

# Human Brain Laterality - An Overview

Vishram Singh<sup>1</sup>, Ruchira Sethi<sup>2</sup>, Rahul Rai<sup>3</sup>

<sup>1, 3</sup> Department of Anatomy, Santosh Medical College and Hospital, Ghaziabad, Delhi, NCR, India.

<sup>2</sup>Department of Anatomy Heritage Institute of Medical Sciences, Varanasi, Uttar Pradesh, India.

## ABSTRACT

### BACKGROUND

The dominance of one cerebral hemisphere over the other helps a human brain to acquire laterality, which is defined as the ability to perform majority of day to day tasks more effectively with one hand of our body. The laterality is a measurable tool and various standardized questionnaires have been proposed to define the types of laterality in an individual. This is discussed in detail in the main text of the article. The predominant markers of laterality (handedness) are dependent on various internal and external factors, which include genetic social and cultural factors. The age, gender, social and cultural environment play a major role in defining as well as fixation of laterality. It is believed that lateralized behaviours are expressed in a very early stage of development. Functional lateralization occurs in the paired organs such as hands, legs, eyes and ears in relation to cerebral hemispheres. Intelligence may be defined as the ability of a person to react or respond to various problems for the survival in natural and social environment. In broad terms, it may be regarded as the capacity of reasoning, planning, and problem solving, thinking comprehension ideas and learning from experiences rather than just having a textual knowledge. Intelligence reflects broader capacity of developing ideas, senses, and provides appropriate thought pattern for various life situations. The individual difference in the levels of intelligence is imported with respect to life outcomes such as achievements in school, occupational benefit, social achievements, and job performances. Differences have been observed among left and right handers with regard to cognitive ability and levels of intelligence. Effects of intrauterine environments in defining laterality, how various neurological disorders are associated with it and future areas of research are discussed thoroughly in the article.

### KEYWORDS

Brain, Cerebrum, Laterality

*Corresponding Author:*

*Dr. Rahul Rai,*

*PHD Scholar,*

*Department of Anatomy,*

*Santosh Medical College & Hospital,*

*Ghaziabad, Delhi, NCR, India.*

*E-mail: rahulrai.ra158@gmail.com*

*DOI: 10.18410/jebmh/2020/478*

*How to Cite This Article:*

*Singh V, Sethi R, Rai R. Human brain*

*laterality - an overview. J Evid Based Med*

*Healthc 2020; 7(40), 2305-2310. DOI:*

*10.18410/jebmh/2020/478*

*Submission 13-07-2020,*

*Peer Review 18-07-2020,*

*Acceptance 22-08-2020,*

*Published 05-10-2020.*

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**BACKGROUND**

The intellect of human beings is very high which makes them unique in comparison to other species in the world. Their mental ability made it possible to explore the newer facts and achieve greater progress in all aspects of human endeavours. However, many differences do exist in between each individual making them different from one another.<sup>1</sup> The individuality of a person is best assessed by observing the lateralization of human brain.<sup>2</sup>

Human brain lateralization can be defined as the preference of using one side of body more frequently than the other while performing various day to day tasks. This is dependent on the dominance of one half of cerebrum over the another.<sup>3</sup> As for example if the dominant hemisphere of the individual is left then the person tends to be right-handed and vice versa. Human fore brain appears as two hemispheres which when viewed from top can be assumed to be mirror images of each other. These two parts are commonly known as right and left cerebral hemispheres<sup>4,2</sup> but each hemisphere is specialized in different abilities and tends to perform different functions. The right hemispheres is more specialized in nonverbal, spatial and perpetual processing while left hemisphere is specialized in tasks such as music, mathematics, baseball and cricket, architect and artistic activities.<sup>2</sup>

**BRIEF HISTORY OF LATERALIZATION**

Various theories have been proposed by earlier researchers where distribution of work and function is clearly evident between the two mirror images of cerebral cortices. The roles of ethnicity, gender, age, even social cultures and rituals have been defined as contributing factors towards lateralization.<sup>5</sup>

A theory developed by Neuroscientist Dr. Roger W Sperry is referred to as "Split - Brain Experiments" where he studied patients post resection of corpus callosum. The result of the study generated the concept of an individual having two separate minds post-surgery. The patients having damage on the left side of the brain tends to copy the whole outline of the diagram but skips the details whereas if the damage is present on the right side only details are copied, and outline is by-passed.<sup>2</sup>

Theory developed by Ned Herrmann also known as the father of Brain Dominance Technology suggests that individuals have different and dominant modes of preference to thinking. As per Herrmann when people develop, they adjust themselves to their strongest abilities which provide them quick and short-term achievements. He developed the model known as "A four Quadrant Model of Cognitive Preferences" and the Questionnaire being known as "Herrmann Brain Dominance Instrument (HBDI)". This model is explained in Table 1.

Eventually many earlier researchers worked on patients with physical deficit in one half of the cerebrum to

authenticate the different working modalities of each cerebral hemisphere. An investigation done by Paul Broca's in around 1861 on the physical and clinical history of a boy named Tan with speech deficit revealed a cyst on the left side of his brain. Due to the cyst boy could only pronounce the word called Tan and hence nickname Tan was given to him. Appearance of cyst on left side and speech impairment indicated that linguistic functions were present in the left hemispheres. Since then many other studies were conducted and various specific areas of brain were identified, which are assumed to play significant role in language function (Table 2).

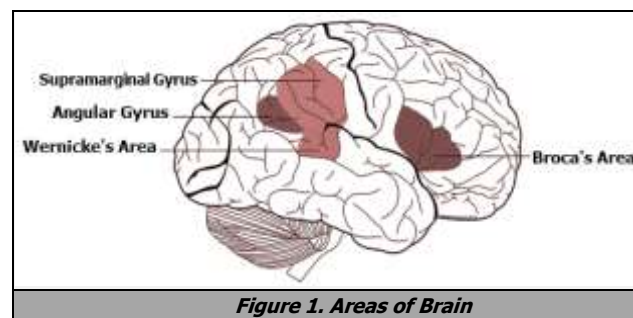
Brain Quadrants	Features	Keyboard	Preferred Activities
A	Analytical thinking	Logical critical factual, technical and quantitative	Collecting data, listening to information lectures, judging, reading, logical reasoning
B	Sequential thinking	Structured, organized, conservative, detailed, planned.	Following direction solving problems, schedule and time management
C	Interpersonal thinking	Sensory, emotional, spiritual, kinaesthetic	Sharing ideas, listening to ideas, group study, sensory input
D	Imaginative thinking	Innovative, intuitive, conceptual, visual, holistic	Initiative taking, simulation, brain storming, problem solving, visual aids

**Table 1. Modified Version of Dominance Model as Proposed by Ned Herrmann**

Apart from linguistic functions other actions of day to day tools are also located in either of the hemisphere and this determines the handedness, footedness, eyedness, hair whorls pattern etc. for an individual. Many early research works have proposed various factors which are responsible for such predominance. All these will be discussed in the next section of the article.

Area	Function
Broca's Area	Grammatical processing
Wernicke's Area	Syntactical processing
Angular and Supra-Marginal Gyri	Visual symbol recognition

**Table 2. Brain Area and Linguistic Function<sup>2</sup>**



**METHODS**

The databases (PubMed, PubMed Central, Medline, Scopus, and Google Scholar etc) were thoroughly researched with keywords - lateralization of human brain, cerebral dominance and factor defining lateralization. Number of full-length articles recovered was taken from period 2000 - 2019.

The articles were analysed thoroughly with respect to definition of laterality, cerebral dominance, markers of lateralization, factor affecting lateralization, demographic dependence of laterality. All these are discussed thoroughly in the results section.

**RESULTS**

**Defining Laterality and Its Markers**

The receptive and control centers of one side of body are located on the opposite side of brain hemisphere, which means the person with dominance of left hemispheres shows the preference of right hand while performing several tasks.

Functional Lateralization occurs in paired organs such as hand, legs, eyes and ears<sup>6</sup> and Lateralization is referred to as crossed i.e. if an individual prefers using right hand for one task (as for example writing) and left foot for the other (such as kicking).

Similarly, lateralization is considered undefined, if there is no dominance which means there is no preference for the use of right or left parts (as for example hand of any side). Laterality can also be grouped as complete left or complete right dominance depending upon harmonic use of the body parts. As for example, if a person uses his / her left hand for writing and left foot for kicking, then it is considered a complete left dominance and vice versa<sup>7</sup> only. About 20 % of people prefer to use hand and eye of the opposite side. In the world about 90 % of persons are right-handed, 80 % are right footed and 70 % are right eyed.<sup>8</sup>

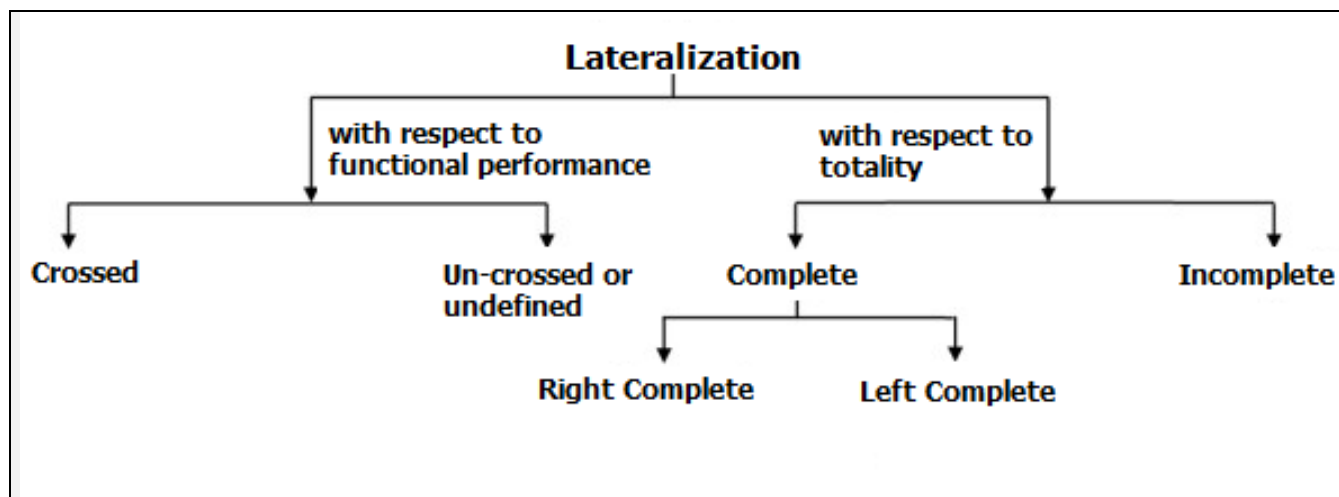
Study of Rajeshwari et al showed ipsilateral correlation relative to hand and foot preferences. According to her study, the tendency of the left-handed females to use right hand is 20 %, i.e. crossed laterality while tendency of the right footed females to use right hand is 98.9 %, i.e. complete right dominance. Similarly, the probability of the left-handed females to use left foot is 100 % i.e. complete left dominance. In case of males, the left-handed individuals with the right foot in 50 %, while the left footed males with

the right foot in around 50 %. Probability of using right hand as per the handedness and footedness are significantly correlated ( $p < 0.001$ ).<sup>9</sup>

Among the various parameters used to study cerebral dominance, handedness has emerged as a good marker and is the most explored one. The coexistence of left hander with right hander has been observed from the upper Palaeolithic age.<sup>7</sup> Hand preferences in Ancient times have been studied using archaeological samples of human skeleton, stone tools be used etc.<sup>8</sup> Handers are categorized in several ways based on the preferences given to the use of one hand in place of others. However, use of non - dominant hand is not ruled out.

Some of the researchers have grouped handedness as right hander's, left hander's and mixed hander's (ambidextrous),<sup>10</sup> while some literatures emphasize on the categorization of handedness as strong right hander's (Use of right hand on most of the activities) and non - right-handed (preferences to left hand for some or most of the motor activities).<sup>11</sup> However the controversy that left handedness or non - handedness can be considered the most relevant trait biologically remains unsolved. This opens various areas for further research in defining the lateralization. To resolve this question various tools in the form of Questionnaire were designed, example Edinburg Handedness Inventory (1971), Annet Hand Preferences Questionnaire and Waterloo Handedness Questionnaire for defining the handedness but their appropriateness till date is controversial. Several theories have been developed to explain the possible cause and the most widely accepted one is hemisphere wise division of brain functions.

According to this theory linguistic and hand functions need fine motor skills and it is predicted to be more effective if the centers for these activities are located on the same hemispheres instead of dividing into both the sides of the brain. Another theory is based on the effect of testosterone and suggests that high levels of testosterone in prenatal age makes the individual left-handed. In spite of multihued theories and predictions still doubt prevails regarding more individuals being right-handed in comparison to left and thus needs further evaluation.<sup>10</sup>



**Figure 2. Flowchart Defining Laterality**

The predominant marker of laterality (handedness) is dependent on various internal and external factors, which include:

### Genetic Factors

Handedness is thought to run in families. Hand preference may be transmitted from, parents to their offspring's either at genetic levels or at learning levels. If both the parents are right-handed, the smaller number of offspring could be left-handed while both left-handed parents tend to deliver higher number of left-handed children.<sup>10</sup>

Similarly, if the father is right-handed and mother is left hander, there is higher tendency of a child to be left-handed compared to left-handed father and right-handed mother. Tguis indicates maternal impact on handedness of offspring's which may be attributed to sex-linked inheritance or social influence extorted by mother on her child. However, McKee veer observed such maternal factors effects only or sons while paternal effects were observed for daughters. Only Van Agtmael et al (2003) in their study involving 25 nuclear families showed that genetic linkage for handedness is present on chromosome region 10g26. Similarly, Worren et al demonstrated that chromosomal region 12q 21 - 23 contain linkage signal related to handedness relative to drawing and writing.<sup>12</sup> These studies have opened the door for the role of genes on hand preferences which should be further elaborated by better coverage of human genome to identify more genes involved in hand preferences and hand skills.<sup>13</sup>

### Social and Cultural Factors

Human societies are predominantly right sided, and many cultural rituals are accepted for performance by only right hand. Right side dominance can be observed throughout the history with negative connotations to left handedness. The word left was derived from Anglo-Saxon word list, meaning useless or weak, while the word right means correct or straight. Similarly, French word gauche (synonym for left) means awkward or tactless.<sup>12</sup>

The two hemispheres are dominant in human the processing of distinct cognitive tasks, such as the left hemisphere is specialized in processing language, and the right hemisphere is specialized in spatial processing and social recognition.<sup>14</sup>

The use of left hand is an inauspicious practice in many cultural rituals especially in India. Hence most of the left-handed individuals are forced to or encouraged to do the activities using right hand, during their childhood age. Most often, females are pressurized towards the right-hand preferences.<sup>9</sup>

According to Faria (2004) et al, lateral dominance starts around 2 years of age; however, it is undefined till the age 5. From 6 to 7 years of age onwards, the child starts to develop perception that both right and left hands are independent of each other. But in our society, it is observed that children wishing to write using left hand are forced to convert to right hand. More so, it has been observed and reported that during the development of left handed

children, conversion to the right creates multiple problems like dyslexia, spluttering or learning or speech disorders.<sup>10</sup> Most of the tools and basic equipment such as knives, corkscrews, computer key boards, surgical instruments, firearms etc are designed in a way congenial for right hander's and thus this may create pain and other disorders for left hand users.<sup>10</sup> It is also considered disrespectful to offer anything to other using left hand. No matter whichever might be the dominant hand, right hand is preferred for eating, social interactions and food handling while left hand is preferred for defecating voiding or doing things of less or no value.<sup>2</sup>

### Brain Lateralization in Intrauterine Environment

It is speculated that lateralization may also be influenced by the intrauterine environment and it is believed that lateralized behaviors are expressed in a very early stage of development. Geschwind and Galaburda, two decades ago were the first ones to develop an insight on the human brain dominance and its relation with gestational environment, functional asymmetry of different paired organs or limbs during development.<sup>15</sup> It was observed that 9 - 10 weeks old fetus shows greater right arm movement in majority of cases (75 %), while left movement was seen in 12.5 % of cases.<sup>16</sup> Similar pattern of movement was also observed in a study on the fetus of 12 - 27 weeks age. At 15<sup>th</sup> weeks of gestation and onwards, there is increased preferences of right thumb sucking, which is associated with future handedness (or hand preferences) in the adult stage. The fetus shows high preferences for moving its hand toward the right side relative to left.<sup>15</sup> This was ascertained by the high levels of testosterone in intra-uterine life. During fetal development, there is increase in level of as well as sensitivity to testosterone which alters the neural development and leads to various physiological changes, along with increase in probability of anomalous dominance (such as left handedness or weak lateralization). Several researchers had hypothesized that there occurred delay in maturation of left hemispheres in comparison to the right hemisphere which may be further aggravated by the increased levels of testosterone in prenatal life.<sup>10</sup>

Geschwind et al. Suggested that climate also affect the levels of pre - natal hormones which in turn affects laterality. During winter there is decrease in testosterone levels which are attributed to the decreased activity of ovaries caused by decrease in activity of pineal gland and vice- versa. Pineal gland activity increases causing subsequent elevations in the levels of testosterone.<sup>17</sup>

Wisniewski and Nelson et al. observed and reported that the levels of testosterone rise in autumn and lowers in spring in females. They also speculated testosterone to be chief determinant of fetal brain lateralization.<sup>15</sup>

## 1. Fixation of Laterality and Dependent Factors

### a. Age

In humans, the reflection of laterality is not stable throughout the generation. The functional lateralization is slowly established during adolescence and decrease in older

age.<sup>18</sup> Most of the children prefer either of hand till the age of 18 month and by the age 3 years they become right or left-handed. While in some studies reveals that the dominance starts at the age 2 year and fixes at the age of 6 or 7. Still using left hand is a mystery. It depends on the hormone testosterone in males that's why most of the boys are left-handed than the girls in their initial years of life.

### b. Gender

Lateralization of brain connectivity is important for normal brain function and may be sexually dimorphic. Short-range (implicated in functional specialization) was right lateralized and asymmetrical in areas around the lateral sulcus, whereas long-range (implicated in functional integration) was right lateralized in lateral sulcus and leftward lateralized in inferior prefrontal cortex and angular gyrus. The posterior inferior occipital cortex was leftward lateralized (short - and long - range connectivity). Males had greater rightward lateralization of brain connectivity in superior temporal (short - and long - range), inferior frontal, and inferior occipital cortices (short-range), whereas females had greater leftward lateralization of long-range connectivity in the inferior frontal cortex.<sup>19</sup>

### c. Brain Damage

Laterality is usually related with different psychiatric and neurological disorders, such as Parkinson's disease, schizophrenia, depression and autism spectrum disorders.<sup>20</sup> Age is related to lateralization in the regions of brain including sensory-motor network. The networks are visual, attention network and frontal network. During damage of brain in early stages of life may causes left handedness.

## 2. Intelligence and Its Relation to Laterality

Intelligence may be defined as the ability of a person to react or respond to various problems for the survival in natural and social environment. In broad terms, it may be regarded as the capacity of reasoning, planning, and problem solving, thinking comprehension ideas and learning from experiences rather than just having a textual knowledge. Intelligence reflects broader capacity of developing ideas senses and provides appropriate thought pattern for various life situations.<sup>21</sup>

The individual difference in the levels of intelligence is with respect to life outcomes such as achievements in school, occupational benefit, social achievements and job performances.<sup>22</sup> Differences have been observed among left and right handers in regard to cognitive ability and levels of intelligences.

Individuals having higher IQ levels respond instantly to the problem, process information and are able to perform the perpetual tasks. As per various studies right hemisphere remains highly active during the performance of perpetual tasks, indicating right hemisphere to be more specialized in intelligent people. Therefore, it is speculated that left-handed people are more intelligent to right-handed ones. Left hander individuals are also found to be more creative and with better conceptuality as per the dominance and these functions reside in right hemisphere.<sup>21</sup> This can be

supported by the fact that most of the geniuses and creatives in the world are left handed, for example Julius Caesar, Leonard's da Vinci, Napoleon, Michelangelo, Lewis Carrd, Picasso, Benjamin Franklin, Chaplin etc.<sup>9</sup> Mathematician, musicians, baseball and cricket players, artists and architects are more with left handedness.<sup>21</sup>

To have high IQ level and creativity is a key to career success, financial and social achievements that finally lead to better survival and persistence; not only for today's generation but this has been observed from the history also. Deny et al (2007), in their study showed that the earnings of left-handed males per hours was greater (around 4 % excess) than the right-handed but this is with gender discrimination. Similarly, Rvebeck et al also found significantly high wages for left-handed males than females.<sup>8</sup>

In contrast to above, some researchers have shown that the average intelligence of left-handed persons is less than that of right-handed. Cole et al in 1997 demonstrated that handedness and IQ levels are not correlated. It means left-handed individuals are neither more nor less intelligent than right-handed individuals, rather both have equal IQs on an average (Needle Man, 2001). Many other researchers have also shown no significant association of right or left hander's based on IQ levels.<sup>22</sup>

Through left hander's are considered to be more intelligent by several researchers, some of the researchers have regarded it as a disadvantage because as per them handedness have been found to be associated with many disorders such as autoimmune disorders allergies, autism, alcoholism, learning disorders, migraine, schizophrenia etc.<sup>16</sup> Extensive review of literature leads to a debatable conclusion of relation of IQ with handedness of individuals. This aspect needs better defined study designs to define appropriate correlation.

## CONCLUSIONS

Laterality denotes asymmetry shown by human right and left cerebral hemispheres while performing different activities like linguistic and symbolic functions. Handedness is the most commonly studied trait to assess cerebral lateralization. The person who is left-handed has right hemisphere dominance and vice versa. Brain dominance and handedness is influenced by genetics, gestational environment, socioeconomic and cultural aspects. Though a general population agrees upon with left hander's being more intelligent, but review of literature provides variable results. Left handers are also at greater risk of various neurologic and immune disorders.

### Scope of Further Research

- Various standardized subjective tools to define laterality have been correlated with IQ in adults, but with variable results.
- Thus, longitudinal studies planned from the intrauterine to laterality fixation age should be able to provide definitive outcomes. Correlation of handedness with IQ

in young as well as in adolescence age would be able to guide towards definitive goals extraneous factor effects.

- Also forced right hander's can be assessed and examined for various neurological disorders if relevant population's base data is available.
- Further research is required into genesis of left handedness in some individuals and reasons for right dominance in majority of populations globally.

Financial or Other Competing Interests: None.

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