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Developmental Aspects of Left-handedness

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Abstract: Investigations to explore human handedness have been conducted for ages. It is still uncertain what causes people to use the left or the right hand. Clues supporting the genetic origin of handedness have been accumulating and provide the best evidence. Nevertheless, in some populations there are different types of left-handers that do not seem to be explained solely by genes and differ from others for pathological reasons. An increased frequency of left-handers in clinical populations with central nervous system disorders may be due to early brain injury. Thereby, some birth stress or pathological factors may disrupt normal development and causing a switch in hand preference. It is commonly taken that interactions between a strong genetic influence and early life environment (pre, peri and post-natal) and learning processes play a role in the actual manifestation of hand preference.

Key words: Left-handedness, birth stress, birth weight

INTRODUCTION

The aim of this review is to identify developmental causes involved in human handedness. Concerning to pathological left-handedness, our first attempt is introducing and comparing different models represented by some authors like Satz, Bakan and Coren. Furthermore, we try to characterize two main questions involved: (i) Which early life environmental conditions may influence to be left-handed and (ii) Which developmental mechanisms inducing a switch in hand preference. Finally, the hormonal factors as a proposed source of development of left-handedness will be discussed.

In western societies today, about 90% of the adult population is said to be right-handed, with the remaining 10% consisting of persons variably identified as left-handed, ambidextrous, and/or ambiguously handed (McManus, 2002; Soper, Satz, Orsini, Henry, Zvi, and Schulman, 1986; Ferrari, M. 2007). Cognitive performance and left-handedness: comparative analyses in adults with seizures, physical, psychological and learning disorders in a rehabilitation setting, Journal of Rehabilitation , Jan-March. Genetic-, biological and environmental models have been proposed to explain the population-level left-handedness. The genetic factors may play a role is supported by the observation that approximately 70% of individuals born to two left-handed parents are right-handed, which is significantly lower than the proportion of right-handed individuals born to two right-handed parents (McGee and Cozad, 1980; McManus & Bryden, 1992).Genetic explanations account for only part of the variances, however, leaving error or other factors to explain the remaining variability (Hopkins and Dahl, 2000). Environmental influences, in terms of timing, may act prenatally, peri-natally or post-natally. As for prenatal environmental influences, the most intriguing theory comes from Geschwind (Behan) and Galaburda (GBG theory), who stated that asymmetry of the brain which influences hand preference is caused by high intrauterine hormonal exposure (testosterone or other sex hormones). This exposure was also proposed to alter other structures such as the thymus and therefore induce atypical changes in the immune system.

In the perinatal period, the human brain is susceptible to adverse environmental influences such as hypoxia. Birth trauma or other conditions, such as maternal anxiety, ultrasound during pregnancy, and prematurity which may result in brain hypoxia or other types of brain injury, are proposed to cause atypical handedness (left or mixed handedness). After birth (postnatal period), subsequent social exposures (cultural, educational, physical environment) may alter the existing innate handedness (Made Klaci Ramadhani 2006).

Developmental Causes of Left-handedness:

As early as 1920, Gordon reported that roughly two and one-half times as many children with mental

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retardation in the London school system were left-handed compared to a control group of children in schools for the non-mentally retarded (Gordon, 1920). Since then, this finding has been echoed many times and confirms not only a relationship between the increased occurrences of left-handedness in persons with mental retardation, but also a relationship with the degree of mental retardation (Bishop D.V.M., 1990; Bradshaw-McAnulty, Hicks, and Kinsbourne, 1984; M. Ferrari,2007).

The existence of associations between left-handedness and various health problems have often led to a distinction being made between *pathological left-handedness*, which would arise from developmental stresses and *familial left-handedness*, which would be due to genotype (Harris and Carlson, 1988; V. Llaurens *et al*. 2008).

The term pathological left-handedness has emerged around 30 years ago, referring to some right-handers who became left-handed due to an early life brain insult (Made Klaci Ramadhani, 2006). Satz and his colleagues (Satz, 1977; Satz, Orsini, Saslow and Henry, 1985; Orsini and Satz, 1984,) have represented a model that describes how manifest left-handedness (MLH) may develop in more than one way (two type model). They suggested that for the majority of left-handers, MLH is determined by genetic and / or environmental factors. For a smaller group of left-handers, MLH reflects neurological trauma and is therefore reflected to as pathological left-handedness (PLH). Satz notes that the incidence of MLH is elevated among individuals with early brain injury. He put forward that this group includes natural right-handers for whom an early (*i.e*., before 6 years of age) left-hemisphere injury causes motor impairment of the contra lateral hand and thereby leads to a shift in hand preference. Satz *et al*. (1985) also proposed that the incidence of familial sinistrality would be similar to that of right-handers since these left-handers would presumably have been right-handed were is not for the early brain injury (Elliott, Roy, 1996).

Birth Stress:

Bakan and his colleagues (Bakan, 1971; Bakan, Dibb, & Reed, 1973) first reported and theorized about the relationship between birth order and hand preference in humans. Bakan (1971) reported that there was a higher percentage of left-handedness in first- and latter-born offspring (defined as more than 4 birth orders) and postulated that the effects were due to birth trauma experienced by offspring born to primiparous or older women. Bakan (1971) proposed that birth trauma is more likely in women who are giving birth for the first time or for older women who present a higher risk group for prenatal insult (Hopkins W.D. and Dahl J.F., 2007). According to him, left-handedness is a manifestation of underlying brain damage sustained around the time of birth, due to an oxygen deficiency induced by birth stress (*e.g.* premature birth, prolonged labour, Rhesus incompatibility, breech delivery, multiple birth, respiratory distress syndrome, primiparity, maternal age). He presented evidence that hypoxia is more common in difficult births and that the left hemisphere is more vulnerable to the effects of hypoxia than right (Bakan *et al*., 1973; Llaurens *et al*. 2008) . The notion has been partially supported by Coren and Porac (1980), Schwartz(1988); Williams *et al*.(1992), but refuted in studies by Hicks *et al.* (1979), Annett & Ockwell (1980); MacManus(1981);Ashton (1982); Nachshon and Denno (1986) and Peters & Perry (1991; Spreen *et al*.,1995). Bakan's views have been criticized in regarding all case of left-handedness as the consequence of brain damage (one-type model) (Bishop, 1990). Coren (1992) suggested that about half of left-handers results from some pathology or birth stress, while the genetic models of Annett (1985) and McManus and Bryden (1992) considered pathological left-handedness to be sufficiently rare, that it can be ignored in their formulations. It is difficult, however, to demonstrate more frequent birth stress among left-handers (Searleman *et al*., 1989; Elliott,Roy,1996).

Birth Weight:

Prematurely-born babies and those with a low birth weight have a greater propensity to being left handed. Very-low-birthweight (VLBW) individuals are at high risk of brain injury in the perinatal period (Allin *et al*. 2004) or of foetal brain development interrupting by birth (O'Callaghan *et al*. 1987). Small or premature babies would have reached a different stage of cortical growth than heavier or full term ones. Structural asymmetry of the brain appear *in utero* (Chi *et al*., 1977), and are statistically related to hand preference (Beaton, 1977), although this relationship between brain asymmetries and handedness is not strict (V. Llaurens *et al.* 2008). The clearest evidence for a link between left-handedness and perinatal condition comes from studies of infants of extremely low birth weight (O'Callaghan *et al*., 1987; Powls *et al*., 1960, Bishop D. V. M., 1990). D. Nettle has proposed that birth weight and its consequences may be the unifying causal factor of "pathological left-handedness "(V. Llaurens *et al*., 2008).

In Utero Environment:

Some have suggested that prenatal sex hormones such as estrogen (Hines, 1982) and testosterone (Geschwind and Galaburda, 1985) can differentially affect the development of each cerebral hemisphere (Wisniewski, 1998, Hopkins W.D. and Dahl J.F., 2007). Testosterone is the quintessence of the Geschwind-Behan-Galaburda (GBG) model of cerebral lateralisation (Geschwind and Behan, 1982; Geschwind & Galaburda, 1985). It is produced from maternal ovarien, adneral glands, and other tissues such as fat; in males, testosterone is produced by the fetus's own developing tests (Spreen, Rissey,Edgell,1995). The elevated levels of testosterone *in utero* were hypothesized to slow down the growth of the left brain with a consequent compensatory growth of the right brain. This would, in turn, decrease the degree of naturally occurring dominance of the left brain and increase the dominance of the right brain. This would cause a weakening of right-handedness towards left-handedness. As stated by Bryden, McManus, and Bulman-Fleming (1994), ''it is obvious that here we are dealing with a major scientific phenomenon, of sudden onset and immediate influence.'' This hypothesis, however, did not find a general support from the laterality community, although it actually was successful in stimulating a great deal of research (Halpern, 1994; Tan and Tan, 2001). Delayed growth in the left hemisphere as a result of testosterone would account for the greater frequency of left-handedness in males. When testosterone effects are more marked and neuronal migration is interfered with to a greater extent, abnormalities in the formation of the left hemisphere will result---especially in males--- such as those described by Galaburda and Kemper in the left temporal speech area of a severe childhood dyslexic. This type of effect would account of a much greater incidence of learning disorders in boys (Geschwind and Behan, 1982).

During fetal life the immune system is also maturing. Geschwind and Galaburda (1987), claimed that, in addition to a learning disability, increased testosterone levels or abnormal sensitivity to this hormone predispose the individual to immune dysfunction (asthma, allergies, migraine headaches, *etc.*), because such an increase delays the development of the thymus gland that controls the immune system(Spreen, Rissey,Edgell,1995). There are studies that support the hypothesis that the fetal thymus controls development of lymphocytes which are responsible for recognition of self-antigens and thus for prevention of autoimmunity (Rocklin, 1979). Suppression of thymic growth during fetal life might, therefore, favor the development of autoimmunity in later life (Geschwind and Behan, 1982). Numerous case control studies were performed to test the association between handedness and immune disorders. The correlations between left-handedness and various diseases are unclear, as positive (Searleman & Fugagli 1987; Tonnessen *et al*. 1993) and negative (Pennington *et al*. 1987) results were both published. The Geschwind and Galaburda model therefore remains controversial (Llaurens *et al*., 2008). Finally, both a birth trauma and hormonal explanation together could explain the higher incidence of non-right-handedness. Non-right-handedness in first-born individuals could be due to factors related to birth trauma or periparturitional stress, whereas non-right-handedness in latter-born subjects could be due to hormonal factors related to increasing maternal age. Clearly these different explanations warrant further investigation in both human and nonhuman species (Hopkins W.D. and Dahl J.F., 2007).

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