect brain growth with mental growth, the quesiton arises about the implications of a quantitive difference in brain growth during a spurt period. In this instance of a quantitive difference, it might be possible to discover the implications because it accompanies a sexual dimorphism so that the two classes of individuals are readily distinguished.

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*Herman Epstein, "Growth Spurts During Brain Development: Implications for Educational Policy and Practice" in J.S. Chall and A.F. Mirsky, <u>Education and the Brain</u>, University of Chicago Press, 1978.

A simple hypothesis would be that girls need a very different, and more challenging, curriculum from that of boys at both ages, the input being far more intense and complex for girls around age eleven, and correspondingly less intense and complex around age fifteen. One can imagine that curricula developed mainly for boys could be inadequate or even harmful for girls at age eleven. Indeed, the failure to adapt educational inputs at this age to the far greater capacities of girls might be responsible for the relative lack of females in the more theoretical or abstract professions. Presumably, moreover, the inadequate program for age eleven girls would later make the girls' smaller development at fifteen even less effective.

This line of thought can be related to the famous proposition enunciated by Bruner stating that "the foundations of any subject may be taught to anybody at any age in some form." Our failure to recognize the higher-level form accessible to girls around age eleven may deprive them fo the needed background on which to build their subsequent intellectual growth.

Topics for Discussion (continued)

Learning Disabilities

- Left/right brain research implies that some learning disabilities are correctable. New techniques using EEGs promise some indications for new directions for exploration in such cases.

One of the most important implications of brain research and a "spin off" of left/right brain studies concerns learning disabilities. Chall and Mirsky* conclude that

> "For educators who fear that physical brain dysfunctions or defects are permanent and irreversible, the evidence presented in this volume is reassuring. At appropriate times, the research indicates, stimulation will produce a change for the better. Because of this strong relationship between the brain and the stimulation it is given, many of the authors state directly that collaboration of educators and brain scientists in research and in practice is essential." (p. 372)

Articles by Kinsbourne and Hiscock entitled "Cereberal Lateralization and Cognitive Development" and by Rita G. Rudel,** entitled "Neuroplasticity: Implications for Development and Education", both take up this theme. Herman Epstein cites *** the area of learning disabilities as the most important new frontier for neurophysiology. New techniques in EEG use offer promising new insights, according to Epstein.

The question of brain plasticity is particularly important. One interpretation of left/right brain studies stresses that thought, memory, and learning seem to be network functions. They bridge various areas of the brain

*Chall and Mirsky, Education and The Brain, op. cit.

**in Chall and Mirsky, op. cit.

***in personal communication to authors.

rather than remaining localized functions. To be sure, the brain tends to specialize, as do all highly complex systems. But the particular ways in which it specializes seem to vary across individuals.

Neuroplasticity suggests that different points in the brain can take on new functions if necessary. According to Karl Pribram, "within any (brain) system and to some extent between (brain) systems, the laws of mass action and equipotentiality hold."* This means that unless a brain lesion is massive, it will not necessarily have long and lasting specific effects. Further, by referring to "equipotentiality", Pribram means that remaining healthy brain tissue can often take up the function of tissue that has been damaged or destroyed. One cannot jump to the conclusion that a high percentage of those afflicted wth brain damage can develop as though nothing has occurred.** Rather, it indicates that for many learning disabled children the plasticity of the brain -- allied with appropriate remedial intervention -- will permit considerably richer development than would be the case were the brain not so flexible in its functioning. What would be useful for educators to explore, in this regard, are new insights into "appropriate remedial intervention" that can be suggested by neurophysiologists such as Marcel Kinsbourne (see description on page 18) and perhaps Dr. Peter Fuller (note mention on page 30).

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*Karl Pribram, "The Functional Role of Muscle Spindles -- Facts and Hypotheses", Brain, 1975, Vol. 98, pp. 581-86.

**For insight into the intricacy involved see Rita G. Rudel, "Neuroplasticity: Implications for Development and Education", from J. Chall and A. Mirsky Education and the Brain, University of Chicago Press, 1978, pp. 269-307.

Nutrition: Renewed Interest in the Impact of Improper Nutrition on Learning and Behavior

Essential to maximizing learning potential is proper brain growth and functioning, and essential to both of these is proper nutrition. A growing awareness of this need has led to increasing attention by many to the deleterious effects on learning of inadequate and/or improper nutrition. Inadequate nutrition and its effect on learning has been recognized in Third World countries for many years; now improper nutrition is being viewed with increasing alarm in developed countries like the United States and other nations where so-called "junk foods" may exacerbate problems in learning capacities.

The research work on nutrition, brain development and functioning, and learning and behavior is extensive. To assess it properly would require a report at least equal to this survey on brain sciences. Since the constraints of the present project did not permit the necessary review, we present only several comments here. These are intended to alert educational policy makers to the renewed political interest in nutrition as well as to the existence of extensive research work.

The literature on nutrition and education, already large, is growing. A recent issue of the Teachers College Record, summer 1980, Vol. 81, no. 4 is devoted to "Learning and Eating: The New Nutrition Education". Other relevant representative articles are: B. Ashern and M.D. James, "Deleterious Effects of Chronic Undernutrition on Cognitive Abilities", Journal of Child Psychology and Psychiatry, vol. 19 (1), 1977 pp. 23-31; Monckeberg, F. et al. "Malnutrition and Mental Development", American Journal of the Clinical

Nutrition no. 25, 1972 pp. 766-772; and Scrimshaw, N.S. and Gordon, J.E. Malnutrition, Learning and Behavior, Cambridge, Mass: M.I.T. Press, 1968.

At the same time that the research is expanding, public interest and controversy over nutrition is growing. A burgeoning interest in the relationship between diet and such "disorders" as hyperactivity (a catchall classification), childhood depression, etc. has been the subject of a number of publications directed at the general public. Furthermore, the Congress, motivated by the skyrocketing costs of medical care, has become sufficiently interested in proper nutrition that it may stimulate new research and development in the area of nutrition education. We think it is reasonable to expect expanded interest and activity during the 1980s in research that relate nutrition, human development (including its physical, neurophysiological and cognitive components) and education.

There are likely to be many direct implications and programs resulting from this growing interest in nutrition. Most obviously, it augers for new curriculum materials and teacher training in areas like nutrition education and health. It may also cause reviews* and restructuring of school lunch programs and lead to efforts to curtail or restrict sales of "junk food" on school premises.

In addition there may be efforts to target particular populations who may be suffering from chronic inadequate nutrition. For example, in "A Proposal to Provide Expanded Nutrition Counseling Services for Disadvantaged Urban Adolescents" (1980), the staff at "The Door" of the International Center for

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*Such as mandated by the National School Lunch Act of 1946, passed "to safeguard the health and well-being of our children".

Integrative Studies recommends programs to increase adolescents' knowledge of the principles of nutrition and to establish a greater concern and sense of self-responsibility for their own bodily and mental well-being. There is great room here for some innovative thinking about how programs such as this could be made part of the standard secondary school experience, and where appropriate, taught in vocational schools.

The Brain: Two Halves or One Whole? Implications for Holistic Education

For educators, one of the most important implications of brain research and especially of left/right brain studies is that teachers need to focus afresh on the WHOLE learner. By viewing the brain as one whole rather than separate halves, an emerging concept of "holistic education" becomes possible. While still the subject of considerable disagreement, increasing numbers of scholars are beginning to interpret cerebral lateralization in this integrated way.

Most people still think about this research in terms of the dichotomy between left and right hemispheres. Many claim that one side (usually the left) receives greater attention than the other, and that relatively speaking the right side is "neglected". Titles of articles and books, such as "Educating for Both Halves of the Brain" or Drawing on the Right Side of the Brain may also reinforce a tendency to think of polar opposites. One implication of the "polar opposites" view is to search for ways to develop, or remediate, whichever side is "underdeveloped". This remedial approach is limited in two important ways.

First, we still lack adequate descriptions about what each hemisphere of the brain does. For example, the two sides are sometimes referred to as "verbal" for the left hemisphere and "imagistic" for the right. Yet, in actuality, the right hemisphere has some language capacity and both hemispheres process images. What may differ is not so much <u>what</u> they process as <u>how</u> they process. J.E. Bogen has suggested technical terms for clarifying this issue: He calls the process of the left hemisphere "propositional" and the process of the right hemisphere "appositional".*

A second problem with the remedial approach is that <u>differences</u> across individuals vary considerably. Identifying such differences through standardized testing may lead to labelling some people inadequate because they fail to conform to certain standard patterns. Should such tendencies occur, the resulting stereotyping may be more costly in its effects than any benefits accruing to individual learners.

The alternative -- and a more accurate and productive one in our opinion -- is to stress the interdependence of the two halves of the brain; and therefore to search for ways that <u>integrate</u> the functioning of the two into some higher order. Using this integrative interpretation of left/right brain research leads naturally to consideration of activities which may be thought of as "holistic education".

Merlin Wittrock addresses this issue:

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*The term propositional characterizes a process which tends to name, categorize and sequence information. The term "appositional" is best described as "gestalt oriented", or simply "not propositional". In Betty Edwards' work appositionality amounts to being able to process information in a way that allows the drawer to see things afresh -- in an unnamed uncategorized way. One advantage of the terminology "propositional" and "appositional" is that they avoid pre-existing notions associated with terms like "intuition and emotion".

"Before beginning the review of empirical studies of hemispheric brain processes, I wish to emphasize that the cortical hemispheres overlap greatly in ability function and are richly connected with each other through the cerebral commissures and other tissues . . . the so-called dichotomy between the hemispheric functions probably results from a slight advantage one strategy has over another strategy which is sufficient to produce specializations of some functions . . . The brain also specializes within each hemisphere as well as across hemispheres. No dichotomy of function does justice to the sophistication and complexity of the human brain."

and again

"(R)esearch . . . indicates the importance of understanding that people process information in different and multiple ways which may interact with one another . . . the art of teaching needs to devise sophisticated ways to facilitate the multiple processing systems of the brain. . . . In matching teaching methods to apptitudes and processes, there is the issue of which mode should be [used]. Instruction may often be better when multiple modes are used--not just the learner's dominant mode."*

*M.C. Wittrock, "The Generative Processes of Memory" in The Human Brain, pages 66 and 179-180.

Lists of dichotomies such as those offered by Joseph Bogen and Betty Edwards can all be seen as parts to be creatively integrated in a holistic approach to mental functioning and learning. This is the underlying assumption in the presentation of such lists. Further, it matters more that these dichotomies have the power to attract and motivate people than whether or not they accurately reflect propositional and appositional functioning of the left and right hemispheres of the brain--which, in fact, many of them do not.*

Parallel Ways of Knowing

intellect	intuition
convergent	divergent
digital	analogic
secondary	primary
abstract	concrete
directed	free
propositional	imaginative
analytic	relational
lineal	nonlineal
rational	intuitive
sequential	multiple
analytic	holistic
objective	subjective
successive	simultaneous

Source: J.E. Bogen

*A few caveats about such lists are in order here. First, we refer back to the section on Sex Differences and reiterate the notion that there is no left/right "duality of consciousness in the brain." Second, the question of such lists and dichotomies has become so widespread that Psychiatrist David Galin has issued a warning against "dichotomania". Third, critical perusal of such lists raises many questions about why particular phenomena are listed where they are. For example, synthetic thinking certainly can be identified as a step in analytical thinking as it is employed in dialectical anaylsis and General System Theory.

A Comparison of Left-Mode and Right-Mode Characteristics

L — MODE	R — MODE
Verbal: Using words to name, describe, define.	Nonverbal: Awareness of things, but minimal connection with words.
Analytic: Figuring things out step-by-step and part-by-part.	Synthetic: Putting things together to form wholes.
Symbolic: Using a symbol to *stand for* something. For example, the drawn form stands for *eye*, the sign + stands for the process of addition.	Concrete: Relating to things as they are, at the present moment.
Abstract: Taking out a small bit of information and using it to represent the whole thing.	Analogic: Seeing likenesses between things; understanding metaphoric relationships.
Temporal: Keeping track of time, sequencing one thing after another: Doing first things first, second things second, etc.	Nontemporal: Without a sense of time.
Rational: Drawing conclusions based on *reason* and *facts*.	Nonrational: Not requiring a basis of reason or facts; willingness to suspend judgment.
Digital: Using numbers as in counting.	Spatial: Seeing where things are in relation to other things, and how parts go together to form a whole.
Logical: Drawing conclusions based on logic: one thing following another in logical order — for example, a mathematical theorem or a well-stated argument.	Intuitive: Making leaps of insight, often based on incomplete patterns, hunches, feelings, or visual images.
Linear: Thinking in terms of linked ideas, one thought directly following another, often leading to a convergent conclusion.	Holistic: Seeing whole things all at once; perceiving the overall patterns and structures, often leading to divergent conclusions.

Source: Betty Edwards

Looking carefully at these lists, one does not need to know much about brain research in order to recognize that integration would be desirable in the service of full human development and functioning. Perhaps it is most reasonable to read in all this a crying out for more holistic models, for greater awareness of the whole human being as learner, and for more holistic and integrative goals and strategies for educational practice and for richer, more stimulating learning environments.

Calls for more holistic education are likely to continue and intensify over the next decade. One cannot help being impressed by the vitality of the holistic health movement which has arisen as people have begun to recognize the limits of the medical model. We suggest that the basis for a similar movement in education exists and that such a movement has already been emerging for some time.

For a variety of reasons, however, this assessment may be overoptimistic. Perhaps the most sobering sign that such thinking is likely to remain on the margins of educational thought is the persistent vitality and wide-spread acceptance of the back-to-basics movement. Nevertheless, we regard much of the interest in the left/right brain model as reflecting the continuing emergence of the value of holism since the middle 1960's (with the rise of the ecology movement more generally and the affective movement in education). This continuing emergence is likely to have an even more powerful impact on educational practice than the brain research be associated with it.

V. APPENDIX

Abstract of Key Articles
Describing Research in
the Brain Sciences

Included in this section of the notebook are several articles which, taken together, provide a good overview of neurophysiology and its relation to learning and education.

The first article

> Timothy J. Teylor, "An Introduction to the Neurosciences" from M.C. Wittrock et al. The Human Brain, Prentice Hall, 1977, pp. 3-37

provides an illustrated introduction to the anatomy, chemistry, and physiology of the brain. He emphasizes the brain's structures and functions, including arousal, motivation, learning and memory, in a manner that is accessible to non-experts and relevant to the interests of educators.

The second article is by

> Merlin C. Wittrock, "Learning and the Brain", from M.C. Wittrock, editor, The Brain and Psychology, Academic Press, 1980, pp. 371-403.

Wittrock is an educational and cognitive psychologist whose primary interests are in cognitive processes of learning and memory, and in the relation between these and brain functioning. His work is notable for its inclusiveness and even-handed treatment of a wide variety of relevant research.

The article by

> Marcel Kinsbourne and Merrill Hiscock, "Cerebral Lateralization and Cognitive Development", from Jeanne S. Chall and Allen F. Mirsky, Education and the Brain, University of Chicago Press, 1978, pp. 169-222

provides an excellent and comprehensive review and evaluation of the literature of left/right lateralization as it relates to cognitive functioning and learning disabilities. It is a careful analysis which points out many of the contradictions and competing hypotheses in the research.

The fourth article

> Susan Leigh Star, "Sex Differences and the Dichotomization of the Brain: Methods, Limits, and Problems in Resarch on Consciousness" from Ruth Hubbard and Marian Lowe, editors, Genes and Gender II: Pitfalls in Research on Sex and Gender, N.Y., Gordian Press, 1979, pp. 113-130

has been referred to extensively in our section on sex differences in left/right brain research. Her whole article bears reading not only as a careful and articulate feminist critique of research and hypotheses, but also as a picture of the important relationship beween the hypotheses and cultural stereotypes, a relationship which is mostly overlooked in other literature.

The article by

> Rita G. Rudel, "Neuroplasticity: Implications for Development and Education", from J. Chall and A. Mirsky, Education and the Brain, University of Chicago Press, 1978, pp. 269-307

is included because the concept of brain plasticity is at least as important as that of lateralization and probably more so in relation to learning disabilities related to brain damage and dysfunction--which, in turn, are areas of educational practice to which neurophysiological research may make its foremost contributions.

The final article is by

> Jeanne S. Chall and Allan F. Mirsky,
> "The Implications for Education", from
> Education and the Brain (same authors),
> University of Chicago Press, 1977, pp. 371-378

and is included because it briefly and usefully summaries the conclusions from their edited book, which was the seventy-seventh yearbook of the national society for the study of education. It is cited by many as the book on the brain most relevant to educators.

It is followed by a Glossary of relevant terms prepared by

> Kenneth J. Talbot, from M.C. Wittrock, et al.
> The Human Brain, Prentice Hall, 1977, pp. 185-207.