Brainstages

GENDER DEPENDENCE AND ASYMMETRY OF BRAIN AND MIND GROWTH

by

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Abstract

Developmental gender differences in human brain and mind growth have been found in brain weight, head circumference, EEG, laterality, and sensitivity to non-verbal cues. Most differences appear during the age spans of rapid brain growth: 2-4, 6-8, 10-12, and 14-16 years.

Brain weight gender differences are found most strikingly during the last two brain growth spurts: in age spans 10-12 years and 14-16 years. Although both genders have spurts in brain growth during those spans, during the first one females have about twice as much brain weight increase, while the situation reverses during the 14-16 year span. A similar difference is found in the data on head circumference and on the percentage of energy in the alpha frequencies. Non-verbal cues assayed by the PONS test show a sharp increase of female lead during the 10-12 year period.

Females have a symmetrizing brain growth during the first of those two age spans while males are having relatively less increase. During the last spurt, males have a more asymmetrizing brain growth while females are having relatively less increase. As a result, female brains end up much more symmetrical while male brains end up relatively more asymmetrical.

The study of gender differences in human brain structures and functions is constrained by the same factors affecting general brain research today: brain complexity is so great that attempts at reductionist portrayal is simply not yet achievable. That progress is being made can be illustrated by a fairly recent study of neuronal density [20] that found a gender difference with potentially interesting ramifications. Fortunately, less reductionist gender differences in human brain organization and functioning have been described in enough not-so-recent reports that highly worthwhile novel inferences can begin to be drawn from them.

PET scans were used [1] to display functional differences between adult females and adult males because the brain regions activated by various inputs were processed mainly in different brain regions.

MRI was used [2] to uncover gender differences in the brain regions involved in reacting to the same language inputs. Memory differences have been found using MRI [26]. Taken together, these studies demonstrate significant gender differences in both brain organization and brain functions. More recent MRI studies have found gender differences in some structures [21, 22] that do little more than confirm results of older studies to be described.

Such reports [23]invoked the possible effects of upbringing and other environmental factors as sources of gender differences in brain function without referring to the kinds of data sketched below showing significant *developmental* gender differences in brain anatomy. Significant cerebral lateralization and related anatomical and functional gender differences during development were long ago convincingly demonstrated and discussed in a review [3].

A fairly common belief is that differences between brains of males and females appear mainly at puberty when concentrations of the gender-related hormones begin to increase significantly. This belief is not entirely valid for both anatomical and functional reasons.

Functional reasons are readily noted in children as young as 1 to 3 years, by which ages most females tend to prefer toys such as dolls and doll-houses while most males show an extremely marked interest in trucks and other such moving toys. This is far earlier than significant puberty-related hormonal changes and seems not to depend only on culture-bound experience.

A relevant finding is that a major anatomical difference appears between 10 and 12 years during which period a rapid brain growth spurt is found in both genders [4,5,6]. However, the amount of new brain growth in females is about twice as much as in males. After puberty, during the 14-16 year brain growth spurt, males have at least twice as much brain growth as females. The net result is that female brain/body ratio exceeds that of males: it takes relatively more brain to be a functioning female.

There is also a large functional gender difference in sensitivity to non-verbal cues starting at the youngest age measured: 6 years. Using the PONS test (Profile Of Nonverbal Sensitivity), it was found [7] that females test almost a full standard deviation higher than males between ages 6 and 10 years. The female's large lead on the PONS test *doubles* during the 10-12 year brain growth spurt. Later, the males gain back but only to the pre-age-10 year level of difference.

The anatomical difference appearing during the 10-12 year period serves to support the functional difference on the PONS test and could be explained as having been selected for to enable females to become more sensitive to the most non-verbal of all humans: their imminent newborn babies.

The greater brain growth in females during the 10-12 year age period might be the result of a chromosome effect: females have two x-chromosomes while males have one x plus one y chromosome. If the factors responsible for increasing brain growth at the 10-12 year period depend positively on the x chromosome and less strongly or negatively on the y chromosome, females will have more brain growth. Then, if the factors regulating brain growth during the 14-16 year period are connected predominantly with the y chromosome, males should have far more brain growth around age 15 years than females who have no y chromosome. That sex chromosome genes contribute directly to sex differences in the brain has been shown for mice [24,25].

In any event, the markedly greater increase in female brain weight during the 10-12 year period should generate investigations into the functional consequences of that greater increase. Perhaps schooling should incorporate some gender-related differences due to the greater brain development of the females which is likely to be located in particular brain regions involved in characteristic functions.

There are still other gender-connected brain differences. One of the lesser-known ones was discovered while studying humans [8] in the observation that most right-handed males have a slight protrusion of the right front cerebrum and forehead compared to their left forehead while female foreheads are much more nearly symmetrical in that respect. The article also pointed out that, for reasons we will not discuss here, the left rear side (occipital) brain growth correlates with a greater protrusion of the right frontal side of the brain and forehead, while right rear side (occipital) brain growth correlates with a protrusion of the left frontal side of the brain and forehead. This finding thereby ties the forehead protrusion to the brain growth symmetry or asymmetry.

EEG data [9] show a tendency for some predominantly right-sided brain development around ages 4 and 11 years, with left-sided predominance and development around ages 7 and 15 years. These characterizations correlate fairly well with those inferred from the asymmetry studies [8].

The asymmetry can now be related to predominant growth of one or the other of the two halves of the brain during stages of rapid brain growth. Humans start out with a slightly greater left side brain size. During the 10-12 year period, there is somewhat more right side brain growth. The greater right side growth of female brains in that 10-12 year period means that their brains become more symmetric. During the 14-16 year brain growth stage, there is a slight predominance of left side brain growth. Perforce, the females who had more symmetrizing brain growth around age 11 years now have less asymmetrizing brain growth around age 15 years. And, males who had less symmetrizing brain growth around age 11 years now have greater brain growth around age 15 years when it adds to the asymmetry.

(It is interesting to note that persons who tend to be more artistic use more right side brain [10]. Thus, both female and male artists tend to have a greater chance of a left forehead protrusion than most other persons. In a broad statistical way this permits some level of classification of humans just from observation of their foreheads.)

These anatomical gender differences parallel the kinds of functional differences [2] which revealed the greater functional asymmetry of male brains and the lack of as much asymmetry of female brains.

Simple Reactive Systems

It is important to stress that neuroanatomical differences that derive from genetic programs are not the only source of such neuroanatomical differences.
Such programmed functions are built in to the genetic makeup of the organism and will emerge without instruction provided there are no noxious inputs to the fetus during gestation or to the organism during postnatal growth. If an input always evokes a particular response, this is a simple reactive system; it only reacts.

As humans mature, they acquire additional behaviors whose manifestations can appear in an almost reactive manner so that some culture-based behaviors can seem to be programmed.

If the organism is capable of learning non-programmed functions, there must be unused parts of the brain and/or (more likely) additional connections which allow the organism to put together already existing functions into more complex functions. Since brains initially contain a huge oversupply of neurons, unused ones of which are later discarded by dying, there are indeed extra neurons and networks that can serve as sources for additional mental functions.

But, unless a deity programs these extra neurons and networks they can be presumed not to have built-in functions. It is well-known that connections among brain areas are modified and, thereby, sharpened during maturation [11,12,13,14,15] ;and many other earlier publications. Such a sharpening bespeaks the neural networks' dependence on learning.

Learning-Dependence

This dependence of actual neural network structures on learning has been called experience-expectancy [11, 12, and 13]. Because such effects can also result from instruction, it could be more generally called learning-dependence. It depends on having inputs that are adequate in their nature, timing, and relevance for the particular individual to learn. Inasmuch as such learning by humans takes place throughout life, it follow that the actual structures of our brains, not just our minds, are dependent on adequate and timely inputs from other individuals and from experience. Thus we arrive at the inference that human brain structure and development depend strongly on such inputs from parents, siblings, teachers, and all other individuals with whom humans are in contact. Based on such a scenario, it is more readily imagined how disadvantaged children can be deprived and underdeveloped if raised by parents without the background, resources, and time to do their parts in the instruction of their children. It is also imaginable that, for lack of optimal early childhood inputs, later inputs might not be able to achieve an optimal organization of the brain because the efficiency of instruction may have evolved based on optimal inputs at a series of turning points in maturation of children.

South African studies [16, 17] found that rehabilitation of very young malnourished children restored both height and weight to the range of normal values but the deficit in head circumference became greater!

The ability to learn new functions makes it almost impossible for evolution to select for those functional programs any more than dogs can be selected for fetching newspapers. Thus, we humans are destined to remain learning-dependent for the neuroanatomical changes that underlie the higher cognitive functions that are the basis of most of our intelligent behaviors. Of course, selection could act to enhance the instructability of the brain.

It will be very useful if the two first-mentioned research groups [1,2] extend their studies to the developmental aspects of the differences they found, for that would tell us if there are contributions of experience and/or maturation to these functional properties. If such developmental aspects are found, it will then present the challenge of finding whether they stem from learned behaviors or from changes associated with genetically programmed brain development processes. Such processes could appear during the respective brain growth stages when there are significant increases in brain weight and significant changes in lateralization.

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