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ABSTRACT

The document looks at left/right brain research as it relates to learning styles and teaching styles, particularly in special education. An initial section on brain basics covers the history of brain research, methods of investigation, cerebral dominance, divisions of labor of the bifunctional brain, language and related functions, bilingualism, learning styles, traditional education and the single brain, and emotions and the brain. A second section considers the need to integrate both convergent left-hemisphere modes in learning experiences. Another section examines determinants of neurologically based learning styles including the impact of age, sex, and handedness on left or right brain learning style preference. The effects of relaxation and diet upon brain functioning is the topic of the fourth section. The fifth section discusses findings relative to the study of learning disabilities, mental health, and creativity. Methods for educational assessment of learning styles are reviewed, such as the Structure of Intellect Learning Abilities Test and the Wechsler Intelligence Scale for Children-Revised. Steps toward dealing with the whole child in the educational system should incorporate consideration of teachers' verbal and nonverbally expressed attitudes, relaxation strategies, general strategies which more fully involve the brain in learning, and curricular strategies which promote integrated processing of information. Following a summary and a list of implications for education are appendixes which contain 35 activities to stimulate integrated/right brain processes and a brief report on the deprivation of estimates for national prevalence of right brain children. (SW)

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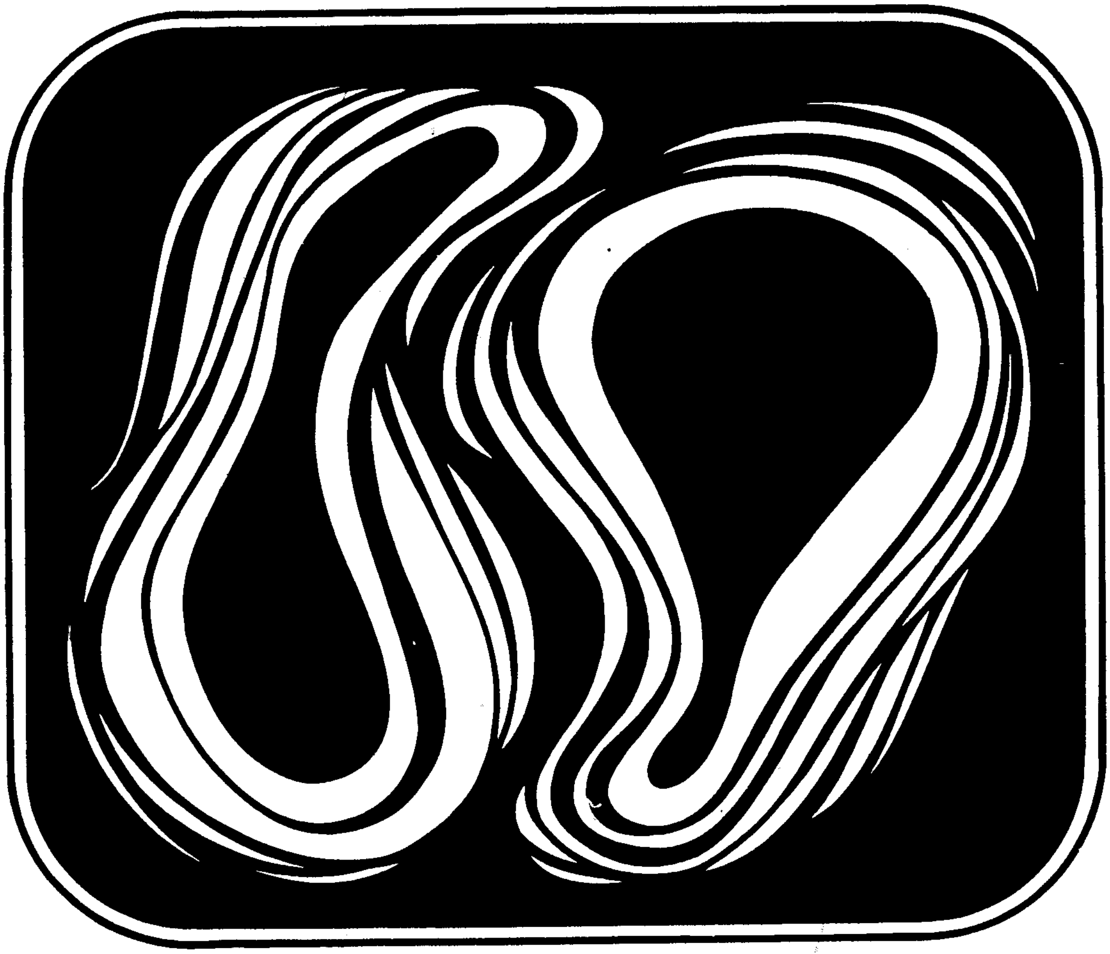
Educating the Other Half: Implications of Left/Right Brain Research

Ronald L. Rubenzer



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INTRODUCTION

How well can the brain understand itself? This question may prove to be the most intriguing, challenging, and critical query ever raised. The degree to which we can answer this question may determine the limit of our evolution as a species, for the key to our destiny lies in our understanding of the creative functions and aberrant dysfunctions of the brain. The highly prestigious Nobel Prize for Medicine (1981) was awarded to Roger Sperry, David Hubel, and Torsten Wiesel for their significant and innovative contributions to the field of brain research (Facts on File, 1981). The award emphatically highlighted the timely significance of unravelling the intricate mysteries of the brain.

The primary educational rationale for studying the relationship between brain structure/functions and human behavior stems from the potentially significant contributions of brain research to the fields of education in general and special education in particular. Useful and even predictive models of cognitive and affective functioning and dysfunctioning could be constructed with unparalleled precision by studying the neurological basis for these mental processes.

Traditionally, psychoeducational theories have been built upon the results of paper/pencil tests. Test performance is typically influenced to varying degrees by such factors as: a) the accuracy and consistency of the test measures, b) the level of expertise of the examiner, and c) the characteristics of the examinee (e.g., stress level, attitude, fatigue, cultural, and educational experiences). By measuring the brain's activity during intellectual/emotional performance, the influence of the aforementioned factors could be accurately accounted for or even circumvented, leading to great advances in the understanding of the brain mechanisms involved in learning abilities/disabilities, behavioral disorders, creative genius, and other important mental processes. Through brain studies, an unprecedentedly clear picture of the biological bases for intellectual and emotional functions will be obtained, establishing a strong research foundation for the development of highly effective psychometric, pedagogical, and remediational techniques.

A secondary, yet more immediate, justification for turning our attention to left/right brain research is the need to close the gap that exists between predominantly left brain teaching strategies and right brain learning styles that exist in education today. Based on what is currently known about brain dominance as related to various individual characteristics (age, sex, handedness, learning/behavioral abilities/disabilities, bilingualism), it can be conservatively estimated that nationally there are between two million and three million students in grades K-12 who are predominantly right brain in their learning style. (The derivation of these estimates appears in the Appendix.) In every regular education classroom there are probably at least two students who are right brain dominant in their approach to understanding and mastering information. Students who are creatively talented in visual and performing arts, as well as those who are learning or behaviorally handicapped, would be included in this sizable minority.

Since the teaching profession selectively favors individuals who are successful in left brain thinking and teaching, a disharmony between left brain teaching methods and right brain learning styles assuredly exists on a national level. Right brain children in our left brain educational system undoubtedly experience frustration in the classroom. "Turned off" by their inability to learn comfortably and/or be understood by left brain oriented teachers, they may eventually join the ever-enlarging pool of dropouts or enter the ranks of "student burnouts." The loss of potential personal and societal contributions of these millions of children may be more than our nation can tolerate. Sensitive to the discordance between traditional left brain teaching methods and right brain learning styles of many children, the Japanese school system at the preschool to fourth grade level is systematically and concertedly developing right brain thinking abilities using the Structure of Intellect approach (Meeker, 1981).

A further educational contribution of left/right brain research will be the identification of new teaching methods that are particularly effective in enhancing creative thinking in all students. Research indicates that right brain processing plays an indispensable role in creative thinking (Gowan, 1972) and that the "creative mode" can be greatly facilitated through inducing deep levels of relaxation (Green, Green, & Walters, 1970). Teaching relaxation in the classroom setting may indeed powerfully augment the teacher's skill in nurturing—and even stimulating—the creative process in every student.

Teaching strategies that do not address both left and right brains will contribute to lopsided development of individuals. It is common knowledge that we are tapping only the tip of the brain's "potential iceberg." Furthermore, in order to equip the future citizens of the 21st century with the skills to creatively use the vast information storage, retrieval, and manipulation capacities (all left brain processes) of the computer, it is imperative that educators today understand and cultivate right brain creative processing skills so that these students will be able to maximally exploit the computer's left brain potential. Our future depends not so much on how much information we have but how creatively we can put that information to use. Brain studies may well provide answers that will allow us to more fully cultivate and further develop our mental capacities to the benefit of society and perhaps even all mankind.

BRAIN BASICS

The human brain, composed of about 10 billion cells, is divided nearly equally between the left and the right hemispheres, which are interconnected by a neural bridge (corpus collasum) (Lightman, 1982). Generally, most of the information processed by the left hemisphere is received from the right sensory field and, respectively, information processed by the right hemisphere is received from the left sensory field. It grows at a phenomenal rate of a quarter million cells per minute during prenatal development (Cowan, 1979) and weighs about 50 ounces at maturity. Ounce per ounce the brain requires 10 times more oxygen than any other bodily organ (Kety, 1979), produces its own painkillers (enkephalins), and even generates about 12 watts of electrical power (Iversen, 1979). We more thoroughly understand the dynamics of electricity than the intricacies of the mind. The brain represents the most mysteriously complex living organ on earth.

History of Brain Research

Although the relationship between damage to the left side of the head and resultant language impairment was noted several thousand years ago by the Egyptians (Pribram, 1977), the first clearly documented account of the idea of hemispheric specialization of function was attributed to Goethe in 1796 in his description of the association between lesions in the left hemisphere and the inability to speak. Marc Dax is credited with presenting the first formal theory of localization of speech in the left hemisphere in 1811 (Goodglass & Quadfasel, 1954), followed by Broca in 1865 (Eccles, 1973), who also forwarded a theory of specialization of the left hemisphere for speech. In 1866, Jackson performed the first medical investigation to determine the relationship between brain lesions and aphasia (Hinsie & Campbell, 1960). Roger Sperry's most significant "split brain" experiments in the 1950's marked an upsurge in hemisphericity research that has continued to grow over the last three decades. Sperry's studies (1974a) revealed that when the neural bridge (corpus collasum), physically connecting and relaying neural signals between the two hemispheres, was cut (to reduce seizure activity in epileptic patients), the left and right brains functioned nearly independently in receiving and controlling various types of stimuli. Stimuli received from the body's right sensory/motor fields were processed and controlled by the left side of the brain, while the right side of the brain processed the information and controlled the responses of the left sensory/motor fields. Further research indicated that hemispheric processing preferences varied according to the types of information received (verbal, spatial, etc.) and the cognitive style demands of the task (convergent, divergent, etc.). Evidence concerning specific involvement in cognitive/affective functioning has been collected for over a century.

Methods of Investigation

It is beyond the scope of this paper to review the specific methods used to study the brain. Suffice it to say that prior to the mid-1960's, most brain studies employed medically intrusive techniques (i.e., post mortem examination of lesions, observations of stroke, split brain, lobotomy, lobectomy, and hemispherectonomy patients). Since the 1970's, however, much more reliance has been placed on brain measurement techniques that neither alter the structure nor function of the brain itself. Among these procedures are specialized listening (Kimura, 1967) and visual tasks (Williams, 1976). The electroencephalogram (EEG), which is the recording of changes in electrophysiological patterns of the brain during particular activities, is becoming increasingly popular as a research tool.

A promising and exquisitely precise technique now being used to assess brain functions is the measurement of how much glucose (the brain's primary fuel source) specific parts of the brain use in comparison to other parts during selected activities. Basically, a glucose solution with a harmless radioactive trace is injected into the bloodstream. The differing rates of consumption of this radioactive solution by the left and/or right side(s) of the brain can be detected by specialized equipment and projected on a viewing screen. The result is a live picture of what regions of the brain are actually involved in specific mental/emotional or motor processes. The technique is called positron emission transaxial tomography or PETT III (Landis, 1980) and possibly represents as significant a technological advance in brain research as the development of the telescope in astronomy.

Dominance

The left hemisphere has been considered historically to be the dominant or major hemisphere because it was held that this hemisphere was primarily responsible for the processing of language and planning—the two functions that clearly distinquish man from the rest of the animal kingdom (Bronowski, 1973). Interestingly, it has been found that the left hemisphere is, in fact, anatomically larger than the right hemisphere (Geschwind, 1970). Furthermore, it has been found (Darvaj & Smyk, 1972) that the left hemisphere is predominantly more active than the right in most adults. The dominance relationship between the left and right hemispheres in daily functioning can be compared to that of the coexistence of the sun and stars. Although right brain functions are always occurring, they are dominated by left brain functions, just as the sun obscures the presence of the other stars in the sky during the day (Rubenzer & Rubenzer, 1981).

Divisions of Labor

Although anatomical differences in brain structure between individuals vary as much as facial features, generalizations concerning the divisions of labor of the bifunctional brain can be made based on extensive research findings. In order to avert the field of brain research from becoming merely a "modern phrenology," it is imperative that conclusions be drawn from scientifically reputable studies. The generalizations regarding the functional organization of the brain presented herein are based on a review of over 150 studies conducted within the last 30 years (Rubenzer, 1978). The majority of these studies dealt primarily with right-handed, English-speaking adults; therefore, all statements made will be limited to that population unless stated otherwise. Variations in brain processes for left-handed and non-English speaking individuals, children, and learning/behaviorally handicapped students will be addressed separately.

Inherent in the attempt to reduce the complex workings of the brain to orderly patterns is the tendency to perhaps artificially simplify the functional organization of the brain. Although one hemisphere may predominate in a particular task, a portion of the processing load may, in fact, be distributed to the other hemisphere, particularly in higher level mental functions (Springer & Deutsch, 1981). Therefore, a "functional spillover" relationship between the predominant and subordinate hemispheres may best reflect the brain's actual processing patterns.

Language and Related Functions

Evidence in support of the left hemisphere's involvement in verbal language processing is substantial (Basser, 1962; Brown, 1976; Cherlow & Serafetinides, 1976; Faglioni, Spinnler, & Vignolo, 1969; Fromholt, Christensen, & Stromgren, 1973; Gruzelier & Hammond, 1976; Kimura, 1967; Ornstein, 1978). As more research on hemisphericity is being conducted, it is becoming evident that the right hemisphere is not totally silent and attains about a 5-year-old language capacity (Moscovitch, 1973). Studies clearly demonstrate that the right hemisphere is capable of processing language if the discriminations are uncomplicated (e.g., a positive from a negative statement) (Butler & Glass, 1974) and if sufficient time is allowed (Bogen & Gazzaniga, 1965; Gazzaniga & Hillyard, 1971; Nebes & Sperry, 1971; Weisenberg & McBride, 1935). Moscovitch, Scullion, and Christie (1976) found that sufficient time for right hemispheric processing of "uncomplicated" discriminations was about double that required for the left hemisphere. Research also suggests that braille and sign language, both nonverbal communication systems, draw heavily on right brain processing (Kimura, 1973; Neville, 1977).

The analysis of voice intonation, an integral component of spoken language, is a right hemisphere function (Van Lanker, 1975). The primary expressive mode of the right hemisphere is believed to be metaphorical (poetry, analogies) (Eccles, 1973; Ornstein, 1972; Samples, 1975); in general, however, the verbally communicative ability of the right hemisphere is relatively limited and dependent upon the left hemisphere.

With respect to the expression of language through speech, it has been concluded that it is processed primarily in the left hemisphere

(Eccles, 1973; Nebes, 1974; Sperry, 1974a). Written communication and hemispheric involvement are not as clearly defined. Although the verbal aspect of writing is predominantly a function of the left hemisphere, the visual motor aspect of writing appears to be within the realm of the right hemisphere (Benton, 1969; Brandwein & Ornstein, 1977; Vega & Parsons, 1969); thus, a transference from left hemispheric processing to right hemispheric processing appears to be involved in writing.

The interpretation of complex visual patterns is predominantly a right hemisphere function (Compton & Bradshaw, 1975; Goyvaerts, 1975; Moscovitch et al., 1976; Schwartz, Davidson, & Pugash, 1976). Furthermore, the right hemisphere is much more adroit in the recognition of faces (Hillyard, 1973; Muller, 1973), while the left hemisphere remembers the names that go with the faces. The retention of visual patterns, such as geometric designs and graphs, belongs in the dominion of the right hemisphere (Vega & Parsons, 1969). It is argued that iconic presentation of information (e.g., graphic displays, diagrams, flow charts, etc.) greatly facilitates both the comprehension and retention of information and that this iconic memory is primarily a function of the right hemisphere (Taylor, 1978). Visual/spatial perception and reasoning, which are posited to be right hemispheric operations (Benton, 1969; Kinsbourne & Smith, 1974; Knox & Kimura, 1970; Warrington & Rabin, 1970), are the processing skills that are required in such tasks as architecture and sculpture. Without specific training in the development of visual/spatial reasoning skills, competency in these areas does not typically increase beyond the 13-year-old level (Leiter, 1976).

For most individuals, the perception and retention of complex non-verbal auditory patterns, such as music or morse code, occurs in the right hemisphere (Dumas & Morgan, 1975; Entus, 1975; Faglioni et al., 1969; Kimura, 1973; Molfese, 1973; Olson, 1977; Schwartz et al., 1976). It should be noted, however, that Bever and Chiarello (1974) reported that experienced musicians analyze musical patterns via the left hemispheric processing mode, similar to the manner in which most individuals analyze speech patterns.

Bilingualism

Preliminary research on the processing of non-English languages, interestingly enough, has pointed to important differences in how the brain processes languages. A right brain dominance language processing pattern has been found for Spanish (DeLorenzo, 1980), Hebrew (Silverberg, Bentin, Gaziel, Obler, & Albert, 1979), Hopi (Rogers, TenHouten, Kaplan, & Gardiner, 1977) and Navajo (Hynd & Scott, 1980).

The reasons for the right brain's favored processing of these languages range from the linguistic characteristics of the language (Sibatani, 1980) to the actual thought modes the languages may reflect (e.g., global, holistic) (Carroll, 1973). If indeed, as suggested by Whorf (1956), language directs an individual's perception of reality, it may be that students whose primary language is right brain processed will prefer a right brain learning style. Suffice it to say that educators should be

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sensitive to possible variations in learning style preferences among non-English speaking students. Further research will highlight the impact of bilingualism on processing/learning styles. (The reader is directed to The Bilingual Brain by Albert and Obler, 1978.)

Learning Styles

The type of thinking strategies most characteristic of the left hemisphere appear to be analytical (Brandwein & Ornstein, 1977; Salk, 1973), sequential (Gruzelier & Hammond, 1976; Luria, 1970), and logical (Kraft, 1976; Lawson, 1975; Papcun, 1974). When fine discriminations or differentiations of stimuli are required, the left hemisphere is predominantly involved (Epinas, 1975; Semmes, Weinstein, Ghent, & Teuber, 1960; Wood, Goff, & Day, 1971).

The right hemispheric cognitive styles are those skills that are indispensable for generating solutions to problems. The functions of the right hemisphere have been described as creative (Harnad, 1972; Tart, 1972), and divergent (Kinsbourne & Smith, 1974; Perrone & Pulvino, 1977; Samples, 1975; Williams, 1976). The ability to obtain a global view or a "gestalt" of a situation or task also appears to be a primarily right hemisphere capacity (Dimond & Beaumont, 1974; Papcun, 1974).

The right brain demands immediate results or closure on tasks, while the left brain is willing to wait for planned events to unfold. The right hemisphere has been described as being satisfied with "approximate knowledge" (Prince, 1976) and is more diffuse and less clearly demarcated in its cognitive style than the left hemisphere (Semmes et al., 1960). When aesthetic judgment is required in a task, the right hemispheric processing mode is hypothesized to be prevalent according to the findings of Hadamard (1945) and Hebb (1966).

Traditional Education and the Single Brain

The role of the left hemisphere in education with respect to the traditional Basic Skills or "3 R's" is well documented. Reading is considered to be principally a left hemisphere function (Newton, 1975; Sperry, 1974a). As previously mentioned, writing appears to require cooperation from both hemispheres. Mathematical functions, particularly calculation, (Day, 1964; Dumas, 1975; Olson, 1977) and algebra, are left hemisphere operations. Learning to use the computer, which is considered by some to be the fourth basic skill (Droegemueller, 1982), relies heavily on a sequential, orderly, analytical style of thinking. Hence, computer skills, particularly the programming aspect, appear to be predominantly left brain oriented.

The subjects that are processed predominantly by the right hemisphere are art, dance, music, and physical education (Samples, 1975). Geometry, which is primarily iconic (graphic) in its format, is also attributed to right hemispheric processing (Taylor, 1978).

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Emotions and the Brain

It has been found that positive emotions are present when the left hemisphere is processing information that is orderly and consistent (Dimond, Farrington, & Johnson, 1976). Emotional irritation is the result of the left hemisphere's processing of information that is contradictory or inconsistent (Hadamard, 1945; Hebb, 1966).

The right hemisphere plays a predominant role in the affective domain and is generally involved in aesthetic judgment. When the information being processed is perceived as aesthetically harmonious, the accompanying affective state is pleasurable and positive. The "affectively uneducated" right hemisphere tends to be negative in its emotional outlook (Cacioppo & Petty, 1980).

The shift from the negative emotional perspective of the right brain to the positive outlook of the left brain is commonly experienced upon awakening. The right brain is dominant in the state between sleeping and waking (Deikman, 1971) and as the left brain comes more into focus, alertness increases. (See Table 1 for a summary of functional divisions of the brain.)

COMMUNICATION BETWEEN THE HEMISPHERES

The need to integrate both convergent left-hemisphere and divergent right-hemisphere modes in learning experiences is well supported by research. A study conducted by Kraft (1976) or 6- to 8-year-olds engaged in selected "Piagetian" tasks showed that those children who were using both hemispheres (as indicated by the EEG reading) throughout all tasks performed better on both nonverbal (right hemisphere) and verbal (left hemisphere) activities. In other words, when the relatively nonverbal right hemisphere was used in processing the verbal task in concert with the left hemisphere, performance on this task was better than for those who used only their left hemisphere on verbal tasks.

Stimulation of right hemisphere processing also increases measured intelligence. Rennels (1976) found that 60% of the abilities IQ tests are reported to measure were found to involve right hemisphere processes. Short term memory which is primarily within the realm of the left hemisphere (DeRenzi & Nichelli, 1975) is significantly decreased when communication between the hemispheres is impaired (Zaidel & Sperry, 1973). A major study by Noller and Parnes (1972) found that the divergent production scores on the Structure of Intellect (SOI) test significantly increased as the result of creativity training. Such training procedures provided opportunities for individuals to shift back and forth from left-hemisphere to right-hemisphere processing (integrated) depending upon the task demands. It was discovered that left brain (convergent) task performance on the SOI also improved significantly by creativity (integrated)

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TABLE 1

BRAIN FUNCTION MATRIX

FUNCTIONS	Predominant Brain Processing Mode LEFT	 INTEGRATED OR ALTERNATING	 RIGHT
General	Facts	Intuition	Feelings
Thinking Styles	Verbal Orderly Temporal Convergent	Problem Finding/Solving	Spatial Random Simultaneous Creative
Emotions	Positive	Well-adjusted	Negative
Education	Reading Writing Arithmetic Computer Programming	Singing Poetry Geometry Computer Graphics	Music Art (Logos) Tangrams Computer Videogames

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training. These findings suggest interdependency between the hemispheres for optimal cognitive functioning.

Even if the only goal of education were the lopsided development of traditional left brain skills (giving "correct" answers, scoring well on IQ tests), it would behoove educators to stimulate both left and right brain skills. It goes without saying, however, that the ultimate of education must be the cultivation of creative functioning that encompasses the highest levels of convergent (left brain) and divergent (right brain) thinking (DeBono, 1967). Norman (1977), through examination of brain activation patterns of over 8,000 individuals, emphatically concluded that "insights on problems represented a higher level of organization of the brain" (p. 13). In Survival of the Wisest (1973), Jonas Salk stressed the importance of the synthesis of the rational/logical (left hemisphere) and intuitive/metaphoric (right hemisphere) processing modes in major scientific breakthroughs. Although the alternating or synchronous use of both left and right hemispheres is atypical (Gazzaniga & Hillyard, 1971), the coordination of both hemispheres can be enhanced through various curricular activities (Ornstein, 1978; Samples, 1975).

It is important that the effort to stimulate both hemispheres is initiated in the early grades. Studies of brain growth reveal that cortical structures that are critical to the ability of the hemispheres to communicate are not mature until about age 8 (Denckla, 1974; O'Leary, 1980; Yakovlev, 1962). The two hemispheres do not work cooperatively on tasks until about the third grade, and information learned by one hemisphere is not necessarily shared with the other. Attention must be directed toward both hemispheres so that functional, cooperative dialogues will occur between the two brains. By only stimulating left brain processes, a competitive antagonistic relationship with the right brain may result because of the overdevelopment of left brain skills. The antagonistic relationship between the two hemispheres is intensified as the child progresses through school. This phenomenon is amply supported by the fact that a student's measured creativity (right brain function) actually decreases as the child proceeds through the educational system (Torrance, 1968). The reduction in creative thinking abilities can be effectively counteracted by providing and encouraging right brain processes.

DETERMINANTS OF NEUROLOGICALLY BASED LEARNING STYLES

The Impact of Age, Sex, and Handedness on Left or Right Brain Learning Style Preference

Age. The development of the brain is initially marked by very rapid growth. It doubles in weight within 6 months after birth and attains half its adult weight at 9 months. By age 2, the brain has tripled its birth weight of about 12 ounces (335 grams) (Smith, 1968), achieving

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nearly three quarters of the maximum adult weight (50 ounces). This pace of the brain's physiological development during the infant years is closely paralleled somewhat later by rapid psychological growth. By age 4, a child has achieved the majority of his/her adult intelligence (Bloom, 1964). It is crucial that appropriate amounts and types of stimulation, as well as sound nutrition, be provided during the early infant through preschool years since many of the brain's physiological and the child's psychological milestones are reached by age 4. A need clearly exists to conduct extensive brain research in the assessment, stimulation, and enhancement of cognitive/affective and perceptual/motor development for the early infancy through preschool stages. (The reader is referred to Your Baby and Child from Birth to Age Five (Leach, 1978).)

The brain continues in its maturation without interruption until about age 12. At this point, brain growth slows down considerably, and Epstein and Toepfer (1978) suggest that it is pedagogically more sound to concentrate on improving previously acquired skills than to introduce skills or concepts. Previously, it was held that brain growth continued only until the late teens; however, it has been found that the brain does not reach maximum weight until about age 30 (Smith, 1968), and the neurological structure responsible for an integrated (left and right brain) perception of information is not fully developed until age 40 (Westby, 1980). Although brain growth continues into the 60's, those parts of the brain related to memory functions do experience deterioration in the mid to late fifties, according to Weintraub (cited in Mazer, 1982). By 90 years of age, the brain's weight decreases to approximately 80% of its maximum weight (Smith, 1968). Advances in medical research have made great strides in effectively countering the effects of aging on the physiology and functions of the brain, particularly with respect to memory (Wurtman, 1982).

Although the left hemisphere is preferred in processing phonetic discriminations (a language function) at birth (Eimas, Siqueland, Jusczyk, & Vigorito, 1971; Entus, 1975; Molfese, Freeman, & Palermo, 1975), left hemisphere dominance for language is not clearly established until age 5 (Klein, 1980). There is considerable plasticity between hemispheres for processing before 5 years of age (Calearo, 1975; Harris, 1975; Pincus & Tucker, 1974). The interchangeability of function between hemispheres is supported by the observation that if a child experiences brain damage to the left hemisphere before 5 years of age, language function is often successfully shifted to the right hemisphere; after the age of 5, the older the individual is when damage to the left hemisphere occurs, the greater the degree and duration of the loss of language function (Pincus & Tucker, 1974).

As the brain matures, so do a person's interests and abilities. Children have a typically right brain orientation toward life as shown by their preference for magical, musical, large motor, and playful activities. Interests in reading adventure and science fiction stories, which reflect left (reading) and right (emotions) brain processes, emerge with the maturation of the brain structures coordinating communication between the left and right brains at about 8 years of age. After 10 years of age, the student's gender has considerable impact on the brain's development and resultant cognitive style(s). These diverging sex-linked brain developmental and functional patterns are discussed in the following section.

Close attention must be given to the rapid changes in cognitive abilities and learning styles that occur as the child matures, particularly during the infancy through preschool period. Greater research efforts need to be directed toward early cognitive/affective development as a majority of the brain's physical growth in weight and the child's intellectual abilities have been acquired by age 4. Scientific breakthroughs on the effects of aging on the brain may well provide important keys to improving and even prolonging the brain's neurological efficiency with a concomitant increase in the mind's ability to function more effectively.

Sex. In general, it has been found that females exhibit a greater preference for processing both verbal and spatial information in the left brain in comparison to males (Harris, 1975; Kimura, 1973). According to Hier (1979) and Levy (cited in Durden-Smith, 1980), females tend to utilize the left brain more than the right brain in processing information, whereas the opposite is true for males. Females' tendency for a left-hemisphere learning style is a distinct advantage in a left brain oriented education system. The result of this favorable interaction between left brain teaching and learning styles is revealed by the fact that females usually score higher on both IQ and achievement tests and obtain better grades in school than their male grade peers. The fact that males outperform females on spatial reasoning tasks lends strong support to a right brain preference for information processing for males in comparison to females (Restak, 1979b).

The difference between males and females in brain growth patterns becomes most distinct during the middle-school years. From about 11 to 12 years of age, females experience a rate of brain growth which is triple that for males during this period. At about 12 years of age, there is almost a brain growth "moratorium" for both sexes. Then between the ages of 14 and 15, male brain growth rate surpasses female brain growth by 3 to 1 (Epstein & Toepfer, 1978).

By way of summary, females tend to establish definite brain preference for language (lateralize) about 2 to 3 years earlier than their male grade peers and are more likely to be left brain lateralized in their learning styles than males. These marked sex differences in brain growth patterns point to a critical need to utilize both left and right brain oriented approaches to teaching, particularly in the middle-school levels. Indeed, middle school represents the period of greatest contrasts between the sexes in terms of rate of brain development.

It appears that a student's learning style, based on the lateralization of the brain, would be fairly well established by the time high school begins. Since research indicates that neurologically based learning styles are quite resistant to change (Restak, 1979b), it is our responsibility as educators to teach with the student's learning style in mind. Equally important is the need to aid the student in knowing the strengths and weaknesses of his/her particular style and how to best use this preference.

Handedness. A left hand preference for tasks is related to cortical language processing patterns that differ from the typical left brain language processing pattern. Goodglass and Quadfasel (1954) found that out of 123 left-handed individuals about half used their right brains for language processing, whereas the other half exhibited the typical left brain dominance pattern for language. Levy (1969), however, contends that language is processed by both hemispheres simultaneously for some left-handed individuals. The above two studies represent the controversy over language processing for left-handed individuals (Corballis, 1980). However, research indicates that left-handed individuals will probably tend to have different learning styles (favoring either the right or both hemispheres) than their right-handed schoolmates. Since at least 10% (Coren & Porac, 1977) of the K-12 grade population (representing about four million students nationally) or about 3 students per classroom are left handed, attention toward these students' learning styles is needed.

Since each student's neurologically based learning style depends on the unique interaction of that individual's age, sex, and handedness, variations in optimal learning styles will undoubtedly occur within the classroom. As most teachers are successful with a left brain learning style (verbal, sequential) and therefore may assume that a left brain teaching style is the most effective, educators must be sensitive to the wide variations in learning styles in their classrooms. Middle school is a particularly critical time to be aware of individual differences in learning styles, for the age and sex of the student interact most powerfully in determining his/her predominant and perhaps lifelong learning preference.

THE EFFECTS OF RELAXATION AND DIET UPON BRAIN FUNCTIONING

Relaxation. The negative relationship between anxiety and performance on cognitive tasks is substantially documented (Schuchman, 1977). The unpleasant and debilitating effects of math anxiety (Tobias, 1978), computer phobia, or test anxiety (Sarason, Hill, & Zimbardo, 1964) are experienced by almost all individuals at one time or another. Since mathematics, computer programming, and test taking require high levels of neurological organization (Norman, 1977), it appears that interferingly intense anxiety levels contribute to the temporary disorganization of the brain's smooth functioning as evidenced by suppressed performance on these tasks during periods of high stress (Schuchman, 1977).

The cognitive style used during a test or math anxiety task, characterized by guessing, the inability to retrieve previously learned verbal material, and reversals in sequence, all reflect a predominantly right brain problem-solving approach that is oriented toward satisfaction with approximate knowledge (Prince, 1976), is nonverbal (Nebes & Sperry, 1971), and random (Semmes et al., 1960). It is a common experience that under stress, recall of verbal information is reduced to simple, familiar terms or phrases, which also reflect right brain processing.

It is the author's contention that access to the left brain's verbal, orderly cognitive processes is denied during stress reactions because one is virtually locked into a right brain mode that is readying the individual for "fight or flight" rather than higher level cognitive functioning. Just as it is most difficult to dream on command (right brain function) while in a left brain dominant state, similarly, when the right brain is dominant, as in a stress reaction, it is difficult to respond in a highly verbal and orderly fashion (left brain function). Experiencing a mental block from test anxiety may well represent a right brain response to a left brain situation that can lead to future avoidance of testing situations. Numerous test anxiety studies have found that inappropriate anxiety responses can be successfully reduced through relaxation training and that improvement on traditional cognitive and creativity tasks results (McManus, 1971; O'Dell, 1981). Relaxation training should be taught as a "meta-skill" (Tannenbaum, 1977) to enhance the student's performance within the classroom.

Diet. The functional efficiency and even the very structure of the brain are influenced by our diets (Fernstrom & Wurtman, 1974). Wurtman (1982), a research nutritionist at the Massachusetts Institute of Technology, has clearly demonstrated that both intellectual and emotional functioning can be enhanced through the intake of choline (found in lecithin) and tyrosine (present in amino acids). Both these nutrients amplify the neural impulse within the brain and improve the brain's physiological efficiency and hence cognitive/affective functioning.

Choline, which is commonly found in liver, soybeans, and egg yolks, is a component of lecithin. High dosages of lecithin have been found to be effective in improving recall ability of individuals with memory impairments (Corkin, Davis, Growdon, Usdin, & Wurtman, 1981). A study sponsored by the National Institute of Mental Health revealed significant memory increases in normal adults as the result of a daily 10-gram intake of choline (Mazer, 1982). Tryosine, a nutrient which is abundant in carbohydrate-rich foods, has been found to have a definite antidepressant effect in chronically depressive individuals (Wurtman, 1982). Vitamin B_6, which is believed to also increase the transmission rate of neural signals within the brain, has been found to be effective in improving memory (Davis, 1970). Brenner (1982) has found that administration of niacin or combinations of B-complex vitamins with minerals successfully reduced hyperactive behavior in some children. Indeed "food(s) for thought" may

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soon be a prescription to enhance cognitive and emotional functioning rather than a mere figure of speech. Research on the effects of choline (lecithin), tyrosine, niacin, and vitamin B on improving the functions of the brain clearly points to the need to take a closer look at dietary habits and to consider the importance of a nutritionally balanced diet for students. Although the role of vitamins in the occurrence and control of brain functions remains unclear at this time (American Psychiatric Association, 1973; Deliz, 1973), further investigation will reveal the degree to which vitamins and minerals can be employed in lessening the effects of or even preventing the occurrence of cognitive/behavioral disorders.

LEARNING DISABILITIES, MENTAL HEALTH, CREATIVITY: RELATED BRAIN RESEARCH

Through the scientific investigation of the fundamental brain processes that underlie learning, creativity, and emotional functioning/dysfunctioning, great advances will be made in the assessment and remediation of learning/emotional disabilities and the maximization of creative potential. A discussion of representative findings relative to the study of learning disabilities, mental health, and creativity follows.

Learning Disabilities

The learning disabled child is often likely to be an example of a right-brained child in a left-brained educational system. Research on learning disabled students consistently reveals a high prevalence of right brain information processing styles (Gordon & Harness, 1977; Hunter & Johnson, 1971; Philips, 1980; Symmes & Rappaport, 1972; Stanley, Kaplan, & Poole, 1975). The characteristic processing difficulties encountered by the learning disabled child, such as language and sequencing disorders (reading/writing difficulties, letter reversals, inversions), are indicative of the right brain's nonverbal random information processing style.

In further support of a right brain dominant processing approach for the learning disabled child, it has been found that the proportion of left-handed students in the learning disabled population is about triple the expected frequency. Learning disabled males outnumber learning disabled females by a four to one ratio (Kline & Kline, 1975). As noted earlier, left-handed individuals and males both tend to use right brain learning styles.

It would appear that learning disabled children would benefit from a more right brain teaching style in the classroom. Remediational strategies for the learning disabled do rely heavily on visual/spatial, tactile teaching strategies that are predominantly right brain in their orientation (Blau & Sinatra, 1981; Fadely & Hosler, 1979).

Mental Health

A growing number of psychiatrists are of the opinion that the primary cause for chronic mental illness (schizophrenia, manic depressive disorders) is the interference with the normal neurotransmission of signals within the brain (Wurtman, 1982). Furthermore, Kety (1979) contends that there is a definite organic, genetically based component to schizophrenic and manic depressive disorders. In controlled studies, it was found that the rate of schizophrenic and manic depressive disorders was 5 times greater among identical twins than fraternal twins.

Innovative research at Brookhaven National Laboratory by Wolfe and Farkas (cited in Landis, 1980) using the PETT III scanning procedure (described earlier) has clearly identified salient abnormalities in blood flow patterns in the brain as related to schizophrenic and manic depressive disorders. PETT III scans of schizophrenic patients pointed to pronounced circulation deficits in the frontal lobe area of the brain (the frontal lobe area is responsible for planned and controlled behavior) (Luria, 1970). That is, the activity of the frontal lobes of the brain was significantly depressed in clinically diagnosed schizophrenic patients. Wolfe's and Farkas' research also indicated that unusual overactivity was present in the right brain of manic depressives during the manic phases.

Other researchers, applying more traditional diagnostic strategies, have found that hyperactive children exhibit a high incidence of frontal lobe dysfunction (Barkley, 1981). Right brain dominance has also been discovered to be related to autism (Blackstock, 1978; Colby & Parkinson, 1977). The finding that individuals suffering from mental health disorders often exhibit right brain dominant patterns lends further support to the contention that the right brain is negative in its emotional perspective (Rossi & Rosadini, 1967).

The suicide rate among children between the ages of 10 and 13 has increased by 170% over the last decade (Elkind, 1981). This fact, in itself, strongly points to the need to provide more attention to affective education (a right brain function) within the schools. Gowan (1980) has stated that a predominant cause of mental illness stems from the discrepancy between the developmental levels of the left and right brains. A study by Crinella, Beck, and Robinson (1971) demonstrated that failure to stimulate both hemispheres during early childhood may be a causal factor in behavioral and emotional difficulties. Education would be seriously remiss if it did not enhance a facilitative and positive dialogue between the left and right hemispheres.

To summarize, definite relationships between atypical functional properties of brain and mental illness are being revealed by left/right brain research. Limited research has indicated that a right brain dominance pattern is prevalent among individuals exhibiting manic and

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autistic behaviors. The "uneducated" right brain is considered to predominate in negative emotional activity. The recent, great increase in emotional health problems among our youth highlights the importance of affective (right brain) education in our schools. A dialogue between the left and right brain functions must be facilitated if the trend toward increasing mental health problems among our youth is to be counteracted.

Creativity

In 1965, Jerome Bruner indicated that the right hemisphere is more creative than the left. The weight of evidence since that time has most definitely supported Bruner's initial assertion (Brandwein & Ornstein, 1977; Tart, 1972). More important than the physical localization of the creative function in the brain are the specific processing patterns which contribute to outstanding creative production.

Pioneering research (Green et al, 1970) conducted at the Menninger Foundation has shown that highly creative individuals exhibit distinguishingly unique cerebral processing patterns. Their research indicated that the EEG brain wave patterns of innovative scientists reflect a marked downshift in the level of cortical arousal during the creative state. When the scientists in the study entered a creative state (rich with fluency of ideas and images), their brain wave patterns were typified by a very low frequency EEG reading, called the theta pattern. While in a theta state, individuals report a feeling of drowsiness that is often accompanied by dreamlike images and reverie. The theta state is usually experienced during the period between waking and sleeping and occurs only about 5% of the time for most individuals (Green et al., 1970). It is during this hazy transitional state between dreaming and waking that insight-reverie states most often occur (Budzynski, Stoyva, & Adler, 1970; Green et al., 1970; Norman, 1977).

Walkup (1965) has suggested that eminently creative individuals have somehow learned to bring about this relatively rare reverie or insight state at will. Green et al. (1970) have stated that "there are hundreds of anecdotes which show beyond doubt, that in some way, not perfectly understood, reverie and creativity are associated" (p. 18). It has beer reported that Thomas Edison experienced some of his greatest insights upon waking from "catnaps."

It is not possible to directly and consciously elicit a shift from the normal, everyday level of awareness, characterized by the beta EEG pattern (Deikman, 1971; Salamon & Post, 1965), to the theta or insight-reverie state. Research does demonstrate, however, that the activity pattern of the brain can be greatly modified indirectly. Insight and reverie states can be brought about through obtaining very deep levels of muscle relaxation or by concentrating on particularly relaxing thoughts (Budzynski et al., 1970; Green et al., 1970; Honorton, Davidson, & Bindler, 1972; Kamiya, 1969; Schwartz et al., 1976). It can be stated confidently that relaxation is an indispensable catalyst in the creative process. In fact, research on the relationship between relaxation and enhancement of brain activation states conducive to the creative process may well identify "creativity/relaxation profiles." Just as the writing, artistic, or athletic styles of eminently talented individuals are emulated by aspiring novices, perhaps the "creativity/relaxation profiles" experienced by prominent writers, artists, and athletes could be identified and practiced. By cultivating through relaxation, the physical/affective states that nurture reverie, ideational fluency, and visual imagery, the yield of truly innovative ideas emerging from the creative process could be greatly increased.

Systematic relaxation training could be practiced by students to more readily and actively bring about a creative "frame of mind" rather than waiting for this rare (theta) state to occur. In a well-designed study, O'Dell (1981) found that relaxation strategies could be effectively taught in the classroom setting, and that performance on both verbal and nonverbal creativity measures was significantly improved after systematic relaxation training. Similarly a study by Hershey and Kearns (1979) demonstrated that relaxation training enhanced performance on creative writing tasks. Much research is being conducted on the specific effects of relaxation on the brain's creative processing of information (Honorton et al., 1972; Schwartz et al., 1976).

The term "visionary," often used in reference to outstandingly innovative thinkers, emphasizes the crucial role of right brain visualization processes in creativity. Einstein at age 14 queried, "What would the world look like if I rode on a beam of light?" (Bronowski, 1973, p. 274). Kekule discovered the ringlike Benzene structure when, in a dreamlike state, he saw a snake biting its tail (McKellar & Simpson, 1954). There are numerous similar accounts throughout history that powerfully attest to the importance of cultivating the right brain's ability to visually depict (mentally and/or graphically) a problem to be solved or a desired end product. Common phrases such as "a picture is worth a thousand words" or to "see the light" point to the well-recognized role of right brain visualization in comprehending concepts or obtaining insights. The visual image appears to be a major communication medium of the right brain; therefore, if the essence of a problem can be reduced to visual form, (pictures, diagrams, etc.), the tremendous creative capacities of the right brain can be more fully utilized in problem solving.

In summary, Green, Green, and Walters' research (1970) on the qualitative shifts in the brain's activity level during highly creative states represents a most significant contribution to the study of creativity. By relating the brain's "creative" processing of information to levels of physical relaxation, their research addresses the physical/affective aspects of the creative process. This work complements the previous, more cognitively oriented, studies of the creative process (Wallas, 1926).

Current research emphasizes the indispensibly important role that relaxation plays in creativity (Budzynski et al., 1970) and that relaxation can be taught effectively in the classroom (O'Dell, 1981). As the result of future left/right brain studies, "creativity/relaxation profiles" may be identified and specifically applied to existing models of the creative process (Rubenzer, 1979). The use of the right brain's visualization abilities has been found to be a hallmark of eminently creative individuals throughout history. Thomas Edison's famous equation for the inventive process—"99% perspiration and 1% inspiration"—may someday be changed to 98% perspiration and 2% inspiration as a result of creativity/relaxation and visualization training. The doubling of our "inspirational" production could well result in unforeseen solutions to the many enigmatic problems mankind is faced with today.

EDUCATIONAL ASSESSMENT OF LEARNING STYLES

A direct way of determining a student's neurologically based learning style within the context of the classroom is through the application of a diagnostic teaching approach. Simply stated, select or develop teaching approaches that reflect left brain, integrated, and right brain, information processing, styles. See Table 2 for examples as applied to the major subject areas. Provide students with the opportunity to learn through these different styles and observe the comfort and mastery levels displayed by the students during the application of the various approaches.

A second, albeit less direct, approach would be to ask the students what their favorite hobbies or interests are (not those imposed by peer or parental expectations). If a student's extracurricular interests center around reading, writing (diaries, stories), word puzzles/games, jokes/puns, or computer programming, then a more left brain teaching style may be effective for this student. Students who seek extracurricular activities such as art, photography, constructing models and puzzles, sports, and playing musical instruments may well learn more effectively through a right brain learning style.

A third strategy for ascertaining a student's learning style is to administer an instrument especially designed to provide a learning style profile. A paper and pencil self-report forced-choice questionnaire, developed by Torrance, Reynolds, Riegel, and Ball in 1977 appears to be a useful tool in determining learning styles. This device, entitled <u>Your Style of Learning and Thinking</u> (Form C), was developed from an extensive review of the literature on hemispheric functioning as it relates to education. The questions posed in this group-administered questionnaire seem to correspond to associations between preferred cognitive styles and predominant hemispheric processing modes. The standardization sample for this device consisted of over 1,000 subjects. This instrument is designed to be administered to high school and college students to provide

TABLE 2

A BALANCED APPROACH FOR TEACHING CONTENT

Content	Left	Integrated	Right
Arithmetic	Calculation Drills	Graph presentation of calculation results (pie graphs with different colors).	Determine number of different shapes which can be made from limited number of cubes
Science	Prepare experimental report write-ups	Develop hunches—hypotheses. generate methods of investigating hunches. Conduct actual experiment.	Build a model demonstrating procedures and dramatize results of experiment (science fair).
Language Arts	Write topical paper	Conduct "newspaper interview" with tape recorder and write human interest story with accompanying photographs.	Communicate pictorial messages in secret code relating important event(s).
Social Studies	Produce term paper on social structure of society X	Create a weekly diary relating humorous, trying experiences living in the society.	Develop artifacts of the society 50 years in the future.

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information to the student and teacher on what learning/teaching styles may be most appropriate for the student. The learning style profiles are expressed in terms of left, integrated, or right brain preferences. (Torrance, 1982a).

Through the hand scoring or computer analysis of the Structure of Intellect (SOI) Learning Abilities Test (Meeker, 1981), learning style profiles can be constructed for students from first grade to adulthood. Performance on the semantic areas of the test measure primarily left brain processing skills. The SOI test items that deal with the ability to process symbolic information require information processing capacities from both the left and right brains. A right brain processing style is assessed through the figural tasks on SOI Learning Abilities Test. The SOI Learning Abilities Test has also been effective in accurately diagnosing particular types of aphasia (a left brain dysfunction) in adults (Meeker, 1982). The SOI Learning Abilities Test is a well-validated, easily administered and scored group test useful in determining student learning styles. Other instruments are available to assess student learning style (Dunn & Dunn, 1978); however, the length limitation of this paper does not allow for a cogent discussion of these devices.

A quick approximation of a student's learning style preference can be derived from the interpretation of group achievement and aptitude test results. For example, if the student's verbal scores, which would include language usage, analogies, and arithmetical reasoning, were much higher than his/her nonverbal test scores on spatial/mechanical reasoning, figural analogies, and pattern analyses tasks (Anastasi, 1968), a left brain learning style may be indicated. It goes without saying that due to the factors that significantly affect test performance, test scores—particularly on group tests—must be interpreted cautiously and by professionals educated in the area of testing.

Undoubtedly the most accurate method of ascertaining a student's learning style in the school setting would be through the careful interpretation of individually administered diagnostic test results. Analyses of the subtest results for the Wechsler Intelligence Scale for Children-Revised (WISC-R) (Wechsler, 1974) appear to be a particularly accurate method of determining a student's learning style. The reader is referred to Kaufman's (1979) work on WISC-R pattern analyses. Test scores on most of the commonly used individual diagnostic instruments can also be translated into Structure of Intellect (SOI) terms, which provide an understandable profile of the student's strengths or weaknesses in the use of left (semantic), integrated (symbolic), or right (figural) brain learning styles.

Through diagnostic teaching, observation of the student's extracurricular interests, and interpretation of general and specialized test results, educators can determine with varying degrees of accuracy a student's learning preference. These same strategies can, of course, be applied by the educator to obtain a better understanding of his/her learning styles and where it may be necessary to augment or broaden one's teaching style to achieve a consonant, interactive teaching/learning relationship with students of differing learning styles.

TOWARD WHOLE-CHILD EDUCATION

Since we deal with the whole child in our educational system, teaching strategies that do not address accordingly the development of the whole child through education of both left and right brain are at best incomplete. Curricula that rely primarily on left brain skills quite literally represent only a "half-minded" approach to education. Devotion of more attention to the balanced cultivation of integrated processing (involving left and right brains) will result in improved performance in the traditional academic skills as well as creative production (Kraft, 1976; Noller & Parnes, 1972). Strategies for enhancing integrated and right brain thinking skills are featured in an annotated bibliography. See Appendix A for "35 Activities to Stimulate Integrated/Right Brain Processes."

Teacher Attitude

All aspects of the educational environment—particularly the teacher's verbal and nonverbally expressed attitudes and even the physical arrangement of the classroom—have significant impact on how the brain readies itself to handle information (Languis, Sanders, & Tipps, 1980). It is exceedingly important that the teacher carefully engineers the classroom setting to enhance a positive "mind set" toward integrated learning and creativity.

It is interesting to note that the average amount of time a teacher allows for students to answer questions is from 2 to 3 seconds (Brandwein & Ornstein, 1977). Rewarding students only for speed rather than richness and/or depth of answers strongly encourages a very left brain "mind set" for cognitive tasks. Asking students to provide the greatest number of possible solutions rather than the best, correct answer(s) to a problem, stimulates the fluency of ideas (divergent, right brain processing) rather than only the accuracy of responses (convergent, left brain processing).

Students should be permitted to daydream about ideas periodically with the expectation that they will learn to trust and productively use the incubative processes of the right brain that are activated by "daydreaming about" or "sleeping on" ideas. Students should be instructed to record related, but perhaps unpolished, ideas that emerge, often times unpredictably, from the subconscious, incubative state. They should become familiar with the numerous accounts throughout history pointing to the masterful use of the silent, yet powerful, incubative processes by outstandingly creative and productive individuals. (Wallas, 1926).

The nonverbal and ostensibly passive characteristics of the incubative/intuitive processes of the right brain, are in sharp contrast to the revered verbal and action-oriented characteristics of traditional, left brain educational experiences. Encouragement will be needed in the use of these dormant right brain skills. It becomes increasingly more difficult to activate these skills the longer they are neglected (Gowan, 1980).

Relaxation Strategies

Research shows that optimal learning occurs in a relaxed, nonthreatening (yet structured) classroom setting (Schuchman, 1977). Relaxation is also an essential ingredient in the creative process (Budzynski et al., 1970; Green et al., 1970). A successful deep relaxation and visualization audio tape program specifically for children has been developed by O'Dell (1981). This system entitled Relaxation and Re-Creation for Children (R & R for Children) represents a research-based and field-tested classroom implementable method of teaching students how to bring about deep levels of relaxation associated with the creative process. In addition to providing students with the skills to lessen the occurrence and/or effects of test/math anxiety, the mastery of deep relaxation exercises will allow students greater access to those right brain processes (ideational fluency and visual imagery) that are enhanced by relaxation and are fundamental to creative production.

General Strategies

The more fully the brain is involved in learning, the more readily information will be retained and retrieved (Buzan, 1976). Undoubtedly one of the most sophisticated and powerful applications of this principle is demonstrated by the parade of advertising witnessed daily. The primary goal of advertising is the selective, immediate recall of a specific product message out of a vast field of other sensory input. It is most interesting to note that highly memorable advertisements feature aspects that attract and stimulate left brain processing (verbal, pseudological) and right brain processing (visually appealing, musical, emotionally loaded). The retention and ease of recall of these artistically composed messages (jingles) clearly illustrate the considerable teaching effectiveness of using strategies that draw on processing aspects of both brains. Similarly, the ability to recall nursery rhymes from decades past further attests to the potent impact of whole person (left and right brain) involvement in learning.

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Curricular Strategies

One curricular approach to enhancing whole child learning is to orchestrate the expression of the traditional content area subjects through concrete, experiential, artistic, musical, and dramatic media. Examples of integrated and more right brain teaching approaches for arithmetic, science, language arts, and social studies appear in Table 2. It may be useful to introduce a subject in the traditional, familiar left brain style; then assign a type of student product that requires integrated or right brain processing styles. In the case of difficult concepts, it may be better to initiate the explanation through more right brain or integrated approaches and then conclude with a written assignment. Due to the fact that students may lack both experience and confidence in performing academically through a more integrated or right brain style, additional time and encouragement from a teacher may be necessary. It might be well for the teacher to work from his/her strongest content area initially in developing an integrated lesson plan.

Representative activities that promote integrated processing of information are:

- Defining highly emotive words (trust).
- Describing personally important events.
- Reading mysteries, science fiction, and adventure stories.
- Cartooning, humor, puns.
- Rhyming, poetry, singing, dramatization.
- Engaging in guided fantasy and mental visualization exercises.
- Diagramming ideas using audiovisual aids.

A second teaching approach to encourage more integrated processing of information is the development of aesthetic awareness throug art, music, drama, and dance. Students should be given the opportunity to gain confidence in and derive pleasure from their own artistic expression. Edwards (1979) has developed a "confidence-building" approach for acquiring drawing skills that rely heavily on right brain processing.

A third method for facilitating integrated and right brain functioning in the classroom is through the direct development of integrated and right brain processing abilities. The symbolic and figural dimensions of the Structure of Intellect SOI activities concentrate on integrated and right brain processing styles respectively (Meeker, 1981). The SOI activity workbooks offer literally thousands of easy-to-implement exercises and worksheets for students kindergarten through twelfth grade. As mentioned previously, the SOI Learning Abilities Test can highlight relative strengths and weaknesses in left, integrated, and right brain processing areas through subtests that measure semantic, symbolic and figural skills respectively. The SOI Learning

Abilities Test appears to be a useful pre/post treatment instrument to measure the effectiveness of a program designed to enhance symbolic (integrated) and figural (right brain) thinking skills.

A well-developed "scope and sequence" series of activities concentrating on the development of figural/spatial reasoning skills has been developed by Black and Black (1981). The activities are cross-referenced with other commercially prepared materials to provide a wide array of approaches to improve visualization skills that "open up" and stimulate the right brain's processes.

A left/right brain research based, highly effective curricular approach to teaching the "whole child" has been developed by McCarthy (1980), Entitled 4MAT System, this educational model concentrates on teaching toward the child's left/right brain learning style strengths, resulting in enhanced learning and interest on the student's part (Torrance, 1982b).

SUMMARY

How one views and responds to reality is, in large part, dependent on a constellation of neurological factors. The development of each individual's learning style is the result of a complex interaction of physiological characteristics (age, sex, handedness, neurological intactness) and other varying states (anxiety level, nutrition, psychological status, language dominance, and physical environment). Indeed, the brain's structural composition is altered by our experiences.

It is evident that wide variations in learning styles will occur in the classroom setting. It is conservatively estimated that there are two million right brain oriented children (about two in a class) in a predominantly left brain dominated educational system. These students' needs can be better met by increasing sensitivity to and skill in right brain pedagogical techniques that utilize visual, concrete, kinesthetic, and experiential modes of expression. Ultimately, left/right brain research will lead to the development of assessment and teaching strategies allowing educators to fully capitalize on and even nurture right brain learning styles to the benefit of all children.

Current research suggests the following divisions of function between the left and right hemispheres. The majority of verbal processing takes place in the left hemisphere for right-handed individuals over 10 years of age, with the exception of several non-English languages, which tend to be processed by the right brain. For a large portion of left-handed adults and for children under 5 years of age, language processing tends to be right-brain dominant or more equally divided between the hemispheres. The right brain's linguistic skills develop to about a 5-year-old level of competency for most right-handed adults. The right hemisphere deals with making sense out of and remembering complex nonverbal visual and auditory patterns such as the recognition of facial features or recall of melodies. The visual/spatial reasoning abilities of the right brain do not typically improve beyond the 13-year-old level unless specific activities are provided to cultivate these skills. The left hemispheric processing mode plays a predominant role in education, as the traditional "3 R's" (reading, writing, arithmetic) are generally processed in the left hemisphere. Computer programming activities also appear to rely primarily on left brain processing skills. The right hemisphere generally predominates in processing the "artistic subjects" (art, music, dance) and physical education.

The cognitive styles that are best described as logical, sequential, and convergent are within the realm of the left hemisphere, whereas the right hemisphere is more adroit at processing tasks that require simultaneous and divergent cognitive styles. The right hemisphere is more involved with the emotions than the left hemisphere and tends to be negative in its outlook if uncultivated. Emotional responses related to aesthetic judgments or perceptions are usually products of the right hemisphere. Emotional reactions associated with evaluations concerning the logical order or consistency of information appear to be the psychological manifestations of left-hemispheric processing.

Although the brain is "bifunctional," the most productive and creative intellectual functioning occurs when there is a dialogue between hemispheric processes. This integrative mode can be encouraged and facilitated through exposure to appropriate learning experiences that require simultaneous processing from both hemispheres (e.g., defining as many words as possible relating to feelings of brotherhood encourages the use of both the left [defining words] and the right [relating to feelings] hemispheres).

By the age of 12, most females will have established a more left brain learning style (verbal), while males develop a more right brain (visual, spatial) approach toward learning by 14 years of age. The 12- to 13-year-old period represents the slowest brain growth stage for both sexes; therefore, students may not be as receptive to new information at this time as during preceding phases of development.

High anxiety has a disorganizing effect on the efficiency of the brain's functioning as evidenced by depressed academic performance during tests and math-anxiety reactions. Recent dietary science breakthroughs have demonstrated that the brain's delicate biochemical balance is influenced by selective nutrient therapies, resulting in significantly enhanced cognitive and emotional/behavioral functioning.

Research has suggested that learning disabled children are likely to be right brain dominant in information processing. Right brain dominance also appears to play a significant role in various types of mental health disorders (manic-depressive reactions, hyperactivity, and autism).

Outstanding creative production appears to result from bringing about a "frame of mind" conducive to right brain processing (ideational fluency, visual imagery), through deep levels of physiological relaxation. Relaxation plays a central role in the creative process and can be learned through systematic training.

Involving both left and right brains in learning results in improved performance in both traditional subject areas and creative thinking. A supportive attitude toward the use of the often silent, subconscious, yet powerful processes of the right brain—such as incubation and intuitive reasoning—must be demonstrated by the teacher. A more balanced approach toward teaching involves broadening the student's curricular experiences to facilitate the integration of traditional content areas with the arts.

IMPLICATIONS FOR EDUCATION

1. Today's educational system is predominantly left brain oriented; it therefore behooves educators to be aware of those students whose learning styles may not be "mainstream." A formal or informal assessment of both the teachers' and students' learning styles will provide a good reference point for developing a satisfying, productive teaching/learning style interaction.

2. Proportionately, more of the brain's physiological/functional development occurs during the first four years of life than at any other time. Future research must be directed toward understanding and nurturing cognitive/affective development for these highly formative years.

3. The middle-school years (7th-8th grades) represent the period of slowest brain growth for students; therefore, teachers should concentrate on expanding and mastering previously acquired skills rather than developing new ones (Epstein & Toepfer, 1978).

4. Females and males appear to have somewhat different orientations toward learning, particularly after 14 years of age. Females may learn relatively better through reading about concepts, while males learn through "hands on" (manipulative) activities that demonstrate the concepts. For example, females may learn chemistry principles better by reading, males by conducting an experiment. Both left and right brain learning styles, however, should be developed by both sexes.

5. Teachers should model confidence in, and willingness to use, right brain thinking skills. Greater emphasis should be placed on rewarding students for variety and richness of responses rather than only for speed. Provide opportunities for students to "daydream" about ideas in order to "exercise" the intuitive/incubative processes of the right brain.

6. Relaxation is an indispensable catalyst in the creative process. Teaching relaxation skills will enable students to reduce test and math anxiety, improve performance in the traditional subjects, and stimulate right brain creative processes. Systematic relaxation training will also assist students in managing positively the emotional aspects of the right brain.

7. In order to maximize integrated and right brain processing of information, lesson plans should reflect the expression of left brain content (arithmetic, language arts, social studies, science, computer programming) through right brain media (drawing, cartooning, photography, dance, music, "hands on" materials, and audio-visual presentations).

8. Greater attention needs to be focused on the direct enhancement of right brain processing through developing heightened appreciation for and skill in aesthetic subject areas (art, music, dance). The communication channel to the right brain's unfathomable creative capacities will be further opened through the cultivation of visual-imaging and spatial-reasoning abilities.

We have both the privilege of and responsibility for "educating the other half." It is crucial that students of today be provided with the creative, imaginative powers to be contributing citizens of the 21st century. The greater precision we gain in understanding the fundamental processes underlying learning and creativity, the more effective our efforts will be in facilitating the actualization of each student's potential. Perhaps these future adults will have access to the other half of their mental capacity that now lies mostly dormant, waiting to be called forth.

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APPENDICES

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APPENDIX A

35 ACTIVITIES TO STIMULATE INTEGRATED/RIGHT BRAIN PROCESSES

Activities taken from the Brain Owner's Manual (Rubenzer & Rubenzer, 1981).*

Activity	Description of Activity	References
RELAXATION STRATEGIES:		
Biofeedback	Have students raise finger temperature as measured by a small hand-held thermometer through suggestions of warmth and relaxation of the hands. Only a 1- to 2-degree rise is necessary.	Brown, B. Stress and the art of biofeedback. New York: Harper & Row, 1977.
Autogenic training	After students have been progressively relaxed, make suggestions of overall health, energy, and relaxation.	Green, E. Autogenic training phrases in Brown, Ibid.
Breathing concentration exercises	Students attend to the rhythm of their breathing patterns. Students should say subvocally "IN RELAXATION" during inhalation, and "OUT TENSION" during exhalation. (Do this 5 to 10 minutes.)	Hendricks, G. & Wills, R. The centering books: Awareness activities for children, parents and teachers. Englewood Cliffs, NJ: Prentice-Hall, 1973.
Progressive relaxation	Suggest feelings of warmth and heaviness in all muscles, particularly the forehead, jaw, and shoulder muscles for 10-15 minutes.	Jacobson, E. Teaching and learning new methods for old arts. U.S. Foundation for Progressive Relaxation, 1973.
Relaxation training for children ages 7 to 12.	A field tested, audio-cassette tape that provides breathing, muscle relaxation and visualization exercises, which effectively bring about deep levels of relaxation. Systematic application (2-3 times weekly has significantly reduced general/math-anxiety levels and has improved performing on creativity tasks.	O'Dell, D.K. Relaxation and Re-Creation (R&R) for Children, 238 Fairway St., Eden, NC 27288, 1981.
GENERAL STRATEGIES:		
Eidetic imagery training (photographic memory)	Have students closely observe their surroundings for 1 minute. With their eyes closed, have them rebuild what they remember seeing either by tape recording their verbal descriptions or by having someone else take notes. Reconstruction should be in terms of color, dimension, etc. This exercise should start off with simple descriptions and after each session should become "richer" with respect to detail. Eventually, have students recall everyday scenes (routes to school) without concentrated observations first.	Author**
Dimensionalization activities	Translating verbal or two-dimensional concepts or expressions into three-dimensional objects (e.g., sculpting a heart out of clay which would capture the essence of "puppy love").	
Nonverbal illustrations of concepts, ideas, etc.	Students should draw out (on large sheets of paper) their most important goals or concerns (e.g., students may create their own logos, with no accompanying caption, which best describe what they believe in, or want to achieve).	
Sustained concentration on nonverbal stimuli	To demonstrate the typical verbal left hemisphere's dominance in daily cognitive processes, have students concentrate on nonverbal stimuli without allowing any internal verbal chatter. For example, instruct students to give 1 minute of undivided attention to the movement of a second hand on a watch or clock without subvocalization, internal verbal description or evaluation of the activity. This exercise involves the conscious elicitation of right brain processes and will enhance the student's ability to engage nonverbal right hemisphere processes at will.	
Transfer activities (Mirror drawing)	Have students trace through a maze while looking only in a mirror and not at his/her hand. Do this for 5-10 minutes.	
Temporary dominance shift	Use opposite (nondominant) hand, foot, etc., to perform everyday functions (e.g., write with left hand if right handed, kick a ball with right foot if "left footed").	

* The illustrated Brain Owner's Manual, which serves as the study guide for educationally oriented left/right brain workshops, is available at cost. Address manual/workshop inquiries to author at 2916 La Veta Dr., N.E., Albuquerque, NM, 87110.

** Activities developed/described by the author unless otherwise indicated.

Musical rhythmic expression	It is a common experience that information that is presented in a rhythmic and/or musical fashion is retained to a much greater degree than only verbally coded information (advertising invests heavily into pairing verbal and musical messages that "stick"). Rhythm and music are both "fortes" of the right brain and should be brought into play whenever possible. Have students develop jingles that convey an important message, or sell a real or imagined product.	
Visualization of an end product	It has been found consistently that those individuals who can best visualize a finished product or end result are most successful at achieving a goal or solving a problem. Encourage vivid visualization of end products to the fullest extent possible.	
Utilization of the consolidation principle	The subconscious right brain often times repeatedly processes or reorganizes (consolidates) information we concentrate on just prior to sleep. To take advantage of the consolidation principle, it is best to simplify and repeat an idea or information seven to eight times prior to going to sleep. The information may then be reorganized into a novel format and/or stored in long-term memory. Upon waking, we may very well have a new combination of the information we registered just prior to sleep. This new consolidation of information could be the key to insight in solving a particular problem.	
Visualization or diagramming of problems	A <u>concise</u> picture is worth a thousand words. Accustom students to diagramming or pictorally illustrating the basic components of an idea or problem. This simplification of the problem requires true understanding of the problem and puts it into visual terms which will facilitate right brain processing.	Buzan, T. <u>Use both sides of your brain</u>. New York: E.P. Dutton and Co., 1976.
Emotionalize	Make material to be learned as personally relevant and "emotional" as possible. The more the emotions can be involved in acquiring information, the more it will be registered in the right brain. When information is retained by both the left (orderly, verbal information) and the right brain (highly emotionally charged input), it is more likely to be remembered. A "discovery approach" to learning may facilitate the personalization of information.	Buzan, op. cit.
Guided fantasty	Guided fantasy experiences, which can be facilitated by the student's listening to especially designed tapes, enhance the right brain imaginative visualization processes. As indicated previously, visualization appears to be an important component in problem solving. Students should be encouraged to compose their own fantasies as lavishly as possible. This primes the imaginative properties of the right brain for use in problem solving.	Good Apple. <u>Flights of Fantasy</u>, Box 299, Carthage, IL 62321, 1980.
Analogize	Since the right brain is metaphoric and analogic in its orientation, analogic thinking will stimulate right brain processing of information.	Harnadek, A. <u>Antonyms Synonyms, similarities and differences</u>. Troy MI: Midwest Publications Co., Inc., 1977.
Creativity	This is a compilation of 109 teacher-made activities that are classified under 15 creative processes. Many of these processes are directly related to right brain stimulation (centering, sensory awareness, brainstorming, creative dramatics).	Jensen, L., & Harwood, B. <u>Creativity activities from: The duality of the brain project</u>. Temple University, College of Education, 445 Ritter Hall, Philadelphia PA 13122, 1981.
Humor	Humor draws on both left (verbal) and right (emotional) brain processes. Have students read, cut out, and bring in humorous material. Simple word puzzles are also most effective in enhancing integrated (left and right brain) processing. Encourage the student's creation of cartoons, clever sayings, etc.	Mulac, M. <u>Perceptual games and activities</u>. New York: Harper and Row, 1977.
Left/right brain independent study guide for high school students	Provides practical, independent study activities that lead to the understanding and application of left and right brain learning strategies.	Phelan, P. <u>Right/Left Brain: An individual learning project demonstrating how to double thinking power by using both hemispheres of the brain</u>. Interact, Box 262, Lakeside, CA 92040, 1978.
Accelerated learning	Presents innovative teaching strategies that draw on both left and right brain processes. Related research is discussed, and this reference appears to be a helpful guide in providing specific suggestions to facilitate "whole-child" learning.	Pritchard, A. & Taylor J., <u>Accelerated Learning</u>. Novato CA: Academic Therapy Publications, 1980.

Instructional strategies	Practical suggestions are provided for stimulating both left and right brain processing of information in the classroom.	Samples, Robert. Neurophysiology and a new look at curriculum. Burlingame CA: Thrust for Education Leadership, 1976.
Transmodal exercises	Crossing sensory modality experiences (e.g., what colors would certain musical tones have; how heavy, hot or cold would particular colors be, etc.).	Standish, B. Sunflowering: thinking, feeling, doing activities for creative expression. Carthage IL: Good Apple, Inc., 1977.
Cognitive (Left Brain) Affective (Right Brain) Curricular Activities	Numerous and specific strategies for stimulating both cognitive (left brain) and affective (right brain) functioning in the classroom are presented.	Williams, F.E. Models for encouraging creativity in the classroom by integrating cognitive-affective behaviors. Englewood Cliffs NJ: Educational Technology, 1969.
CURRICULAR STRATEGIES		
Art activities	Over 15 readily implementable units in art, specifically designed to stimulate right brain processes, are provided (grade three and up). Reproducible student activity sheets are included in this curriculum guide.	O'Dell, D., Kerr, P., and Rubenzer, R.L. Artistic expression through right brain activities. 238 Weaver St., Eden NC 27288.
Negative space drawing (Copying drawings that are upside down and/or reversed in orientation)	Two photographs/pictures upside down. Have students reproduce what they see from this new perspective.	Edwards, B. Drawing on the right side of the brain. Los Angeles CA: Tarcher, Inc., 1979.
Art	General suggestions and defenses for art as related to cultivating right brain functioning.	Samples, Robert E. New perspectives—on art education. Burlingame CA: Thrust for Educational Leadership, 1978.
Poetic expression	Both the verbal processes of the left brain and emotional qualities of the right brain are brought into play through poetry. Expose students to good, relevant (age appropriate) poetry and provide opportunities for students to be poetically expressive.	
Mime, charades, interpretive dance	Communication of ideas through facial and bodily expression. Teaches students to simplify concepts to the most elemental components and "fine tune" bodily movements (e.g., "mime" the concept of trust or friendship).	
Illusions	By exposing students to illusions such as "Escher" prints, students become accustomed to right brain perception overriding left brain logic processes; that is, their right brain visual processes "see" something that their left brain logic cannot explain.	Beeler, N.F. & Branley, F.M. Experiments in optical illusions. Binghamton NY, 1951.
Origami (paper folding)	These activities rely heavily upon visual/spatial abilities of the right brain and also improve visual/motor coordination.	Benjamin, R. Origami for everyone: Paper folding step by step in photographs and games. Blauvelt NY: Biograf Books, 1973.
Photography	Right brain processing of information through photographic activities in the classroom is encouraged through the curricular suggestions forwarded in this paper.	Routh, R.D. Photography as therapy. Paper, May 11-14, 1977 at the Annual Meeting of the International Visual Literacy, Association (9th, Iowa City IA).
Mathematics	Curricular activities related to enhancing integrated brain functioning.	Elliott, Portia C. Going "back to basics" in Mathematics won't prove who's "right," but who's "left" (Brain duality and mathematics learning). International Journal of Mathematical Education in Science and Technology, April, 1980.
Science (elementary)	Elementary science teaching methods for enhancing right brain processes.	McCormack, Alan J. Lemons, mealworms, and the giant amoeba: A eureka trip through school science. National Elementary Principal, 1980, 59(2), 54-60.

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APPENDIX B

OERIVATION OF ESTIMATES FOR NATIONAL PREVALENCE OF RIGHT BRAIN CHILDREN

The estimated national prevalence (two to three million) of right brain oriented children was derived from hemisphericity research on "left handedness," creativity, and learning disabilities. The national K-through 12th-grade population for 1980-81 was approximately 41,000,000.* At least 10% (4,100,000) of this population is left handed. Research studies predict that between 30% and 50% of left-handed individuals utilize a predominantly right brain processing style; therefore, it can be estimated that between 1,230,000 and 2,050,000 left-handed children favor a right brain cognitive style. Brain research studies also point to a strong preference for a right brain processing style for creative (in visual/performing arts) and learning disabled students. If only one out of a hundred students were identified as being creative in the visual/performing arts, another 400,000 students would be added to the "estimate" pool. Approximately 1,200,000 students (3%) have been identified as learning disabled. Collectively the creatively talented and learning disabled represent 1,600,000 students. Adjusting this initial figure to exclude the predicted 30% of this population who are left handed (triple the normal frequency), the creative and learning disabled students would enlarge the right brain oriented "projected" portion of the school population by 1,120,000. Combining the estimates of the left-handed (1,230,000 to 2,050,000), creatively talented, and learning disabled students (1,120,000) with a right brain learning style resulted in a total ranging from 2,350,000 to 3,170,000 children equalling from 6% to 8% of the total population, or at least 2 students per classroom of 30.

It should be noted that this total does not include any estimate of the prevalence of right brain dominance for the 16,000,000 right-handed learning disabled males in the school population. Extensive studies have demonstrated a right brain dominant processing style for males.

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* Source: Dr. Paul Burns—U.S. Office of Education, Washington, D.C., April, 1982. See pertinent sections (handedness, creativity, learning disabilities) for research references.

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