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Developmental Differences Between Same-Sex and Opposite-Sex Twins

by

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Abstract

In 1985, Geschwind and Galaburda proposed that testosterone plays a mediating role in the development of immune disorders, developmental problems, nonrighthandedness, and spatial skills. All these variables have been reported to have a higher incidence in males than in females. In order to test this proposed mechanism of action, same-sex (SS) and opposite-sex (OS) twins were studied. It is believed that a female *in utero* with a male should be exposed to elevated levels of testosterone, as should a male *in utero* with another male. If testosterone is having the effect as proposed by Geschwind and Galaburda, then females of OS twins should be more "masculinized" than females of SS twins and female singletons. Similarly, males of SS twins should be more "masculinized" than males of OS twins and male singletons. One hundred and thirty-seven twin pairs and 138 singletons were recruited with ages ranging from 8-20 years. Questionnaires concerning development were completed by the parents of the subjects. For the females, the only differences found were in the twin/singleton comparisons: female twins, regardless of type, were found to have more developmental problems than female singletons. For the males, males of SS twins had more immune problems (in particular, skin reactions), higher incidence of giftedness, and some indication of better spatial skills than males of OS twins. Further, males of SS twins had more

immune problems (skin reactions) than male singletons. For all the twin/singleton comparisons, greater pregnancy and birth complications and lower birth weights were found in the twins. The results are discussed in terms of the Geschwind and Galaburda model, the aromatization hypothesis (i.e., conversion of testosterone to estrogen), the mediating role of estrogen, and the paradoxical effect of testosterone.

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Dedication

To the unique phenomenon of twinning that provided the natural environment for this investigation, and to the twins and their parents who shared their histories with me.

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Introduction

There has been a recent focus in the scientific literature on the differences in behaviour and skills of opposite-sex (OS) twins as compared to same-sex (SS) ones. For example, Resnick, Gottesman, and McGue (1993) reported that female members of OS twins demonstrated an increase in sensation seeking behaviour as compared to females of SS twins. Cole-Harding, Morstad, and Wilson (1988) found that females of OS twins scored higher on spatial tasks than the females of SS twins. McFadden (1993) found that females with male co-twins exhibited about half the average number of spontaneous otoacoustic emissions per ear than females of SS twins or female singletons. Less recently, Record, McKeown, and Edwards (1970) reported that females of OS twins performed worse on measures of verbal ability than females of SS twins (and more similarly to their male co-twins). In all four of these investigations, the females of OS twins have performed in a more "masculine" way than females in SS pairs.

The interesting question is whether the prenatal or postnatal environment (or both) is responsible for the results of these studies. One way to determine if sex differences in behaviour are related to prenatal events is to investigate whether there are correlations between hormonal stimulation *in utero* and later behaviour (Breedlove, 1994). For many skills and behaviours, there is growing evidence in the literature that the prenatal

hormonal environment is an important factor. For instance, in females with congenital adrenal hyperplasia (CAH), prenatal testosterone levels are elevated to within or above the male range (Carson et al., 1982). Resnick, Berenbaum, Gottesman, and Bouchard (1986) investigated the effect these elevations may have on females and found that females with CAH had enhanced spatial skills and lower verbal IQ scores as compared to matched female controls, a pattern of cognitive abilities more typical of males. Further, Berenbaum and Hines (1992) determined that girls with CAH who were exposed to high levels of androgens in the prenatal and early postnatal periods showed increased play with boys' toys as compared to unexposed females. Helleday, Bartfai, Ritzen, and Forsman (1994) also determined that CAH women displayed a more "masculine" cognitive pattern as well as a relative postpubertal verbal disadvantage as compared to matched controls. Although the prenatal levels of testosterone may not be causal in the observed behavioural patterns, the differences are striking enough to suggest the possibility of such a link.

Mutations in the gene that encodes for the androgen receptor can reduce or eliminate the ability of the receptor to bind androgen, resulting in Androgen Insensitivity (AI) in humans (Breedlove, 1994). In other words, AI men are irresponsive to androgens despite normal levels of plasma testosterone. It has been determined that AI men have poorer spatial skills as compared to normal men (Hier & Crowley, 1982), but higher verbal IQs

over performance IQs on the Wechsler intelligence scale (Imperato-McGinley, Pichardo, Gautier, Voyer, & Bryden, 1991), a pattern of cognitive performance more common to females (Breedlove, 1994). Again, it appears that variations in hormonal stimulation *in utero* affect later cognitive abilities.

Another paradigm of interest is that of the effect of synthetic hormones administered during pregnancy on later behaviour of the affected offspring. Hines and Shipley (1984) found that daughters of mothers administered diethylstilbestrol (DES) during pregnancy (a synthetic hormone that is known to masculinize neural organization and behaviour in rats) were more "masculinized" than matched controls. Another indication that DES might masculinize the human brain is that although most DES-exposed women are heterosexual, a higher proportion of them are homosexual or bisexual than non-exposed women (Ehrhardt et al., 1985). Further, Reinisch and Sanders (1992) determined that males exposed to DES exhibited reduced hemispheric laterality and lowered spatial ability as compared to controls. In all three of these described anomalies (CAH, AI and DES), it is consistent that when the action of hormones is altered, "normal" sexual differentiation of the CNS is impaired.

Very little research has been carried out in human twins to investigate if the occurrence of having multiple fetuses *in utero* can affect the "normal" balance of hormones and in turn, change postnatal

development and behaviour. The possibility that the hormonal environment *in utero* varies according to the presence of a male co-twin and influences the development of a female co-twin provides the rationale for the current investigation. The outcome variables of interest are derived from another field of research, which will now be reviewed.

Testosterone Hypothesis

It has been well established in the world literature that males have a higher rate of immune disorders, learning disabilities and other developmental disorders as well as a higher incidence of left-handedness. The trends in the literature also indicate small but significant differences between male and female verbal and spatial skills; males tend to perform better on spatial tasks, females tend to perform better on verbal ones (Breedlove, 1994). Geschwind and Galaburda (1985a) proposed that aberrant levels of testosterone, or an increased sensitivity towards it, play a key role in the development of these disorders as well as the intra-individual relationship of each. They hypothesized that testosterone slows the growth of the left hemisphere and consequently there is a shift towards right hemisphere skills. According to the theory, the right side compensates for the deficiency of skills on the left side such as language and right-hand preference. If underdevelopment of the left hemisphere is severe enough, it may result in some form of developmental handicap.

Geschwind and Galaburda (1985a) believed that these aberrant levels of testosterone are involved in a number of developmental problems. For instance, they suggested that the higher predominance of autism, dyslexia, stuttering and other developmental disorders in males is caused by the action of testosterone on the developing brain. As the left hemisphere is the one more adversely affected by testosterone, the right hemisphere shift results in a higher incidence of left-handedness. Consequently, as developmental handicaps are often a result of left hemisphere damage, many of these individuals are left-handed as well. However, there can also be advantages to right hemisphere dominance. For instance, left-handedness has been found to be more common in architects, mathematically-gifted children and lawyers (Fry, 1990) as well as in musicians (Byrne, 1974; Peterson, 1979). Thus, superior spatial skills have been linked to sinistrality.

Geschwind and Galaburda (1985a) believed that the most powerful factors involved in lateralization are variations in the chemical environment in fetal life and to a lesser extent in infancy and early childhood. Chemical variations, such as hormonal variations, also affect the development of many other systems, for example, the organs involved in immune response. Because they found a markedly higher frequency of immune diseases in strongly left-handed individuals than in strongly right-handed individuals (these results have been replicated by Searleman & Fugagli, 1987; Smith,

1987; Tonnessen, Lokken, Hoien, & Lundberg, 1993), Geschwind and Galaburda believed testosterone may also be acting on the immune system, particularly the thymus. They hypothesized that testosterone has a suppressive effect on the thymus, a gland which is involved in the development of lymphocytes that recognize self-antigens. More recent research supports this hypothesis. Lahita (1992) described how sex steroids affect the immune system during pregnancy: estrogens stimulate T-cell responses and increase immunoglobulin whereas androgens (such as testosterone) have the opposite effect, suppressing T-cell responses and decreasing immunoglobulins.

In developing hypotheses about laterality and immune disorders, it is important to first distinguish between the immune disorder subtypes. There are two main classes: autoimmune and immune disorders. Autoimmune disorders occur when lymphocytes mount an attack on the body's own cells (for example in Hashimoto's thyroiditis, ulcerative colitis and myasthenia gravis). Immune disorders appear when there are defensive reactions to non-invading harmless substances, resulting in the formation of specific antibodies (for example in eczema, asthma and rhinitis [Smith, 1987]). Particularly because the thymus is involved in recognition of self-antigens, it follows that if increased levels of testosterone, or increased sensitivity towards it, are suppressing the action of the thymus, sinistrality should be more correlated with autoimmune disorders. In

support of the distinctions made, Searleman and Fugagli (1987) determined that certain disorders of a suspected autoimmune origin (Crohn's disease and ulcerative colitis) were more prevalent in left-handers. Weinstein and Pieper (1988) also found a significantly higher frequency of left-handedness in an atopic population as compared to controls. However, this hypothesis has not been supported by all research. For example, Burke, Yeo, Vranes, Garry, and Goodwin (1988) did not observe a relationship between hand preference and immune history. Cosi, Citterio, and Pasquino (1988) did not determine a relationship between hand preference and myasthenia gravis.

Searleman and Fugagli (1987) further elaborate on immune disorders subtypes. They distinguish between those that have an onset prior to puberty and those with an onset post-puberty. It has been hypothesized that after puberty, testosterone actually protects males from developing immune disorders. Consequently, as a result of the dual nature of testosterone, only those immune disorders with onset prior to puberty should be significantly related to left-handedness in males. For example, Type I diabetes has an onset prior to puberty and is caused by an autoimmunity response in contrast to Type II diabetes which has an alternate etiology. Consequently, males should show a higher incidence of Type I diabetes than females. Further, those males with Type I diabetes should also demonstrate an increased frequency of left-handedness as compared to controls due to its early onset and the influence of testosterone

on its development. The research of Searleman and Fugagli supported these expectations.

It has thus been postulated that some of the processes that influence cerebral lateralization also affect the development of the immune system, protecting from certain disorders while increasing susceptibility to others. There is also growing evidence of the relationship between high frequency of sinistrality, immune diseases and learning disorders (Tonnessen et al, 1993), particularly in men. This triadic relationship suggests that the three conditions may share a common underlying factor. Elevated levels of prenatal testosterone (or increased sensitivity towards it) may be acting on both the embryonic thymus and the embryonic brain, offering an explanation for the association among the three conditions. However, although the theoretical rationale for these associations appears well founded, certainly many studies refute the proposed triadic association. For example, although Hugdahl, Synnevag, and Satz (1990) determined that there was a positive correlation between immune and autoimmune diseases and dyslexia, no association was found with left-handedness. Similarly, Salcedo (1987) and Schur (1986) also found no association between left-handedness and systemic lupus erythematosus.

The Formation and Action of Testosterone

Testosterone is formed by the interstitial cells of Leydig (20 percent of the testis) which begin to secrete testosterone at about the seventh week of embryonic life (Guyton, 1991). Testosterone's mode of action is quite complex. In animals, its effects are mediated through its conversion to estrogen by the activity of the aromatase complex enzyme (MacLusky, Naftolin, & Goldman-Rakic, 1986). In fact, it has been demonstrated conclusively that estrogen is the active agent organizing the brains of rodents (Breedlove, 1994). This evidence comes from studies on Tfm male rats (Tfm represents the gene that controls for sensitivity to androgens). Although these rats have severely reduced levels of androgen receptors compared to their normal siblings, they do show normal CNS levels of estrogen receptors. Consequently, they can undergo sexual differentiation (MacLusky & Naftolin, 1981). Therefore, the androgen receptors cannot play a key role in masculinization; instead it must be the estrogen receptors that do.

MacLusky et al. (1986) have found that there are higher concentrations of aromatase complex in the hypothalamus-preoptic areas as well as throughout the cortical structures. This implies that locally-formed estrogen (through the aromatization of testosterone) is acting on areas of the association cortex concerned with cognitive processes. Consequently, if there are higher levels of testosterone, then it follows that cognitive

development in these areas will be more extensive. However, the conversion of testosterone to estrogen is not deemed essential for changes to take place as synthetic testosterone can induce the same effects as estrogen. In addition, it is still not clear whether the presence and action of aromatase complex can be fully extrapolated to humans. Nevertheless, with respect to the human literature, it is important to be aware that although testosterone is the produced hormone, it may be estrogen that directs masculinization of the nervous system (Breedlove, 1994). However, it would be premature to conclude that testosterone plays no direct role in the differentiation of the central nervous system as androgen antagonists can be equally effective as estrogen antagonists in inhibiting sexual differentiation (MacLusky & Naftolin, 1981).

With respect to female development, a number of questions arise. First, how is the female protected from the masculinizing effect of estrogen and second, can females be affected by increased levels of circulating androgens? There are a number of factors that can influence whether a female fetus will be sensitive to increased levels of circulating aromatized testosterone. For instance, the X chromosome contains the Tfm locus, mentioned earlier as one of the genes that controls sensitivity to androgens. Consequently, presence of this gene may make a female fetus more sensitive to maternally- and placentally-produced testosterone than a male fetus,

especially in the earliest stages of embryogenesis (Geschwind & Galaburda, 1985b).

Further, it has been established that in rats and mice, there is also a protection factor in both the female and male fetus that influences the amount of active circulating aromatized testosterone (i.e., estrogen). It is believed that this protection factor is an enzyme, fetoneonatal estrogen binding protein (FEBP) also called alpha fetal protein, which circulates in the blood of the fetus but which gradually disappears over the first few weeks of postnatal life (MacLusky & Naftolin, 1981). It binds to circulating estrogen (such as the estrogen produced by the developing ovaries or the mother), rendering the action of estrogen ineffective. Thus, a female fetus is protected from masculinization. However, in the male, testosterone ignores this binding protein, enters the brain and is then intracellularly aromatized to estrogen. As FEBP cannot bind intracellularly, this intracellularly aromatized estrogen can then alter neuronal development in the male (Breedlove, 1994). As aromatization appears to occur once the testosterone has passed into the brain cells, FEBP can do little to counter the effects of excess testosterone or increased sensitivity towards it (which normally does not occur in the female fetus as it produces very little testosterone as compared to the male).

In the case of higher than normal levels of circulating estrogen, protection from excess hormones by FEBP is not complete. In fact, research

has found that this protective mechanism from the masculinizing effects is of limited effectiveness in humans and even may be non-existent (MacLusky & Naftolin, 1981). Consequently, the higher the levels of both testosterone and estrogen, the more likely that the female fetus will be adversely affected by it (Licht et al., 1992). Further, elements of the aromatization-estrogen response mechanism are clearly present in humans although it cannot be confirmed that FEBP regulates free circulating estrogen levels during gestation (MacLusky & Naftolin, 1981). However, the DES research does add evidence to the presence of a binding protein. As DES is a synthetic estrogen, FEBP would not necessarily recognize it and thus it would not bind it. Consequently, DES can act on the developing brain in a fashion similar to testosterone, providing an explanation for the reported masculinization of females exposed to DES in utero. Overall, it is expected that when a female is exposed to aberrant levels of testosterone, she is more likely to be vulnerable to its "masculinizing" effects.

Prenatal Testosterone Levels and Later Cognitive Functioning

Aberrant levels of testosterone should affect cerebral development in both males and females. Researchers attempting to determine this relationship have investigated how testosterone levels *in utero* are related to later developmental factors in normal subjects. For instance, Jacklin, Wilcox, and Maccoby (1988) assayed hormones from the umbilical cord blood

at birth and then studied the behaviour of these children several months to six years later. They found an inverse relationship between spatial ability and testosterone in girls. This failure to find the expected result as hypothesized by Geschwind and Galaburda (1985a) may be a reflection of the time the assays were performed. It is probable that hormonal levels at birth are not comparable to those present during critical periods of brain development. According to Smail, Reyes, Winter, and Faiman (1981), it is during weeks 8 to 24 of gestation that hormonal levels are particularly high as compared to the other weeks of gestation. Further, the hormonal assays may also reflect the maternal hormones.

Finegan, Niccols, and Sitarenios (1992) investigated whether a correlation existed between prenatal testosterone levels and cognitive abilities in children aged 4, 7, and 10 years by measuring testosterone levels in amniotic fluid at 14-20 weeks of gestation. Consistent with Jacklin et al. (1988), but in contrast with the studies performed with CAH girls, prenatal testosterone levels were inversely related to spatial abilities. Further, prenatal testosterone levels showed a curvilinear relationship to language comprehension and classification abilities. Inverse linear relations were observed between testosterone levels and counting abilities, number facts, and block building scores. These results provide little support for the Geschwind and Galaburda hypothesis. However, the levels of testosterone in the females, although higher for some, may not have been sufficiently

high to produce an effect. Certainly, the CAH girls are exposed to much higher levels of testosterone than these females. Also, the time of measurement of testosterone levels was not consistent with the critical period of brain development of the skills measured. Recently, Grimshaw, Bryden, and Finegan (1995) studied these same children at the age of 10. Consistent with their previous trends, girls with higher levels of prenatal testosterone have been found to be more strongly right-handed and to have stronger left hemisphere speech representation. Boys with higher prenatal testosterone levels had stronger right hemisphere specialization of emotion.

Postnatal Testosterone Levels and Development

Recent research has investigated the relationship between current postnatal testosterone levels (either through saliva or serum) and various cognitive and intellectual abilities as well as the rate of non-right-handedness. Although some of the results have not been entirely consistent with the testosterone hypothesis, a general pattern has emerged. Gouchie and Kimura (1991) found that women who had higher concentrations of salivary testosterone scored higher on measures of spatial/mathematical ability, although the opposite was true for males. Tan discovered that serum testosterone levels were related to visual-spatial performance in males (1990a) as well as left hemisphere motor skills (1990b). Tan (1990a,b) also found that as serum testosterone levels increased, right-hand

skill and IQ decreased in women but increased in men. Further, the degree of right-handed preference decreased with increasing levels of serum testosterone in both men and women. This suggests that the female brain seems to be more sensitive to circulating testosterone than the male brain, provided that serum testosterone in young adults is associated with prenatal testosterone (Tan, 1990c). Kirkpatrick, Campbell, Wharry, and Robinson (1993) determined that the presence of learning disabilities in children was significantly associated with higher salivary testosterone. Finally, Christiansen and Knussmann (1987) found that there was a positive relationship between spatial ability and serum testosterone levels in men. However, although this research suggests that there is a relationship between current testosterone levels and cognitive abilities, there is no evidence that those individuals who showed higher levels as measured by the saliva or serum would also have had higher levels prenatally.

In summary of the research investigating testosterone effects, there appears to be very little consistent data from one study to the next and from one population to another. The discrepancy between what Geschwind and Galaburda predicted and some of the results currently being obtained suggests a number of possible explanations. First, testosterone may play an opposite effect (or at least a different one) in females as compared to males. Secondly, different levels of testosterone may have different effects

depending on the dosage. Another potential explanation is that other mechanisms are involved that increase the complexity of the directionality of the effect. For example, Witelson (1991) proposed the callosal hypothesis to explain the relationship between prenatal testosterone and cerebral lateralization. Witelson believed that the pruning of callosal axons (that is, axon death) during fetal and neonatal development is mediated by testosterone. Further, she suggested that callosal axon elimination and development of associated structures is related to functional asymmetry. However, the research on corpus callosum size indicated that the action of testosterone on axons may not be operative in the development of these brain regions in females (Witelson & Nowakowski, 1991).

Witelson (1991) hypothesized that high levels of testosterone lead to more axon elimination and consequently more functional asymmetry. In other words, low levels of testosterone are associated with less asymmetry, such as greater incidence of left-handedness. Consequently, in direct contrast to Geschwind and Galaburda's hypothesis, if testosterone has any effect on females it would be in the opposite direction to that of males. Further, males exposed to increased levels of testosterone should demonstrate greater incidence of right-handedness as compared to those males exposed to lower levels of testosterone *in utero*. Ultimately, the discrepancy in directionality between levels of testosterone and various

developmental measures across studies indicates that testosterone may serve simply as one cog in a highly complex system of interrelated factors.

Animal Behaviour and Testosterone

In the animal literature, it is well established that testosterone has major influences on neuronal development and behaviour. For example, in rats, testosterone induces a change in specific nuclei in the hypothalamus and limbic system (Geschwind & Galaburda, 1985a). It has also been found to retard the growth of structures involved in immunity in rabbits, rats and fetal chicks (Geschwind & Galaburda, 1985a). If animals are exposed to masculinizing hormones during critical periods of brain development, the females will display "masculinized" behaviour. This has been demonstrated repeatedly across a variety of species, including rodents, spotted hyaenas, songbirds, and primates (Arnold & Gorski, 1984; Beatty, 1979; Gandelman, vom Saal, & Reinisch, 1977; Licht et al., 1992; MacLusky & Naftolin, 1981). For example, in female rhesus monkeys administered testosterone prior to birth, Goy and Phoenix (1971) found increased frequencies of mounting that closely resembled those of normal males. Goy, Bercovitch, and McBrair (1988) investigated the effect of exposing female rhesus macaques to testosterone either early or late in gestation. It was found that these females displayed different male behaviours depending on when the testosterone was administered. For example, those given the testosterone

early showed more mother mounting, more peer-mounting and less mother-grooming than normal females. Those given testosterone late in gestation displayed more rough play and mounting with peers. Such results suggest that different behaviours have different critical developmental periods for the organizational effects of androgens.

Animal studies also provide the opportunity to investigate how hormones of one fetus can influence the development of another fetus. For example, when a female fetus shares the uterine environment with male fetuses, it has been found in rats that there is a greater degree of androgen effects on the females, such as increased aggression and decreased lordosis behaviour (Hauser & Gandelman, 1983). This effect is particularly prominent when the female is in front of the males (Houtsmuller & Slob, 1990; Meisel & Ward, 1981). Meisel and Ward believed the vasculature carries testosterone from the males in an anterior direction such that testosterone is being passed directly from the venous drainage of the male into the arterial supply of the female. It is certainly important to understand the mechanism of how testosterone circulates *in utero* in order to predict its effects. Meisel and Ward believed that testosterone is being passed directly from the venous drainage into the arterial supply. If this is the case, then it may be that the simple theory of diffusion across adjacent amniotic membranes is not the mechanism of intra-uterine exchange among fetuses. However, Even, Dhar, and vom Saal (1992) determined through

the use of radioactively-labelled testosterone that transport between fetuses does occur across the fetal membranes via the amniotic fluid by diffusion. This conclusion has also been drawn for transport of steroids in mice (vom Saal & Dhar, 1992). Certainly, the animal research provides clues that can be helpful in understanding human female and male susceptibility to the effects of testosterone from another fetus.

Hauser and Gandelman (1983) also showed evidence of the testosterone effects on female fetuses. They found that the influence of male contiguity on female mice is one of masculinization, apparently caused by stimulation of female fetuses by testicular androgen. Breedlove (1994) discussed the phenomenon of fetal cross-talk in cattle, where it is very likely that androgens are crossing from one placenta to the other. Further, in rats, elevated levels of androgens have been measured in the amniotic fluid and plasma of females sharing the uterus with a male and these levels correlate well with expected levels of exposure to their brothers (vom Saal, 1989). It is certainly possible that hormonal transfer from one fetus to another can occur in humans.

Human Evidence of Placental Transfer

There is some research that indicates cross-fetal transfer of hormones can occur in human twins. It is known that transmission of compounds across the placental barrier occurs by diffusion and carrier-mediated

transport (Schneider, 1991). Schneider further described how the bidirectional nature of this transplacental exchange requires asymmetry in flux from the maternal to the fetal side or vice versa which can be assured by a concentration gradient or an active transport system. Further, although the research is scarce in this area, it is also believed that the levels of hormones in the amniotic fluid are related to fetal hormone levels, indicating that diffusion does occur across the fetal skin (Finegan, Bartleman, & Wong, 1989).

Gurpide, Marks, de Ziegler, Berk, and Brandes (1982) investigated the movement of estrogen and its metabolites. They indicated that more estradiol (the active form of estrogen) is released toward the maternal circulation than to the fetal circulation in humans, possibly as a result of a carrier system. In the case of testosterone movement across the placenta, it appears that metabolic transformation to estrogen (i.e. aromatization) is a prerequisite for a transfer (Pasqualini & Kincl, 1986). Further, research on testosterone transfer indicates that the transfer is mostly in the direction fetus to mother (Pasquilini & Kincl, 1986). More specifically, Meulenberg and Hofman (1991) determined through assays during pregnancy that as a consequence of a maternal-fetal gradient, unbound testosterone crosses the placenta from the male fetus towards the maternal circulation. However, with female fetuses, the movement was determined to be in the opposite

direction. Consequently, it is plausible that hormones, specifically testosterone, can move from the male fetus into the female.

Knowledge of the physiology of vascular transportation between twins does not greatly aid in understanding hormonal transfer. Although it is known that in dichorionic placentas (which occurs with dizygotic twins) blood vessels never cross from one placenta to the other, and thus there is no intervascular communication (Garcia & Gall, 1990), it does not rule out the possibility that hormones can first transfer from the first fetus to the mother's circulation and then into the circulation of the second fetus, with the aid of concentration gradients. The transfer of hormones in the case of monozygotic twins is more obvious. They tend to have monochorionic placentation where intervascular communication is highly likely (Garcia & Gall, 1990). Further, there can be the presence of anastomoses (areas of villous transfusion due to union of parts between the fetuses) which can influence the extent of the vascular communication (Garcia & Gall, 1990). The frequency of dichorionic placentas is 80 percent and that of monochorionic placentas, 20 percent (Chitkara & Berkowitz, 1991).

Unfortunately, most investigations on hormonal transfer have concentrated on singletons. There is certainly no contrary evidence to suggest that hormones from the first fetus that have passed into the placenta cannot be transported via the mother's circulation to a second fetus, as is the case for multiple births in rats. Further, it is known that

when a mother ingests hormones (such as DES) there are known effects to the fetus. Also, it is well known that cortisol, a compound of similar weight and structure to testosterone, does cross from the mother to the fetus and thus it is hypothetically plausible that testosterone may also transfer across the barrier with ease (Miller, 1994). Consequently, the assumption that such a transfer can occur is a reasonable one. Further, even if only a small amount of hormones from one fetus reaches the other fetus, the quantity could still be large relative to what is required to initiate a detectible behavioural change (Miller, 1994).

Summary and Hypotheses

The research on testosterone effects is fraught with complexities and inconsistencies. Certainly, the relationships between developmental variables and testosterone are not as clearly connected as Geschwind and Galaburda believed. It appears that the level of exposure to testosterone plays a crucial role in the directionality of the relationship. Further, the cause of the variation in the level of testosterone may also be a contributing factor (i.e., whether it was caused by a dysfunctional adrenal gland, a genetic abberation, or a random fluctuation). The diverse number of targets in the nervous system on which testosterone can have an effect may also play a determining role in the ultimate outcome of testosterone's action. Certainly, the directionality of the effect, if there is an effect, has not been

clearly delineated. Nevertheless, there is a strong indication, particularly in the animal literature, that testosterone from a male fetus does transfer across the placental barrier and have a significant impact on the development of the affected fetus(es). Consequently, research that investigates the impact of hormonal transfer is necessary in order to further explore the complex action of testosterone on human brain development and behaviour.

If testosterone is having the effect on the male fetus as hypothesized by Geschwind and Galaburda, then the natural environment of twins provides us with the opportunity to further test this theory. Females of opposite-sex (OS) twins are believed to have been exposed to higher levels of testosterone from having shared the uterine environment with a male. Further, males of same-sex (SS) twins should also have been exposed to higher levels of testosterone due to the presence of another male producing large quantities of testosterone. However, although the hypotheses of how testosterone's action affects development provides the rationale for this investigation, regardless of the mechanism, the phenomenon of co-twin differences does require further research.

I hypothesize that the females of opposite-sex twins will be more vulnerable to the disorders and patterns of cognitive skills that are more common in males. Thus, I expect that, compared to female singletons and female SS twins, the females of OS twins will have more immune diseases

(particularly auto-immune ones which have an onset prior to puberty), more learning disabilities, show more left-handedness, and have stronger right hemisphere skills.

Further, I expect that, compared to male singletons and males of OS twins, males of SS twins will also show greater incidence for the above variables.

Method

Subjects

A total of 137 twin pairs ranging from 8 to 20 years of age participated in the study. Of these, 33 were female/male, 57 were male/male (of which 34 were identical and 23 fraternal), and 47 were female/female twin pairs (30 identical, 17 fraternal). Subjects were recruited through a variety of ways. First, we advertised across Canada for interested individuals to contact us (see Appendix A). Advertisements were placed in the Globe and Mail, the Parents of Multiple Births Association newsletter, the neighbours section of the Calgary Herald, the Gazette at the University of Calgary, the Gauntlet also at the University of Calgary, the Varsity at the University of Toronto and Today's Parent. Other twin registries were contacted (in Australia, Vancouver, Toronto and Denver); however, it was not feasible to access these established registries due to the time constraints of a Master's thesis. In each case where we advertised in the media, the advertisement simply said that we were looking for twins; interested people should contact us. Out of the 42 families who responded to the ads, 37 returned the questionnaires. Information on 6 twin pairs was obtained from an ongoing project at the Behavioural Research Unit.

The Calgary Health Service (CHS) agreed to help us, using procedures which protected the confidentiality of their clients. Questionnaires were sent to parents of twins aged between 8 and 10 as

their database began halfway through 1984. The birth records were updated by verifying which children had been immunized on entering school in Calgary. Although 267 twin pairs were born between 1984 and 1986, only 198 of those pairs had been immunized in grade 1. It is assumed the other families with twins had moved away from Calgary. We supplied CHS with copies of our questionnaires and a cover letter to send out, and they addressed and mailed the envelopes. In this way, confidentiality was protected, and the decision whether to participate was made voluntarily by the family. The advantage of using the Calgary Health Service as a primary method of subject recruitment was that the sample was less likely to be biased by self-selection as questionnaires were sent to all parents of twins aged 8 to 10 born in Calgary. Out of these 198 questionnaires sent by CHS on our behalf, 35 completed questionnaires were returned. This low response rate was in part a result of outdated addresses. Seventy-five questionnaires were returned unopened to the CHS as the addresses were either non-existent, the family no longer resided at the residence or the family did not have twins. Consequently, CHS updated 33 of the addresses which resulted in 10 more completed questionnaires being returned.

Finally, the president of the Calgary Parents of Multiple Births Association (CPOMBA) volunteered to send questionnaires out to parents of twins aged 10 to 20 from the association. Addresses from old mailing lists were updated with the phonebook. Out of the 113 questionnaires sent out,

46 completed questionnaires were returned and 5 were returned unopened as the family no longer resided at the address. Through the president of CPOMBA, three other twin clubs were contacted in Alberta, one of which (Medicine Hat Parents of Multiple Births Association, otherwise known as MHPOMBA) agreed to send out 7 questionnaires. Of these 7 mailed out, 3 were returned completed. The response rates from these three methods of recruitment are summarized in Table 1. Unfortunately, as the majority of the mailings were anonymous to us, it is not possible to determine the response rate for each group of twins.

One hundred and thirty-eight singletons also participated in the study. The data for these singletons was obtained from the Master's research project conducted by Susan Crawford (1990). These singletons had been recruited randomly from schools in Calgary. The singletons were matched to the twin groups by age and by sex. For those twins up to 17 years of age, the controls were matched by age within one year. For the three pairs of twins above 17 years of age, controls were matched within 2 years of age.

Sample Selection for the Analyses

Two studies were performed: the first study involved comparing the twin groups, the second study involved comparing the twin groups with the singletons. The rationale for performing two studies, both of which involved two group comparisons, rather than one study using three group

Table 1

Response Rates

Source	# Packages sent out*	# Returned	Response Rate
Newspaper ads	42	37	88%
CHS	198	45	24%
CPOMBA	113	46	41%
MHPOMBA	7	3	43%
TOTAL	360	131	36%

*These numbers refer to the number of families who received packages. Consequently, twice as many questionnaires were sent out, one for each twin.

comparisons (i.e., males of SS twins, males of OS twins and male singletons) was twofold: first it is well documented that twin pregnancies pose greater risks over singleton pregnancies (Akerman & Fischbein, 1991) and consequently, in order to control for these risks as well as the entire phenomenon of twinning, twin comparisons were considered more meaningful. Second, as the group sizes were so unevenly distributed within the twins, in order to increase the power of the analyses, the analyses were split into two studies. Through this separation, we were able to benefit from the larger sample sizes rather than having the small OS twin sample size limit the entire set of analyses.

Within the first study, three main analyses were conducted. Within the second study, four main analyses were conducted. All of the analyses were two group comparisons where the subjects were matched by age. Neurological disorders were considered for this matching; twins who were reported to suffer from a neurological disorder were removed from the study as the neurological disorder may have confounded the results of the developmental questions. Three twins fell into this classification: one twin suffered from epileptic seizures, another was reported as hydrocephalic and the third had suffered from bacterial spinal meningitis at 6 months of age. No twins needed to be removed as a result of DES exposure as no mothers reported having taken this drug during pregnancy. If it was possible, those twins with a significant amount of missing data were not used in the

matching process. The rationale for matching the samples by age was to control for developmental skills and problems that change with age. For example, some immune diseases do not occur until after puberty or certain skills become more prominent with age.

The first main analysis involved comparing females of SS twins with females of OS twins. The following analysis compared males of SS twins with males of OS twins. For both of these analyses, only one member of each SS twins was used. The chosen twin matched the birth order of the comparison twin of the OS pair. For example, if the female of the OS pair was first born, that child was matched with the first born female of the SS pair. The third analysis compared matched male twins with matched female twins.

For the second study, the singletons were compared to the four groups of twins: female singletons to females of SS twins, female singletons to females of OS twins, male singletons to males of SS twins, and male singletons to males of OS twins. Again, only one twin of each pair was used in order to control for dependency and genetic effects. As none of the singletons were related, it would not have been appropriate to compare two independent singletons with two twins of the same pair. Consequently, the twins used in the analyses were randomly selected from each twin pair unless the pair involved a twin with a neurological disorder. In these cases, neither twin was used. For these four analyses, it is important to note that

the normal control group of singletons had fewer variables available to analyze. Table 2 summarizes sample sizes for the 14 sub-groups and the average age of the children in each group at the time their questionnaires were completed.

Procedure

Approval to conduct this study was obtained from the Office of Medical Bioethics in the Faculty of Medicine at the University of Calgary. The study was also approved by Donna Lentjes, the chair of the Calgary Health Services' Research Committee and by Leslie Phillips, the president of CPOMBA. A thesis grant was obtained from the University Research Grants Committee (University of Calgary).

Parents of subjects were sent a cover letter, the two questionnaires, and a consent form to keep (see Appendix B). Depending on the destination of the questionnaires, either an additional cover letter from CHS (see Appendix C) or CPOMBA (see Appendix D) was included. A stamped, addressed return envelope was also included. Six weeks after the initial mailing, reminder letters were sent either by us directly to those who responded to our ads (see Appendix E), or through CHS (see Appendix F) and CPOMBA (see Appendix G). A third mailing went to only parents of male/female twin pairs as the response rate from this group was particularly low, relative to the other two groups.

Table 2

Sample Size and Age Distribution per Group

Group	n	Age(SD)
STUDY 1:		
Twin Comparisons:		
Females of SS twins	33	11.97(3.16)
Females of OS twins	33	12.13(2.96)
Males of SS twins	33	11.81(2.97)
Males of OS twins	33	12.13(2.96)
Sex comparison within twins:		
Matched female twins	121	12.23(2.90)
Matched male twins	121	12.29(2.90)
STUDY 2:		
Twin vs singleton comparisons:		
Females of SS twins	47	12.31(3.16)
Singletons matched with female SS twins	47	12.23(2.75)
Females of OS twins	33	12.13(2.96)
Singletons matched with female OS twins	33	11.94(2.93)
Males of SS twins	57	12.00(2.90)
Singletons matched with male SS twins	57	12.42(2.47)
Males of OS twins	33	12.13(2.96)
Singletons matched with male OS twins	33	12.12(2.93)

Measures and Scoring Protocol

Two questionnaires were used in this study, Twin Questionnaires #1 and #2. The first questionnaire was developed specifically for the first born twin and his or her relatives; the second one was a modified and shortened version of the first, addressing development of the second born twin. The Twin Questionnaires are modifications of questionnaires developed under the supervision of Dr. B. Kaplan (Crawford, 1990; Glogauer, 1991; McAllister, 1994). They include measures of general skills and abilities, family and child developmental histories, physical health, handedness, pregnancy and birth complications and socioeconomic status.

Twin Information

The cover page of the first Questionnaire asked the parents to identify which twin was first born and second born in order for the twins to be identified as Twin #1 (first born) and Twin #2 (second born). Parents were then asked to categorize their twins as either "identical" or "fraternal" (although more recent research is indicating that the terms "identical" and "fraternal" are inaccurate and misleading; instead, the terms "monozygotic" and "dizogotic" should be used). Twins that were "identical" were coded "1" and twins that were "fraternal" were coded "2". They were then asked to give evidence of zygosity. The answers were coded according to the following categories: the twins looked the same, the twins looked different, results of DNA/blood/dental x-rays/placental examinations indicated that

the twins were either monozygotic or dizygotic, the twins were mirror-images of each other or they were opposite-sex twins. These categories are summarized in Table 3. Parents were also asked whether at birth there was one or two placentas. Although this information was not directly related to the research proposal, it was hypothesized that there would be greater effects from hormonal transfer between monozygotic twins due to the greater possibility that they shared placentas.

General Skills and Abilities

The first section addressed the cognitive development of the child. This section was a modification of one developed by Glogauer (1991). Parents were asked to report their child's abilities, as compared to other children of the same age, for the following skills: reading, spelling, arithmetic, communication, spatial abilities, creativity, imagination and memory. For each of the items, the following points were allocated: no points for a response of "don't know", 1 point for a response of "much worse", 2 points for a response of "below average", 3 points for a response of "average", 4 points for a response of "above average", and 5 points for "much better". As illustrated in Table 4, the Overall Skills and Abilities Index was calculated by summing the child's scores for reading skill, reading comprehension, spelling, arithmetic ability, communication, memory/recognition of familiar faces, memory/recognition of familiar places, map reading, constructing things, finding way around, musical ability,

Table 3

Categorization of Other Variables

Variable	Categories
Evidence of zygosity	Look the same Look different DNA/blood/x-rays/placental examination mirror images opposite-sex
Gifted/deficient	Composition/reading Communication skills Languages Social skills Art/drama/music Athletics Math/science/problem solving
Allergies (child)	Type 1: drugs Type 2: food Type 3: animals Type 4: pollens Type 5: mould and dust Type 6: soaps Type 7: insects Type 8: sun Type 9: miscellaneous
Other chronic disorders	Cancer Arthritis Other immune disorders Mental illness Miscellaneous disorders

(table continues)

Variable	Categories
Types of learning disabilities	Spelling Dysgraphia Writing Language Reading Dyslexia Short term memory Others, not specified
Other birth defects (child)	Congenital abnormalities Fetal distress Respiratory distress Organ damage Hydrocephalus Organs not fully developed Miscellaneous birth defects
Current medications taken (child)	Antidepressants Stimulant medications Miscellaneous medications
Pregnancy medications	Prednisone NSAIDS Anti-nausea medications Fertility drugs Miscellaneous medications Medications not specified
Other pregnancy problems (mother)	Severe nausea Infections (not colds or flu) Problems related to toxaemia Breech birth/forceps used Pregnancy induced diabetes Miscellaneous problems

Table 4

Composition of Overall Indices

Overall Index	Variables Included
Child skills and abilities index *indicates verbal subscale **indicates non-verbal subscale ***indicates creativity subscale	Reading* Reading comprehension* Spelling* Arithmetic** Communication* Memory/recognition faces** Memory/recognition places** Map reading** Constructing things** Finding way around** Musical ability*** Artistic ability*** Performing arts*** Creativity*** Imagination***
Developmental problems index	Stuttering Pronunciation problems Language delays Hyperactivity Attention problems Reading problems Spelling problems Math problems Memory problems Motor problems Other learning problems Repeated grade in school

(table continues)

Overall Index	Variables Included
Immune disease index	Allergies Hay fever Asthma Skin reactions Stomach or gut disease Thyroid disease Insulin-dependent diabetes
Non-immune disease index	Non-insulin dependent diabetes Migraine headaches Neurological disorders
Disease control index	Heart disease High blood pressure
Pregnancy complications index	Bleeding first trimester Bleeding second trimester Bleeding third trimester Toxaemia Smoking during pregnancy Induced labour Delivery by caesarian section Difficult delivery Put to sleep for delivery Medications during pregnancy Infections during pregnancy Other pregnancy problems
Birth complications index	Injured during birth Breathing problems at birth Jaundice at birth Cyanosis at birth Twin Supplemental oxygen at birth Problems sucking More than 7 days in hospital Born with heart defect Born with other defect

artistic ability, performing arts, creativity and imagination. Subscale indices were similarly calculated for verbal ability, non-verbal ability, and creativity as indicated in Table 4.

Parents were also asked whether their child was either gifted or deficient in any area. The answers were scored as either "0" (no) or "1" (yes). Specific areas of giftedness or deficiencies included composition, reading, languages, social skills, art, drama, music, athletics, communication skills, mathematics, science and problem solving. These areas are listed in Table 3.

Developmental Problems, Immune and Non-Immune Disorders

The next two sections addressed child and family histories of development problems and immune and non-immune disorders. These sections comprised an adapted version of the Medical History Questionnaire (Burke et al., 1988). It was adapted by Crawford (1990). For these sections, the scoring protocol of Burke et al. (1988) was used. For each item, 1 point was given if the child had the problem, 0.5 points for each parent and each sibling identified with that problem, and 0.25 points for each relative (grandparents, aunts, uncles, and cousins) with the problem. Parents were asked to provide only information concerning the child's biological relatives.

As indicated in Table 4, the overall Developmental Problems Index was calculated for the child and family by adding prevalence of stuttering problems, pronunciation problems, language delays, hyperactivity, attention

problems, reading problems, spelling problems, math problems, memory problems, motor problems, other learning difficulties, and school failure.

Similarly, an overall Immune Index was calculated by adding prevalence of hay fever, asthma, skin reactions, stomach or gut disease, thyroid disease and insulin-dependent diabetes. As shown in Table 3, child allergies were classified into nine types which included drugs, food, animals, pollens, mould or dust, soaps, insects, sun, and a miscellaneous category. An overall Non-Immune Disease Index was calculated by adding prevalence of non-insulin dependent diabetes, migraine headaches, and neurological disorders. The overall Disease Control Index consisted of heart disease and high blood pressure. As is also illustrated in Table 3, other chronic disorders in the child and family were classified into cancer, other immune disorders, arthritis, mental illness, and miscellaneous disorders.

The parents were asked for the child's approximate height and weight in order to compare these two variables across the twin pair. Koch (1966) described how weight differences between twins at birth continue throughout development. We felt that following such a developmental trend could be of potential interest. The parents were also asked if the child had ever taken any medication for mood or behavioural problems to further verify answers given to the developmental questions. These medications are listed in Table 4 and include stimulants, anti-depressants, and miscellaneous medications.

Parents were then asked if their child had ever been diagnosed as having Attention Deficit Hyperactivity Disorder or a Learning Disability, again to cross reference and to provide further elaboration of the developmental questions. These questions were coded either "0" (no) or "1" (yes). If the child had been diagnosed with either ADHD or LD, the parents were asked who had made the diagnosis. Individuals making the diagnoses were coded as either physicians, psychologists, or teachers. Further, the specific type of learning disability was coded. Table 3 illustrates the types of learning disabilities included, such as short term memory, dysgraphia, reading, writing, dyslexia, spelling, language, and others not specified.

Handedness

Handedness was measured using a modified version of the abbreviated scale of handedness of the Montreal Neurological Institute (Crovitz & Zener, 1962). The scale was modified by Crawford (1990). Further, questions concerning the handedness of the child's immediate family were also included in order to determine the overall prevalence of familial non-right-handedness. According to the protocol of Crawford, a handedness score for the child was generated from the child's hand preference for five tasks: printing, throwing a ball, holding scissors, drawing a picture, and unscrewing the lid of a jar. For each task, zero points were given for a response of "always right", 1 point for "usually right", 2 points for "either hand", 3 points for "usually left", and 4 points for "always left".

Points given for each item were then added to get a Handedness Index for the child, ranging from zero points (indicative of strong right-handedness) to 20 points (indicative of strong left-handedness). A Familial Handedness Index was also determined according to the protocol of Burke et al. (1988), described in the previous section. Points were awarded as follows: 1 point was given if the child's handedness score from above was greater than zero, 0.50 points for each parent and/or sibling who was reported as left-handed, and 0.25 points for each left-handed relative. The Familial Handedness Index reflected the summation of the points awarded from the described procedure.

Pregnancy and Birth

The next section addressed pregnancy and birth complications using a modified version of Levine's Pregnancy and Birth Complications questionnaire (Levine, 1980). This section first examined whether the mother experienced any birth complications during the pregnancy with the twins. For each item, responses of "true" were allocated 1 point and responses of "not true" were given 0 points. An additional point was awarded if the parent listed other pregnancy problems not included in the pregnancy items. These additional pregnancy problems are listed in Table 3 and include severe nausea, problems related to toxaemia, breech birth/forceps used, pregnancy induced diabetes, infections other than colds or flu, and miscellaneous problems. As illustrated in Table 4, the overall

Pregnancy Complications Index consisted of adding the responses for the pregnancy items. These items included problems related to toxaemia, the occurrence of bleeding during one or more trimesters, whether the mother smoked cigarettes during the pregnancy, problems related to labour, including the need for a caesarian section and whether any medications were taken during pregnancy, particularly DES or fertility drugs. As described in the introduction, hormonal drugs have been determined to affect the development of the fetus, and consequently, such information is necessary to control for variations in the hormonal environment induced by oral medications. Table 4 lists the other medications, including prednisone, non-steroidal anti-inflammatory drugs (NSAIDS) such as aspirin, acetominophen, paracetemol, etc., anti-nausea medications, fertility drugs, miscellaneous medications, and medications not specified.

The parents were also asked to state the age of the mother at the birth of the twins, her weight gain during pregnancy, and the total number of pregnancies she had had. These questions are useful for assessing the potential risks of the pregnancy.

The next part of this section asked questions relating to birth complications. The various birth complications were again scored as 1 point for a response of "true" and 0 points for a "not true" response. As indicated in Table 4, the overall Birth Complications Index was calculated by adding together the responses for the following variables: injured during birth, had

trouble breathing, was jaundiced, had cyanosis, was a twin, had seizures, required oxygen, had trouble sucking, stayed in hospital more than 7 days, had a heart defect, and whether there were other defects. Categories of other birth defects included congenital abnormalities, fetal distress, respiratory distress, organ damage, underdeveloped organs, hydrocephalus, and miscellaneous defects. These categories are listed in Table 3.

Socioeconomic Variables

Finally, the parents were asked to indicate the highest level of education completed by each parent and/or guardian living with the child and their respective occupations. Education level was used as one measure of socioeconomic status (SES). Education levels were scored as follows: 1 point for no high school education, 2 points for some high school education but without a diploma, 3 points for completion of high school, 4 points for some post-secondary education but without obtaining a degree or a diploma, 5 points for obtaining a post-secondary diploma, and 6 points for obtaining a university degree.

The Blishen Index (Blishen, Carroll, & Moore, 1987) was also used as an indicator of SES. Occupations listed in Blishen et al., were used to designate parental occupations with a socioeconomic score. For each family, the score of the parent whose occupation rated highest was used to represent the family's socioeconomic score. These scores were then converted into one of six socioeconomic levels: levels 1 and 2 indicated low

socioeconomic status, levels 3 and 4 indicated middle socioeconomic status, and levels 5 and 6 indicated high socioeconomic status (Crawford, 1990).

Results

Analyses conducted

Seven main analyses within two studies were conducted as described in the method section: females of SS twins with females of OS twins, males of SS twins with males of OS twins, male twins with female twins, females of SS twins with female singletons, females of OS twins with female singletons, males of SS twins with male singletons and males of OS twins with male singletons. All of the analyses were two group comparisons. For the twin comparisons, a number of sub-analyses were conducted in order to investigate whether there were any birth order or placental effects. Consequently, the effect of birth order was studied by comparing twin #1 and twin #2 for the SS twins. To investigate the placental effect, twins from one placenta were compared with twins from two placentas.

For each main analysis, it was first determined if any covariates needed to be included in the group comparisons. To do this, a number of univariate analyses of variance (ANOVA) and multivariate analyses of variance (MANOVA) were performed. Variables considered for use as covariates were the overall pregnancy complications index, overall birth complications index, birth weight, Blishen SES index, education of mother, education of father, and family histories of developmental problems, handedness and health, mother's age at the birth of the twins and weight gain during pregnancy. The mother's age and weight gain were considered

for inclusion as covariates for the first two analyses only; the mother's age had not been collected for the singletons and it was felt that weight gain for mothers carrying singletons was not comparable to weight gain for mothers carrying twins. For the sex comparisons, as most of the twins were included in the analyses, regardless of twin membership, only the pregnancy and birth complication indices and birth weight were considered as covariates. The other covariates would have been redundant because of the overlapping of information across the two groups due to the inclusion of the opposite-sex twins. For these twins, the pairs were split up between the two groups for the obvious reason that each pair consists of two opposite-sex members.

The described variables were considered as covariates due to the possible effect they may have had on the development of the children. For example, education of parents has been found to be correlated with the educational achievement of their children (Sattler, 1992). Birth and pregnancy complications as well as low birth weights have been found to play a role in developmental difficulties, immune histories, and handedness (Akerman & Fischbein, 1991; Akerman & Thomassen, 1992; Fraser, Picard, Picard, & Leiberman, 1994; Gray, Dean, Strom, Wheeler, & Brockley, 1989; Raz et al., 1994; Segal, 1989). Family histories were included as possible covariates in order to control for any group differences caused by genetic

contributions. A high maternal age during pregnancy could be indicative of higher risks to the child during delivery.

Covariates would only be considered for use in subsequent analyses if group differences were found. As all the group comparisons involved equal sample sizes, even if the box's M statistic was found to be significant (that is, the assumption of homogeneity of variance had been violated), or the assumption of normality was violated, it was not necessary to revert to non-parametric statistics as the statistical package used is robust to these violations as long as the samples are equal across group comparisons (Maxwell & Delaney, 1990).

MANOVAs and ANOVAs were used to perform the main group comparisons for child variables: handedness, the overall developmental problems index, immune index, non-immune index, control index, verbal skill index, non-verbal skill index, and creativity index. If a MANOVA or ANOVA revealed significant differences, it was followed up, if necessary, with a multivariate analysis of covariance (MANCOVA) or a univariate analysis of covariance (ANCOVA). If the MANCOVA still revealed significant group differences, either ANOVAs or chi-square analyses were performed.

Chi-square analyses were performed to investigate group differences on dichotomous variables (i.e., those variables that had "yes" or "no" answers). Dichotomous variables included the individual variables that

made up the developmental problems index, the immune index, non-immune index, control index, and the questions that asked specifically whether the child was gifted or deficient in any area, or suffered from ADHD or a learning disability. For each chi-square analysis, percentages were calculated that illustrated the extent to which a particular group suffered from a particular developmental or health problem. Although none of the analyses revealed significant differences on the handedness index, percentages of twins who were reported to be "left-handed" were calculated according to cutoffs determined by Crawford, Kaplan, and Kinsbourne (1994). Crawford et al. selected a cutoff of 9 on the handedness scale developed by Crovitz and Zener (1962). With their control group, a cutoff of 9 resulted in 11% of their children from their public school sample to be left-handed, a value consistent with most published data. Consequently, those twins with a score of 9 or greater were classified as "left-handed", those with a score less than 9 were classified as "right-handed".

Regardless of significance, trends were investigated for all the continuous variables across the two groups of the seven main comparisons using means and box-plots. As many of the groups were small, there was very little power to detect group differences even though they may have existed. Through examination of the means and box-plots, it could be determined first if outliers were playing a significant role in the outcome of

the analyses, and second in which direction trends were occurring, if any (see Williamson, Parker, & Kendrick, 1989).

For the majority of the analyses, $p<.05$ was considered the alpha level at which a difference was interpreted as significant. Only if the MANOVA was found to be significant were the follow-up ANOVAs interpreted. The alpha level used for these follow-up ANOVAs was also $p<.05$ as, according to Leary and Altmaier (1980), the alpha level does not need to be corrected, as long as the MANOVA was significant. However, if a chi-square analysis was conducted with a number of correlated variables, the chosen alpha level was determined by dividing 0.05 by the number of variables in the analysis (Maxwell & Delaney, 1990).

Study 1

Analysis 1: Females of SS Twins versus Females of OS Twins:

Covariates

Table 5 illustrates the results of a MANOVA for parental educational level and Blishen SES index and shows that there were no group differences for these variables. Table 6 shows that there were no group differences between mother's weight gain and mother's age. Table 7 illustrates that there were no group differences on the pregnancy complications index, the birth complications index and birth weight. Table 8 shows that there were no group differences on any of the family variables: developmental problems, immune diseases, non-immune diseases, disease control index, and handedness. Consequently, overall, no covariates were included in the subsequent analyses.

Table 5

Female Twin Comparisons: Multivariate and Univariate Results for Parental Education Levels and Blishen SES Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	0.46	Blishen	0.94
		Education - mother	0.30
		Education - father	0.44

For the multivariate F tests, df=3,54; for the univariate F tests, df=1,56.

Table 6

Female Twin Comparisons: Multivariate and Univariate Results for Mother's Age at Birth of Twins and Mother's Weight Gain During Pregnancy

Source	Multivariate F	Dependent Variables	Univariate F
Group	2.40	Mother's age	0.33
		Weight gain	4.69

For the multivariate F tests, df=2,56; for the univariate F tests, df=1,57.

Table 7

Female Twin Comparisons: Multivariate and Univariate Results for Pregnancy Complications Index, Birth Complications Index and Birth Weight

Source	Multivariate F	Dependent Variables	Univariate F
Group	0.34	Pregnancy index	0.23
		Birth index	0.03
		Birth weight	0.41

For the multivariate F tests, df=3,61; for the univariate F tests, df=1,63.

Table 8

Female Twin Comparisons: Multivariate and Univariate Results for Family History (FH) Indices

Source	Multivariate F	Dependent Variables	Univariate F
Group	0.60	Developmental Index	0.70
		Immune Index	0.46
		Non-immune Index	0.64
		Control Index	0.26
		Handedness	0.69

For the multivariate F tests, df=5,58; for the univariate F tests, df=1,62.

Multivariate and Univariate Analyses of Variance

MANOVAs were conducted to investigate group differences on the verbal, non-verbal and creativity indices. As no differences were found, the ANOVAs of the individual items of each index were not interpreted. ANOVAs were performed on the handedness index and on the developmental problems index. An ANOVA was also performed on the immune index; as both the non-immune means and the control disease means were equal across groups, a MANOVA could not be performed. The results are shown in Tables 9, 10, 11, and 12. No group differences were found.

Chi-Square Analyses

Chi-square analyses were conducted on specific items comprising the developmental problems index and the immune index. Again, no significant group differences were obtained, although one trend emerged: females of SS twins were found to have more skin reactions than females of OS twins. The results are illustrated in Table 13. Table 14 indicates the percentages of each group who were reported to have suffered from a particular developmental or health problem as well as the incidence of left-handedness.

Table 9

Female Twin Comparisons: Multivariate and Univariate Results for the Verbal Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	0.42	Communication	0.05
		Spelling	0.06
		Understanding	0.00
		Reading	0.21

For the multivariate F test, df=4,60; for the univariate F tests, df=1,63.

Table 10

Female Twin Comparisons: Multivariate and Univariate Results for the Non-Verbal Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	0.55	Memory of places	0.20
		Memory of faces	0.00
		Map reading	1.21
		Building	0.46
		Mathematics	1.65
		Lost	1.47

For the multivariate F test, df=6,53; for the univariate F tests, df=1,58.

Table 11

Female Twin Comparisons: Multivariate and Univariate Results for the Creativity Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	1.82	Imagination	0.42
		Creativity	0.43
		Performing arts	0.02
		Musical talent	0.02
		Artistic ability	0.21

For the multivariate F test, df=5,56; for the univariate F tests, df=1,60.

Table 12

Female Twin Comparisons: Univariate Results for Immune, Developmental, and Handedness Indices

Source	Dependent Variables	Univariate F
Group	Immune index	1.35
	Developmental index	0.01
	Handedness	0.06

For the univariate F tests, df=1,64.

Table 13

Female Twin Comparisons: Chi-Square Analyses of Variables Comprising Developmental Problems Index and Immune Index, and Giftedness and Deficiency

Variable	Chi-Square Value
Developmental problems index:	
Stuttering	1.02
Pronunciation	0.11
Hyperactivity	1.02
Spelling	0.10
Reading	0.06
Math	0.36
Gifted	0.00
Deficient	0.13
Immune index:	
Allergies	1.45
Asthma	0.17
Hay fever	0.13
Skin reactions	2.75^{***},p=.1

***trend

Table 14

Female Twin Comparisons: Percentage Rates for Dichotomous Variables

Variable	Group	Percentage
stuttering	F of SS	3
	F of OS	0
pronunciation	F of SS	15
	F of OS	18
attention	F of SS	12
	F of OS	12
hyperactivity	F of SS	3
	F of OS	0
spelling	F of SS	21
	F of OS	18
reading	F of SS	18
	F of OS	21
mathematics	F of SS	18
	F of OS	24
memory	F of SS	9
	F of OS	12
motor	F of SS	3
	F of OS	3
learning disability	F of SS	9
	F of OS	0

(table continues)

Variable	Group	Percentage
ADHD diagnosis	F of SS	0
	F of OS	3
LD diagnosis	F of SS	12
	F of OS	9
allergies	F of SS	27
	F of OS	15
asthma	F of SS	12
	F of OS	16
hay fever	F of SS	15
	F of OS	12
skin reactions	F of SS	36
	F of OS	18
left-handedness	F of SS	12
	F of OS	12
gifted	F of SS	43
	F of OS	46
deficit	F of SS	16
	F of OS	13

Analysis 2: Males of SS Twins versus Males of OS Twins:

Covariates

Table 15 illustrates the results of a MANOVA for parental educational level and Blishen SES index. As the multivariate analysis was significant, it was followed with the univariate analyses. Only the education level of the father was found to be different between groups, with the fathers of males from SS twins reporting higher levels of education. As it was hypothesized that males of SS twins would have significantly more developmental problems, a *higher* education level of their fathers should not confound these variables. Consequently, father's education level was not used as a covariate in the subsequent analyses.

Table 16 shows that there were no group differences between mother's weight gain and mother's age. Table 17 illustrates that there were no group differences on the pregnancy complications index, on the birth complications index or on birth weight. Table 18 shows that there were no group differences on any of the family variables: developmental problems, immune diseases, non-immune diseases, disease control index, and handedness. Consequently, overall, no covariates were included in the subsequent analyses.

Table 15

Male Twin Comparisons: Multivariate and Univariate Results for Parental Education Levels and Blishen SES Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	6.85*, p=.001	Blishen	0.09
		Education - mother	1.22
		Education - father	17.41*, p=.000

For the multivariate F tests, df=3,55; for the univariate F tests, df=1,57.

*significant

Table 16

Male Twin Comparisons: Multivariate and Univariate Results for Mother's Age at Birth of Twins and Mother's Weight Gain During Pregnancy

Source	Multivariate F	Dependent Variables	Univariate F
Group	1.86	Mother's age	2.80
		Weight gain	1.43

For the multivariate F tests, df=2,56; for the univariate F tests, df=1,57.

Table 17

Male Twin Comparisons: Multivariate and Univariate Results for Pregnancy Complications Index, Birth Complications Index and Birth Weight

Source	Multivariate F	Dependent Variables	Univariate F
Group	1.97	Pregnancy index	3.12
		Birth index	0.13
		Birth weight	2.54

For the multivariate F tests, df=3,60; for the univariate F tests, df=1,62.

Table 18

Male Twin Comparisons: Multivariate and Univariate Results for Family History (FH) Indices

Source	Multivariate F	Dependent Variables	Univariate F
Group	1.18	Developmental index	0.94
		Immune index	0.14
		Non-immune index	0.66
		Control index	0.40
		Handedness	0.57

For the multivariate F tests, df=5,58; for the univariate F tests, df=1,62.

Multivariate and Univariate Analyses of Variance

MANOVAs were conducted to investigate group differences on the verbal, non-verbal and creativity indices. The group difference on the creativity index neared a significant level and consequently, the ANOVAs of the individual items comprising this index were interpreted. ANOVAs were performed on the handedness index and the developmental problems index. An ANOVA was also performed on the immune index; as both the non-immune means and the control disease means were equal across groups, a MANOVA could not be performed. The results are shown in Tables 19, 20, 21, and 22. Two significant group differences were found on the creativity index. The groups differed on the scales of imagination and creativity, with the males of the SS twins demonstrating a higher incidence of both. A number of trends were also observed (i.e., p values neared significance). Males of SS twins were reported to have better communication skills, memories of faces and better building skills than males of OS twins. Further, the ANOVA for the immune index neared significance, indicating that males of SS twins suffered from more immune disorders than males of OS twins.

Chi-Square Analyses

Chi-square analyses were conducted on specific items comprising the developmental problems index and the immune index. Two significant group differences were obtained. The two groups differed significantly on

measures of giftedness and skin reactions, the males of SS twins showing a higher incidence of both. With Bonferroni corrections, however, the groups no longer evidenced differences on giftedness ($p<0.03$), although there were still group differences on measures of skin reactions ($p<0.01$). The results are illustrated in Table 23. Table 24 indicates the percentages of each group who were reported to have suffered from a particular developmental or health problem as well as the incidence of left-handedness.

Table 19

Male Twin Comparisons: Multivariate and Univariate Results for the Verbal Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	0.84	Communication	2.77
		Spelling	0.29
		Understanding	0.07
		Reading	0.01

For the multivariate F test, df=4,59; for the univariate F tests, df=1,62.

Table 20

Male Twin Comparisons: Multivariate and Univariate Results for the Non-Verbal Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	1.96	Memory of places	0.03
		Memory of faces	3.38
		Map reading	0.33
		Building	3.12
		Mathematics	0.52
		Lost	0.28

For the multivariate F test, df=6,48; for the univariate F tests, df=1,53.

Table 21

Male Twin Comparisons: Multivariate and Univariate Results for the Creativity Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	2.35**, p=.05	Imagination	9.40*, p=.003
		Creativity	7.29*, p=.009
		Performing arts	0.67
		Musical talent	1.85
		Artistic ability	0.69

For the multivariate F test, df=5,51; for the univariate F tests, df=1,55.

*significant
**marginally significant

Table 22

Male Twin Comparisons: Univariate Results for Immune, Developmental Problems, and Handedness Indices

Source	Dependent Variables	Univariate F
Group	Immune index	2.62***, p=.1
	Developmental index	0.08
	Handedness	0.00

For the univariate F tests, df=1,63.

***trend

Table 23

Male Twin Comparisons: Chi-Square Analyses of Variables Comprising Developmental Problems Index and Immune Index, and Giftedness and Deficiency

Variable	Chi-Square Value
Developmental problems index:	
Stuttering	2.13
Pronunciation	0.14
Hyperactivity	1.07
Spelling	0.00
Reading	1.10
Math	0.18
Gifted	3.85**, p=.05
Deficient	0.10
Immune index:	
Allergies	1.04
Asthma	0.17
Hay fever	0.10
Skin reactions	6.79*, p=.009

*significant.
**not significant with Bonferroni correction.

Table 24

Male Twin Comparisons: Percentage Rates for Dichotomous Variables

Variable	Group	Percentage
stuttering	M of SS	0
	M of OS	6
pronunciation	M of SS	18
	M of OS	21
attention	M of SS	18
	M of OS	18
hyperactivity	M of SS	9
	M of OS	3
spelling	M of SS	18
	M of OS	19
reading	M of SS	12
	M of OS	21
mathematics	M of SS	9
	M of OS	6
memory	M of SS	6
	M of OS	0
motor	M of SS	6
	M of OS	9
learning disability	M of SS	6
	M of OS	3

(table continues)

Variable	Group	Percentage
ADHD diagnosis	M of SS	6
	M of OS	9
LD diagnosis	M of SS	18
	M of OS	9
allergies	M of SS	46
	M of OS	33
asthma	M of SS	12
	M of OS	16
hay fever	M of SS	15
	M of OS	13
skin reactions	M of SS	45
	M of OS	16
left-handedness	M of SS	9
	M of OS	13
gifted	M of SS	55
	M of OS	31
deficit	M of SS	21
	M of OS	19

Analysis 3:Comparison of Males and Females across Groups:

Covariates

The groups were compared for the pregnancy and birth complication indices and the birth weights only. The other covariate variables would have been redundant due to the overlap in information across the two groups due to the inclusion of the OS twins. Table 25 illustrates the results of the MANOVA performed for these variables. No group differences were found.

Table 25

Sex Comparisons for all Twins: Multivariate and Univariate Results for Pregnancy Complications and Birth Complications Indices, and Birth Weight

Source	Multivariate F	Dependent Variables	Univariate F
Group	1.73	Pregnancy index	2.22
		Birth index	0.82
		Birth weight	0.11

For the multivariate F tests, df=3,234; for the univariate F tests, df=1,236.

Multivariate and Univariate Analyses of Variance

MANOVAs were conducted to investigate group differences on the verbal, non-verbal and creativity indices. As group differences were found on the verbal and non-verbal indices, the ANOVAs for the individual items were interpreted. The results for these ANOVAs are illustrated in Table 26, 27, and 28. ANOVAs were performed on the handedness index and the developmental problems index. A MANOVA was performed on the immune, non-immune, and control indices. The results are shown in Tables 29 and 30. A number of group differences were found. Overall, on the non-verbal index, males were reported to have better memories for places, faces, better map reading and building skills, and were better at finding their way around without getting lost. On the creativity index, females were reported to have better musical talents.

Chi-Square Analyses

Chi-square analyses were conducted on specific items comprising the developmental problems index and the immune index, as well as on measures of giftedness and deficiencies. Three group differences were obtained: females were reported to have more math problems and males were reported to suffer from more allergies and hyperactivity. With Bonferroni corrections, however, the groups no longer evidenced differences on allergies ($p<0.01$) or on hyperactivity ($p<.01$), although there were still group differences on measures of mathematical problems ($p<0.01$). One of

the chi-square analyses neared significance: males were reported to have more stuttering problems. The results are illustrated in Table 31. Table 32 indicates the percentages of each group who were reported to have suffered from a particular developmental or health problem as well as the incidence of left-handedness.

Table 26

Sex Comparisons for all Twins: Multivariate and Univariate Results for the Verbal Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	0.93	Communication	0.08
		Spelling	0.05
		Understanding	0.45
		Reading	0.06

For the multivariate F test, df=4,228; for the univariate F tests, df=1,231.

Table 27

Sex Comparisons for all Twins: Multivariate and Univariate Results for the Non-Verbal Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	4.03*,p<.001	Memory of places	5.26*,p=.02
		Memory of faces	6.63*,p=.01
		Map reading	8.63*,p=.004
		Building	20.87*,p=.000
		Mathematics	1.93
		Lost	5.55*,p=.02

For the multivariate F test, df=6,207; for the univariate F tests, df=1,212.

*significant

Table 28

Sex Comparisons for all Twins: Multivariate and Univariate Results for the Creativity Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	2.82*, $p<.017$	Imagination	1.02
		Creativity	0.42
		Performing arts	0.28
		Musical talent	9.36*, $p=.003$
		Artistic ability	1.20

For the multivariate F test, df=5,210; for the univariate F tests, df=1,214.

*significant

Table 29

Sex Comparisons for all Twins: Univariate Results for Developmental Problems and Handedness Indices

Source	Dependent Variables	Univariate F
Group	Developmental index	0.19
	Handedness	1.44

For the univariate F tests, df=1,239.

Table 30

Sex Comparisons for all Twins: Multivariate and Univariate Results for Immune, Non-Immune, and Control Indices

Source	Multivariate F	Dependent Variables	Univariate F
Sex	0.79	Immune index	2.07
		Non-immune index	0.41
		Control index	0.00

For the multivariate F tests, df=3,238; for the univariate F tests, df=1,240.

Table 31

Sex Comparisons for all Twins: Chi-Square Analyses of Variables Comprising Developmental Problems Index and Immune Index, and Giftedness and Deficiency

Variable	Chi-Square Value
Developmental problems index:	
Stuttering	3.68,***,p=.06
Pronunciation	0.12
Hyperactivity	3.76**,p=.05
Spelling	0.42
Reading	0.04
Math	7.58*,p=.006
Gifted	0.01
Deficient	0.55
Immune index:	
Allergies	3.79**,p=.05
Asthma	0.29
Hay fever	0.03
Skin reactions	1.05

*significant
**not significant with Bonferroni correction
***trend

Table 32

Sex Comparisons for all Twins: Percentage Rates for Dichotomous Variables

Variable	Group	Percentage
stuttering	M	5
	F	1
pronunciation	M	17
	F	16
attention	M	15
	F	9
hyperactivity	M	7
	F	2
spelling	M	22
	F	18
reading	M	19
	F	20
mathematics	M	6
	F	17
memory	M	3
	F	7
motor	M	7
	F	2
learning disability	M	3
	F	5
ADHD diagnosis	M	5
	F	2
LD diagnosis	M	11
	F	12

(table continues)

Variable	Group	Percentage
allergies	M	32
	F	21
asthma	M	15
	F	13
hay fever	M	14
	F	13
skin reactions	M	29
	F	23
left-handedness	M	12
	F	16
gifted	M	49
	F	50
deficit	M	15
	F	13

Placental and Birth Order Comparisons

As it was hypothesized that twins carried within one placenta should be more likely to be exposed to the hormones of the other fetus, the twins were divided according to the number of placentas present at birth and compared within each sex. No significant differences were obtained on any of the indices. The effect of birth order was also investigated across the groups of twins by sex. It had also been hypothesized that birth order might be an important mediating factor. It is possible, particularly if the results from the animal literature can be extrapolated to humans, that one fetus is more highly exposed to circulating hormones than the other fetus due to their position *in utero*. However, the results of these analyses did not reveal any significant differences.

Weight Trends Within Twin Pairs

As mentioned in the method section, Koch (1966) determined that if one twin of a pair was heavier at birth, he/she would continue to be the heavier twin. My data did not support this finding. For the male twins, 50% of the sample continued with the same weight order whereas the other 50% reversed their order for weight. For the females, 33% reversed and 67% stayed with the same weight trend.

Study 2

For Study 2, not all the variables from study 1 were available to analyze as the data for the singletons was collected independently and previously to the data collection for the twins. Consequently, only the following variables were analyzed in these comparisons: developmental problems index, immune, non-immune and control indices, pregnancy complications and birth complications indices, education of mother and father, Blishen SES index, birth weight, family variables, and handedness. Also, the developmental problems index comprised the following variables only: pronunciation, stuttering, hyperactivity, attention, reading, and learning disabilities. Further, the birth complication index did not include the variable that asked whether the child was a twin or not as it was felt this would elevate the birth complication indices of the twins unnecessarily.

Analysis 4: Comparison of Female Singletons with Females of SS Twins:

Covariates

Table 33 illustrates the results of a MANOVA for parental educational level and Blishen SES index. The education levels of both the father and the mother were found to be different between groups, with the mothers and fathers of twins reporting higher levels of education. As it has already been documented that twins have significantly more developmental problems, a *higher* education level of their mothers and their fathers should

not confound these variables. Consequently, education levels were not used as covariates in the subsequent analyses.

Table 34 illustrates the results of the MANOVA for the pregnancy complications index, the birth complications index, and birth weight. As the multivariate analysis was found to be significant, the univariate analyses were interpreted. The groups were found to be different on all three variables. As these variables are known to have effects on development, it was decided to use them all as covariates. Table 35 shows that there were no group differences on any of the family variables: developmental problems, immune diseases, non-immune diseases, disease control index, and handedness.

Table 33

Female Singletons vs Female SS Twins: Multivariate and Univariate Results for Parental Education Levels and Blishen SES Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	6.84*, p=.000	Blishen	1.70
		Education - mother	16.82*, p=.002
		Education - father	10.75*, p=.002

For the multivariate F tests, df=3,72; for the univariate F tests, df=1,74.

*significant

Table 34

Female Singletons vs Female SS Twins: Multivariate and Univariate Results for Pregnancy Complication Index, Birth Complications Index and Birth Weight

Source	Multivariate F	Dependent Variables	Univariate F
Group	17.71*,p=.000	Pregnancy index	4.12*,p=.04
		Birth index	9.22*,p=.003
		Birth weight	47.67*,p=.000

For the multivariate F tests, df=3,77; for the univariate F tests, df=1,79.

*significant

Table 35

Female Singletons vs Female SS Twins: Multivariate and Univariate Results for Family History (FH) Indices (Excluding Child)

Source	Multivariate F	Dependent Variables	Univariate F
Group	1.00	Developmental index	0.12
		Immune index	4.17
		Non-immune index	1.30
		Control index	0.63
		Handedness	0.03

For the multivariate F tests, df=5,75; for the univariate F tests, df=1,79.

Multivariate and Univariate Analyses of Variance

ANOVAs were performed on the handedness index and the developmental problems index. ANOVAs were also performed on the immune and non-immune indices but not on the control index as the means on that index were identical. The results are shown in Table 36. Group differences were found on the developmental problems index. However, this difference was no longer present when the covariates were included in the analysis. Table 37 illustrates the results of the ANCOVA for this variable.

Chi-Square Analyses

Chi-square analyses were conducted on some specific items comprising the developmental problems index and the immune index. One group difference was obtained: females of SS twins were reported to have more pronunciation problems than female singletons. However, with Bonferroni corrections, the groups no longer evidenced differences on this variable ($p<0.01$). Two of the chi-square analyses neared significance: females of SS twins were reported to have more attention problems and reading problems. The results are illustrated in Table 38. Table 39 indicates the percentages of each group who were reported to have suffered from a particular developmental or health problem as well as the incidence of left-handedness.

Table 36

Female Singletons vs Female SS Twins: Univariate Results for Immune, Non-Immune, Developmental Problems, and Handedness Indices

Source	Dependent Variables	Univariate F
Group	Immune index	2.24
	Non-immune index	1.03
	Developmental index	4.53*, p=.04
	Handedness	1.41

For the univariate F tests, df=1,92.

*significant

Table 37

Female Singletons vs Female SS Twins: Univariate Result for Developmental Problems Index Using Pregnancy Complications and Birth Complications Indices, and Birth Weight as Covariates

Source	Dependent Variable	Univariate F
Group	Developmental index	0.32

For the univariate F test, df=1,75.

Table 38

Female Singletons vs Female SS Twins: Chi-Square Analyses of Variables Comprising Developmental Problems Index and Immune Index

Variable	Chi-Square Value
Developmental problems index:	
Stuttering	0.99
Pronunciation	5.17**, p=.02
Hyperactivity	0.00
Attention	3.03,***, p=.08
Reading	3.30,***, p=.07
Immune index:	
Allergies	1.34
Asthma	0.55
Hay fever	2.28
Skin reactions	0.25

**not significant with Bonferroni correction
***trend

Table 39

Female Singletons vs Female SS Twins: Percentage Rates for Dichotomous Variables

Variable	Group	Percentage
stuttering	F of Singletons	0
	F of SS	2
pronunciation	F of Singletons	0
	F of SS	11
attention	F of Singletons	0
	F of SS	6
hyperactivity	F of Singletons	0
	F of SS	0
reading	F of Singletons	7
	F of SS	19
learning disability	F of Singletons	7
	F of SS	4
allergies	F of Singletons	11
	F of SS	19
asthma	F of Singletons	6
	F of SS	11
hay fever	F of Singletons	4
	F of SS	13
skin reactions	F of Singletons	19
	F of SS	23
left-handedness	F of Singletons	11
	F of SS	19

Analysis 5: Comparison of Female Singletons with Females of OS Twins:

Covariates

Table 40 illustrates the results of a MANOVA for parental educational level and Blishen SES index. As the multivariate analysis was not significant, the univariate analyses were not interpreted. Table 41 illustrates the results of the MANOVA for the pregnancy complications index, birth complications index, and birth weight. The groups were found to be different on the pregnancy complications index and birth weight. As these variables are known to have effects on development, it was decided to use them as covariates. Table 42 shows that there were no group differences on any of the family variables: developmental problems, immune diseases, non-immune diseases, disease control index, and handedness.

Table 40

Female Singletons vs Female OS Twins: Multivariate and Univariate Results for Parental Education Levels and Blishen SES Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	1.60	Blishen	0.07
		Education - mother	3.39
		Education - father	1.01

For the multivariate F tests, df=3,54; for the univariate F tests, df=1,56.

Table 41

Female Singletons vs Female OS Twins: Multivariate and Univariate Results for Pregnancy Complications Index, Birth Complications Index, and Birth Weight

Source	Multivariate F	Dependent Variables	Univariate F
Group	12.65*,p=.000	Pregnancy index	4.81*,p=.03
		Birth index	1.08
		Birth weight	30.23*,p=.000

For the multivariate F tests, df=3,53; for the univariate F tests, df=1,55.

*significant

Table 42

Female Singletons vs Female OS Twins: Multivariate and Univariate Results for Family History (FH) Indices (Excluding Child)

Source	Multivariate F	Dependent Variables	Univariate F
Group	1.07	Developmental index	3.30
		Immune index	1.95
		Non-immune index	0.55
		Control index	0.82
		Handedness	0.01

For the multivariate F tests, df=5,56; for the univariate F tests, df=1,60.

Multivariate and Univariate Analyses of Variance

ANOVAs were performed on the handedness index and the developmental problems index. ANOVAs were also performed on the immune and non-immune indices but not the control index as the means on that index were identical. The results are shown in Table 43. The groups differed on the developmental problems index. However, this difference was no longer present when the covariates were included in the analysis. Table 44 illustrates the results of the ANCOVA for this variable.

Chi-Square Analyses

Chi-square analyses were conducted on some specific items comprising the developmental problems index and the immune index. One group difference was obtained: females of OS twins were reported to have more pronunciation problems than female singletons. With Bonferroni corrections, the groups still evidenced differences on this variable ($p<0.01$). One of the chi-square analyses neared significance; females of OS twins were reported to have more reading problems. The results are illustrated in Table 45. Table 46 indicates the percentages of each group who were reported to have suffered from a particular developmental or health problem as well as the incidence of left-handedness.

Table 43

Female Singletons vs Female OS Twins: Univariate Results for Immune, Non-Immune, Developmental Problems, and Handedness Indices

Source	Dependent Variables	Univariate F
Group	Immune index	0.15
	Non-immune index	0.34
	Developmental index	3.94**, p=.05
	Handedness	0.14

For the univariate F tests, df=1,64.

**marginally significant

Table 44

Female Singletons vs Female OS Twins: Univariate Result for Developmental Problems Index Using Pregnancy Complications Index and Birth Weight as Covariates

Source	Dependent Variable	Univariate F
Group	Developmental index	1.84

For the univariate F test, df=1,56.

Table 45

Female Singletons vs Female OS Twins: Chi-Square Analyses of Variables Comprising Developmental Problems Index and Immune Index

Variable	Chi-Square Value
Developmental problems index:	
Stuttering	0.00
Pronunciation	6.60*, p=.01
Hyperactivity	0.00
Attention	1.95
Reading	3.22, ***, p=.07
Immune index:	
Allergies	0.11
Asthma	0.64
Hay fever	1.95
Skin reactions	0.10

*significant
***trend

Table 46

Female Singletons vs Female OS Twins: Percentage Rates for Dichotomous Variables

Variable	Group	Percentage
stuttering	F of Singletons	0
	F of OS	0
pronunciation	F of Singletons	0
	F of OS	18
attention	F of Singletons	3
	F of OS	12
hyperactivity	F of Singletons	0
	F of OS	0
reading	F of Singletons	6
	F of OS	21
learning disability	F of Singletons	0
	F of OS	6
allergies	F of Singletons	18
	F of OS	15
asthma	F of Singletons	9
	F of OS	15
hay fever	F of Singletons	3
	F of OS	12
skin reactions	F of Singletons	21
	F of OS	18
left-handedness	F of Singletons	9
	F of OS	12

Analysis 6: Comparison of Male Singletons with Males of SS Twins:

Covariates

Table 47 illustrates the results of a MANOVA for parental educational level and Blishen SES index. As the multivariate analysis was significant, the univariate analyses were interpreted. The two groups differed on education of father, with the fathers of twins reporting greater levels of education. However, as discussed previously, as twins are expected to have more developmental problems, higher levels of education in the fathers should not affect the results. Consequently, education of father was not used as a covariate in subsequent analyses.

Table 48 illustrates the results of the MANOVA for the pregnancy complications index, the birth complications index and birth weight. The groups were found to be different on the birth complications index and birth weight. As these variables are known to have effects on development, it was decided to use them as covariates. Table 49 shows that there were no group differences on any of the family variables: developmental problems, immune diseases, non-immune diseases, disease control index, and handedness.

Table 47

Male Singletons vs Male SS Twins: Multivariate and Univariate Results for Parental Education Levels and Blishen SES Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	5.90*,p=.001	Blishen	1.37
		Education - mother	1.66
		Education - father	17.81*,p=.000

For the multivariate F tests, df=3,96; for the univariate F tests, df=1,98.

*significant

Table 48

Male Singletons vs Male SS Twins: Multivariate and Univariate Results for Pregnancy Complications Index, Birth Complications Index and Birth Weight

Source	Multivariate F	Dependent Variables	Univariate F
Group	18.30*,p=.000	Pregnancy index	0.54
		Birth index	15.14*,p=.000
		Birth weight	55.89*,p=.000

For the multivariate F tests, df=3,91; for the univariate F tests, df=1,93.

*significant

Table 49

Male Singletons vs Male SS Twins: Multivariate and Univariate Results for Family History (FH) Indices (Excluding Child)

Source	Multivariate F	Dependent Variables	Univariate F
Group	1.68	Developmental index	5.12
		Immune index	4.80
		Non-immune index	0.02
		Control index	0.07
		Handedness	0.15

For the multivariate F tests, df=5,94; for the univariate F tests, df=1,98.

Multivariate and Univariate Analyses of Variance

ANOVAs were performed on the handedness index and the developmental problems index. ANOVAs were also performed on the immune and non-immune indices but not on the disease control index as the means on that index were identical. The results are shown in Table 50. The groups differed on the immune index. However, this difference was no longer present when the covariates were included in the analysis. Table 51 illustrates the results of the ANCOVA for this variable.

Chi-Square Analyses

Chi-square analyses were conducted on some specific items comprising the developmental problems index and the immune index. One group difference was obtained; males of SS twins were reported to have more skin reactions than male singletons. With Bonferroni corrections, the groups still evidenced differences on this variable ($p<0.01$). One of the chi-square analyses neared significance; males of SS twins were reported to have more reading problems. The results are illustrated in Table 52. Table 53 indicates the percentages of each group who were reported to have suffered from a particular developmental or health problem as well as the incidence of left-handedness.

Table 50

Male Singletons vs Male SS Twins: Univariate Results for Immune, Non-Immune, Developmental Problems, and Handedness Indices

Source	Dependent Variables	Univariate F
Group	Immune index	3.83**, p=.05
	Non-immune index	0.22
	Developmental index	0.93
	Handedness	0.79

For the univariate F tests, df=1,110.

**marginally significant

Table 51

Male Singletons vs Male SS Twins: Univariate Results for Immune Index Using Birth Complications Index and Birth Weight as Covariates

Source	Dependent Variable	Univariate F
Group	Immune index	2.16

For the covariate F test, df=1,95.

Table 52

Male Singletons vs Male SS Twins: Chi-Square Analyses of Variables Comprising Developmental Problems Index and Immune Index

Variable	Chi-Square Value
Developmental problems index:	
Stuttering	0.96
Pronunciation	0.29
Hyperactivity	0.12
Attention	0.45
Reading	3.13***, p=.08
Immune index:	
Allergies	0.04
Asthma	2.62
Hay fever	0.00
Skin reactions	10.12*, p=.001

*significant
***trend

Table 53

Male Singletons vs Male SS Twins: Percentage Rates for Dichotomous Variables

Variable	Group	Percentage
Stuttering	M of Singletons	2
	M of SS	6
Pronunciation	M of Singletons	11
	M of SS	14
Attention	M of Singletons	15
	M of SS	19
Hyperactivity	M of Singletons	11
	M of SS	9
Reading	M of Singletons	5
	M of SS	16
Learning disability	M of Singletons	0
	M of SS	2
Allergies	M of Singletons	26
	M of SS	28
Asthma	M of Singletons	5
	M of SS	14
Hay fever	M of Singletons	11
	M of SS	11
Skin reactions	M of Singletons	11
	M of SS	36
Left-handedness	M of Singletons	13
	M of SS	7

Analysis 7: Comparison of Male Singletons with Males of OS Twins:

Covariates

Table 54 illustrates the results of a MANOVA for parental educational level and Blishen SES index. As the multivariate analysis was not significant, the univariate analyses were not interpreted. Table 55 illustrates the results of the MANOVA for the pregnancy complications index, the birth complications index, and birth weight. The groups were found to be different on birth weight. As this variable is known to have effects on development, it was decided to use it as a covariate. Table 56 shows that there were no group differences on any of the family variables: developmental problems, immune diseases, non-immune diseases, disease control index, and handedness.

Table 54

Male Singletons vs Male OS Twins: Multivariate and Univariate Results for Parental Education Levels and Blishen SES Index

Source	Multivariate F	Dependent Variables	Univariate F
Group	0.51	Blishen	1.43
		Education - mother	0.21
		Education - father	0.06

For the multivariate F tests, df=3,55; for the univariate F tests, df=1,57.

Table 55

Male Singletons vs Male OS Twins: Multivariate and Univariate Results for Pregnancy Complications Index, Birth Complications Index and Birth Weight

Source	Multivariate F	Dependent Variables	Univariate F
Group	5.46*, p=.002	Pregnancy index	1.89
		Birth index	0.36
		Birth weight	13.60*, p=.001

For the multivariate F tests, df=3,54; for the univariate F tests, df=1,56.

*significant

Table 56

Male Singletons vs Male OS Twins: Multivariate and Univariate Results for Family History (FH) Indices (Excluding Child)

Source	Multivariate F	Dependent Variables	Univariate F
Group	2.12	Developmental index	9.14
		Immune index	0.14
		Non-immune index	0.22
		Control index	0.21
		Handedness	0.07

For the multivariate F tests, df=5,57; for the univariate F tests, df=1,61.

Multivariate and Univariate Analyses of Variance

ANOVAs were performed on the handedness index and the developmental problems index. ANOVAs were also performed on the immune and non-immune indices but not on the disease control index because the means on that index were identical. The results are shown in Table 57. There were no group differences.

Chi-Square Analyses

Chi-square analyses were conducted on some specific items comprising the developmental problems index and the immune index. No group differences were obtained. The results are illustrated in Table 58. Table 59 indicates the percentages of each group who were reported to have suffered from a particular developmental or health problem as well as the incidence of left-handedness.

Table 57

Male Singletons vs Male OS Twins: Univariate Results for Immune, Non-Immune, Developmental Problems, and Handedness Indices

Source	Dependent Variables	Univariate F
Group	Immune index	0.07
	Non-immune index	0.34
	Developmental index	1.94
	Handedness	0.02

For the univariate F tests, df=1,64.

Table 58

Male Singletons vs Male OS Twins: Chi-Square Analyses of Variables Comprising Developmental Problems Index and Immune Index

Variable	Chi-Square Value
Developmental problems index:	
Stuttering	0.00
Pronunciation	1.75
Hyperactivity	0.00
Attention	0.40
Reading	1.75
Immune index:	
Allergies	0.07
Asthma	1.44
Hay fever	0.73
Skin reactions	0.41

Table 59

Male Singletons vs Male OS Twins: Percentage Rates for Dichotomous Variables

Variable	Group	Percentage
Stuttering	M of Singletons	6
	M of OS	6
Pronunciation	M of Singletons	9
	M of OS	21
Attention	M of Singletons	13
	M of OS	18
Hyperactivity	M of Singletons	3
	M of OS	3
Reading	M of Singletons	9
	M of OS	21
Learning disability	M of Singletons	0
	M of OS	3
Allergies	M of Singletons	30
	M of OS	33
Asthma	M of Singletons	6
	M of OS	15
Hay fever	M of Singletons	6
	M of OS	12
Skin reactions	M of Singletons	21
	M of OS	15
Left-handedness	M of Singletons	9
	M of OS	12

Canonical Correlations

As the developmental problems index and the immune index evidenced significant differences between at least one of the singleton/twin comparisons but no longer evidenced differences when the pregnancy and birth complications and birth weight were included as covariates, a canonical correlation analysis was performed. As illustrated in Table 60, the three predictor variables used included pregnancy complications index, birth complications index, and birth weight. The two outcome variables used were the developmental problems index and the immune disease index.

The data from all the twins were entered in this analysis (266 cases). Each of the eigenvalues was tested at alpha=.05 using the greatest characteristic root distribution tables from Harris (1985). The first coefficient of canonical correlation was found to be statistically significant. Correlations between the individual variables and the canonical variates greater than .30 were considered meaningful. The results seemed to suggest that 1) the pregnancy complications index did not appear to be a predictor for developmental problems and immune diseases, 2) twins with a greater birth complications index were at a higher risk for having developmental problems and immune problems, 3) twins with a low birth weight were also at a greater risk for suffering from developmental problems and immune problems, and 4) developmental problems and

immune diseases (although less so) were highly correlated with the canonical coefficient.

The first canonical correlation was .369, as shown in Table 60, indicating that the linear combination of the three predictor variables accounted for 13.6% of the variance in the outcome variables. Unlike multiple regression where R^2 directly tells the proportion of variance in the dependent variable that can be accounted for by the predictor variables, the R^2 in a canonical correlation analysis represents the proportion of variance in one canonical variate that can be accounted for by the other canonical variate. This still leaves undetermined the actual proportion of variance in the dependent variables that can be accounted for by the predictor variables. To determine this, a redundancy analysis was conducted. The pooled redundancy coefficient (Rd) was 0.083, indicating that 8.3% of the variance in the two dependent variables was accounted for by two out of three predictor variables. This demonstrates that the relationship being studied is complex and that two of the three predictor variables included in the canonical correlation analysis account for approximately only one tenth of the variance of the dependent variables, leaving 91.7% of the variance unaccounted for. Consequently, there are multiple causes for the dependent variables included in this analysis.

Table 60

Canonical Correlation Analysis of Developmental Problems and Immune Diseases in the Twins

Variables	Variate	1*	2**
	R^2	.136	.019
	R	.369	.137
Correlations of Predictor Variables with Canonical Variates			
Pregnancy index		.076	
Birth index		.941	
Birth weight		-.838	
Correlations of Outcome Variables with Canonical Variates			
Developmental Problems		.928	
Immune diseases		.477	

*p<.05
**not significant, consequently the correlations with the canonical variates have been omitted

Logistic Regression Analyses

Logistic regression was used to determine the risk a twin had for developing a particular developmental problem based on the information of the child's birth weight, and history of pregnancy and birth complications. Such analyses were necessary to determine whether the significant chi-square results from the singleton/twin comparisons were a direct result of higher birth complications and lower birth weights in the twins or whether there may be other risk factors involved. The problems analyzed included some of the individual variables of the developmental problems index and one variable from the immune index. Forward selection was used as the method of entry in order to minimize problems with multicollinearity (Tabachnick & Fidell, 1989). The data from all the twins were used in the analyses (267 cases). The developmental variables included reading, pronunciation, and attention. The immune variable was skin reactions.

The first logistic regression conducted used the presence or absence of reading problems in the child as the dependent variable. The independent variables were the pregnancy complications index, the birth complications index and the child's birth weight. The model chi-square was significant ($\underline{X}^2(1)=4.60$, $\underline{p}<.05$), and the birth complications index was found to be a significant predictor of the presence/absence of reading problems in the child (Wald (1)=4.74, $\underline{p}<.05$). The odds in favour of the child having reading problems were 1.19 times as high for a child with high birth complications

as for a child with low birth complications, although, using a 95% confidence interval, this value could be as low as 1.02 and as high as 1.38 (see Appendix H for a sample calculation).

Another way to interpret the logistic regression model is to determine its predictive efficacy. Predictive efficacy refers to the ability of the model to generate acurate predictions of a case's status on the dependent variable. The rationale for calculating the predictive efficacy is that it is quite possible to have an excellent fit between the model and data without necessarily having a model with much predictive efficacy. The predictive efficacy of this model was determined to be 0.018 (the scale ranges from 0 to 1). In other words the model showed very poor predictive efficacy in that it was able to predict only 1.8% of the variance in the dependent variable (see Appendix H).

For the pronunciation problems, the model chi-square was significant ($\underline{X}^2(1)=6.97$, $\underline{p}<.05$), and the birth complications index was again found to be a significant predictor of the presence/absence of pronunciation problems in the child (Wald(1)=7.17, $\underline{p}<.05$). The odds in favour of the child having pronunciation problems were 1.24 times as high for a child with high birth complications as for a child with low birth complications, although, using a 95% confidence interval, this value could be as low as 1.06, and as high as 1.46. The predictive efficacy was determined to be 0.03, again a very poor value of prediction.

For the attention problems, the model chi-square was significant ($X^2(1)=17.06$, $p<.05$), and the birth complications index was again found to be a significant predictor of the presence/absence of attention problems in the child (Wald(1)=16.79, $p<.05$). The odds in favour of the child having attention problems were 1.43 times as high for a child with high birth complications as for a child with low birth complications, although, using a 95% confidence interval, this value could be as low as 1.20, and as high as 1.69. The predictive efficacy was found to be 0.079, again quite poor.

For the skin reactions, none of the predictor variables was able to predict skin reactions significantly. Consequently, there appears to be little relation between complications and low birth weight with skin problems. In other words, it is highly unlikely that the differences found between the male SS twins and the male singletons on skin reactions was a result of complications and low birth weights in the twins.

In summary, the odds ratios for the twins to suffer from reading problems, pronunciation problems, and attention problems given their history of birth complications were 1.19, 1.24, and 1.43 respectively. Consequently, although the variable of birth complications does provide some insight as to why the twins may have suffered more from some of these problems, as the odds ratios were not that far from 1, it is highly likely that other factors may be involved in the significant outcomes of the chi-square analyses. None of the predictor variables increased the risk for

the twins to develop skin reactions. Further, the predictive efficacy for all the dependent variables was very low and consequently, birth and pregnancy complications and birth weight cannot be assumed to be causing the differences found on the dichotomous variables.

Summary of Significant Results

Table 61 provides a summary of the significant findings from the multivariate, univariate and chi-square analyses conducted for the two studies. The results reported in the table include significant findings after Bonferroni corrections of alpha levels*, findings of marginal significance ($p=.05$) or findings with $p<.05$ but not significant following Bonferroni correction or inclusion of covariates**, and interesting trends that were not significant***. The individual analyses will be abbreviated according to the following key: 1. F SS vs F OS (Females of SS Twins vs Females of OS Twins), 2. M SS vs F OS (Males of SS Twins vs Males of OS Twins), 3. M Twins vs F Twins (Male Twins vs Female Twins), 4. F Sing vs F SS (Female Singletons vs Females of SS Twins), 5. F Sing vs F OS (Female Singletons vs Females of OS Twins), 6. M Sing vs M SS (Male Singletons vs Males of SS Twins), and 7. M Sing vs M OS (Male Singletons vs Males of OS Twins).

The overall validity of the study is supported by the confirmation of known medical or psychological facts. For example, in the male/female twin comparisons, the following known results were obtained: 1) male twins were reported to have overall better skills at spatial tasks (for example, map reading, finding their way around without getting lost, memories of faces and places, and building), 2) female twins were reported to have more difficulties with mathematics, 3) there was a trend that indicated that male twins were more likely to be hyperactive and had more stuttering problems,

and 4) there was also a trend that indicated that male twins had more allergies.

Further evidence of internal validity comes from the twin/singleton comparisons, where the results confirmed higher levels of pregnancy and birth complications and lower birth weights in the twin groups. The female twins were also reported to have more developmental problems than the singletons.

From study 1, the potentially interesting findings with respect to the hypotheses include 1) males of SS twins were reported to have more skin reactions than males of OS twins, with the immune index nearing significance, 2) the trends from the non-verbal index suggest that males of SS twins may have some spatial skills that are better than those of males of OS twins, and 3) male SS twins were found to be more gifted, imaginative, and creative than male OS twins.

From study 2, the potentially interesting findings include 1) males of SS twins were reported to have more immune problems than singletons (in particular, skin reactions), although this effect was eliminated when the covariates were included in the analyses, 2) females of OS twins were reported to have more developmental problems than female singletons (in particular, pronunciation problems, and reading problems), although again this effect disappeared when the covariates were included in the analysis,

and 3) no differences were reported for any of the variables between the males of OS twins and the male singletons.

The results from study 1 which are not supportive of the hypotheses include 1) the trend for skin reaction differences was in the direction of females of SS twins suffering from more skin reactions than females of OS twins, 2) no differences were found on the handedness, non-verbal, and developmental problems indices for the female twin comparisons, and 3) no differences were found on the handedness, and developmental problems indices for the male twin comparisons.

The results from study 2 which are not supportive of the hypotheses include 1) females of SS twins were reported to have more developmental problems than female singletons, in particular pronunciation problems, attention problems, and reading problems, although this effect was removed on inclusion of the covariates, 2) no differences were found between females of OS twins and female singletons on the handedness, and immune indices, and 3) no differences were found between males of SS twins and male singletons on the handedness or on the developmental indices.

Finally, the canonical correlation analysis revealed that birth complications and birth weight play a significant role in predicting developmental and immune outcomes, explaining 8.3% of the variance in these variables. Consequently, as this effect is relatively large, it may simply have been too large to detect any role hormones may play in

development. The logistic analyses revealed that high birth complications do increase the odds that a twin will evidence certain developmental problems; however, as they were not that far from 1, it is extremely likely that other factors also provide some risk to the development of these problems. Further support for this conclusion comes from the results of the predictive efficacies, all of which were extremely low.

Table 61

Summary of Significant Findings

Dependent Variable	Groups Compared	Direction of Finding
Covariates		
Pregnancy index	4. F Sing vs F SS	F SS>F Sing*
	5. F Sing vs F OS	F OS>F Sing*
Birth index	4. F Sing vs F SS	F SS>F Sing*
	6. M Sing vs M SS	M SS>M Sing*
Birth weight	4. F Sing vs F SS	F SS<F Sing*
	5. F Sing vs F OS	F OS<F Sing*
	6. M Sing vs M SS	M SS<M Sing*
	7. M Sing vs M OS	M OS<M Sing*
Education - father	2. M SS vs M OS	M SS>M OS*
	4. F Sing vs F SS	F SS>F Sing*
	6. M Sing vs M SS	M SS>M Sing*
Education - mother	4. F Sing vs F SS	F SS>F Sing*
Main Indices		
Developmental index	4. F Sing vs F SS	F SS>F Sing**
	5. F Sing vs F OS	F OS>F Sing**
Immune index	2. M SS vs M OS	M SS>M OS***
	6. M SS vs M Sing	M SS>M Sing**
Non-verbal index	3. M Twins vs F Twins	M Twins>F Twins*
Creativity index	2. M SS vs M OS	M SS>M OS**
	3. M Twins vs F Twins	F Twins>M Twins*

(table continues)

Dependent Variable	Groups Compared	Direction of Finding
Developmental Variables		
Pronunciation	4. F Sing vs F SS	F SS>F Sing**
	5. F Sing vs F OS	F OS>F Sing*
Stuttering	3. M Twins vs F Twins	M Twins>F Twins***
Hyperactivity	3. M Twins vs F Twins	M Twins>F Twins**
Attention	4. F Sing vs F SS	F SS>F Sing***
Reading	4. F Sing vs F SS	F SS>F Sing***
	5. F Sing vs F OS	F OS>F Sing***
	6. M Sing vs M SS	M SS>M Sing***
Mathematics	3. M Twins vs F Twins	F Twins>M Twins*
Immune Variables		
Skin reactions	1. F SS vs F OS	F SS>F OS***
	2. M SS vs M OS	M SS>M OS*
	6. M SS vs M Sing	M SS>M Sing*
Allergies	3. M Twins vs F Twins	M Twins>F Twins**
Verbal Variables		
Communication	2. M SS vs M OS	M SS>M OS***

(table continues)

Dependent Variable	Groups Compared	Direction of Finding
Non-Verbal Variables		
Memory/places	3. M Twins vs F Twins	M Twins>F Twins*
Memory/faces	2. M SS vs M OS	M SS>M OS***
	3. M Twins vs F Twins	M Twins>F Twins*
Map reading	3. M Twins vs F Twins	M Twins>F Twins*
Building	2. M SS vs M OS	M SS>M OS***
	3. M Twins vs F Twins	M Twins>F Twins*
Lost	3. M Twins vs F Twins	M Twins>F Twins*
Creativity Variables		
Musical talent	3. M Twins vs F Twins	F Twins>M Twins*
Imagination	2. M SS vs M OS	M SS>M OS*
Creativity	2. M SS vs M OS	M SS>M OS*
Gifted	2. M SS vs M OS	M SS>M OS**

*significant
**marginally significant (p=.05) or not significant with Bonferroni correction or inclusion of covariates
***trend

Discussion

Study 1

Female Twin Comparisons

None of the results for these comparisons supported the stated hypotheses. In other words, females of OS twin pairs were not more vulnerable to the disorders and patterns of cognitive skills more common in males. Female OS twins did not have more immune diseases, did not show a greater incidence of left-handedness, did not have more developmental problems, and did not evidence stronger right hemisphere skills than female SS twins. However, there are two potentially interesting hypotheses to explain these null findings. These include 1) the potentially masculinizing effect estrogen may play in the development of females in SS twin pairs, 2) the ambiguous and paradoxical role testosterone may play in the development of female OS twins, and 3) it may be necessary to have aberrant levels of testosterone present during both the organizational and activational phases of development in order for changes to the CNS to be detectable.

As mentioned in the introduction, it has been demonstrated conclusively in rodents that estrogen is the active agent organizing the brain through the aromatization of testosterone to estrogen. It was also discussed that females are believed to be protected from the masculinizing effect of estrogen by fetoneonatal estrogen binding protein (FEBP).

However, the strength of this protective mechanism is uncertain when high levels of estrogen are involved. Further, it is also unclear the extent to which aromatization and FEBP protection occur in humans. Regardless of the mechanisms, it is logically possible that, if these mechanisms extrapolate to humans, when a female becomes exposed to excessive levels of estrogen, she should theoretically be adversely affected by them. Consequently, just as it was hypothesized that females exposed to high levels of testosterone, due to the presence of a male *in utero*, are likely to be vulnerable to its masculinizing effect, it is equally possible that females *in utero* with another female are also vulnerable to the high levels of estrogen circulating.

Certainly, the research on females exposed to DES (a synthetic estrogen) *in utero* supports this proposal (Hines, 1982; Reinisch, Ziemba, & Sanders, 1991; Schachter, 1994) in that DES has been found to "masculinize" the female brain. Further, Tan (1990c) found that increased levels of estradiol postnatally (a structurally similar form of estrogen) were correlated with increased incidence of left-handedness. In fact, a number of researchers have described estrogen's role to be primary in masculine development in rodents (Breedlove, 1994; Hines, 1982; MacLusky & Naftolin, 1981; MacLusky et al., 1986). Other areas of research demonstrate a more ambiguous relationship between hormones and behaviour, finding evidence to both support and contradict the

aromatization hypothesis and the masculinizing effect of estrogen. For example, when females are exposed to exogenous estrogens, there are reports of both hypomasculinization of play behaviour and increased spatial skills (Meyer-Bahlburg, Feldman, Cohen, & Ehrhardt, 1988). On the other hand, some researchers more consistently define estrogen's role as one of feminization (see Fitch & Denenburg [1995] for a review). For example, Silverman and Phillips (1993) determined that spatial skills in females vary with the menstrual cycle; when estrogen levels were low, spatial skills were higher and vice versa. Overall, the research in the area of estrogen's role in development makes it difficult to determine with any degree of certainty as to the directionality of its effect on female twin development.

If estrogen is playing as significant a role in prenatal development as testosterone, the results of this study support the aromatization hypothesis (and the masculinizing effect of estrogen) as no differences were detected. Had estrogen been playing a feminizing role, even greater differences would have been expected as the females of SS twins would have been more "feminized" while females of OS twins would have been "masculinized". As this was not the case, it is very possible that the null findings were due to masculinizing effects occurring in females of both types of twins (i.e., opposite and same-sex pairs). Therefore, despite the null findings, it is still possible that testosterone does play a role in the development of female twins but that this effect may not be detectable through this type of

comparison. Indeed, if the role of estrogen is taken into account, the results may still be supportive of the proposed hypotheses but require the twin/singleton comparisons to detect the differences.

Another possible explanation of the results has to do with the paradoxical role testosterone plays in the brain development of the female. As described in the introduction, the research that has investigated testosterone's effect has been inconsistent and also fraught with many mediating factors that increase the complexities of the observations. Further, a number of researchers believe testosterone's effect may be opposite depending on the sex or that it may serve a protective rather than a facilitatory effect in the development of left-handedness, autoimmune diseases, and learning disabilities (Berenbaum & Denberg, 1995; Grimshaw et al., 1995; Witelson, 1991; Witelson & Nowakowski, 1991). Consequently, the fact that differences were not found between the two types of twins may simply be an artifact of testosterone's complex interactional effect with the central nervous system.

Finally, another viable explanation for the null findings is based on the fact that some research has indicated that hormonal levels need to be high during both the organizational phase *and* the activational phase of development in order for there to be a detectable change in development. Unlike CAH individuals, twins are hypothesized to be exposed to aberrant levels of testosterone only during the organizational phase. Consequently, it

is possible that the changes in the central nervous system are not evident without the consistent presence of aberrant levels of hormones throughout postnatal development. Certainly, female finches, even if they are exposed to androgens prenatally, must also be exposed to androgens as an adult in order to sing, a behaviour most typical of the male finch (Gurney & Konishi, 1980). However, as there is a wealth of literature that demonstrates that it is not necessary to expose individuals to hormones during both the activational and organizational phases, it is unlikely to have mediated these null findings.

Male Twin Comparisons

There was limited support from the male twin comparisons for the stated hypotheses. Males of SS twins were found to have more immune disorders, specifically skin reactions, and there were trends that indicated that males of SS twins had better spatial skills than males of OS twins (specifically in building and memories of faces). Further, although giftedness was not specifically discussed in the introduction as a variable that should be related to testosterone levels, Geschwind and Galaburda did postulate that higher levels of testosterone should co-occur with giftedness as well as with immune disorders (1985a). In this study, it was found that males of SS twins were more imaginative, more creative, and more gifted than males of OS twins. Further, these variables were significantly

correlated with immune diseases (see Appendix I). However, there were no differences in developmental problems and handedness.

There are a number of explanations to explain the null findings on the last two variables. First, it is possible that the null findings were due to the already higher risk that twins will suffer from developmental problems and higher incidence of left-handedness (Akerman & Fischbein, 1991: Davis & Annett, 1994). Consequently, any effect excess levels of testosterone may have on brain development in males could be masked by the greater and stronger effect of twinning. Second, it is also possible that, just as testosterone plays a paradoxical role in the development of the female, it is equally likely that its effect on the male could be ambiguous. Certainly, the research has not consistently proven testosterone's "masculinizing" effect in the male. For example, Tan (1990c) found that males with higher levels of testosterone evidenced higher rates of right-handedness. Indeed, it is very likely that higher prenatal levels of testosterone mediate the development of some "masculine" behaviours but not of others.

Third, it is also possible that, just as estrogen was hypothesized to mediate the obtained results in the female twin comparisons, it could also be mediating the findings in these male comparisons. However, there is little research to aid in predicting the directionality of estrogen's effect on males, if any. Ehrhardt and Meyer-Bahlburg (1979) found that exogenous

estrogens tended to demasculinize the male, and Reinisch and Sanders (1992) reported that males exposed to DES *in utero* had decreased spatial abilities as compared to normal male controls. Certainly, if males sharing the uterine environment with a female are exposed to aberrant levels of estrogen and if this estrogen tends to "demasculinize" the male, it would be expected that the male twin comparisons would reveal even greater differences. Unfortunately, without more information on the role estrogen has on the developing male, it is impossible to speculate on its ultimate mediating effect.

The fact that the differences obtained on the questions related to spatial ability were only trends may simply have been a result of the small sample size. Had a larger sample been obtained, this difference may have been significant. However, this lack of a significant difference may also have been due to the age of the majority of the twins. As the mean age was approximately 12 years, it is possible that the spatial skills of these males had not yet developed to their fullest potential. Fitch and Denenberg (1995) reported that superior spatial skills do not become evident in males until puberty. Consequently, as the sample consisted primarily of pre-pubescent boys, it could explain the weak findings for the spatial variables.

Overall, the results from the male twin comparisons are promising as far as lending some support to the stated hypotheses. In particular, males

of SS twins showed higher incidence of giftedness, immune diseases, and spatial skills as compared to males of OS twins.

Sex Comparisons Across the Twins

These comparisons served more as a test to the internal validity of the model and the questionnaire. The differences found between the male and the female twins were consistent with those reported in the literature. As they were summarized in the results section, they will not be repeated here.

Study 2

Female Singletons vs Female SS Twins

As females of SS twins are not believed to be exposed to aberrant levels of testosterone, no differences were expected to be found when compared to female singletons. However, one difference was observed: females of SS twins were found to have more developmental problems, specifically pronunciation, attention and reading problems, than female singletons, a result consistent with the research performed by Akerman and Fischbein (1991). This effect was no longer present when pregnancy complications and birth weight were included in the analyses as covariates. This obtained difference could potentially be explained by two factors. The most obvious one relates to the general effect of twinning. Perinatal

complications have been implicated in the development of disabilities (Gray et al., 1989) as have low birth weights (Akerman & Thomassen, 1992). Consequently, as twins are known to have more pregnancy and birth complications than singletons and tend to be smaller at birth (differences that were also obtained in this study), it is expected that they would suffer from more developmental problems. Further evidence for this effect came from the canonical correlation analysis. Birth complications as well as birth weight were found to account for a significant amount of the variance in the developmental problems index. Indeed, it appears that the differences found between female singletons and female SS twins are most likely the direct result of problems with twinning. In fact, Fraser et al. (1994) found that low birth weight was the single best predictor of perinatal outcomes in twin births.

There is another intriguing hypothesis that could partially play a role in the obtained differences on the development problems index that may have been masked by the much larger effect of twinning. As mentioned in the discussion of study 1, females of SS twins may be adversely affected by excess exposure to estrogen. Consequently, if estrogen is acting like testosterone, in that it is "masculinizing" the female developing brain, we would expect more developmental problems in the SS twins when compared to female singletons. Certainly, it is possible that this is occurring;

however, due to the overriding effect of twinning, it is not possible to confirm this hypothesis from these data.

Female Singletons vs Female OS Twins

There was limited support from the results of these comparisons for the stated hypotheses. Females of OS twins were found to have more developmental problems, specifically pronunciation and reading problems, than female singletons, although this effect disappeared when covariates were included in the analyses. As mentioned in the preceding section, this result may simply have been an artifact of twinning. However, it is also possible that testosterone was playing a role in producing this difference but that its effect was far smaller than the large and significant one caused by birth complications and low birth weight.

For both comparisons of the female twins with the singletons, it is necessary to consider the results of the logistic regression analyses and the canonical correlations when interpreting the results of the ANCOVAs. Otherwise, it would be easy to simply regard all the significant results as artifacts of difficult deliveries and low birth weights. In the logistic regression analyses, birth complications did appear to introduce a small risk to the development of specific problems; however, the odds ratios were minimal (i.e., very close to 1) and also had poor predictive efficacy. Consequently, it is highly likely that other factors mediated the outcome of

the individual developmental problems variables. Further, although the canonical correlation analysis was able to account for 8.3% of the variance of the developmental problems and immune disease indices, there is 91.7% still unaccounted for. Consequently, these results do indicate that other mediating factors were involved in the obtained results (such as a testosterone effect); however, it is not possible from this study to determine with any amount of certainty precisely what those factors may have been.

Male Singletons vs Male SS Twins

There was again limited support for the hypotheses from the results of these comparisons. Males of SS twins were found to suffer from more immune disorders, specifically skin reactions, than male singletons. This effect disappeared on including the covariates in the analyses. It is certainly possible that this difference was due to the effect of aberrant levels of testosterone *in utero* as the role that pregnancy and birth complications play in the development of immune diseases is less well established as a predictor than for the developmental problems. In fact, in the logistic regression, none of the covariates was able to predict skin reactions, indicating that other factors mediated the significant difference obtained. Consequently, this difference does lend some support to the hypotheses.

Male Singletons vs Male OS Twins

No differences were found between male singletons and male OS twins. This result is significant for at least two reasons. First, according to the hypotheses, no differences would be expected between these two groups as these male twins should not have been exposed to aberrant levels of testosterone. Second, as no differences were found on the immune index for the male OS twins but differences were found on this index for the SS twins, it suggests that the difference found was unlikely to have been caused by pregnancy and birth complications. Had the complications been the causal factors in the higher levels of immune problems for male SS twins, we would have expected to see differences across both types of twins, regardless of membership. As this was not the case, it lends further support to the hypothesis that the immune difference found between male singletons and male SS twins was a result of *in utero* exposure to aberrant levels of testosterone.

Brief Summary and Discussion of the Salient Results

Overall, males of SS twins were different from males of OS twins and male singletons on the prevalence of immune diseases, in particular, skin reactions. As far as I know, this result has never been documented in the research literature. Male SS twins were also found to be more creative, more imaginative, and more gifted than male OS twins, a result consistent

with Geschwind and Galaburda's model. Further, these variables were significantly correlated with immune diseases, consistent with the results of Benbow and Benbow (1984) and the Geschwind/Galaburda model. The male twins did not differ on any of the other variables except that some trends were observed on the questions regarding spatial abilities between the male SS and OS twins. No differences were found on the handedness and developmental problems index.

For the female comparisons, only developmental differences were found when the twins, regardless of twin membership, were compared to the singletons. The similarities between the OS twins and the SS twins may have been due to a combination of the complex interactional effect testosterone has on the female developing brain and the possibility that estrogen was also acting in a similar way to testosterone. There is no way, however, to confirm or refute these possible explanations with these data.

With respect to previous research on female twins, these results were not consistent. As summarized in the introduction, Cole-Harding et al. (1988), McFadden (1993), Resnick et al. (1993), and Record et al. (1970) all found that females of OS twins performed in a more "masculine" way than females of SS twins. Unfortunately, it cannot be determined from this study why there were discrepant results except that the sample sizes for these cited studies were all larger with the exception of the McFadden study (where the sample sizes were comparable to this one). Further, the

differences found in the study investigating sensation-seeking behaviour may have been due to psychosocial effects rather than hormonal effects. It is also possible that the developmental variables chosen to analyze in this study develop during different critical periods than the ones investigated in other studies and consequently are unaffected (or less affected) by excess circulating hormones. Also, as mentioned previously, testosterone may "masculinize" some behaviours while "feminizing" others, explaining some of the obtained inconsistencies. Unpublished data from a study performed by Henderson and Berenbaum (1993) also postulated that critical periods may have been involved in their results. They compared females of SS twins with females of OS twins and female singletons with an older brother to determine whether there were hormonal influences on sex-typed play. As with this study, no differences were found. Certainly, their null findings may similarly have been due to low exposure to testosterone during the critical periods for the development of sex-typed play or due to the fact that, in the female, testosterone masculinizes some behaviours while having no effect or opposite effects on others, such as play behaviour.

Potential Mediating Variables

There was an attempt to control for a number of variables that could have affected the direction and strength of the results. Most of them have been described in other sections and thus will just be briefly summarized here: 1) education of father and mother, and socioeconomic factors, 2) genetic contributions, 3) mother's age and weight gain during pregnancy, 4) birth and pregnancy complications, 5) birth weight, 6) birth order, and 7) number of placentas present at birth.

It is very likely that higher educated parents and those of a higher SES responded to the questionnaires, despite the mailout from the Calgary Health Services which distributed questionnaires to all parents of twins, regardless of educational and SES variables. However, as there were no differences on these variables across groups (except for the higher educational level of fathers in the male SS twins and that of both mothers and fathers in the female SS twins), SES and education should not have played a role in the differences obtained. In fact, had the fathers and mothers of SS twins been less educated, more differences may have been found, particularly on the skills and developmental problems variables.

As no differences were found across groups on the family histories, it is highly unlikely that differences obtained were due to a genetic contribution. Particularly as no differences were determined for the control

disease index, it is unlikely that recall bias played a role in any differences found.

Mother's age at the birth of the twins, weight gain, birth weight, pregnancy and birth complications were all viewed as potential mediating variables that needed to be controlled for. As no differences were found across the twin groups, it is unlikely that these factors played a role in affecting the obtained results. However, there were differences in the twin/singleton comparisons on birth weight, and pregnancy and birth complications. As these have been discussed in greater detail elsewhere, they will not be repeated here.

Birth order and placental number were investigated as possible mediating variables for the intensity and direction of the circulating hormones. Particularly as the animal literature has shown that the closer the animals are *in utero*, the larger the testosterone effect, birth order was examined (although crudely) in this study. Clark, vom Saal, and Galef (1992) have determined that in gerbils, intra-uterine positions and testosterone levels are correlated. It was assumed that the first twin to be delivered was anterior to the other twin. In the animal literature, Meisel and Ward (1981) determined that the vasculature carries hormones in an anterior direction which would mean, if this also applies to human fetuses, that the first-born twin should be more highly affected by the hormones of the other twin. However, due to the high rate of caesarian sections in these

twin pregnancies (26%), it is likely that the first-born twin was arbitrarily chosen. Consequently, although a birth order effect was not found, this finding is likely because, first, the birth order was not reflective of the circulation of hormones, and second, human fetuses are unlikely to be directly similar to animal fetuses. Certainly, it would be necessary to determine a more accurate method of reporting birth order (or more importantly, fetal location) before discarding it as a potential mediating variable.

For the number of placentas, it was expected that twins with one placenta during the pregnancy were likely to be closer and to have more hormonal transfer from one fetus to the other than twins with two placentas. Again, no effect was found; however, because of the small sample sizes in these comparisons, it is unclear whether number of placentas plays a role as a mediating variable.

Study Limitations

There were a number of study limitations including: 1) selection biases, 2) some threats to the internal validity, particularly with the handedness index, 3) the samples were too small to detect what may have been a small to medium effect, 4) hormonal levels were not assayed during the pregnancy, 5) the role other hormones play in development, 6) the measures were not sensitive enough to detect an effect, even though there

may have been one, and 7) the reliability of a self-report questionnaire. Each of these limitations will be addressed in sequence.

First, it is possible that there was a selection-bias that confounded the results. It is possible that parents who had twins with more severe developmental problems chose not to participate in the study (or vice-versa) and consequently, the sample may have been biased towards more healthy or more unhealthy twins. It is likely that the twins were representative of a healthy bias due to the low reports of problems on the majority of the variables.

The fact that on the handedness index, no differences were found across any of the group comparisons, despite well-known differences reported in the literature (i.e., twins and males are known to be more left-handed) does serve as a potential threat to the internal validity of the study. However, it is possible that these differences were not found because of the small sample size and not because there were no differences present. Had there been more power to the analyses, these differences may have emerged. Further, as there was support for a number of known facts about development from this study, the lack of differences on the handedness index may simply have been a random sampling effect. It is important to note that across all the twins, the percentage of twins classified as left-handed was 14%, a figure consistent with the literature (Segal, 1989).

As for the expected higher incidence of left-handedness for female OS twins and male SS twins, it is possible that prenatal testosterone levels are not directly related to anomalous dominance, rather that the higher incidence of left-handedness in males is a consequence of other mediating factors (Berenbaum & Denberg, 1995). Certainly, as some males with androgen insensitivity have been reported to be left-handed, testosterone cannot be the only mediating variable in its development (Imperato-McGingley et al., 1991). If this is true, then the obtained results give further support to the criticisms of the Geschwind and Galaburda model for this particular variable.

The third limitation could certainly provide some explanation for the findings. It is possible that there is a testosterone effect but that the sample was too small to detect it. According to Cohen (1992), in order to detect a small effect using an alpha level of 0.05, it would be necessary to have collected a sample of 785 twins for the chi-square analyses, 393 for the ANOVAs, or 481 for the MANOVAs. Obviously, this sample size of 33 per group for the majority of the comparisons would hardly be sufficient to detect such an effect.

The fourth limitation addresses the fact that hormones were assumed to transfer from one fetus to the other but the hormones were not actually measured in the study. It was simply assumed that hormones can transfer from one fetus to the other although there was no direct evidence of this

mechanism from the human research. Certainly, it is possible, despite the evidence from the animal research, that hormones do not transfer from one twin to the other *in utero*. Consequently, the lack of transfer could explain some of the null findings. It is also possible that some behaviours can be influenced by low levels of testosterone but that other behaviours may require higher levels in order to effect a significant change. Consequently, if there is a transfer of hormones but this transfer is incomplete, the level of hormones transferring may not be high enough to cause a change in the variables measured.

Fifth, it is also possible that other hormones are mediating testosterone's masculinizing effect. For example, progesterone has been hypothesized to serve a protective effect from androgens in females (Ehrhardt & Meyer-Bahlburg, 1979). Thus, even if there is hormonal transfer from one fetus to the other, the elevated levels may be counteracted by progesterone. Another hypothesis that may override the effect of testosterone was proposed by Reuss, Paneth, and Susser (1994). They suggested the possibility that loss of placental hormones (released by the placenta) due to premature delivery could result in neurodevelopmental disabilities in preterm infants, offering an alternate explanation for the results found.

It is also possible that the measures used were not sensitive enough to detect real differences. For the majority of the variables, this is a highly

unlikely explanation as parents were asked mostly unambiguous "yes"/"no" questions. The only section for which such a criticism may apply is the skills section. However, as significant differences were found within this section between male and female twins, it is unlikely that insensitive measures were key mediating variables in the obtained results. Further, the questionnaire has revealed significant differences in a number of other studies performed at the Behavioural Research Unit (Crawford, 1990; Glogauer, 1991; McAllister, 1994).

Finally, although it is a major advantage for a study like this to have participants complete questionnaires as it can tremendously increase the sample size, the disadvantage is that it relies on the memories of the participants to answer the questions accurately. Certainly, a number of researchers have questioned the reliability and validity of a self-report study, particularly with respect to recall-loss and recall-bias (Satz & Soper, 1986). One concern is the discrepancy between maternal report and hospital records on the pregnancy and birth questions (Schwartz, 1988; Simons, Ritchie, Mullett, & Liechty, 1986; Bryant, Visser, & Love, 1989). However, Gray et al. (1989) reported a very high correlation between maternal reports and hospital records for pregnancy and birth complications. Further, parental reports of family histories of developmental problems have been demonstrated as reliable (Rugel, 1978).

Implications For Twins

This study has a number of implications for twins and their development. The already well documented implications include higher rates of birth and pregnancy complications as well as lower birth weights. According to the chi-square results, it appears as if males of SS twins are at risk for developing more skin reactions, with nearly 50% of this sample suffering from them. Approximately one fifth of the male twins suffer from attention, spelling, reading, and pronunciation problems, levels slightly higher than singletons. The levels for immune diseases in male twins range from 12 to 46%. For female twins, both OS and SS twins are at a greater risk to develop pronunciation and reading problems, ranges varying from 11 to 21%. Their risks for immune disease range from 12 to 23%. For all the twins, the levels of left-handedness, ADHD and LD diagnoses are comparable to singletons (see tables 14, 24, 32, 39, 46, 53, and 59).

Conclusion

In conclusion, this study provides some support for the testosterone hypothesis originally proposed by Geschwind and Galaburda. However, it demonstrates more that testosterone's action on development is complex, paradoxical, and inconsistent. There was no indication that exposure to high levels of testosterone resulted in a protective effect as all differences found were in the expected direction; that is, twins believed to be exposed to

the high levels were at greater (or same) risk. In particular, the results from the male comparisons were promising in that they confirmed the hypothesis that male SS twins would be at greater risk for developing immune problems than male OS twins and male singletons.

However, according to Appendix I, the correlations between handedness, immune diseases and developmental problems were very low, indicating that these variables may not co-occur in an individual twin, contrary to what Geschwind and Galaburda would predict (although they would more strongly predict these associations would cluster within families [1985a]). My results are more consistent with numerous reports in the recent research that have attempted to test the hypotheses proposed by Geschwind and Galaburda but have failed to find the predicted associations (Betancur, Velez, Cabanieu, le Moal, & Neveu, 1990; Chavance, Dellatolas, & Bousser, 1990; Gilger, Pennington, Green, Smith, & Smith, 1992; McKeever & Rich, 1990; Van Strien, Bouma, & Bakker, 1987. Also see Bryden, McManus, & Bulman-Fleming, 1994, for a thorough and critical review.)

Due to the similarity in structure between estrogen and testosterone, it is possible that this factor confounded the expected results, particularly for the female twins. Certainly, it would be necessary to investigate whether the hormonal levels of testosterone and estrogen are comparable, whether they have temporal compatibility and whether they have equal

transferring capabilities. This could only be achieved by assaying hormonal levels at various times during pregnancy from the amniotic fluid of both twins, which unfortunately is intrusive and could be dangerous to the developing fetuses. Further, more exploratory types of analyses are necessary to begin clarifying the directionality of the effect hormones, both estrogen and testosterone, in varying levels, play on the developing brain in humans. It is also necessary to establish the critical periods for the development of the variables being investigated in order to better understand the results obtained.

Future prospective studies would need to use more sensitive measures, particularly for the skills and developmental problems indices. A much larger sample size is required to truly assess whether a testosterone effect does exist above and beyond the problems associated with higher levels of birth and pregnancy complications and low birth weight.

This study has increased our knowledge of twin development. However, it has raised more questions than it has answered and future research would be required in order to better understand the obtained results and to better provide direct evidence of the suggested hypotheses. Overall, although the results do confirm some of the predictions of Geschwind and Galaburda, they provide more support for the growing body of literature that has failed to confirm the predictions. Indeed, future models need to take into account the complexities of testosterone's action on

the central nervous system as well as its seemingly paradoxical effects depending on both the variable being studied as well as the sex of the affected individual. Further, it is also necessary to establish more assuredly that testosterone is, ultimately, the critical hormone affecting brain development. Certainly, testosterone does not appear to warrant the numerous developmental responsibilities attributed to it so indiscriminantly.

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APPENDIX A:

Subject Recruitment Advertisements

Ad for the Calgary Herald, Gazette, Gauntlet, and Globe and Mail:

ATTENTION! PARENTS OF TWINS: Are your twins over 8 years?
Do you have about a half an hour to fill out a questionnaire?
Call Dr. Kaplan at (403) 229-7365 and ask about the twin project.

Ad for Today's Parent:

TWINS. If you know of a twin aged 8-20, we would like to hear from them for a research project about brain development and behaviour. Call Dr. Kaplan at (403) 229-7365 and ask about the twin project.

Ad for the Parents of Multiple Births Association:

1. Are your children TWINS aged 8 to 20?	YES	NO
2. Are you curious about what effects one child has on the other *in utero*?	YES	NO
3. Do you want to help advance scientific research in a blossoming field?	YES	NO
4. Do you have a half hour to spare to fill out a questionnaire in the comfort of your home?	YES	NO

If you answered YES to those questions, please fill out the attached form and send it to:

Dr. B.Kaplan
Alberta's Children Hospital
1820 Richmond Rd NW
Calgary, Alberta

or call us collect at (403) 229-7365 and ask about the twin study.

APPENDIX B:

Cover Letter, Twin Questionnaires #1 and #2,

and Consent Form

THE UNIVERSITY OF
CALGARY

Programme in Clinical Psychology

Date, 1994

Dear Parent,

I am a graduate student at the University of Calgary in the Programme of Clinical Psychology and I am currently working on my Master's thesis with Dr. Bonnie Kaplan. For my thesis, I am investigating differences in learning skills and health between same sex and opposite sex twins. I need to find parents of twins to fill out two questionnaires, one for each twin. By completing the questionnaires, you will be contributing greatly to my research project.

I have enclosed two questionnaires: a WHITE one and a GREEN one. The WHITE questionnaire asks questions ONLY about your FIRST born twin and his/her relatives. The GREEN questionnaire addresses specifically your SECOND born twin. Please ensure that the questionnaires correctly correspond with the birth order of the twins. In order to avoid confusion, the twins will be labelled TWIN #1 and TWIN #2 (see page 1 of the white questionnaire) as well as being identified on each questionnaire by sex. You will also notice that the green questionnaire is shorter than the white one. The reason for this discrepancy is that there are questions in the white one concerning the pregnancy with the twins and family related questions for which the answers would be the same for both twins. Therefore we asked the questions only once.

The answers that you provide will be strictly confidential and will not be used for any purposes other than for the completion of this study. The questions regarding each twin will be coded to eliminate any identifying features and will be reported only as group data. The data are kept in a locked area.

Once you have completed the questionnaires, please return them and the information sheet *as soon as possible* in the enclosed self-addressed envelope. By the way, if you answered one of our ads in the Calgary area, you may accidentally get two mailings of questionnaires. We apologize and ask that you simply discard one set (or pass it on to another family with twins).

Thank you for volunteering your time to complete my questionnaires. Your contribution to my research project is greatly appreciated. If you would like a summary of the results, be sure to print your name and address where requested.

Julia Rucklidge, B.Sc.
Student in Clinical Psychology

Room 292, Education Block,
2500 University Drive N.W., Calgary, Alberta, Canada T2N 1N4
Telephone: (403) 220-5659 Fax: (403) 284-9516

TWIN QUESTIONNAIRE*

First name of first born twin: _____
(we will refer to this twin as **TWIN #1**).

Date of birth: _____ Male Female
Month Day Year (please circle one)

First name of second born twin: _____
(we will refer to this twin as **TWIN #2**).

Date of birth: _____ Male Female
Month Day Year (please circle one)

Your relationship to the twins (please circle one):

Mother Father Other: please specify_____

Do you believe these twins are **IDENTICAL** or **FRATERNAL**? Please answer below and tell us what information you have which leads to this conclusion:

_____

_____

_____

Do you know if there was one or two placentas? If so, please circle one:

ONE PLACENTA TWO PLACENTAS DON'T KNOW

*This version of the questionnaire is to be completed by a parent, preferably the mother (because of questions regarding pregnancy and birth.

Subject Number: _____ Sex of Twin #1 (circle one): Boy Girl

For all the questions in this questionnaire, please answer only with reference to the first born twin (TWIN #1).

I. GENERAL SKILLS AND ABILITIES

In this first section, we will be asking you to describe your child's abilities. We would like you to rate your child in comparison to the typical (or average) children of his/her age. If your child is already an adult, please answer the questions in terms of what he/she was typically like as a child. Please circle your answer in the appropriate column.

MUCH BETTER or MUCH MORE means ***much better or much more than average*** for the child's age.

ABOVE AVERAGE or MORE THAN means ***above average or more than average*** for the child's age.

AVERAGE means ***average*** for the child's age.

BELOW AVERAGE OR LESS THAN means ***worse or less than average*** for the child's age.

MUCH WORSE or MUCH LESS means ***much worse or much less than average*** for the child's age.

1. Please describe TWIN #1's:

a) Basic reading skills:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
b) Understanding of what he/she reads:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
c) Spelling:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
d) Ability to do arithmetic problems:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
e) Communication skills:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
f) Memory/Recognition of familiar faces:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW

Please turn over to Page 3.

g) Memory/Recognition of familiar places:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
h) Ability to read maps:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
i) Ability to build or construct things (e.g., blocks, lego, 3-D drawings):	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
j) Ability to find his/her way around without getting lost:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
k) Musical ability:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
l) Artistic ability:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
m) Talent for the performing arts (Drama, Dance):	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW

2. Does your child do or think about creative, original things?

MUCH MORE	MORE THAN	AVERAGE	LESS THAN	MUCH LESS	NEVER

3. Is your child imaginative?

MUCH MORE	MORE THAN	AVERAGE	LESS THAN	MUCH LESS	NEVER

4. Would you say your child is gifted in any area? (e.g., music, math, art, reading)

NO DON'T KNOW YES If yes, what area: _____

5. Would you say your child is delayed or deficient in any area?

NO DON'T KNOW YES If yes, what area: _____

Please turn to Page 4.

II. FAMILY INFORMATION:

Now we would like to ask a few questions about whether your child (TWIN #1) or any of your child's relatives (including mother, father, brothers, sisters, grandparents, aunts, uncles, first cousins) have had certain problems. Please EXCLUDE the child's twin sibling, since that information is on the other questionnaire. Please include ONLY BIOLOGICAL RELATIVES of your child. Circle your answer in the appropriate column.

6. Has your child and/or a relative of your child had:

	TWIN #1		RELATIVE		
a) Stuttering problems?	NO	YES	NO	YES	IF YES, WHO?_____
b) Pronunciation problems?	NO	YES	NO	YES	IF YES, WHO?_____
c) Slow in learning to talk?	NO	YES	NO	YES	IF YES, WHO?_____
d) Hyperactivity?	NO	YES	NO	YES	IF YES, WHO?_____
e) Attention problems?	NO	YES	NO	YES	IF YES, WHO?_____
f) Reading problems?	NO	YES	NO	YES	IF YES, WHO?_____
g) Spelling problems?	NO	YES	NO	YES	IF YES, WHO?_____
h) Math problems?	NO	YES	NO	YES	IF YES, WHO?_____
i) Memory problems?	NO	YES	NO	YES	IF YES, WHO?_____
j) Motor problems? (e.g., coordination or balance problems)	NO	YES	NO	YES	IF YES, WHO?_____
k) Other learning difficulties?	NO	YES	NO	YES	IF YES, WHO?_____
l) Repeated a grade in school?	NO	YES	NO	YES	IF YES, WHO?_____

Please turn over to Page 5.

III. PHYSICAL HEALTH:

7. What is your child's approximate: Please specify:

a) Height:_____ _____ cm _____ ft. in.

b) Weight:_____ _____ kg _____ pounds

8. Does your child and/or relative of your child have:

	TWIN #1		RELATIVE		
a) Allergies?	NO	YES	NO	YES	IF YES, WHO?_____
If YES, TYPE OF ALLERGIES:_____					
b) Hay fever?	NO	YES	NO	YES	IF YES, WHO?_____
c) Asthma?	NO	YES	NO	YES	IF YES, WHO?_____
d) Skin reactions? (e.g., hives, eczema, psoriasis, vitiligo)	NO	YES	NO	YES	IF YES, WHO?_____
e) Stomach or gut disease? (e.g., celiac disease, ulcerative colitis, Crohn's disease, other bowel disease)	NO	YES	NO	YES	IF YES, WHO?_____
f) Thyroid disease? (e.g., underactive or overactive thyroid gland)	NO	YES	NO	YES	IF YES, WHO?_____
g) Insulin-dependent diabetes? (juvenile onset diabetes, controlled by insulin injections)	NO	YES	NO	YES	IF YES, WHO?_____
h) Non-insulin dependent diabetes? (Adult onset diabetes, controlled by diet or pills)	NO	YES	NO	YES	IF YES, WHO?_____
i) Migraine headaches? (diagnosed by a doctor)	NO	YES	NO	YES	IF YES, WHO?_____
j) Neurological disorders? (epilepsy, cerebral palsy, muscular dystrophy)	NO	YES	NO	YES	IF YES, WHO?_____

Please turn to Page 6.

	TWIN #1		RELATIVE		
k) Heart disease?	NO	YES	NO	YES	IF YES, WHO?_____
l) High blood pressure?	NO	YES	NO	YES	IF YES, WHO?_____
m) Other chronic disease?	NO	YES	NO	YES	IF YES, WHO?_____
n) Suffer from any other longterm or recurring health problem?	NO	YES	NO	YES	IF YES, WHO?_____

Thank you. We would now like to ask you about any medications your child is taking.

9. Has your child ever taken medication for mood or behaviour problems? (e.g., ritalin, a tranquilizer, or an antidepressant)

NO_____ YES_____ If YES, please specify NAME of medication and REASON for taking medication:

_____

10. Has your child ever been diagnosed as having an Attention Deficit Disorder (ADD) or Attentional Deficit Hyperactivity Disorder (ADHD)?

NO_____ YES_____ If YES, please specify who made the diagnosis (physician, psychologist, etc.):

_____

11. Has your child ever been diagnosed as having a Learning Disability?

NO_____ YES_____ If YES, please specify who made the diagnosis (teacher, physician, etc.):

_____

PLEASE ADD ANY ADDITIONAL COMMENTS YOU MAY HAVE ABOUT YOUR CHILD'S PHYSICAL HEALTH:

_____

_____

_____

Please turn over to Page 7.

IV. HAND PREFERENCE:

Now, we would like to ask a few questions about HAND PREFERENCE in your child's family.

12. Please indicate hand preference for TWIN #1 on the following tasks, by putting a circle around your answer. If you don't know your child's hand preference for any of these tasks, just ask your child to demonstrate the task in question.

	PREFERRED HAND TO COMPLETE TASK (Circle your answer)				
To print.	ALWAYS LEFT	USUALLY LEFT	EITHER HAND	USUALLY RIGHT	ALWAYS RIGHT
To throw a ball.	ALWAYS LEFT	USUALLY LEFT	EITHER HAND	USUALLY RIGHT	ALWAYS RIGHT
To draw a picture. . . .	ALWAYS LEFT	USUALLY LEFT	EITHER HAND	USUALLY RIGHT	ALWAYS RIGHT
To hold scissors.	ALWAYS LEFT	USUALLY LEFT	EITHER HAND	USUALLY RIGHT	ALWAYS RIGHT
To unscrew the lid of a jar. . .	ALWAYS LEFT	USUALLY LEFT	EITHER HAND	USUALLY RIGHT	ALWAYS RIGHT

13. Is either <u>biological</u> parent of this child lefthanded?

YES_____ NO_____ DON'T KNOW____

If YES, which parent?

MOTHER__ FATHER__

If YES, which hand does the mother use for writing?

RIGHT____ LEFT_____

If YES, which hand does the father use for writing?

RIGHT____ LEFT_____

Please turn to Page 8.

14. **How many <u>biological</u> brothers and sisters does this child have?**

    NUMBER OF BROTHERS_____ NUMBER OF SISTERS_____

15. **How many of this child's <u>biological</u> brothers and sisters are lefthanded (particularly for writing)?**

    NUMBER OF LEFTHANDED BROTHERS____ NUMBER OF LEFTHANDED SISTERS___

16. **Do you know of any other lefthanded <u>biological</u> relatives of this child?**

    NO_____ YES_____

    If YES, please state the relationship of the relative to the child; for example, paternal grandfather, father's sister, mother's brother's son.

    _____

    _____

PLEASE ADD ANY ADDITIONAL COMMENTS YOU MAY HAVE ABOUT HANDEDNESS IN YOUR CHILD'S FAMILY:

_____

_____

_____

Please turn over to Page 9.

V. PREGNANCY AND BIRTH

17. How old was the mother when she gave birth to these twins? _____ years _____ months

18. a) How many pregnancies (including miscarriages and abortions) has the mother had?_____

b) Which pregnancy were the twins? _____

19. How many pounds or kilograms did the mother gain during pregnancy?_____ Please Specify:

__ lbs ___ kg

20. Please indicate the characteristics of the mother's pregnancy with this child, by circling your answers.

	CHARACTERISTICS OF PREGNANCY (Circle your answer)		
Had bleeding during first three months.	TRUE	NOT TRUE	CANNOT SAY
Had bleeding during second 3 months.	TRUE	NOT TRUE	CANNOT SAY
Had bleeding during last 3 months	TRUE	NOT TRUE	CANNOT SAY
Had toxemia (Pregnancy-induced high blood pressure).	TRUE	NOT TRUE	CANNOT SAY
Smoked 1 or more packs of cigarettes/day . . .	TRUE	NOT TRUE	CANNOT SAY
Labor was induced	TRUE	NOT TRUE	CANNOT SAY
Had a caesarean section	TRUE	NOT TRUE	CANNOT SAY
Had a difficult delivery	TRUE	NOT TRUE	CANNOT SAY
Was put to sleep for delivery	TRUE	NOT TRUE	CANNOT SAY
Had to take medications***	TRUE	NOT TRUE	CANNOT SAY

***Specify any medications given for pregnancy, if applicable (e.g., diethylstilbestrol "DES"):_____

_____

21. Did the mother take any fertility drugs prior to the pregnancy?

___No ___Yes IF YES, which drug?_____

Please turn to Page 10.

Thank you. We would now like to ask you a few questions about TWIN #1 at birth.

22. Please indicate below whether there were any problems with this child AS A NEWBORN AT THE TIME OF BIRTH. Please put a circle around your answer in the appropriate column.

	NEWBORN INFANT PROBLEMS AT BIRTH		
Injured during birth	TRUE	NOT TRUE	CANNOT SAY
Had trouble breathing	TRUE	NOT TRUE	CANNOT SAY
Got yellow (jaundice)	TRUE	NOT TRUE	CANNOT SAY
Turned blue (cyanosis)	TRUE	NOT TRUE	CANNOT SAY
Was a twin or a triplet	TRUE	NOT TRUE	CANNOT SAY
Had seizures (fits, convulsions)	TRUE	NOT TRUE	CANNOT SAY
Needed oxygen	TRUE	NOT TRUE	CANNOT SAY
Had trouble sucking	TRUE	NOT TRUE	CANNOT SAY
Was in hospital more than 7 days	TRUE	NOT TRUE	CANNOT SAY
Born with heart defect	TRUE	NOT TRUE	CANNOT SAY
Born with other defect(s)***	TRUE	NOT TRUE	CANNOT SAY

***Please specify other defect(s), if applicable:_____

_____

23. **How much did this child weigh at birth?**_____ Please Specify:

_____ lbs _____ kg

PLEASE ADD ANY OTHER INFORMATION YOU MAY HAVE ABOUT THE PREGNANCY AND BIRTH OF THIS CHILD:

_____

_____

_____

Please turn over to Page 11.

NOW, we would like to ask you a few questions about yourself.

24. From the list below, please indicate the highest level of education completed by:

MALE PARENT/GUARDIAN LIVING WITH THE TWINS:* _____

FEMALE PARENT/GUARDIAN LIVING WITH THE TWINS:* _____

1 No high school
2 Some high school, didn't graduate
3 High school diploma
4 Some post-secondary, but no diploma or degree
5 Post-secondary diploma (e.g. technical diploma)
6 University degree

25. Please indicate below the occupation of:

MALE PARENT/GUARDIAN LIVING WITH THE TWINS:* _____

FEMALE PARENT/GUARDIAN LIVING WITH THE TWINS:* _____

*If your child is now an adult, please answer these questions with reference to the majority of his/her childhood years.

Thank you very much. Please go on to the second questionnaire (the green one).

Subject Number: _____ Sex of Twin #2 (circle one): BOY GIRL

For all the questions in this GREEN questionnaire, please answer only with reference to the second born twin (TWIN #2). Please note that this questionnaire is SHORTER than the first one as we have removed the questions concerning the pregnancy and the family.

I. GENERAL SKILLS AND ABILITIES

In this first section, we will be asking you to describe your child's abilities. We would like you to rate your child in comparison to the typical (or average) children of his/her age. If your child is already an adult, please answer the questions in terms of what he/she was typically like as a child. Please circle your answer in the appropriate column.

MUCH BETTER or MUCH MORE means ***much better or much more than average*** for the child's age.

ABOVE AVERAGE or MORE THAN means ***above average or more than average*** for the child's age.

AVERAGE means ***average*** for the child's age.

BELOW AVERAGE OR LESS THAN means ***worse or less than average*** for the child's age.

MUCH WORSE or MUCH LESS means ***much worse or much less than average*** for the child's age.

1. Please describe TWIN #2's:

a) Basic reading skills:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
b) Understanding of what he/she reads:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
c) Spelling:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
d) Ability to do arithmetic problems:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
e) Communication skills:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
f) Memory/Recognition of familiar faces:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW

Please turn over to Page 2.

g) Memory/Recognition of familiar places:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
h) Ability to read maps:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
i) Ability to build or construct things (e.g., blocks, lego, 3-D drawings):	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
j) Ability to find his/her way around without getting lost:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
k) Musical ability:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
l) Artistic ability:	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW
m) Talent for the performing arts (Drama, Dance):	MUCH BETTER	ABOVE AVERAGE	AVERAGE	BELOW AVERAGE	MUCH WORSE	DON'T KNOW

2. Does your child do or think about creative, original things?

MUCH MORE	MORE THAN	AVERAGE	LESS THAN	MUCH LESS	NEVER

3. Is your child imaginative?

MUCH MORE	MORE THAN	AVERAGE	LESS THAN	MUCH LESS	NEVER

4. Would you say your child is gifted in any area? (e.g., music, math, art, reading)

NO DON'T KNOW YES If yes, what area: _____

5. Would you say your child is delayed or deficient in any area?

NO DON'T KNOW YES If yes, what area: _____

Please turn to Page 3.

II. FAMILY INFORMATION:

Now we would like to ask a few questions about whether your child (TWIN #2) has had certain problems. Circle your answer in the appropriate column.

6. Has your child (TWIN #2) had:

a) Stuttering problems?	NO	YES
b) Pronunciation problems?	NO	YES
c) Slow in learning to talk?	NO	YES
d) Hyperactivity?	NO	YES
e) Attention problems?	NO	YES
f) Reading problems?	NO	YES
g) Spelling problems?	NO	YES
h) Math problems?	NO	YES
i) Memory problems?	NO	YES
j) Motor problems? (e.g., coordination or balance problems)	NO	YES
k) Other learning difficulties?	NO	YES
l) Repeated a grade in school?	NO	YES

Please turn over to Page 4.

III. PHYSICAL HEALTH:

7. What is your child's approximate: Please specify:

a) Height:_____ _____ cm _____ ft. in.

b) Weight:_____ _____ kg _____ pounds

8. Does your child (TWIN #2) have:

a) Allergies?	NO	YES

If YES, TYPE OF ALLERGIES:_____

b) Hay fever?	NO	YES
c) Asthma?	NO	YES
d) Skin reactions? (e.g., hives, eczema, psoriasis, vitiligo)	NO	YES
e) Stomach or gut disease? (e.g., celiac disease, ulcerative colitis, Crohn's disease, other bowel disease)	NO	YES
f) Thyroid disease? (e.g., underactive or overactive thyroid gland)	NO	YES
g) Insulin-dependent diabetes? (juvenile onset diabetes, controlled by insulin injections)	NO	YES
h) Non-insulin dependent diabetes? (Adult onset diabetes, controlled by diet or pills)	NO	YES
i) Migraine headaches? (diagnosed by a doctor)	NO	YES
j) Neurological disorders? (epilepsy, cerebral palsy, muscular dystrophy)	NO	YES

Please turn to Page 5.

k) Heart disease?	NO	YES
l) High blood pressure?	NO	YES
m) Other chronic disease?	NO	YES
n) Suffer from any other longterm or recurring health problem?	NO	YES

Thank you. We would now like to ask you about any medications your child is taking.

9. Has your child ever taken medication for mood or behaviour problems? (e.g., ritalin, a tranquilizer, or an antidepressant)

NO_____ YES_____ If YES, please specify NAME of medication and REASON for taking medication:

_____

10. Has your child ever been diagnosed as having an Attention Deficit Disorder (ADD) or Attentional Deficit Hyperactivity Disorder (ADHD)?

NO_____ YES_____ If YES, please specify who made the diagnosis (physician, psychologist, etc.):

_____

11. Has your child ever been diagnosed as having a Learning Disability?

NO_____ YES_____ If YES, please specify who made the diagnosis (teacher, physician, etc.):

_____

PLEASE ADD ANY ADDITIONAL COMMENTS YOU MAY HAVE ABOUT YOUR CHILD'S PHYSICAL HEALTH:

_____

_____

_____

Please turn over to Page 6.

IV. HAND PREFERENCE:

Now, we would like to ask a few questions about HAND PREFERENCE in your child (TWIN #2).

12. Please indicate hand preference for TWIN #2 on the following tasks, by putting a circle around your answer. If you don't know your child's hand preference for any of these tasks, just ask your child to demonstrate the task in question.

	PREFERRED HAND TO COMPLETE TASK (Circle your answer)				
To print.	ALWAYS LEFT	USUALLY LEFT	EITHER HAND	USUALLY RIGHT	ALWAYS RIGHT
To throw a ball.	ALWAYS LEFT	USUALLY LEFT	EITHER HAND	USUALLY RIGHT	ALWAYS RIGHT
To draw a picture. . . .	ALWAYS LEFT	USUALLY LEFT	EITHER HAND	USUALLY RIGHT	ALWAYS RIGHT
To hold scissors.	ALWAYS LEFT	USUALLY LEFT	EITHER HAND	USUALLY RIGHT	ALWAYS RIGHT
To unscrew the lid of a jar. . .	ALWAYS LEFT	USUALLY LEFT	EITHER HAND	USUALLY RIGHT	ALWAYS RIGHT

Please turn over to Page 7.

V. PREGNANCY AND BIRTH

We would now like to ask you a few questions about TWIN #2 at birth.

13. Please indicate below whether there were any problems with this child AS A NEWBORN AT THE TIME OF BIRTH. Please put a circle around your answer in the appropriate column.

	NEWBORN INFANT PROBLEMS AT BIRTH		
Injured during birth	TRUE	NOT TRUE	CANNOT SAY
Had trouble breathing	TRUE	NOT TRUE	CANNOT SAY
Got yellow (jaundice)	TRUE	NOT TRUE	CANNOT SAY
Turned blue (cyanosis)	TRUE	NOT TRUE	CANNOT SAY
Was a twin or a triplet	TRUE	NOT TRUE	CANNOT SAY
Had seizures (fits, convulsions)	TRUE	NOT TRUE	CANNOT SAY
Needed oxygen	TRUE	NOT TRUE	CANNOT SAY
Had trouble sucking	TRUE	NOT TRUE	CANNOT SAY
Was in hospital more than 7 days	TRUE	NOT TRUE	CANNOT SAY
Born with heart defect	TRUE	NOT TRUE	CANNOT SAY
Born with other defect(s)***	TRUE	NOT TRUE	CANNOT SAY

***Please specify other defect(s), if applicable:_____

_____

14. How much did this child weigh at birth?_____ Please Specify:

_____ lbs _____ kg

PLEASE ADD ANY OTHER INFORMATION YOU MAY HAVE ABOUT THE PREGNANCY AND BIRTH OF THIS CHILD:

_____

_____

_____

Thank you very much. Your contribution to this study is greatly appreciated.
Please mail your completed questionnaires back to us in the enclosed self-addressed stamped envelope ***AS SOON AS POSSIBLE.***

INFORMATION SHEET

1. If you would like to receive a summary of the results of the study, please print your name and address below:

   Name (please print)_____

   Address_____

   _____

   City_____ Province/State_____ Postal Code _____

2. Occasionally it helps us to be able to call a family to clarify one of their answers. Please provide us with your name and phone number if you are willing to be called in the event we need such clarification.

   Family name: _____ Phone Number: _____

3. We may do additional research in the future about twins and their behavioural development. Please indicate your willingness to be contacted about further research (circle one):

   YES NO

   _____

STATEMENT OF UNDERSTANDING AND CONSENT

By signing this questionnaire I acknowledge that I understand the manner in which the information I have provided will be used and agree to that use. I have discussed participation with my children, if I felt this was appropriate. I also understand that the researcher will protect my right of confidentiality and will not release my name to other researchers without my permission. I understand that the information that I have provided will be used only for the project described in the cover letter. I am keeping a copy of this consent form (which has been enclosed), and which provides me with the following phone numbers: the researchers (Dr. Kaplan and Ms. Rucklidge) 403-229-7365 if I have questions about the nature of the study, and the Office of Medical Bioethics (403-220-7990) if I have questions about my rights as a research participant.

APPENDIX C:

Cover Letter From CHS

Dear Client:

I am writing to you on behalf of Calgary Health Services. As you may know, Calgary Health Services maintains a registry of all births in the city. Recently we were approached by Dr. Kaplan, a researcher with the Behavioral Research Unit at Alberta Childrens Hospital and her graduate student Julia Ruckledge about the possibility of using our computerized registry to approach parents of twins in order to invite them to participate in a research project.

In order to protect the confidentiality of clients and information related to individuals, we do not release names to researchers. However, Calgary Health Services has reviewed and approved Dr. Kaplan's project and are therefore sending you a copy of the research questionnaire. If you are interested in participating please return these directly to the researchers in the enclosed envelopes.

Please be assured that your names have not been given to the researchers and that your participation is entirely voluntary and in no way has any impact on your relationship to Calgary Health Services.

If you have any questions or concerns please fell free to contact the researchers or myself at 228-7431.

Yours sincerely,

Donna Lentjes
Chair, Research Committee
Calgary Health Services

DL/po/research/letters.'94

APPENDIX D:

Cover Letter From CPOMBA

Calgary **P**arents **O**f **M**ultiple **B**irths **A**ssociation
(formerly Calgary Twin and Triplet Club)

P.O. Box 32038
2619 - 14 Street S.W.
Calgary, Alberta T2T 5X6

October 1, 1994

Dear Parents,

On behalf of the **Calgary Parents of Multiple Births Association** (CPOMBA), I am writing to you to invite you to participate in a research project involving twins between the ages of 8 and 20. Recently, we were approached by Dr. Bonnie Kaplan, a researcher with the Behavioral Research Unit at Alberta Children's Hospital, and her graduate student, Julia Rucklidge, about the possibility of using our old directories to contact parents of twins in this age range.

In order to protect the confidentiality of our membership records from the present and the past, we have not released names to these researchers. However, CPOMBA has agreed to assist Dr. Kaplan's research project by sending you a copy of the research questionnaires on her behalf. If you are interested in participating, please return them directly to the researchers in the enclosed envelope.

Please be assured that your names have not been given to the researchers and that your participation is entirely voluntary. If you have any questions or concerns, please feel free to contact the researchers at 229-7365 or myself at 247-3281.

Yours sincerely,

Leslie D. Phillips

Leslie Phillips
CPOMBA Membership Chairperson

cc: Diane Gaska, CPOMBA President
/ldp

APPENDIX E:

Reminder Letter - Ads

THE UNIVERSITY OF
CALGARY

Programme in Clinical Psychology

Date, 1994

Dear Parents,

As you may recall, in September of this year, we sent you two questionnaires concerning the development of each of your twins. It is still not too late to return the questionnaires; however, if you could complete them and return them as soon as possible, it would be greatly appreciated. If by chance you have misplaced the questionnaires, simply give us a call (if out of town, call us collect) and we will send you a new set. The phone number at the Behavioural Research Unit is: (403)-229-7365.

We appreciate the time you are committing to furthering the research of twin development and behaviour. We look forward to receiving your completed questionnaires.

Yours sincerely,

Julia Rucklidge, BSc.
Student in Clinical
Psychology

Dr. Bonnie Kaplan, PhD.
Director of the Research
Unit

Room 292, Education Block,
2500 University Drive N.W., Calgary Alberta T2N 1N4
Telephone: (403) 220-5659 Fax: (403) 284-9516

APPENDIX F:

Reminder Letter - CHS

Calgary Health Services

P.O. Box 4016, Station "C", 320 - 17th Avenue S.W., Calgary, Alberta T2T 5T1 (403) 228-7400 Fax 245-1736

November 3, 1994

Dear Client:

In late October, we sent you two questionnaires on behalf of Julia Rucklidge and Dr. Bonnie Kaplan, researchers at the Alberta Children's Hospital.

If you have misplaced the questionnaires but are sill interested in volunteering the time to complete them, please give the researchers a call at 229-7365 and they will send you another set.

Once again, be assured that your name has not been given to the researchers, and that your participation is entirely voluntary and in no way has any impact on your relàtionship with Calgary Health Services.

If you have any questions or concerns please feel free to contact the researchers, or myself at 228-7431.

Yours sincerely,

Donna Lentjes
Chair, Research Committee
Calgary Health Services

DL/ke

APPENDIX G:

Reminder Letter - CPOMBA

THE UNIVERSITY OF
CALGARY

Programme in Clinical Psychology

Date, 1994

Dear Parents,

As you may recall, in October of this year, we sent you two questionnaires concerning the development of each of your twins. The questionnaires were sent through The Calgary Parents of Multiple Births Association, in order to maintain confidentiality. It is still not too late to return the questionnaires; however, if you could complete them and return them as soon as possible, it would be greatly appreciated. If by chance you have misplaced the questionnaires, simply give us a call (if out of town, call us collect) and we will send you a new set. The phone number at the Behavioural Research Unit is: (403)-229-7365.

We appreciate the time you are committing to furthering the research on twin development and behaviour. We look forward to receiving your completed questionnaires.

Yours sincerely,

Julia Rucklidge, B.Sc.
Student in Clinical
Psychology

Bonnie Kaplan, Ph.D.
Director
Behavioural Research Unit

Room 292, Education Block,
2500 University Drive N.W., Calgary Alberta T2N 1N4
Telephone: (403) 220-5659 Fax: (403) 284-9516

THE UNIVERSITY OF
CALGARY

Programme in Clinical Psychology

Date, 1995

Dear Parent,

As you may recall, in October of this year, we sent you two questionnaires concerning the development of each of your twins. The questionnaires were sent through the Calgary Parents of Multiple Births Association, in order to maintain confidentiality (this letter has also been sent by them). In summary, we are conducting a study comparing the development of opposite sex twins with same sex ones. The response has been wonderful; however, we have received a significantly greater number of questionnaires from parents who have same sex twins (i.e., either boy/boy or girl/girl). In order to do an appropriate analysis of the data, we need to find more opposite sex twin pairs.

We are appealing to parents who have girl/boy twins to assist us.

If you have not yet completed the questionnaires sent to you but are still interested in participating in our study, it is not too late. However, as we are currently preparing to analyze the data, if you could complete them as soon as possible, it would be greatly appreciated. If by chance you have misplaced them, simply give us a call (if out of town, call us collect) and we will send you a new set. The phone number at the Behavioural Research Unit is: (403) 229-7365.

We appreciate the time you are committing to furthering the research on twin development and behaviour. We look forward to receiving your completed questionnaires.

Yours sincerely,

Julia Rucklidge, B.Sc.
Student in Clinical
Psychology

Bonnie Kaplan, Ph.D.
Director
Behavioural Research Unit

Room 292, Education Block,
2500 University Drive N.W., Calgary Alberta T2N 1N4
Telephone: (403) 220-5659 Fax: (403) 284-9516

APPENDIX H:

Sample Calculation of Odds Ratios

and Predictive Efficacy

Calculation of Odds Ratio for Reading Problems:

Off of the printout, the odds ratio (OR) = 1.19

$= e^{B}$

$= e^{.1704}$

To calculate the 95% confidence intervals (CI):

95% CI = B +/- 1.96 * SE(B)

from the printout, SE(B) = .0782

Therefore, 95% CI = .1704 +/- (1.96)(.0782)

= .1704 +/- .1533

= (.0171, .3237)

$e^{.0171} = 1.1017$, $e^{.3237} = 1.382$

Consequently, the odds ratio for reading problems is 1.19 but this value could be as low as 1.02 and as high as 1.38.

Calculation of the Predictive Efficacy for Reading Problems:

Predictive Efficacy = RL^2

= [(-2log(L0) - (-2log(L1)]/[-2log(L0)]

From the printout,

-2log(L0) = 232.72295, -2log(L1) = 225.756

RL^2 = (232.72295 - 225.756)/232.72295

= .030

Therefore, the predictive efficacy for the reading problems is 3%.

APPENDIX I:

Correlations Between Main Variables

CORRELATIONS BETWEEN HANDEDNESS, IMMUNE DISEASES, DEVELOPMENTAL PROBLEMS, AND GIFTEDNESS
n=220 twins

Correlations	Dev. Index	Immune	Gifted	Handedness
Dev. Index	1.00	0.14	-0.04	0.01
Immune	0.14	1.00	0.19*	0.04
Gifted	-0.04	0.19*	1.00	-0.05
Handedness	0.01	0.04	-0.05	1.00

*p<.01

CORRELATIONS OF MAIN VARIABLES WITH BIRTH WEIGHT, PREGNANCY COMPLICATIONS AND BIRTH COMPLICATIONS
n=220 twins

Correlations	Birth weight	Birth Index	Pregnancy Index
Development Index	-0.31**	0.31**	0.02
Verbal Index	0.15	-0.04	0.01
Non-Verbal Index	0.15	0.01	0.01
Creativity Index	0.16*	0.08	-0.04
Immune Index	-0.08	0.22**	0.08
Handedness Index	0.09	-0.09	-0.02
Attention	-0.20*	0.26**	0.01
Hyperactivity	-0.29**	0.29**	-0.10
Birth weight	1.00	-0.60**	-0.05
Birth Index	-0.60**	1.00	0.13
Pregnancy Index	-0.05	0.13	1.00

*$p<.01$
**$p<.001$

APPENDIX J:

Means and Standard Deviations For Each Variable

Within Each Comparison Group

FEMALES OF SAME-SEX TWINS AND FEMALES OF OPPOSITE-SEX TWINS (numbers in parentheses indicate maximum score)
n=33/group

VARIABLE	FEMALE SS TWINS		FEMALE OS TWINS	
	MEAN	SD	MEAN	SD
Covariates:				
Blishen (6)	4.00	1.22	4.63	3.24
Education - father (6)	4.68	1.19	4.47	1.25
Education - mother (6)	4.68	1.28	4.50	1.23
Mother's age	27.30	4.83	27.90	2.81
Mother's weight gain	45.10	18.69	35.24	16.15
Pregnancy Index (11)	2.09	1.55	2.28	1.63
Birth Index (11)	2.73	1.88	2.81	1.87
Birth weight (lb)	5.35	1.14	5.52	1.03
Developmental - family	0.17	0.55	0.13	0.42
Immune - family	2.65	2.47	2.21	2.22
Non-immune - family	0.36	0.43	0.42	0.61
Control - family	0.34	0.36	0.48	0.60
Handedness - family	0.85	0.70	0.92	0.71
Main Indices:				
Handedness Index (20)	2.85	6.26	3.21	6.10
Development Index (12)	1.30	2.39	1.24	1.94
Immune Index (7)	0.92	1.19	0.60	1.03
Non-Immune Index (3)	0.06	0.24	0.06	0.24
Control Index (2)	0.00	0.00	0.00	0.00
Verbal Index (20)	13.85	3.57	13.58	3.25
Non-Verbal Index (30)	19.76	3.35	19.21	3.50
Creativity Index (25)	16.76	3.18	16.58	2.73

FEMALES OF SAME-SEX TWINS AND FEMALES OF OPPOSITE-SEX TWINS
n=33/group

VARIABLE	FEMALE SS TWINS		FEMALE OS TWINS	
	MEAN	SD	MEAN	SD
Verbal Index Variables:				
Communication (5)	3.58	0.87	3.53	0.72
Spelling (5)	3.36	0.90	3.31	0.78
Understanding (5)	3.46	1.15	3.44	0.88
Reading (5)	3.46	0.97	3.56	0.91
Non-Verbal Index:				
Memory of places (5)	3.45	0.57	3.38	0.68
Memory of faces (5)	3.45	0.68	3.45	0.57
Map reading (5)	3.19	0.75	3.00	0.60
Building (5)	3.16	0.64	3.07	0.37
Mathematics (5)	3.49	0.89	3.21	0.77
Lost (5)	3.32	0.60	3.14	0.58
Creativity Index:				
Imagination (5)	3.44	0.88	3.57	0.68
Creativity (5)	3.53	0.88	3.40	0.68
Performing arts (5)	3.34	0.75	3.37	0.62
Musical ability (5)	3.38	0.66	3.40	0.68
Artistic ability (5)	3.25	0.76	3.33	0.66

MALES OF SAME-SEX TWINS AND MALES OF OPPOSITE-SEX TWINS
n=33/group

VARIABLE	MALE SS TWINS		MALE OS TWINS	
	MEAN	SD	MEAN	SD
Covariates:				
Blishen (6)	3.90	1.50	3.93	1.00
Education - father (6)	5.53	0.78	4.41	1.24
Education - mother (6)	4.60	1.33	4.48	1.24
Mother's age	29.26	3.50	27.86	2.85
Mother's weight gain	39.07	14.55	34.36	15.72
Pregnancy Index (11)	1.46	1.15	2.10	1.72
Birth Index (11)	2.85	1.66	2.68	2.09
Birth weight (lb)	5.22	1.52	5.75	1.11
Developmental - family	0.14	0.29	0.13	0.43
Immune - family	3.11	2.46	2.25	2.12
Non-immune - family	0.38	0.45	0.44	0.57
Control - family	0.37	0.43	0.48	0.61
Handedness - family	0.74	0.62	0.84	0.72
Main Indices:				
Handedness Index (20)	2.42	4.91	2.34	4.93
Development Index (12)	1.39	2.00	1.25	2.03
Immune Index (7)	1.18	1.16	0.75	0.98
Non-Immune Index (3)	0.03	0.17	0.06	0.25
Control Index (2)	0.00	0.00	0.00	0.00
Verbal Index (20)	14.39	2.94	13.50	3.34
Non-Verbal Index (30)	20.58	3.55	20.50	3.34
Creativity Index (25)	16.88	3.57	15.56	3.22

MALES OF SAME-SEX TWINS AND MALES OF OPPOSITE-SEX TWINS
n=33/group

VARIABLE	MALE SS TWINS		MALE OS TWINS	
	MEAN	SD	MEAN	SD
Verbal Index Variables:				
Communication (5)	3.70	0.81	3.39	0.67
Spelling (5)	3.42	1.00	3.29	0.97
Understanding (5)	3.64	0.86	3.58	0.77
Reading (5)	3.58	0.97	3.55	0.93
Non-Verbal Index:				
Memory of places (5)	3.65	0.80	3.69	0.71
Memory of faces (5)	3.89	0.71	3.55	0.63
Map reading (5)	3.35	0.63	3.45	0.69
Building (5)	3.69	0.79	3.35	0.67
Mathematics (5)	3.62	1.06	3.45	0.63
Lost (5)	3.39	0.64	3.48	0.74
Creativity Index:				
Imagination (5)	3.93	0.77	3.35	0.67
Creativity (5)	3.86	0.85	3.24	0.87
Performing arts (5)	3.21	0.79	3.03	0.87
Musical ability (5)	3.18	0.72	2.93	0.65
Artistic ability (5)	3.54	0.96	3.35	0.77

FREQUENCIES FOR ALL TWINS COMPARISON GROUPS FOR BIRTH AND PREGNANCY COMPLICATION VARIABLES
n=33/group

VARIABLE	FEM SS TWINS	FEM OS TWINS	MALE SS TWINS	MALE OS TWINS
	%	%	%	%
Pregnancy variables:				
Bleeding tri-1	22	19	11	19
Bleeding tri-2	6	9	7	9
Toxaemia	25	16	24	16
Smoked during preg.	6	16	7	16
Induced labour	31	28	34	28
Caesarian section	34	34	14	29
Difficult delivery	32	26	7	26
Sleep delivery	25	22	10	22
Took medications**	10	38	14	38
Other problems	13	22	17	22
Birth Variables:				
Injured during birth	3	6	0	6
Trouble breathing	13	25	21	13
Yellow	53	38	60	45
Blue	6	10	11	0
Seizures	0	0	0	0
Needed oxygen	27	22	21	23
Trouble sucking	28	31	30	32
Hospital >7 days	38	34	31	35
Heart defect	3	3	7	3
Other defect	9	10	3	14

**not significant with Bonferroni correction

MALE TWINS AND FEMALE TWINS
n=121/group

VARIABLE	MALE TWINS		FEMALE TWINS	
	MEAN	SD	MEAN	SD
Covariates:				
Pregnancy Index (11)	1.78	1.43	2.07	1.52
Birth Index (11)	3.04	1.96	2.82	1.78
Birth weight (lb)	5.52	1.30	5.47	1.10
Main Indices:				
Handedness Index (20)	2.74	5.36	3.68	6.60
Development Index (12)	1.23	1.85	1.12	1.97
Immune Index (7)	0.89	1.09	0.69	1.05
Non-Immune Index (3)	0.05	0.22	0.03	0.18
Control Index (2)	0.01	0.09	0.01	0.09
Verbal Index (20)	13.77	3.22	13.42	3.44
Non-Verbal Index (30)	20.90	3.72	19.52	3.22
Creativity Index (25)	16.35	3.51	16.57	2.92

MALE TWINS AND FEMALE TWINS
n=121/group

VARIABLE	MALE TWINS		FEMALE TWINS	
	MEAN	SD	MEAN	SD
Verbal Index Variables:				
Communication (5)	3.58	0.77	3.55	0.76
Spelling (5)	3.30	1.00	3.32	0.76
Understanding (5)	3.58	0.87	3.50	0.96
Reading (5)	3.48	0.93	3.51	0.92
Non-Verbal Index:				
Memory of places (5)	3.70	0.69	3.50	0.62
Memory of faces (5)	3.74	0.68	3.43	0.65
Map reading (5)	3.16	0.73	3.16	0.62
Building (5)	3.68	0.81	3.24	0.58
Mathematics (5)	3.58	0.87	3.42	0.80
Lost (5)	3.49	0.69	3.28	0.58
Creativity Index:				
Imagination (5)	3.64	0.78	3.54	0.81
Creativity (5)	3.62	0.83	3.55	0.78
Performing arts (5)	3.24	0.82	3.30	0.68
Musical ability (5)	3.07	0.61	3.33	0.65
Artistic ability (5)	3.46	0.79	3.35	0.73

MALE TWINS AND FEMALE TWINS: FREQUENCIES FOR BIRTH AND PREGNANCY COMPLICATIONS VARIABLES
n=121/group

VARIABLE	MALE TWINS	FEMALE TWINS
	%	%
Pregnancy variables:		
Bleeding tri-1	17	19
Bleeding tri-2	6	8
Toxaemia	23	25
Smoked during preg.	9	8
Labour induced	26	28
Caesarian section*	19	34
Difficult delivery**	19	31
Sleep delivery	15	23
Pregnancy medications	23	21
Other problems	20	14
Birth Variables:		
Injured during birth	4	4
Trouble breathing**	28	16
Yellow	53	51
Blue	9	6
Seizures	0	0
Needed oxygen	30	25
Trouble sucking	35	30
Hospital >7 days	36	37
Heart defect	7	4
Other defect	7	11

*significant
**not significant with Bonferroni correction

FEMALE SINGLETONS AND FEMALES OF SAME-SEX TWINS
n=45/group

VARIABLE	FEMALE SINGLETONS		FEMALE SS TWINS	
	MEAN	SD	MEAN	SD
Covariates:				
Blishen (6)	3.65	1.25	4.03	1.27
Education - father (6)	3.70	1.63	4.77	1.18
Education - mother (6)	3.54	1.39	4.77	1.22
Pregnancy Index (11)	1.50	1.07	2.11	1.61
Birth Index (11)	0.77	0.96	1.65	1.60
Birth weight (lb)	7.25	1.15	5.47	1.17
Developmental - family	0.42	0.81	0.48	0.69
Immune - family	1.63	0.85	2.04	0.96
Non-immune - family	0.25	0.34	0.34	0.33
Control - family	0.44	0.48	0.36	0.37
Handedness - family	0.53	0.60	0.55	0.49
Main Indices:				
Handedness Index (20)	2.55	5.41	4.13	7.29
Development Index (12)	0.13	0.50	0.43	0.80
Immune Index (7)	0.38	0.74	0.66	1.03
Non-Immune Index (3)	0.64	0.25	0.02	0.15
Control Index (2)	0.00	0.00	0.00	0.00

FEMALE SINGLETONS AND FEMALES OF SAME-SEX TWINS: FREQUENCIES FOR BIRTH AND PREGNANCY COMPLICATIONS VARIABLES
n=55/group

VARIABLE	FEMALE SINGLETONS	FEMALE SS TWINS
	%	%
Pregnancy variables:		
Bleeding tri-1	11	24
Bleeding tri-2	2	11
Toxaemia	13	29
Smoked during preg.**	24	7
Labour induced	24	27
Caesarian section*	7	36
Difficult delivery	13	30
Sleep delivery**	7	24
Pregnancy medications	22	19
Other problems	21	11
Birth Variables:		
Injured during birth	0	4
Trouble breathing	6	9
Yellow	36	51
Blue	0	2
Seizures	0	0
Needed oxygen	9	22
Trouble sucking*	6	27
Hospital >7 days**	15	37
Heart defect	0	4
Other defect	4	14

*significant
**not significant with Bonferroni correction

FEMALE SINGLETONS AND FEMALES OF OPPOSITE-SEX TWINS
n=33/group

VARIABLE	FEMALE SINGLETONS		FEMALE OS TWINS	
	MEAN	SD	MEAN	SD
Covariates:				
Blishen (6)	4.07	1.05	4.00	1.05
Education - father (6)	4.11	1.47	4.47	1.25
Education - mother (6)	3.86	1.43	4.50	1.23
Pregnancy Index (11)	1.55	1.15	2.31	1.46
Birth Index (11)	1.00	1.48	1.42	1.58
Birth weight	7.12	1.04	5.67	0.94
Developmental - family	0.42	0.73	0.82	0.99
Immune - family	1.61	0.99	1.98	1.06
Non-immune - family	0.40	0.36	0.37	0.45
Control - family	0.33	0.31	0.44	0.62
Handedness - family	0.55	0.52	0.57	0.62
Main Indices:				
Handedness Index (20)	2.67	5.69	3.21	6.10
Development Index (12)	0.17	0.51	0.52	0.87
Immune Index (7)	0.52	0.87	0.61	1.03
Non-Immune Index (3)	0.03	0.17	0.06	0.24
Control Index (2)	0.00	0.00	0.00	0.00

FEMALE SINGLETONS AND FEMALES OF OPPOSITE-SEX TWINS: FREQUENCIES FOR BIRTH AND PREGNANCY COMPLICATIONS INDICES
n=33/group

VARIABLE	FEMALE SINGLETONS	FEMALE OS TWINS
	%	%
Pregnancy variables:		
Bleeding tri-1	13	19
Bleeding tri-2	3	9
Toxaemia	6	16
Smoked during preg.	23	16
Labour induced	28	28
Caesarian section**	13	34
Difficult delivery	19	28
Sleep delivery	13	22
Pregnancy meds**	16	38
Other problems	21	22
Birth Variables:		
Injured during birth	0	6
Trouble breathing	12	25
Yellow	33	38
Blue	9	10
Seizures	0	0
Needed oxygen	16	22
Trouble sucking*	6	31
Hospital >7 days	15	34
Heart defect	0	3
Other defect	9	10

*significant
**not significant with Bonferroni correction

MALE SINGLETONS AND MALES OF SAME-SEX TWINS
n=56/group

VARIABLE	MALE SINGLETONS		MALE SS TWINS	
	MEAN	SD	MEAN	SD
Covariates:				
Blishen (6)	3.62	1.24	3.93	1.37
Education - father (6)	4.19	1.56	5.32	1.11
Education - mother (6)	4.15	1.23	4.49	1.40
Pregnancy index (11)	1.54	1.42	1.74	1.29
Birth index (11)	0.85	1.24	2.14	1.97
Birth weight	7.67	1.54	5.41	1.38
Developmental - family	0.41	0.92	0.90	1.24
Immune - family	1.63	0.88	2.15	1.43
Non-immune - family	0.32	0.44	0.33	0.42
Control - family	0.39	0.37	0.42	0.47
Handedness - family	0.55	0.58	0.59	0.47
Main Indices:				
Handedness Index (20)	3.02	5.26	2.18	4.71
Development Index (12)	0.43	0.82	0.59	0.95
Immune Index (7)	0.52	0.91	0.89	1.12
Non-Immune Index (3)	0.04	0.19	0.05	0.23
Control Index (2)	0.00	0.00	0.00	0.00

MALE SINGLETONS AND MALES OF SAME-SEX TWINS: FREQUENCIES OF BIRTH AND PREGNANCY COMPLICATIONS VARIABLES
n=55/group

VARIABLE	MALE SINGLETONS	MALE SS TWINS
	%	%
Pregnancy variables:		
Bleeding tri-1	7	19
Bleeding tri-2	4	7
Toxaemia	11	18
Smoked during preg.	4	5
Labour induced	17	30
Caesarian section**	11	18
Difficult delivery	34	16
Sleep delivery	11	18
Pregnancy medications	26	13
Other problems	28	20
Birth Variables:		
Injured during birth	9	5
Trouble breathing*	4	36
Yellow**	37	57
Blue*	2	17
Seizures	0	0
Needed oxygen *	6	35
Trouble sucking*	9	39
Hospital >7 days*	9	42
Heart defect	6	5
Other defect	7	7

*significant
**not significant with Bonferroni correction

MALE SINGLETONS AND MALES OF OPPOSITE-SEX TWINS
n=33/group

VARIABLE	MALE SINGLETONS		MALE OS TWINS	
	MEAN	SD	MEAN	SD
Covariates:				
Blishen (6)	3.62	1.37	4.00	1.05
Education - father (6)	4.38	1.55	4.47	1.25
Education - mother (6)	4.35	1.37	4.50	1.23
Pregnancy Index (11)	1.59	1.50	2.15	1.59
Birth Index (11)	1.09	1.53	1.35	1.65
Birth weight (lb)	7.29	1.55	5.96	1.08
Developmental - family	0.27	0.50	0.75	0.74
Immune - family	1.87	0.83	1.97	1.21
Non-immune - family	0.42	0.53	0.36	0.50
Control - family	0.40	0.36	0.45	0.61
Handedness - family	0.52	0.55	0.56	0.61
Main Indices:				
Handedness Index (20)	2.18	4.69	2.33	4.85
Development Index (12)	0.41	0.67	0.73	1.13
Immune Index (7)	0.67	0.92	0.73	0.98
Non-Immune Index (3)	0.03	0.17	0.06	0.24
Control Index (2)	0.00	0.00	0.00	0.00

MALE SINGLETONS AND MALES OF OPPOSITE-SEX TWINS: FREQUENCIES OF BIRTH AND PREGNANCY COMPLICATIONS VARIABLES
n=33/group

VARIABLE	MALE SINGLETONS	MALE OS TWINS
	%	%
Pregnancy variables:		
Bleeding tri-1	7	19
Bleeding tri-2	3	9
Toxaemia	6	16
Smoked during preg.	13	16
Labour induced**	9	28
Caesarian section	13	28
Difficult delivery	32	24
Sleep delivery	13	19
Pregnancy medications	31	38
Other problems	28	19
Birth Variables:		
Injured during birth	9	6
Trouble breathing	9	13
Yellow	33	47
Blue	0	3
Seizures	0	0
Needed oxygen*	9	22
Trouble sucking	6	31
Hospital >7 days	21	34
Heart defect	9	3
Other defect	6	13

*significant
**not significant with Bonferroni correction