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Chapter 1

Gifted Brain and Twinning: Integrative Review of the Recent Literature

Andrew A. Fingelkurts^{1,2} and Alexander A. Fingelkurts^{1,2}

Co-Heads of Research, PhD

¹ BM-Science Brain & Mind Technologies Research Centre, P.O. Box 77, FI-02601
Espoo, Finland.

² Human Brain Research Group, Human Physiology Department, Biological Faculty,
Moscow State University, 119899, Russian Federation.

Summary:

In this review, on the base of the literature data on the strong connection between high intelligence in pre/adolescents and high testosterone level in the prenatal fetus development and also on the increased concentration of testosterone in the amniotic liquid in the case of monozygotic male-twins pregnancy, the hypothesis of biologically conditioned intellectual giftedness in the monozygotic male-twins is suggested. Taking into consideration new experimental own data and results of other investigators it is assumed that the high involvement of the right frontal cortical area in the ongoing information brain processing may serve as a physiological marker of intellectual giftedness. The prenatal developmental peculiarities and unfavorable psychosocial factors during postnatal twins' development are discussed as the reasons for the phenomenological absence of talented male-twins in human history.

Keywords: Intelligence, Giftedness, Twins, Left-handedness, Cerebral lateralization, EEG.

1. Introduction

A long history of anatomical, morpho-functional, biochemical, neurophysiological and psychophysiological investigations of the human brain hemisphere's asymmetry proves the existence of a special bilateral principle in the

development of such important brain functions like perception, attention, memory and speech.

Recent studies in neuroscience show that interhemispheric asymmetry (particularly in the frontal areas) carries the essential contribution also in the manifestation of high intelligence in humans (see the reviews O'Boyle et al., 1995, Fingelkurts & Fingelkurts, 2002).

The evaluation of functional states (FS) of the frontal cortical areas is significant, because it has been shown that the synthesis of two types of information – current and retrieval – which create the basis for the emergence of subjective feelings (Ivanizky, 1997), takes place in the frontal cortex (Crick & Koch, 1995; Goldman-Rakic, 1996). It has been well documented through experiments using EEG, PET and fMRI that frontal cortical areas play the main role in the mechanisms which provide and regulate working memory¹ (Stuss et al., 1982; Goldman-Rakic, 1996), and conscious perception (Crick & Koch, 1995). It is supposed that information stored in the temporal and parietal cortex, is reread on the neurons of the frontal cortex (Goldman-Rakic, 1996). And at last it has been shown that a “general intelligence” or *g* may in large part be a reflection of frontal functions (Duncan et. al., 1996; Thompson et al., 2001).

Our research (Fingelkurts & Fingelkurts, 1995; Kaplan et al., 1997; Fingelkurts et al., 1998) demonstrates the minimal involvement of the left frontal cortical area of human brain during the process of operational synchronization in *various* FS (from rest conditions to different cognitive tasks). Moreover, applying other methods and approaches has also demonstrated increased involvement of the right frontal cortex in comparison with the left frontal area that remained uninvolved in the ongoing informative-analytical activity of the brain (Kaplan et al., 1998; Fingelkurts Al., 1998; Fingelkurts An., 1998; Fingelkurts et al., 2000).

At the same time, the majority of investigations with rest conditions (Kiroi et al., 1996) and memory testing in humans (Kiroi et al., 1988; Pavlova & Romanenko, 1988) reveal the dominance of the left frontal cortex over the right one. These findings are normally associated with the dominance of the left hemisphere as a feature of the human species (Dobrohotova & Bragina, 1994; Annett, 1999).

However, our data contradicts these findings. Probably, this discrepancy is due to the fact that all subjects in our research were MZ male-twins (Fingelkurts An., 1998; Fingelkurts Al., 1998).

Based on the findings that: 1) there is literature data that enhanced involvement of the right hemisphere in ongoing informational processing of the brain is a marker of extremely high intelligence (see the review, O'Boyle et al., 1995), 2) an increased level of testosterone leads to the faster maturation and cognitive development of the right brain hemisphere only (Geschwind & Behan, 1982), we hypothesize the following (this hypothesis has been suggested in 1998 and briefly discussed in *Questions of Psychology*, 2000): male-twins during prenatal development have an increased exposure to testosterone that leads to a more complicated (see details further) development of the right hemisphere which becomes dominant. These peculiarities of male-twins development result in potential giftedness. However, male-twins rarely realize this potential due to unfavorable socio-psychological conditions during postnatal development. Some of these suggestions are supported by external evidence, and perhaps some will turn out to be false, but meanwhile our hypothesis at least provides explanation for basic but widely scattered findings in physiological and psychological literature about androgens, intelligence, handedness, hemisphere specialization and twins. The synthesis of these findings reveals the many converging lines of evidence that support suggested hypothesis.

2. Intellectual Giftedness

How is giftedness defined? There is no one agreed-upon definition of giftedness or talent that dominates the field (Robinson & Clinkenbeard, 1998). Most definitions are psychologically based or educationally driven. We define giftedness as higher than average efficiency of neurological brain functioning (for details see Fingelkurts & Fingelkurts, 2002). Such a definition covers all areas of giftedness: general intellectual ability, specific academic aptitude, creative or productive thinking, leadership ability, visual and performing arts, and psychomotor ability (Ross, 1993).

¹ Do not mix with short-term memory, which is the storage of newly obtained experience. Working memory is the active part of the constant memory, but it may include as well the signs of "old"

The effectiveness of human brain activity is determined by the number of neurons and the density of neuronal networks, which were organized during the prenatal period and which were active during crucial periods (first 4 years of life) of human development (Kimura, 1994; Rakic et al., 1994; Clinton, 1996; Newman, 1997). Experimentally it has been proven that nearly all aspects of nervous system organization (including cell growth, size regulation, cells' number, form, and neuron network density) are strongly influenced by androgens during prenatal development and immediately after the birth² (Levy & Gur, 1980; Geschwind & Behan, 1982; Geschwind & Galaburda, 1987; Galaburda et al., 1987; Sholl & Kim, 1990; Dempster, 1991; Snyder et al., 1995; Collaer & Hines, 1995).

Thus, the prenatal level of androgens might be the essential link in the organization of the gifted brain.

3. Evidence from Endocrinology: Prenatal Levels of Testosterone

According to Geschwind and Behan, if the fetus gets an increased dosage of testosterone during the crucial period of prenatal development or if it is more sensitive to this hormone, then the brain of such a fetus starts to develop the right nondominant hemisphere more intensively (Geschwind & Behan, 1982); but in ordinary conditions the left hemisphere develops faster and stronger (Thatcher et al., 1987). Selected influence of testosterone on the right hemisphere is explained by a significantly higher average concentration of androgen receptors (AR) in the right hemisphere compared to the left (Diamond, 1991). At the cortical level, the right frontal area is in many of those areas, which significantly overloads the left cortical areas by numbers

memory.

² Although it is obvious that the human brain undergoes several growth spurts, there are periods of development during which the brain is particularly sensitive to certain types of experience (Johnson, 2001). For present discussion it is important that disturbances of the prenatal cerebral cortex development can result in a variety of minor malformations (Sarnat, 1987). These minor neocortical malformations have a direct effect on behavior (Rosen et al., 1995). The mechanism by which these small neocortical anomalies affect behavior remains unknown, but it was shown that these anomalies lead to profound and sometimes pervasive reorganization of the brain (Innocenti & Berbel, 1991). These findings support the idea that early neocortical anomalies have profound effect on cortical connectivity and these widespread changes in connectivity may have wide-ranging behavioral effects (Rosen et al., 1995).

of AR's (Sholl & Kim, 1990). This irregularity in AR density across the human brain is shown only in males. Evidently, the described particular development of morpho-functional brain organization must strongly influence the human cognitive abilities (Hellige, 1993; Halpern, 2000). This data is in agreement with the results of the research of Levy and Gur, which show that an increased level of embryonic sex hormones leads to the faster maturation and cognitive development of the right brain hemisphere (Levy & Gur, 1980).

From animals studies it is well known that testosterone can affect the central nervous system either directly as testosterone or through its metabolites estradiol and dihydrotestosterone (Pomeranz et al., 1985). Ironically estradiol and estrogen in females never reaches the brain. "High levels of alpha fetoprotein in the neonatal serum bind these estrogens and prevent their access to the brain. By contrast, in males the conversion of testosterone to estrogens takes place within the developing brain itself" (Small & Hoffman, 1994, p. 307-308). Injections of testosterone or its metabolites in the brain attenuate the reactive astrocytic response to penetrating wounds to the cortex and hippocampal structures (Garcia-Estrada et al., 1993). Recently it was also shown that circulating androgens in the developmental brain are responsible for male/female differences in brain structures, as well as for sex differences in the behavioral consequences of these brain differences (Rosen et al., 1999). It is assumed that "exposure to the [high levels of] testosterone might enhance the process of normal plasticity, thereby encouraging extraordinary restructuring of connectivity" (Rosen et al., 1999, p. 32).

Studies of the developing human fetal brain also support the hypothesis that testosterone in utero may lead to a more rapid growth of the right hemisphere (De Lacoste et al., 1991). It was shown that on the average, volumetric asymmetries (particularly frontal cortex) in the male brain favor the right hemisphere; in females the left hemisphere is slightly larger than its right counterpart.

Moreover, high levels of testosterone establish the special relation between the two brain hemispheres of the embryo (Galaburda et al., 1987; Geschwind & Galaburda, 1987; Collaer & Hines, 1995). This means an extremely high coordination and distribution of the brain cortical resources within and between the hemispheres (Alexander et al., 1996). These processes most likely result from an unusually strong developed corpus collosum (Habib et al., 1991). These findings together are supposed

to be the causes for intellectual giftedness (Benbow, 1986; O'Boyle et al., 1995; Alexander et al., 1996; Fingelkurts & Fingelkurts, 2000; 2002).

4. Evidence from Morphology: Brain Size/Head Size

It has been long known that testosterone influences brain size (see above) and the size of the skull (Verdonck et al., 1998). If so, then there should be some differences between males and females. Data from longitudinal study on head size of about 16800 newborns recorded over 112 years (1874–1985) clearly indicated that the boys had bigger head size ($p < 0.01$) when compared with the girls (see Fig. 11 in Halberg et al., 2000). However the difference in body size was not found. Recent studies on the brain size in large sample of subjects also indicated that brain volume is bigger in males when compared with females (for the collection of different studies see Posthuma, 2002).

5. Evidence from Anatomy: Corpus Collosum Studies

The corpus collosum (CC) is a white matter structure that connects right and left brain hemispheres through fibers of different sizes (Highley et al., 1999). In most cases a larger CC implies a larger number of collosum fibers. Also the maximal fiber diameters tended to be higher in larger brains (Olivares et al., 2001). If androgens influences the development of various brain structures than there might be some differences between males and females. Differences due to sex have been reported for posterior portions of CC – isthmus size (Steinmetz et al., 1992; Clarke & Zaidel, 1994) and shape (De Lacoste-Utamsing & Holloway, 1982), the angle of the CC (Oka et al., 1999), and for anterior regions of CC and especially the genu (Witelson, 1989) showing a trend for a male advantage. Also it was shown that there is a pathway-specific decrease in interhemispheric connectivity with increasing lateralization (Aboitiz et al., 1992). Hence, abnormal growth of the right hemisphere as a result of increased levels of testosterone results in a more symmetric brain (Geschwind & Behan, 1982) and possibly is the reason for an unusually strong developed CC (Habib

et al., 1991) in such subjects. In line with this supposition is recent research where it was shown that CC is larger in males than in females and is responsive to steroid hormone manipulations during development (Bimonte et al., 2000).

It is interesting that sex differences of CC also interacted with handedness (Clarke & Zaidel, 1994). Area of the midsagittal section of the CC (particularly in the isthmus) was found to be greater in non-consistent-right-handed men than in consistent-right-handed men (Witelson, 1989; Witelson & Golsmith, 1991). This finding supports a relationship between CC anatomy and functional asymmetry. The lack of such a relationship among women suggests that anatomical variation of CC in relation to lateralization is influenced by androgens (Witelson & Nowakowski, 1991). The CC morphology, which varied with hand preference, may be related to individual differences in the pattern of hemispheric functional specialization, which in its turn depends on the prenatal levels of testosterone.

6. Evidence from Behavioral Genetics:

Bigger Brains are Smarter

Positive correlations between head size and psychometric intelligence have been observed (Jensen, 1994). Since head size includes both brain volume and thickness of the skull, the accurate measure of the brain size and its correlation with intelligence is of special interest. The recent study published in *Nature Neuroscience* (Thompson et al., 2001) reported high heritability of grey matter volume in several cortical regions. It is worth to note that the highest heritability (ranging from 95-100%) was shown for frontal regions. It was also shown that grey matter substantially correlated with general intelligence or 'g' (Thompson et al., 2001). However this and other studies of brain volume and intelligence did not have enough statistical power to decompose the observed correlation into genetic and environmental components. The freshest research by Posthuma and colleagues (2002), also published in *Nature Neuroscience* overcame these problems. Using a dataset of 135 individuals the correlation between brain volume and g was decomposed into genetic and environmental components. It was shown that the correlation between both grey and white matter volume and g is completely due to genetic factors (Posthuma et al, 2002). Thus, bigger brains are

smarter. Here it is worth to note, that although intelligence shows very high heritability, it is still very complex trait, which is influenced by a number of quantitative trait loci – QTL (Plomin & Crabbe, 2000). Majority of such QTLs are very sensitive to different factors during early prenatal development³, where the increased levels of testosterone may be one of these factors.

7. Evidence from Cognitive Research: Testosterone and Functional Brain Specialization

Recent research has shown that testosterone (and estrogen) continue to play critical roles in cognitive abilities even throughout the human life span (Halpern & Tan, 2001). For example, the spatial skills of normal males fluctuate in accordance with daily variations (Moffat & Hampson, 1996) and seasonal variations (Kimura & Hampson, 1994) in testosterone levels. It has been also shown the cognitive consequences of testosterone replacement therapies: testosterone treatment in men with naturally low levels improved both their spatial and verbal performance (Cherrier, 1999). Additional support for the role of testosterone levels in cognitive functioning comes from unique studies with female-to-male transsexuals, who were given high doses of testosterone in preparation for sex-change therapy (Van Goozen et al., 1995).

These findings (when the hormonal levels have been controlled experimentally) support the idea that testosterone may influence brain functional specialization and cognitive functioning, and thus participate in development of a “gifted brain”.

8. Evidence from Behavioral Studies: Giftedness and Right Hemisphere Dominance

It has been suggested that the left hemisphere in humans has a very strong potential to manifest its dominant abilities (Annett, 1997). At the same time, in order

³ One must note that heritability for general intelligence increases from infancy (20%) to late adulthood (86%) (see Fig. 12.1 in Posthuma, 2002, p. 180), what leaves a room for influences of non-genetic

to give equal opportunity in the dominant competition, – there must be special conditions allowing the forming of the morpho-functional peculiarities of the right hemisphere (Bogdanov, 1997). The increased levels of prenatal testosterone may play the role of such conditions (Fingelkurts & Fingelkurts, 2000).

Taking into consideration all that is mentioned above, it is possible to conclude that the brain of a gifted person is organized differently than the brain of people with average abilities (Alexander et al., 1996; Halpern et al., 1998). This hypothesis is confirmed by the longitudinal investigation of O’Boyle’ group (O’Boyle et al., 1995). Using various experimental methods this group has shown that increased involvement of the right brain hemisphere (and a special level of coordination of information resources between the right and the left hemispheres) in the process of insurance of higher psychic functions is directly related with intellectual giftedness and may serve as a physiological basis of giftedness (Alexander et al., 1996). In contrast, in subjects with learning disorders, the left-brain hemisphere is involved in basic information processing more than in normal subjects (Obrzut et al., 1980).

The authors have used the operational notion of giftedness. All intellectually gifted subjects had maximally high scores of common test SAT (Scholastic Aptitude Test). Extremely high scores were observed in SAT-M (Mathematical part). Scores in SAT-V (Verbal part) were slightly lower. Nevertheless, these SAT-V scores significantly exceed the analogous scores of subjects with average abilities, and females too (O’Boyle et al., 1995). “This highly selected talented [subjects] performs as well as college-bound high school seniors on tests used for college admission, despite the fact that they have not taken the advanced course work that is provided in high school” (Halpern et al., 1998, p. 91). This means that their high scores do not indicate that they are exceptionally good at the recall of factual knowledge, “[...] instead, they are ‘creating’ or ‘discovering’ new knowledge on their own” (Halpern et al., 1998, p. 91).

These findings are consistent with the concept of “general intelligence” or *g*, according to which people performing better on one task will tend also to perform better on another (Deary, 2001a).

For reasoning of the current paper it is important that *g* may reflect the function of some particular information processing system, contributing in part to the

(biological) factors during early (prenatal) brain development.

organization of many different activities and hence producing some positive correlation between them (Duncan et. al., 1996; Deary, 2001b). Moreover, it was postulated that in large part *g* reflects the action control functions of the brain's frontal lobes (Duncan et. al., 1996; Thompson et al., 2001). In our investigations it has been shown that behavioral functions (attention, memory encoding and retrieval) reflected in *g* arise from joint or cooperative activity in a variety of distinct frontal systems, i.e., through a so-called "operational synchrony" of different neuronal systems (Fingelkurts, 1998; Fingelkurts et. al., 1998; 2000; see also the review Fingelkurts & Fingelkurts, 2001).

9. Evidence from Electrophysiological Studies: Giftedness and Right Frontal Cortex Dominance

Is there a clearer physiological marker of right hemisphere dominance in gifted subjects? The electroencephalogram (EEG) is one of the instruments that reveal brain activity on the neuronal level (O'Boyle et al., 1991). Yet, regarding the study of gifted subjects, researchers, using EEG during several neurophysiological methods have shown that stronger involvement of the right frontal cortical area in ongoing activity in comparison with the left was observed in all experiments with gifted subjects (O'Boyle et al., 1995). Moreover, even in the frame of this gifted subjects' group, the connection between involvement of the right hemisphere and SAT scores was detected: the more pronounced the involvement of the right hemisphere in the current informational processing in the talented subject, the higher the intellectual abilities (as detected by SAT [SAT-mathematics + SAT-verbal]) were.

Here we need to say a few words about right frontal activity in general so that, in the discussion that follows, we can avoid the confusions that may have resulted. We are aware that increased involvement of the right frontal cortex might occur for a number of reasons, only some of which are related to giftedness. However, in this paper it is argued that right frontal cortical involvement in *any* brain activity (even in those cases when left frontal cortical involvement should be observed) and right brain hemisphere dominance in general is the biological predisposition to intellectual precocity (Fingelkurts & Fingelkurts, 2002).

One may suppose that detected dominance of the right hemisphere in experiments described above reflects the increase of emotional tension. It is well known that the right hemisphere is more “emotional” than the left. But in that case, the increased level of ‘false alarms’ and ‘signal omits’ must be detected. This is traditionally associated with the leading role of the right hemisphere in the genesis of errors during perceptive activity under the influence of emotional tension (Windmann & Kruger, 1998). However, this interpretation can be rejected on the basis of results obtained in the study (O’Boyle et al., 1995).

Thus, it has been shown that there is an increased involvement of the right hemisphere (and particularly its frontal cortical area) in the ongoing activity of subjects with high intelligence (Fox et al., 1988; O’Boyle et al., 1995; Haier & Benbow, 1995). EEG analysis also reveals increased involvement of the right frontal cortical areas (O’Boyle et al., 1995) during ongoing brain activity in the number of experimental tasks. Therefore, frontal asymmetry with the dominant right cortical area is supposed to be the physiological marker of a “gifted brain” (Fox et al., 1988; O’Boyle et al., 1991; Bell & Fox, 1992; O’Boyle et al., 1995; Fingelkurts & Fingelkurts, 2000; 2002).

10. Evidence from Functional Specialization of Frontal Cortex

The functional meaning of the involvement of the right frontal cortical area in the ongoing activity of gifted individuals is not fully understood, although it is in agreement with neurophysiological data about the connection of the frontal areas with the higher mental functions and intelligence (Pribram & Luria, 1973; Chen & Buckley, 1988; Ivanizkiy, 1997; Diamond, 1991; Crick & Koch, 1995; Goldman-Rakic, 1996; Duncan et al., 2000).

However, one may argue that despite impairments in “planning”, “problem-solving”, etc., frontal patients have supposedly intact intelligence. Duncan et al., (1996) have shown in their works that this conventional view is misleading. The simple tasks they have introduced suggest a close link between Spearman’s *g* and frontal lobe functions. In patients with severe frontal difficulties, the tendency to

neglect a task requirement (even though it has been understood and remembered) is extreme and relates closely to *g* (Duncan et al., 1996).

Along these lines the recent study at the single-cell level found the existence of large, spindle-shaped neurons in the anterior brain cortex (Nemchinsky et al., 1999). These neurons exist only in primates: the density is highest in humans, next – highest in chimpanzees, lower in other apes. It is supposed that these neurons possibly participate in the integration of sensory and cognitive information and are responsible for higher mental activity.

Moreover, according to previous studies, the right frontal area is primarily responsible for nonverbal image thinking, formation of associations using nonlinear principle, unconsciousness functions, and for higher emotions (Nakamura et al., 1999; Sidorova, 2000). These are the exact functions necessary for the realization of the creative process and of scientific insight. It is generally accepted that the new ideas and artistic images are not the result of someone observations and reflection, – they come to the mental sight at once in complete internal integrity. The reports of highly creative people about their thought processes suggest that a great part of their cognitive work goes on “underneath”, beyond the conscious control of the person (Ghiselin, 1952; Dorfman et al., 1996; Monsay, 1997). For example Einstein described his thinking in the way that words for him do not play any role, but there is some kind of associative play of more or less clear images (Hadamard, 1949). Many scientific discoveries have come to their creators’ as momentary intuitive knowledge (e.g. the discovery of periodic system of elements by D.I. Mendeleev or the structure of benzol ring – by F.A. Kekulé), which were only systematically proven after the fact. Perhaps the unconscious nature of these early stages in the creative process serves to protect the birth of a hypothesis and new ideas from the conservatism of consciousness. A similar phenomenon can be observed, for example, in the reports of split-brain patients when information presented to the right hemisphere (Koriat & Levy-Sadot, 1999; Koriat, 2000).

11. Prediction 1: Testosterone Levels should Influence the Expression of Genes for Cognitive Ability

One prediction of suggested in the present review hypothesis is that increased levels of testosterone during prenatal development should influence the expression of candidate genes for intelligence. Since increased levels of testosterone in utero may lead to a more rapid growth of neurons in the developing human fetal brain (see above), it should influence substances which are responsible for that. Such substances (endophenotypes of cognitive abilities⁴, for discussion see De Geus & Boomsma, 2002) are nerve growth factor, NMDA and some others, which influence neuronal plasticity directly. The production of these substances is dependent on expression of particular genes (nerve growth factor beta polypeptide marker – NGFB, NMDA receptor genes and others), which are associated with intelligence. Thus, the evidence for IQ and NGFB association was provided in the IQ-QTL (Quantitative Trait loci) Project (Petrill et al., 1996). Morley and Montgomery (2001) in their extensive review showed that very promising candidate gene associated with cognitive ability is NMDA receptor genes. It was also shown (Tang et al., 1999) that overexpression of NMDA receptor gene in the forebrain results in a superior ability in learning and memory traits which are generally considered a central part of intelligence⁵ (Posthuma, 2002).

12. Prediction 2: Patients with Left Frontal Cortex Damage should Exhibit Talents

The other prediction of suggested in the present paper hypothesis is that patients with left frontal cortex damage should exhibit right frontal dominance and hence be talented to some extent. It was shown that patients with the left-sided lobe variant of frontotemporal dementia (FTD) showed the emergence of visual and musical talents

⁴ Biological, neurophysiological, electrophysiological and behavioral indices of the pathways that connect genes and cognitive ability are called *endophenotypes* of cognitive ability.

⁵ Working memory had the highest phenotypic and highest genetic correlation with brain volumes (Posthuma et al., 2002), which are correlated with IQ. Also, working memory has often localized in the frontal lobes. These findings may not be surprising since working memory is considered a major component of general intelligence (Posthuma, 2002).

(Miller et al., 2000). Evidently, these studies are consistent with the idea that for facilitation of new skills and talents the dominance of right frontal area is very important (Fingelkurts & Fingelkurts, 2000; 2002).

13. Prediction 3: Gifted Individuals should have Right Hemisphere Dominance

Another prediction of the current hypothesis is that exceptional intellectuals should have a more complicated right brain hemisphere (particularly frontal cortex). Albert Einstein is one of the intellectual giants of recorded history. An intriguing case study has been conducted by Anderson, who studied Albert Einstein's brain (Anderson & Harvey, 1996). In contrast to a control group of autopsied men, the right frontal cortex of Einstein's brain possesses a significantly greater neuronal density. Data about the greater size of specific gyral regions in the right frontal cortex of Einstein's brain were also found in another recent research (Witelson et al., 1999, see Table on p. 2152). Note that in the control group there is slight tendency to left frontal dominance. Thus, it has been suggested that dendritic arborization of frontal areas is correlated with *g* and giftedness (Anderson, 1993).

Moreover, it was shown that reversed hemisphere dominance (right) is related with musical talent and left-handedness (Hassler & Gupta, 1993). In line with these findings is evidence that Einstein was left-handed (at least non-consistent-right-handed) (Winokur, 1984). Also Einstein's corpus collosum area tended to be larger than its predicted value when hand preference and age were taken into consideration (Witelson et al., 1999, see Table on p. 2152). Thus these findings are in an agreement with the idea that right frontal cortex plays a considerable role in gifted brain.

14. Prediction 4: Among Gifted Individuals there should be an Increased Number of Left-Handers

Since handedness is the most obvious index of cerebral dominance, one should expect an increased number of left-handed or at least non-consistent-right-handed (right hemisphere dominance) individuals among gifted individuals. The convergence evidence from multiple paradigms shows that males are more commonly found among extremely gifted young people (Benbow, 1988; Benbow & Lyubinski, 1993; O'Boyle et al., 1995). Also the proportion of left-handers in this extremely precocious group is about double what have been expected from the proportion of left-handers in the population (Halpern et al., 1998). These authors possibly for the first time studied the relationship between handedness and intelligence in a highly selected group of adults. They showed that left-handedness (right hemisphere dominance) “[...] is at a higher rate among the most intellectually gifted than among adults of average intelligence [...]” (Halpern et al., 1998, p. 96). Recent data also supports these findings (for the review see Halpern, 2000).

15. Prediction 5: There Must be Sex Differences in Cognitive Abilities

Although most psychologists agree that there are no meaningful sex differences in general intelligence (Halpern, 2000), it should be mentioned that such differences were found for extremely gifted subjects. In 1980 Benbow and Stanley made a report (based on observation of 9,927 12- and 14-year-olds) stating that males are more successful in mathematics than females (Benbow & Stanley, 1980). This finding may be explained in a biological and/or socio-psychological way. The socio-psychological explanation has been more popular, but detailed investigations have not supported this point of view (Benbow, 1988). Simultaneously, scientists have come to the conclusion that males are more intellectually gifted than females in some parameters of intelligence (McGlone, 1980; Benbow, 1986; Hellige, 1993; O'Boyle et al., 1995) including verbal reasoning (Halpern et al., 1998). During the analysis of recent findings (over a million gifted adolescents), a biological explanation (Benbow, 1986;

Benbow, 1988; Jensen, 1998) of the ontogenesis of the cognitive abilities origin was formed (Thatcher et al., 1987; Reed et al., 1991). Hemispheric volume is considered as an important factor. Thus, it has been shown that hemispheric volumes are higher in men than in women (Gur et al., 1999). It has been assumed that greater hemispheric volumes in the male brain are due to the early effects of testosterone. And if the prenatal levels of testosterone are increased then it results in the right hemisphere dominance (Geschwind & Galaburda, 1987). What are the special conditions of increased levels of testosterone?

16. Prediction 6: Monozygotic Male-Twins should have Increased Levels of Testosterone

It is important to consider the conditions of increased levels of testosterone during the crucial period (7-12 weeks of pregnancy) of the prenatal development (Geschwind & Behan, 1982). There are only a few explanations for increased levels of testosterone. The first explanation may be the innate hyperplasia of the cortex of the adrenals in the pregnant female. This situation leads to increased levels of prenatal testosterone in the fetus (Collaer & Hines, 1995; Berkow, 1997). Another explanation may be the occurrence of a male-twins pregnancy. It has been shown that various levels of hormones in early stages of embryonic prenatal development leads not only to gender formation (for discussion see Lippa, 2002), but also influence the development of the future cognitive and mental functions (Hines, 1982; Halpern & Tan, 2001). The influence of increased doses of androgens during the early stages of embryogenesis is well documented in animal experiments (Reinisch, 1974). The advantage of nonhuman research is that it allows to employ experimental methods that permit strong causal inferences (Halpern & Tan, 2001). These experiments demonstrated that when a female and male embryo are located in close proximity, increased levels of testosterone are detected in the blood and amniotic fluid of the female embryo (Vom Saal & Bronson, 1980). After birth, this female has a more aggressive character (Vom Saal et al., 1981), her sexual behavior would be less orientated on the males (Vom Saal & Bronson, 1980) and would be organized on the males type (Vom Saal et al., 1981). In cattle fraternal twins prenatal blood exchange

between twins leads to sterility in the females – freemartin effect (for details see Segal, 2000).

Similarly, the male embryo, located near the female embryo, has increased estradiol levels in the blood and amniotic fluid. After birth this may result in a female sexual behavior (Vom Saal et al., 1983).

These findings have been clarified in humans. Thus, the evidence for the role of hormones has been shown by studying girls who were exposed to high levels of testosterone because their pregnant mother had congenital adrenal hyperplasia (Collaer & Hines, 1995). These girls had better spatial skills and are more likely to show aggressive behavior (very similar to boys) when compared with other girls. Investigations of different-sex dizygotic twins in humans have also shown that the female embryo in such pairs has the increased concentration of testosterone and in the future this girl displays masculine behavior. Similarly, the male embryo – consequently has the increased dose of estradiol that in the future leads to feminization of a boy (Vom Saal et al., 1983). Thus, according to data, if the twins are two male fetuses, then after starting to produce their own androgens in the 7th week of pregnancy they inevitably will be influenced by the increased levels of testosterone (Geschwind & Behan, 1982; Geschwind & Galaburda, 1987) not only in the amniotic fluid, but will take testosterone inside their bodies by means of feta-fetal (or transplacental) blood transfusion (Kaelber & Pough, 1969). Twin to twin transfusion is a significant clinical phenomenon (Segal, 2000). 70% of monozygotic (MZ) twins and 8% of dizygotic (DZ) twins have had in uterovascular connections (Hall, 1996). In the chronic form of twin-to-twin transfusion syndrome, one of the twins becomes anemic, hypovolemic and growth retarded and the other becomes plethoric, hypervolemic and often has congestive failure (Lopriore et al., 1995; Machin et al., 1996, for the review see Segal, 2000). Although the biological origins of two types of twins (MZ and DZ) may have a lot in common (Segal, 2000) and therefore DZ male-twins would also have higher levels of fetal testosterone, we prefer to limit the argument to MZ male-twins, since they have much more often the same placenta, chorion and amnion (Segal, 2000).

16.1. Evidence From Endocrinology of MZ Twins

The exact mechanism of the accumulation of increased levels of testosterone in embryonic target tissues has not been thoroughly studied. It is suggested that a critical factor is that during this period, embryonic production of testosterone is proportional with that of adult males (Wilson, 1999). Yet the volume of a fetus is significantly less than that of adult males. Thus, the surplus of androgens from each twin fetus enters the amniotic liquid and/or is transmitted through the placenta and the mother organism directly to the organism of the co-twin. Testosterone is a lipophilic hormone, and therefore is practically nonexistent in a free state in blood plasma. It is connected with special transport proteins and transported to target tissues. The brain is one of those organs which actively “need” androgens for its development. Transport proteins using the surplus of testosterone provide the locally increased concentration of testosterone in the embryonic male brain. Here in the male brain the enzyme aromatase converts testosterone to estrogens (Whitacre et al., 1999). The effect of such conditions on prenatal development may result in the right hemisphere dominance in male-twins, which gives them the potential for giftedness (Fingelkurts & Fingelkurts, 2000).

16.2. Evidence From Twins Research

The main group of subjects in our study consisted of MZ male-twins. For determination of twins type we used the Physical resemblance questionnaire (Nichols & Bilbro, 1966). In the introduction section it was mentioned that during several experimental conditions (waiting, encoding, retrieval and keeping information in mind) including rest conditions with eyes open and closed, it was demonstrated the increased involvement of the right frontal cortex in comparison with the left frontal cortex that remained uninvolved in the ongoing informative-analytical activity of the brain (Kaplan et al., 1998; Fingelkurts Al., 1998; Fingelkurts An., 1998; Fingelkurts et al., 2000).

Therefore it is possible to combine the findings described above and discuss them together. In that case, the fact of strong bilateral asymmetry (obtained in our

work during testing of various brain functional states) of the frontal cortical areas with dominance of the right hemisphere becomes understandable. It is probable that this dominance is resulted from the joint prenatal life of the male-twins. Moreover, the investigations described above, allow us to hypothesize the biological potential for high intelligence in all MZ male-twins. Indeed, only gifted subjects showed the dominance of the right frontal area during the various experimental conditions (dichotic listening of the words and phonemes, finger typing with the right and left hand with simultaneous text reading, and perception of the chimeric-faces with EEG recording) (O'Boyle et al., 1991).

Our study included prolonged observation of twins' lives. Data showed that twin sets, which participated in our study, graduating from Moscow State University, earned the highest academic credits (4.9-5 credits based on 5-grade Russian system) and successfully completed their Ph.D. degrees. Also, twin pairs examined in our study had additional talents besides academic, e.g., dancing, painting and music. It should be mentioned here that male-twins in our study were a self-selected sample (they all entered to Moscow State University), so they are not representative of male-twins in general.

Our study included a very small sample size, only six pairs of MZ twins participated. This necessitated the review of other large-scale twins investigations that have revealed the dominance of the right frontal cortical area. Our analysis of an investigation of 2009 pairs of MZ twins of each sex (with retesting after 1.5 year) done by Van Baal et. al., (1996) revealed that in females the absolute and relative power of beta and alpha EEG rhythms of the left frontal area (in comparison with the right) are under strong genetic control; in the males, genetic control was detected for the right frontal area. This data is in line with our study. In another study, sex differences were detected in genetic influence on the coherency (COH) index of the frontal areas with other cortical zones: in females the COH focus was at the left frontal area, in the males – at the right (Van Baal et al., 1997). Thus, this analysis permits us to conclude that male and female pairs of MZ twins have different genetic determinants for the involvement of the right and left frontal areas in the ongoing brain activity. This is also in agreement with the reasoning of the present review.

17. Prediction 7: Among MZ Twins there should be an Increased Number of Left-Handers

It is obvious that left-handedness reflects the dominance of the right hemisphere (for the review see Lippa, 2002). So, one of predictions of our hypothesis is that left-handedness should be more common in twins than in singletons (more pronounced in MZ twins than in DZ), and also more common in men than in women (Benbow et al., 2000). Although separate reports are controversial, analysis of available data together⁶ shows that the percentage of left-handers is higher among the twin population than among single-born individuals (Dobrohotova & Bragina, 1994; Derom et al., 1996; Segal, 2000). Also systematic meta-analytic works of Annett support these findings (Annett, 1978; 1998). In one of her combined research, 45178 individuals participated (Davis & Annett, 1994). It was shown in this study that for each age group the proportion of left-handers was greater in males than females, and substantially greater in twins than in singletons. Recent meta-analysis of literature on twins data and their parents also showed prevalence of left-hand-claspers and left-arm-folders in twins (Reiss, 1999).

Annett suggests the right shift (RS) theory according to which normal human cerebral specialization (left hemisphere dominance and right-handedness) is caused by a gene with the instruction to impair the right hemisphere (Annett, 1978; Annett, 1997). On the basis of meta-analysis she noticed that expression of the rs+ gene is more effective in females than in males and less effective in twins than in single born children (Annett & Alexander, 1996). Moreover, it was shown that the suppression of the rs+ gene leads to high intelligence (Annett, 1999). This suggests that the expression of the rs+ gene might depend on factor(s) influencing cerebral maturation in early fetal life (Annett, 1996). Evidently, these studies are consistent with the idea of the present review that testosterone may be such a factor which suppress the rs+ gene expression.

⁶ Very large samples are needed to yield an adequately large sample size in the upper tails of distribution. Also large samples needed because of the low statistical power associated with the test of any hypothesis about handedness (Halpern et al., 1998). Note also, that extremely low rate of left-handedness (associated with writing) has been reported in some studies, but showed a high degree of left-handedness for activities against which there were no social sanctions (hammer and toothbrush use for example) (Teng et al., 1976, cited on Halpern et al, 1998).

18. Prediction 8: Dermatoglyphic Patterns in MZ Twins Should be More Complicated on the Left Hand

Analysis of the dermatoglyphic patterns of MZ twins are especially interesting since the morphology of the brain and ridge skin developed from the same embryonic tissue and for some time occur during the same prenatal developmental periods (Segal, 2000). Our analysis of dermatoglyphic data, which were collected by M.V. Volozcky (Volozcky, 1936) in 128 pairs of MZ and 106 pairs of DZ twins, shows that more complicated skin patterns in MZ twins are situated often on the left hand (which corresponds to the right hemisphere) in comparison with the single-born population. Determination of the sophisticated embryonic structure of the ectoderm results in the complicated structure of its derivatives, particularly – the morphology of the brain and ridge skin (Gladkova, 1962; Bogdanov & Solonichenko, 1995). Consequently, on the level of the ridge skin it leads to complications of the dermatoglyphic patterns (in this study – the left hand). And on the level of the central nervous system it may be reflected in the complication of its macro- and microstructure (in this study – the right hemisphere) (Bogdanov, 1997). The connection between the central nervous system and dermatoglyphic patterns was shown even with EEG applications (Bogdanov et al., 1994). Also, there is literature data about the interrelation of skin patterns and nerve endings at the end of the fingers (Bonnievie, 1929). Thus, these findings support the idea of the present review that MZ male-twins may have dominant right hemisphere.

19. Summarizing Evidences and Predictions

Taking together convergence lines of evidences and testified predictions that: 1) an increased dosage of testosterone during the crucial period of prenatal development results in the right brain hemisphere dominance (Geschwind & Behan, 1982), 2) the dominant right hemisphere and particularly frontal cortical area is supposed to be the physiological marker of a “gifted brain”, 3) there is a close link between Spearman’s

g and frontal lobe functions which are necessary for the realization of the creative process and of scientific insight, 4) patients with the left-sided variant of frontotemporal dementia (FTD) showed the emergence of visual and musical talents (Miller et al., 2000), 5) the right frontal cortex of Einstein's brain possesses a significantly greater neuronal density if compared with a control group of autopsied men, 6) the population of gifted individuals exhibits the right hemisphere dominance, 7) there is a large number of left-handers among subjects with high intelligence and among the twin population, 8) even in adults the average level of testosterone is significantly higher in blood plasma if they are left-handed, ambidextrous and right-handed with the family left-handedness (when compared with right-handers with the family right-handedness) (Tan, 1991), 9) left-handed individuals have a more strongly developed corpus collosum (Habib et al., 1991; Moffat et al., 1997), which probably compensates for the unusual dominance of the right hemisphere, 10) monozygotic male-twins have increased levels of testosterone, and the right frontal dominance in MZ male-twins may be a result of the joint prenatal life of the male-twins, 11) more complicated skin patterns in MZ twins are situated often on the left hand (what corresponds to the right hemisphere) when compared with the single-born population, we may propose that the subjects' samples in all these cases overlap for the following common reason – *increased levels of testosterone in the crucial period of the prenatal development.*

Thus, it is possible to suppose the biological potential for intellectual giftedness in all MZ male-twins. Also we may stipulate that at least some of famous gifted males where conceived as twins. In that case prenatal twins' conditions provided the appropriate biological basis for the development of giftedness. It should be mentioned that the peculiarities of prenatal development of the MZ twins equally fair the males and females. But for reasoning of present review, because of described peculiarities of the males' organism (testosterone), only MZ male-twins are of the interest.

But an obvious question arises about the extremely small number (except sport, for details see Segal, 2000) of “bright” and gifted twin pairs (even males) in the human history.

20. Why Talented Twins Appeared Very Rarely in Human History?

At first sight, this fact seems to undermine the theoretical underpinning of the present review. However, there are two factors at least, which lead to the extremely small number of talented twins in the human history. First, only one from the embryonic MZ twins' pair is usually born or one of the twins died very early in the life (recall Elvis Presley's early loss of his twin brother Jesse, see Segal, 2000), second, the existence of unfavorable conditions of the joint postnatal twins' development, which preclude further development of potential brain giftedness.

20.1. Unfavorable Prenatal Conditions of MZ Twins

To analyze this, the authors addressed the twins' investigation of Charles Boklage (East Carolina University School). Of 325 examined twins pregnancies, only 19 resulted in the birth of twins. In 125 cases, only one from the twin-pair was born. In 181 cases both fetuses were lost during pregnancy (see also Segal, 2000). This means that in only 6% of pregnancies when twins were fertilized two babies are born. Thus, many single-born babies actually start their lives as part of a twin-set! What are the difficulties of the twins' pregnancy?

Examinations of twins placentas, have led researches to conclude that if a zygote is divided during the first four days after fertilization, then the twins will have different placentas, chorions and amnions (for the review see Segal, 2000). Such twins have the best odds of surviving the pregnancy, and in the future those co-twins will have more differences than similarities. Dichorionic MZ twins had the lowest incidence of preterm birth, perinatal mortality, and birth weight discordance (Machin et al., 1995). If a zygote's division occurs between the fifth and eight days after fertilization, then the twins will have one placenta and chorion, but two amnions. In this case, one of the twins tends to receive more nutrition and develops healthier, as a result of the umbilical cord wrapping around the neck of the other co-twin. Twin-to-twin transfusion syndrome is very often usual in this case, and it leads to a high risk of perinatal morbidity and mortality (Feidstein et al., 2000). Even if both twins are

born successfully, the second twin frequently dies during the first few years of life (Hall & Lopez-Rangel, 1996; Segal, 2000).

A zygote's splitting between 8 and 12 days after fertilization results in the twins having common placenta, chorion and amnion. This results in an inevitable competition for space and nutrition, and the frequent pathology of the umbilical cord, often leading to the death of at least one of the co-twins (Machin et al., 1996). If such a pregnancy and birth are successful, then such twins will be very friendly and similar to each other (Sokol et al., 1995). However, the left-handed twin, who normally is born first, is usually the healthier of the two (Christian, 1979; Bishop, 1990).

Finally, the splitting of a zygote after the 12th day of fertilization leads to the occurrence of so-called "conjoined" twins. In that case, their bodies are already shared, but they frequently have distinctly different temperaments and habits (Segal, 2000). Interestingly, there is an excess of females among conjoined twins (James, 1995).

Another possible birth scenario is that one twin absorbs the body of the other twin – "vanishing syndrome" (Hall, 1996; Segal, 2000). Also there is the situation, when one twin fetus is reabsorbed by the mother organism. These situations also result in a singleton pregnancy (Segal, 2000).

As was described above, among gifted subjects the proportion with dominant left hand is higher than among subjects with averaged abilities (Geschwind & Behan, 1982; Benbow, 1986; O'Boyle & Benbow, 1990). But the percentage of left-handers is higher among the twin population than among single-born individuals (Dobrohotova & Bragina, 1994; Derom et al., 1996; Neimark, 1997). This has caused some researchers to postulate that some of single-born people with a dominant left hand (including "hidden" left-handed and non-right-handed) are survivors from a twin-set (Neimark, 1997). Perhaps such people exist among famous gifted males, but this hold needs experimental checking.

20.2. Unfavorable Socio-Psychological Postnatal Conditions of MZ Twins

Despite data, which support the biological basis (not only genetic) of high intelligence (Meehl, 1992; O'Boyle et al., 1995) it is impossible to derogate the

“environmental” (socio-psychological) factors that provide necessary conditions for the optimal realization of the biological basis (Segal, 2000; Fingelkurts & Fingelkurts, 2002). Such psycho-social factors in the majority of cases are very unfavorable for twins.

Various factors of the psychological and mental development of MZ twins may preclude the prenatal development of biological basis for the high intelligence, and as a result, such intelligence can't be fully realized (Fingelkurts & Fingelkurts, 2000). Thus, it has been shown that in general young twins have IQ scores on average lower than genetically unrelated singletons on 4-7 points (Segal, 2000). However, no evidence of differences between adult twins and their non-twin singletons on cognitive performance was found (Posthuma et al., 2000).

One main factor is that as children the twins are constantly together. This leads to the emergence of two opposite streams of development (Segal, 2000). Their constant communication, their shared environment, and the attitudes that others have towards the twins, leads to the development of a unique form of self-perception in twins, i.e. “twins reaction” (Zazzo, 1960).

As a result, twins have many difficulties distinguishing the concept of “I” from the concept of “We”. This means that twins first distinguish themselves from the external world as a pair and only later as individuals (for review see Talizina et al., 1991). In extreme cases, co-twins perceive the reflection of his/her brother/sister in the mirror as his/her own; they refer to themselves by one name, ascribe their own personalities and psychological characteristics to one another, and even confuse the life events of each other (Neimark, 1997). All this makes the psychological and cognitive development of the twins difficult and complicated.

Another aspect of “twins reaction” is the resulting divergence of similarity between co-twins by means of different social roles. Scientists have determined two manifestations of this phenomenon: “competition with each other” and “competition against each other” (Gruszewska, 1998). Moreover, one may determine different social roles, e.g., “minister of foreign affairs”, who organizes communication and presentation of the pair with the external world, and “minister of internal life” – or the “conscience” of the pair (Von Bracken, 1934 and Stoltenber, 1929, cited on Segal, 2000). Usually these roles change from time to time as twins grow up (Williams & Medalie, 1994).

Language and speech are essential for cognitive changes during the ontogenesis. The majority of researchers conclude that the development of language and speech in the twins is delayed (see review by Talizina et al., 1991; Akerman, 1995; Segal, 2000). Twins usually start to speak later than single-born kids, and the lexical number of words is less than in single-born children (McEvoy & Dodd, 1992). These delays are determined in socialized speech (Talizina et al., 1991). Another significant delay is in the development of communicative speech (McEvoy & Dodd, 1992). There are several reasons for this. Firstly, the unfavorable prenatal conditions (see above) of twins seem to have a lasting effect on their later physical and mental development (Akerman & Fischbein, 1991). The second factor is unfavorable postnatal development of twins (Kantonistova, 1980; Akerman, 1995). Usually, a single-born child is constantly in the company of adults and he (or she) develops the language and speech skills in order to communicate with parents and other children (Talizina et al., 1991). However, twins don't feel this need because each has a constant partner of the same age and at the same stage of physical and mental development, and usually they find ways to communicate without using speech or normal language (Bishop & Bishop, 1998; Segal, 2000).

In cases when only one of the twin-set is born (or twins were separated from the birth) negative factors of joint twins' development in the postnatal period weren't observed (Pedersen et al., 1988). Thus, it was shown that singleton twins (the loss of one twin at birth) performed better than ordinary twins (for the details see Segal, 2000). Also, a Minnesota study reported that twins reared apart (i.e. rearing as the singletons) have an above average IQ score (Bouchard, 1990, cited on Segal, 2000). These findings give strong support to our reasoning that among gifted males there may exist a high percentage of twins "by conception", because in such cases the biological basis for high intelligence was present, but the negative factors of joint twins' postnatal development were absent. However this point could only be proven through specially organized investigations.

21. Negative Factors Accompanying High Intelligence

The owner of high intelligence (the functional marker of which is increased involvement of the right hemisphere in the ongoing brain informational activity, and physiological marker of which is the bilateral asymmetry with the right frontal area dominance) (O'Boyle et al., 1995), has a significant number of accompanying problems, – a so-called “physiological price”⁷ (Fingelkurts & Fingelkurts, 2000). It has been demonstrated that increased levels of testosterone in the critical period of human prenatal development, leads not only to the development of the right hemisphere and as a consequence – to intellectual giftedness, also have a negative influence on the thymus gland. This leads to the increased risk of the immune disorders, such as allergic and autoimmune reactions (Geschwind & Behan, 1982; Benbow, 1986). For example, it was shown that there is a significant correlation between giftedness and myopia (Ashton, 1983). This data was confirmed in recent research. Approximately 10.000 gifted students were tested. The results of the study proved the relationships between myopia and giftedness (Lubinski & Humphreys, 1992). Also it was shown the positive correlation between giftedness and allergy. This positive correlation could be seen when a child reported being told by a physician that he or she had an allergy (Lubinski & Humphreys, 1992). One may argue that testosterone normally has an immunoprotective effect, so many autoimmune diseases are more prevalent in women than in men (Whitacre et al., 1999). Here it should be mentioned that sex hormones show a biphasic dose effect (Whitacre, 2001): for testosterone, normal concentrations protect, while high doses facilitate immune responses acting as triggers of autoimmune events. It is interesting that the autoimmune diseases are more prevalence in MZ twins (Jarvinen et al., 1992; Segal, 2000) and associated with non-right-handedness (McManus et al., 1993). Lastly, the comprehensive recent study clarify that left-handers have a higher incidence of autoimmune diseases (Morfit & Weekes, 2001).

Moreover, gifted people also frequently suffer from depression or depressive episodes (Post, 1994). This is in agreement with findings which showed the increased involvement exactly of the right frontal area in ongoing activity and decreased

⁷ The physiological price – the volume of the physiological and psychological expenditures, which provide the normal vitality of the organism on the given level.

involvement of the left (the diagnostic criteria was EEG) in depressive subjects (Hitt et al., 1995). However, it has been shown that right frontal activation is related to coping strategies in men when depressed, while left frontal activation is related to coping strategies in females (Nolen-Hoeksema, 1987). For instance, highly defensive men are more likely to isolate themselves, whereas highly defensive women are likely to do opposite (Kline et al., 1998). These findings suggest that gifted individuals might prefer solitary activities, which on one hand may represent a defensive coping strategy, and which on the other hand, may also help them to be creative.

Several studies have attempted to prove that extremes in mood are linked with creativity (Jamison, 1989, 1995; Post, 1994). The highly creative people are also known to be difficult in interpersonal relationships, socially harsh, and abrasive (Lubinski, 2000). This supports Eysenck's view that the highly creative are, on average, high on trait psychoticism (Eysenck, 1995).

At the same time, described negative aspects of intellectual giftedness more often occur with left-handed individuals (Dobrohotova & Bragina, 1994). Furthermore, left-handers are more frequently present among schizophrenics and epileptics than among the healthy population (Nasrallah et al., 1981 and Ginoyan, 1985, quotes on Dobrohotova & Bragina, 1994). Schizophrenia or schizophrenic features and epilepsy are also frequent among gifted people (Post F., 1994). It is interesting that postmortem studies of brain anatomy in schizophrenics, "schizoid" and "shizotypal" people, and individuals with Asperger's syndrome have found reduced cortical volumes of the left hemisphere (Chiron et al., 1995; Bullmore et al., 1995; Weinberger, 1995) and especially in the frontal cortex (McGuire & Frith, 1996; Ross & Pearson, 1996). The same results were obtained in recent meta-analysis (Wright et al., 2000). Described factors provide further indirect support for the hypothesis that among the gifted males there should be a high percentage of left-handed (Geschwind & Behan, 1982; Benbow, 1986; O'Boyle et al., 1995), who are possibly the surviving members of an embryonic twin pair (Fingelkurts & Fingelkurts, 2000).

However, it has been shown that children with high intelligence (and left-handers) are physically healthier than their coeval with averaged abilities (Lubinski & Humohreys, 1992). The left-handed individuals also experience very quick reversal of pathological states, and slighter reestablishment of brain functions after trauma and

disorders (Dobrohotova & Bragina, 1994). Possibly the described peculiarities may be the consequences of the special brain organization (Bogdanov, 1997) and, in particular, the right hemisphere.

22. Conclusions

Generalizing the data described in the present paper, we conclude that the potential for giftedness is an innate biological feature. Development of a talent is a biosocial issue, and the realization of a talent is a psychobiological issue (Fingelkurts & Fingelkurts, 2002).

The suggested hypothesis regarding the possible link between high intelligence (the physiological marker of which may be the dominance of the right frontal cortical area in comparison with the left) of the MZ male-twins and a high level of testosterone in the prenatal period is speculative. Therefore, we recommend further study of this question. For example, it is possible to suggest following testing of the suggested hypothesis. If compare intelligence of singletons of both sexes with MZ twins, what the hypothesis predict? As we have mentioned above, female MZ twins would be subject to the same negative environmental and social factors that are identified for MZ males. Thus, on average, we should observe some intellectual deficit in female MZ twins compared with female singletons. For males, the MZ twins have a higher level of fetal testosterone which, according to the hypothesis, should boost their intellectual ability. Thus, the negative intellectual difference that should be found for females should be reduced on average for MZ males or even reversed, when comparing with singleton males. Here it is important to stress that during this testing one must control the birth weight of subjects. It was shown that birth weight is the very important factor and is related to cognitive development (Akerman, 1995). If these predictions turn out to be correct, then the suggested hypothesis regarding the possible link between high intelligence of the MZ male-twins and a high level of testosterone in the prenatal period receives considerable support, but if they turn out to be false, then the hypothesis either must be rejected or at least thoroughly modified.

Question about the more complicated organization of the right brain hemisphere in male-twins is significant. Moreover, most of the current knowledge about the

functions of the right brain hemisphere has been obtained in pathological conditions (heart attacks, strokes, cancer and so on) (Bragina & Dobrohotova, 1988); at the same time gifted intellectuals (or the male-twins) can be the healthy natural model for studying the morpho-functional peculiarities of the right brain hemisphere. Finally, the study of the intellectually gifted is a unique opportunity for the intensive investigation of the human potential in general.

The position presented in the present article should be seen as a working hypothesis that is worth attention, although some of its tenets are still open to debate and further investigation.

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