REVIEW
Chapter -II

REVIEW

Review was based on APA’s Psychological Abstracts retrieval system stored in computer network of National Informatics Centre, New Delhi and National Medical Library, New Delhi. The period was from 1969 to 1999. Retrieval search was guided by handedness and cognitive abilities, genetics of handedness, lateralization, balanced polymorphism with heterozygote advantage, handedness and intelligence, handedness and creativity variables. Retrieval yielded hundreds of studies which were content analysed for their relevance to present study. Many studies deal upon various methods to measure handedness in relation to hand preference and hand skill which were included in the previous chapter. While many studies simply attempted to study handedness in relation to cognitive skills. The present review is an attempt to deal with research and theory that bears directly or indirectly on the present problem. The available studies have been reviewed under the following categories:

(i) Handedness & intellectual abilities in the light of Annett’s model
(ii) Genetic balanced polymorphism with heterozygote advantage
(iii) Gender differences in the expression of cognitive abilities
(iv) Handedness and creativity

(i) **Handedness & intellectual abilities**

The work initiated by Annett’s (1972, 1978, 1985) on language lateralization and handedness and the work of Mc Manus (1985) led to the combination of the study of individual differences in cognitive abilities with
the study of handedness. The first major report on handedness and cognitive abilities appeared in 1969.

Levy (1969) suggested that left-handed persons have verbal functions represented in both-hemispheres of the brain, while right-handers have their verbal functions represented in the left hemisphere. She found her expectations confirmed that the right-handed group had a significantly higher performance (Visuo-spatial), than the left-handers. It was concluded that real differences do exist in the abilities of right and mixed handers.

Hand preference and intelligence of Open University students and their relatives, including children, were described by Annett (1979). There was no evidence of smaller heritability for paternal than maternal grandparents. The results were discussed from the viewpoint of a possible heterozygous advantage in intelligence. The higher proportion of sinisteral children born to sinisteral mothers than fathers can be partly accounted for supposing that the right shift is more effective in females than males.

Annett & Kilshaw (1982) examined the hypotheses that special ability on mathematics is associated with a reduction in bias to dextral preference and skill. The subjects were the students and teachers of mathematics in Universities and Polytechnics. An analysis of the findings in relation to the right shift (RS) theory of (Annett 1972, 1978) suggested that the incidence of left preference and skill is slightly raised in mathematical not because of any intrinsic advantage of left preference but rather because extreme bias to the right, as expected in those carrying a hypothesized rs ++ genotype, is disadvantageous for mathematical thinking. If the role of mathematics can be regarded as one of developing languages to describe
those aspects of human intelligence which have been distinguished as depending differentially on the left-and right hemispheres. These findings suggested that this process might be impeded by a double dose of gene which promotes left-hemisphere language specialization.

Annett (1985) presented a genetic model of handedness that claims to explain the relationship between differences in hand performance, speech lateralization & cognitive abilities on the basis of a hypothetical single gene, called the right-shift factor (rs). She revealed that those with no copy of the gene (rs − − homozygotes) show no impairment of the right hemisphere and no tendency to right-handedness, but they lack the benefits of speech organisation factor in the left hemisphere and are at risk for developmental delays and deficits and language skills. Those having one copy of the gene (rs + − heterozygotes) from the group with optimal chances. They show a mild tendency to right-handedness caused by weak impairment of right hemisphere functioning thereby affecting left hand performance. They enjoy advantages in organisation and development of speech. Individuals with two copies (rs + + homozygotes) show a weak left hand performance and a strong tendency to dextrality due to a substantial impairment of the right hemisphere. They seem to include risks to verbal as well as non-verbal abilities which mean loss of general intelligence.

Annett & Manning (1989) assessed 348 children of mean age 8.7 years of several measures of intellectual ability and differences in hand skill were assessed by Annett’s (1970) pegboard. Grouping of children into four approximately equal sized groups showed a significant linear trend on Raven's Coloured Progressive Matrices, test of non-verbal ability with the most dextral children having the lowest ability scores. Annett’s & Manning
considered the disadvantages of strong dextrals (rs ++ genotype) in conjunction with disadvantages of (rs -- genotype) and provided support to her hypothesis of heterozygote advantage.

Annett & Manning (1990a) described the reading ability of children in relation to R - L differences in hand skill. They reported a significant quadratic relationship between reading quotient (derived from the Schonell Graded Word Reading Test) and R - L differences, with a similar pattern of results when the analysis was restricted to the standardized residuals after the effect of intelligence was partialled out. The children were divided into four approximately equal groups, comprising of the bottom 20% of R - L scores (group I), the next 30% (group II), the next 30% (group III) and the top 20% (group 4). Group 2 showed the highest performance on reading with groups 2 and 4 showing the lowest scores.

Mc Keever (1986) studied possible influences of handedness, a sex & familial sinisterality (FS) on language laterality and on spatial and verbal test performance of 225 right-handers and 134 left-handers. Left-handers and right-handers performed differently on all tasks. Right-handers were significantly more lateralized on language laterality on the spatial visualization task. Left-handers obtained slightly, but significantly, higher vocabulary scores. It was concluded that each of the subject factors studied proved to be of some relevance for a complete understanding of laterality and cognitive ability pattern.

Annett & Manning (1990b) investigated the relationship between arithmatic ability, hand preference and hand skill to a general population
sample of school children, aged 9-11 years. Arithmetic ability was positively associated with left-hand skill but not with right-hand skill.

The relation of mental ability for spatial reasoning (Cattell’s Culture Fair Intelligence) to hand skill assessed by peg-moving task was studied by Tan (1990) among normal left-handers. Non linear quadratic relationships were established between these two parameters exhibiting different characteristics according to sex and writing hand. Output of the brain depended on sex and writing hand as well as degree of left-handedness in left-handers.

Tan (1991a) studied the relationship between the strength of left-handedness and spatial reasoning ability in left-handed male and female subjects with and without family sinisterality (FS). Spatial reasoning was assessed by Cattelle’s Culture Fair Intelligence Test. It was found that there was negative linear correlation between non verbal I.Q. and the strength of left handedness in females with and without FS, a quadratic relationship in male left handers without FS and a positive correlation in male left-handers with FS. The results indicated that the brain may exhibit different patterns of cerebral organization in left-handers to sex and FS.

Natsopoulos, Kiosseglou & Xeromeritou (1992) investigated spatial ability of 60 left-handed and 60 right-handed school children using a battery of nine tasks. The results do not agree with Levy’s (1969, 1976) theory predicting spatial inferiority of left-handed individuals. Instead, higher performance by left-handed children provided support for Annett’s theory of intelligence.
Annett (1992) studied spatial ability in 459 subjects of 14-15 years and 428 undergraduate subjects. She found significant relationship between ability and hand preference when preferences were classified in sub-groups of left-and right-handers. In 14-15 year olds and in female undergraduates, there was a W-shaped relation between hand preference and spatial ability. The highest scores were in the centre for right-handers with strong sinistral tendencies. Male undergraduates showed a linear trend, with spatial ability, highest in strong left-handers and declining from left to right across levels of hand preference. When spatial test scores were considered in relation to differences between the hands skill, a decline of ability with increasing dextrality was found in right-handers and in left-handers. In terms of the right-shift theory (Annett, 1972, 1985), it was suggested that there are costs for spatial ability associated with the presence of rs+ gene, even in single dose (rs+− genotypes), and those who lack the gene (rs−− genotypes), have advantage for spatial ability.

Annett (1993) reported no differences for hand preference and educational success. Findings supported the hypothesis that there was a natural variations for laterality and ability as expected for a genetic balanced polymorphism with heterozygote advantage.

Annett (1995) presented a progress report on research investigating the hypothesis suggested by the right shift theory of handedness (Annett, 1985). Annett reported that there was a human genetic balanced polymorphism for cerebral specialisation. She outlined right shift theory and its prediction for a genetic balanced polymorphism with heterozygote advantage. She considered evidence for 6 main areas of research: hand skill; phonology in the rs− genotype; maths and spatial
abilities in the rs ++ genotype; heterozygote advantage for all round ability; types of dyslexia; and a double dissociation for type of cognitive deficit and type of handedness in normal samples. Findings suggested that individual differences for types of cognitive processing are related to individual differences in hand preference and hand skill in ways predicted by the right shift theory.

Schachter (1995) commented on Annett’s theory and compared it with Geschwind & Galaburda’s Pathology Theory of cerebral development. He commented that a right shift gene, still unidentified was sufficient to account for the development of hemispheric dominance for language and spatial skills and for associated hand skills. With regard to pathology theory he suggested that the RS theory and the pathology theory were equivalent in nature rather than mutually exclusive.

Crow (1995) commented on Annett’s hypotheses that a heterozygote advantage existed for the right shift factor (the hypothetical gene determining hemispheric asymmetry). Annett’s hypothesis was supported by findings on the relationship between relative hand-skill and academic ability at the age of 11 years. It was proposed that Annett’s right-shift factor was in the restricted and evolutionary labile class of genes that were present in homologous form on both the X and the Y chromosomes. Such a location could explain sex differences such as present relative hand skill and cerebral asymmetry. Moreover, a gene of this type would be subjected to sexual selection such selection might have influenced the neotenous process that lead to evolution of language.
Brand (1995) commented on Annett’s right shift theory of handedness and the genetic polymorphism for cerebral dominance and cognitive processing. He agreed with Annett and applied Annett’s theory to modern trait psychology explanations of handedness. Brydan (1995) presented alternatives to Annett’s right shift theory and discussed Annett’s three major points regarding (1) a common model for handedness and cerebral dominance (2) the definition of a balance polymorphism with heterozygote advantage (BP+HA), and (3) cognitive abilities and (BP+HA).

Casey (1995) described a study (Case et. al. 1995) in which Annett’s theory was applied to individual differences in the ability of 464 fifteen year olds and 218 nine year olds to mentally rotate objects in three dimensional space. The study used self-report laterality quotients rather than hand skill measures to categorised subjects. Casey argued that despite Annett’s criticism of self report hand preference measures, the authors succeeded in obtaining consistent findings across a number of samples. Casey also agreed with Annett’s concept of the heterozygote advantage in relation to gender differences and spatial ability.

Dellatolas and Curt (1995) maintained that the right shift theory could account for the reduced phonological ability or the reduced spatial ability of some normal people. These “specific deficits” were reported to be associated to a weak or strong tendency to dextrality, respectively. The authors also provided empirical support for the right shift theory.

Maryutina (1995) while commenting on Annett’s right shift theory of handedness and the genetic polymorphism for cerebral dominance and cognitive processing felt that the attractiveness of the model might be
due to possible relation to evolutionary theory and anthropogenesis, and she applied the field of behaviour genetics to her discussion of Annett’s theory.

Annett (1996 a) reviewed the similarities and differences among the right shift theory of Annett (1985), the genetic theory of McManus (1985) and developmental instability theory of Yeo & Gangestad (1993). Both of the genetic theories could predict the distribution of handedness in families and in twins more efficiently than the developmental instability theory, and the RS theory better than the McManus theory.

Annett (1996 b) reported that the right shift theory of handedness and cerebral specialization suggests that there is an underlying substrate of random lateral asymmetries in all higher animals and a specific factor in humans which increases the probability of left hemisphere advantage. The specific factor displaces the random distribution along a continuum of asymmetry in favour of the left hemisphere and the right hand. The distribution of handedness in families can be explained if the shift to dextrality depends on a single gene, rs +, when the frequency of the gene is estimated from the proportion of dysphasics with unilateral lesions of the versus the right hemisphere. The genotype proportions suggested a genetic balanced polymorphism with heterozygote advantage for laterality and ability. Annett used this the RS model to developmental dyslexia which led to the hypothesis that both homozygotes (rs - - and rs ++ ) are at risk for reading. The critical question was whether the type of cognitive problem differs as expected, speech based processing for the rs - - and non-speech based for the rs ++ . The rs - - should include more left & mixed handers while the rs ++ should be more dextral than controls. Evidence for this
double dissociation between type of cognitive disability and type of handedness was found in poor readers and in other samples.

Natsopoulos, Kiosseoglou, Xeromeritou & Alevriadou (1998) examined 270 children of school age, 135 of whom were left-handed and an equivalent number of whom were right-handed. The subjects were tested on a battery of nine language ability measures: Vocabulary, Similarities, Comprehension (WISC - R), Deductive Reasoning, Inductive Reasoning, Sentence Completion, Comprehension of Sentential Semantics, Comprehension of Syntax, and Text Processing. The data analysis indicated that handedness discriminated between right-handers (superior) and left-handers (inferior) in language ability. The sub groups of left-handed children differed in language ability distribution compared with right-handed children. Sex and familial sinisterality do not affect performance. The results provided support to human balanced polymorphism advocated by Annett (1985, 1993).

Review of studies cited above clearly shows that Annett’s right shift theory with heterozygote advantage is tenable. Annett & Kilshaw (1984) reported superiority of rs + - heterozygote over rs -- & rs + + homozygotes and obtained the expected quadratic relationship between R - L hand skill and Vocabulary I.Q. Annett and Manning (1989) using Raven’s matrices reported that the most dextral subjects obtained lowest scores which provided strong support to the right shift theory. Annett & Manning (1990a) reported a significant quadratic relationship between R - L hand skill differences and reading ability scores. Their group 2 (rs + -) obtained the highest scores whereas group 1 (rs --) and group 4 (rs + +) obtained the
lowest scores, thereby providing strong support to the right shift theory with heterozygote advantage. Using spatial ability test Natsopoulos et al. (1992) and Annett (1992) reported highest scores in left-handers and decline of ability with increasing dextrality in right-handers and in left-handers and concluded that higher performance by left-handed children provided support for Annett's theory of intelligence. Annett's (1993) supported the hypothesis that there was a natural variation for laterality and ability as expected for a genetic balanced polymorphism with heterozygote advantage.

Citing evidences in six main areas of research: hand skill phonology in the rs - genotype mathematics and spatial abilities in the rs + + genotype, heterozygote advantage for all round ability, type of dyslexia and a double dissociation for type of cognitive deficit and type of handedness in normal sample, Annett's (1985) suggested that individual differences for types of cognitive processing are related to individual differences in hand preference and hand skill in ways predicted by right shift theory. Studies of Brand (1995), Casey (1995) also provide support to Annett's genetic polymorphism for cerebral dominance and cognitive processing. Dellatolas and Curt (1995) reported that right shift theory could account for reduced phonological ability or the reduced spatial ability of same normal people. Crow (1995) supported Annett's theory using handskill and academic ability. Annett (1996) suggested a underlying substrate of random lateral asymmetries in all higher animals and a specific factor in humans which increases the probability of left hemi-sphere advantage. Using a battery of nine language ability measures Natsopoulos et al. (1998) also provided support to human balanced polymorphism advocated by Annett (1985, 1993).
But this is only one side of the point and there are studies which fail to provide any support to Annett’s model a brief review of such study is given as under.

Whittington & Richards (1991) investigated the hypothesis that the right shift theory of handedness, is associated with differential patterns of cerebral functioning with contrasting handedness groups. It was suggested that individuals with an rs ++ genotype would be disadvantaged in mathematical performance. A national sample of over 11,000 children from the National Child Development Study in U.K. Some differentiation in cognitive performance between handedness groups was found in the direction predicted by the RS theory but the level of the findings was not statistically significant. The rs ++/ mathematical deficit hypothesis was not confirmed.

McManus, Shergill & Bryden (1993) criticised Annett’s method of dividing subjects into putative genotypes which did not allow the rs + – genotype to be compared with rs – – genotype within handedness groups. They proposed an alternative method which they claim allows heterozygous rs + – right-handers to be compared both with rs ++ and rs – – homozygotes. Using this method McManus et.al. reported no evidence of heterozygous advantage in undergraduate medical students. The heterozygotes were not more intellectually able than homozygotes on tests of verbal I.Q., spatial I.Q., diagrammatic I.Q. or vocabulary. McManus et.al. (1993) also outlined the problems associated with Annett’s model and concluded that Annett and Manning’s paradigm does not demonstrate differences intellectual ability related to skill asymmetry than those differences are unlikely to result from a balanced polymorphism but instead
probably reflect motivational or other differences between the right-handers of high and low degree of laterality.

McManus (1995) reported that Annett's theory is a powerful mathematical theory which built a model of lateralization upon mixture distributions comprised of separate normal distributions each determined by specific genotypes. This is the primary vulnerability of Annett’s Model. Although the right shift theory is inherently quantitative, its predictions are usually stated qualitatively. McManus also expressed concerns regarding the rs–gene and its frequency.

Michel (1995) felt that like most current genetic models of handedness and dominance for speech control, Annett’s model suffers most from the lack of attention to developmental processes underlying the acquisition of various laterlized asymmetries of functions.

Gilger (1995) presented concerns about accepting the right shift theory simply because it fits the handedness data and Annett’s assumptions about the manner in which a right-shift gene might have evolved. Gilger discussed concerns over Annett’s use of brain imaging data and the cognitive and handedness performance of children with dyslexia or math disabilities.

Stein (1995) while commeting on Annett’s right shift theory of handedness and the genetic polymorphism for cerebral dominance and cognitive processing felt that there was only one unsatisfactory aspect of Annett’s theory i.e. the weakness of her explanation of the small concordance difference between monozygotic and dizygotic twins.
Steinmetz (1995) discussed several postmortem and imaging studies that supported Annett’s discussion of another level of analysis of her theory namely the structural level in which asymmetry of the planum temporale is the most prominent feature. Van Strien (1995) felt that the key issue in Annett’s right shift theory of handedness and genetic polymorphism for cerebral dominance and cognitive processing is to what extent variations in cerebral asymmetry are due to genetic factors and to what extent they are due to non genetic factors.

Laland (1995) felt that Annett’s theory is a plausible and sensible explanation for the data on handedness and cerebral asymmetry, it rests on a number of untested assumptions. It was argued that Annett provided circumstantial evidence for all of these assumptions and is able to generate and internally consistent and plausible explanations for the relationship between hand and brain. Nonetheless, Annett’s assumptions are not quite as robust, and her portrayal of the handedness literature is not quite as consistent as her article implies.

Palmer and Corballis (1996), measured word reading hand skill on a peg moving task and hand preference in 203 children aged from 11-13 years. Differences in skill between the hands were largely attributable to variations in left-hand skill, consistent with the view that manual and cerebral asymmetry are due to the loss of cells in the right hemisphere during development - a mechanism that may be dependent on the right shift gene postulated by Annett - 1985. There was only weak evidence for the curvilinear relation between differential hand skill and reading predicted by Annett (1985) theory of balanced polymorphism which posulates a heterozygotic advantage. Reading was better predicted by absolute
measures of handskill then by differences between the hands, especially among boys. For the boys, word reading was predicted significantly from right hand skill while the girls left-hand skill predicted slightly more strongly than right-hand skill. It may be related to differential growth gradients in the two hemispheres, and different environmental influences for boys and girls during a period of right hemispheric growth.

Strehlow, Haffner, Parzer, Pfuller, Resch, Zerahn - Hartung (1996) studied handedness and cognitive abilities in a representative sample of adolescents and young adults. Between 16 and 30 years of age, it was designed as a possible application of Annett’s data supporting her right-shift theory, but included other measures of laterality as well. It was found, as Annett did, that strong right-handedness was associated with a weak left hand rather than a strong right hand. However, two other predictions of right shift theory could not be confirmed. The non-verbal I.Q. was significantly lower in both extreme groups of handedness than in the two middle groups. The authors could not find the linear decline in non-verbal I.Q. from the left to right extreme of handedness as predicted by the right shift theory. Spelling in strong left-handers was worse than in weak left-handers and in strong right-handers. The predicted poorer spelling in the extreme groups than in the middle groups (inverted U) was not found.

Resch, Haffner, Parzer, Pfueller, Strehlow & Zerahn - Hartung (1997) tested the predictions of the right-shift theory of Annett that cognitive abilities would vary with right, left hand skill in a large epidemiological sample of young adults. This study could not confirm the predictions of a genetic balanced polymorphism with heterozygote advantage for laterality and ability as claimed by Annett & Manning (1989,
1990 a) and Annett (1993) claimed that probands at the right end of the R-L hand skill continuum would show lower general intelligence in I.Q. testing and that specific verbal abilities and educational success would be lower at both extremes of the R-L distribution taking the form of an inverted U. Most of the predictions of right shift theory could not be confirmed in this study. This study contrasted with the important & specific prediction of the right shift theory that strong dextrals would be the most disfavoured group. In the sample of this study probands, at the left end of the R-L continuum had significantly lower non-verbal I.Q. scores, while strong dextrals tended to have average or even marginally higher ability scores. The effects, however, were small and decreased when controlling for other variables.

Crow, Crow, Done & Leask (1998) tested the hypothesis that population variation in handedness is in part genetic and, it has been suggested its persistence represents a balanced polymorphism with respect to cognitive ability in a sample of 12,770 individuals in a UK national cohort. They assessed relative hand skill as a predictor of verbal, non-verbal and mathematical ability and reading comprehension at the age of 11 years. The authors reported that modest decrements were present in extreme right handers and the most substantial deficits in ability were seen close to the point of equal hand skill. For verbal ability females performed better than males, but the relationship to relative hand skill was closely similar for the two sexes; for reading comprehension males close to the point of equal hand skill show greater impairment than females.

Cerone & McKeever (1999) tested Annett’s right shift theory’s hypothesis of a ‘heterozygote advantage’ for cognitive abilities. This theory of language dominance and handedness posits three genotypes rs ++, rs + –
and \( rs^- - \), and Annett has hypothesized that there are cognitive ability correlates of these genotypes. The \( rs^+ + \) genotype person is held to be ‘at risk’ for maldevelopment of spatial or other right hemisphere-based cognitive abilities and the \( rs^- - \) genotype individual is held to be at risk for maldevelopment of phonological abilities. Noting that there must be some adaptive advantage conferred by the heterozygous genotype for it to have survived over a presumably long period of evolution. Annett has hypothesized that heterozygotes are afforded an adaptive advantage over homozygotes because of their freedom from ‘risks’ to intelligence generally. Annett et al. have used two different indices, or markers, from which they have inferred differing concentrations of the three genotypes within groups of participants. One marker, based on response to hand preference items of the Annett Handedness Inventory, was found by Annett (1992) to support her theory in that the least dextral of right-handed participants did best on spatial tests. The other marker Annett has used is based on the degree of right-hand advantage on a simple peg moving speed task. The authors utilized both methods and studied the performances of 259 dextral college men and women on two tests of mental rotation ability and two tests of verbal abilities. Results did not support the heterozygote advantage hypothesis, and it was suggested that visuospatial ability was modestly related to greater dextrality of participants.

Studies reviewed in the above section have either provided only partial support (Stein, 1995; Laland, 1995; and Palmer & Corballis, 1996) or failed to provide any support to the right shift theory of Annett. Whittington & Richard (1991) did not find statistically significant differentiation in cognitive performance between handedness groups as predicted by Annett. Mc Manus (1995) expressed concern about the \( rs^- - \)
gene and its frequency and said that Annett's model suffers most from the lack of attention to developmental processes underlying the acquisition of various lateralized asymmetries of functions using mathematical ability, Gilger (1995), Whittington & Richard (1991), non-verbal intelligence and spelling ability Strehlow et.al. (1996) did not provide any support to Annett's model. Stein (1995) reported that Annett’s theory could provide only small concordance between monozygotic and dizygotic twins. Using general intelligence, specific verbal abilities and educational success tests scores and R – L hand skill distribution Resch et.al. (1997) could not find relationship in the direction predicted by Annett. Findings even contrasted with the specific prediction of the RS theory that strong dextrals would be the most disfavoured group.

Mc Manus et.al. (1993) presented a critic of Annett’s right-shift theory and raised several objections. Their most serious objection is that Annett’s method of dividing subjects into putative genotype groups is not correct. Annett's group I and group II are of contaminated genotypes and hence non-comparable. Not only this they provided an alternative method which they claimed better than that of Annett, Annett and Manning. Using this method Mc Manus et.al. (1993) compared heterozygote rs + – right handers with homozygote rs ++ right handers on tests of verbal I.Q., spatial I.Q., diagrammatic I.Q. and vocabulary and found no evidence in support of Annett’s model. Mc Manus et.al. (1993) concluded that if Annett & Manning (1989, 1990 a, 1990 b) paradigm does demonstrate differences in intellectual ability related to hand skill asymmetry than these can be explained by way of motivational and other variables rather than by balanced polymorphism.
The genetic models of handedness developed by Annett and McManus have yielded parsimonious fits to the data on the inheritance of handedness and can account reasonably well for the relations between handedness and cerebral dominance for language. The notion of a heterozygote advantage provides a plausible mechanism for the apparently stable incidence of left-handedness across human cultures and over time. However, the evidence in favour of a heterozygotic advantage can be explained in other ways. For example, extremes of handedness, left or right might be due to pathology (Bishop, 1990) or to polygenic homozygosity (Yeo and Gangestad, 1993). Furthermore, the simulations described earlier show that it would take only a tiny advantage in terms of reproductive fitness to produce stability in a comparatively short stretch of evolutionary time, an advantage so small that it might not be measurable in terms of psychological tests. At the present time, therefore, the case for a heterozygote advantage rests more on its inherent plausibility than on the empirical evidence. It is perhaps unlikely that the gene postulated by Annett and McManus is located on the sex chromosomes, as suggested by Crow (1995). There may well be one or more genes on the sex chromosomes that influence handedness and cerebral asymmetry, perhaps indirectly.

Not only this, questions have also been raised about the size and representativeness of the sample of studies of Annett and Annett & Manning on the basis of which they have demonstrated that handedness is maintained by a balanced polymorphism and there is heterozygote rs + - advantage over homozygotes (rs -- and rs + +). Therefore, present study was designed to empirically validate Annett’s model of balanced polymorphism with heterozygote advantage.
Gender differences in handedness and in the expression of cognitive abilities:

Gender is an important factor influencing handedness & cognitive achievement as well. There had been a consistent finding that females are more biased to right hand than males.

Cashdan, Pumfrey & Lunzer (1970) reported a disproportionately higher incidence of male left-handers and mixed handers in the clinical groups of children with reading and learning disabilities.

Handedness patterns differ in males and females - males are found to be more ambidextrous than females (NewCombe, Ratcliff, Carrivick, Hirous Harrison and Gibson, 1975 and Carter-Saltzman, 1980). These sex related differences in handedness are found across generations when the older and younger groups are comprised off parents and their biological children. (Carter - Saltzman, 1980).

Annett & Kilshaw (1983) and Annett (1985) revealed that sex differences in L – R skill are due to sex modification of the expression of the rs + gene, such that the effects of the gene are stronger in females. Females tend to be more dextrals than males. This was true of right-handers but not of left-handers, as sex differences is due to strong expression of the rs + gene in females than males and this gene is absent in majority of the left-handers.

Annett (1992) studied sex differences in spatial ability among undergraduates and 14-15 years old and reported that a sex difference in
spatial ability could be due to many causes and it is not claimed that the rs locus is the only factor involved. She reported that males were superior to females in spatial ability in both the samples. It was concluded that there is no substantial evidence which contradicts the expectations of the right shift theory that the rs + gene carries costs for spatial ability and is expressed more strongly in females than males.

Tan (1991) studied the relationship between the strength of left-handedness and spatial reasoning ability in left-handed male and female subjects with and without family sinisterality (FS). Spatial reasoning was assessed by Cattelle’s Culture Fair Intelligence Test. It was found that there was negative linear correlation between non verbal I.Q. and the strength of left handedness in females with and without FS, a quadratic relationship in male left handers without FS and a positive correlation in male left-handers with FS. The results indicated that the brain may exhibit different patterns of cerebral organization in left-handers to sex and FS.

Snyder & Harris (1993) found that on spatial tests, males outperformed females with no overall handedness effects. FS was twice as common in left-handers as in right handers. Davis and Annett (1994) reported on the basis of right shift theory of handedness that the rs + gene is expressed more strongly in females than in males, and in the singletons than in twins.

Van-Strien and Bouma (1995) found that females compared to males performed better on numerical reasoning and visuospatial tasks. Within the group of left-handers, the multivariate effect for familial sinisterality was significant. Left-handers with familial left-handedness
exhibited better scores on numerical reasoning, on verbal reasoning, and on visuospatial tasks than did left-handers without left-handed relatives. The non familial left-handers also exhibited lower scores on both inductive reasoning task when they were compared to their right-handed counterparts. The outcome seems contrary to the prevalent conclusion that left-handers with left-handed relatives are more likely to exhibit lower performances on visuospatial tasks than left-handers without such relatives.

Resch, Haffner, Parzer, Pfueller, Strehlow & Zerahn-Hartung (1997) tested the predictions of the right-shift theory of Annett that cognitive abilities would vary with right, left hand skill in a large epidemiological sample of young adults. This study could not confirm the predictions of a genetic balanced polymorphism with heterozygote advantage for laterality and ability as claimed by Annett & Manning (1989, 1990 a) and Annett (1993 c) claimed that probands at the right end of the R-L hand skill continuum would show lower general intelligence in I.Q. testing and that specific verbal abilities and educational success would be lower at both extremes of the R-L distribution taking the form of an inverted U. Most of the predictions of right shift theory could not be confirmed in this study. This study contrasted with the important & specific prediction of the R S theory that strong dextrals would be the most disfavoured group. In the sample of this study probands, at the left end of the R-L continuum had significantly lower non-verbal I.Q. scores, while strong dextrals tended to have average or even marginally higher ability scores. The effects, however, were small and decreased when controlling for other variables.

Crow, Crow, Done & Leask (1998) tested the hypothesis that population variation in handedness is in part genetic and, it has been
suggested its persistence represents a balanced polymorphism with respect to cognitive ability in a sample of 12,770 individuals in a UK national cohort. They assessed relative hand skill as a predictor of verbal, non verbal and mathematical ability and reading comprehension at the age of 11 years. The authors reported that modest decrements were present in extreme right handers the most substantial deficits in ability were seen close to the point of equal hand skill. For verbal ability females performed better than males, but the relationship to relative hand skill was closely similar for the two sexes; for reading comprehension males close to the point of equal hand skill show greater impairment than females.

Cerone and Mc Kever (1999) reported significant effect of sex on Stanford Identical Block Test, Vandenberg Mental Rotation Test and Word Fluency Test with males scoring higher than females in all the four hand preference classes.

Thus, sex differences have assumed quite an importance in handedness and cognitive abilities. So analysing the relation between handedness and cognitive variables, the effects of gender have to be taken into account.

**Handedness and Creativity:**

Interest in creativity research began to grow in the 1950s, and a few research institutes concerned with creativity were founded. However, several indicators of the volume of work on creativity show that it remained a relatively marginally topic in Psychology until recently. Sternberg and Lubart (1996) analysed the number of references to creativity in
Psychological Abstracts from 1975 to 1994. The analysis resulted in 0.5% of the articles indexed in Psychological Abstracts from 1975 to 1994 concerned creativity.

Creativity is a rare trait. This is presumably because it requires the simultaneous presence of number of traits such as intelligence, preservance, unconventionality and the ability to think in a particular manner. None of these traits is especially rare. What is quite uncommon is to find them all present in the same person. One imagines that all of these traits have biological base. There are reasons to believe that creativity should be related to differential activation of right and left hemispheres of the brain, as well as general level of cortical arousal (Martindale, 1999).

Galín (1974) and Hoppe (1977) have argued that the right hemisphere operates in a primary process manner, whereas the left hemisphere operates in a secondary process fashion. Their arguments are based upon findings that verbal, sequential, and analytical processes tend to be carried out in left-hemisphere whereas global, parallel and holistic processes are carried out in right hemisphere.

Penfield and Roberts (1959) performed experiments in which exposed cortex was mildly stimulated. When certain areas of the right temporal cortex were stimulated, their patients reported extremely vivid auditory and visual images. Jaynes (1976) has argued that such quasi-hallucinatory experience is a product of intense right-hemisphere activity.

There is some evidence that procedures known to increase right-hemisphere activation can facilitate creativity. Gur and Raynor (1976)
tested the hypothesis that hypnosis increases right-hemisphere activation and found that hypnotizable subjects performed better on tests of creativity when hypnotized than when not hypnotized.

Marijuana also increases right-hemisphere activation. At least in low doses, it facilitates performance on tests of creativity; however, higher doses produce decrements in performance (Wecknowicz, Fedora, Maron, Radstack, Bay & Yonge, 1975). Music also has been shown to facilitate performance on creativity tests (Katsounis, 1972). Harkins and Macrosson (1990) examined the effect upon creativity of a 10-week course purported to develop right-hemisphere functions. The course led to significant improvements on two tests of creativity, but had no effect on fine other tests of creativity.

A word displayed in the left-visual field is processed first by the right-hemisphere, whereas a word displayed in the right visual field is processed first by left-hemisphere. Words presented in the left visual field elicit more unusual world associations than do words presented in the right visual field (Dimond & Beaumont, 1974).

Torrence (1979) developed an inventory which measured right-left orientation studies. The use of the inventory has shown that both cerebral hemispheres are involved in creative behaviour. On this measure, the scores of the left and integrades are almost identical; the rights tended to have greatest difficulty in the kinds of creative thinking.

"Do left-handers tend to be more creative"? This was the hypothesis of Katz (1980). He studied 100 individuals. Their handedness
was assessed by modified version of the Crovitz and Zener handedness questionnaire. The questionnaire isolated 30 left-and 70 right-handers. The creativity tests were administered. Both the handedness groups failed to differ on any of the measure of creativity.

Sterling and Taylor (1980) attempted a study on creative self perception, hemispheric laterality and sex differences in students. This study investigated the interrelationship between hemisphericity and creativity in 93 females and 64 males. Right dominant, left dominant, integrated and mixed hemisphericity were related to creativity scores measured by Khatna-Torrence Creativity Perception Inventory (KTCPI). The results of the study indicated that the lefts obtained the lowest creativity scores even lower than right, integrated or mixed.

Banks (1981) made a study on creativity and cerebral dominance. This study was designed to explore the relationship between creative ability and cerebral hemispheric dominance. 36 undergraduate students served as subjects. They received three tests of creative ability and three tests of cerebral dominance. One of the test that measured right cerebral dominance was found to have a significant relationship with creative ability.

A study on neurological relationships between creativity, hemisphericity and cerebral asymmetry was attempted by Robert, Rosemary and George (1983). It was found that creative individuals don't differ in cerebral preference or lateralization.
Sharma (1986) found that left-handed as well as right handed male and female subjects were not statistically different on non-verbal flexibility and originality dimensions of creativity. Mixed-handed female subjects performed better than mixed-handed males only on non-verbal flexibility component of creativity. It was demonstrated however, when left-mixed-and right-handed subjects were taken together, the females were found to be more creative only on non-verbal fluency and originality.

Coren (1995) examined the relationship between handedness & divergent thinking. Results indicated significant relations between divergent thinking and handedness in males. Left-handed males had higher divergent scores, and the scores rose systematically with increased sinistrality. Handedness was not related to divergent thinking in females. The study also showed that the differences were not associated with superiority by left-handed subjects in convergent thinking. A nominally normal population was associated with superior divergent thinking ability in males.

Atchley, Keeney and Burgess (1999) studied cerebral hemispheric mechanism linking ambiguous world meaning retrieval and creativity. The Wallach-Kogan similarities subtest was used to group 72 subjects into three levels of verbal creativity to compare their performance on the ambiguity resolution taks. Results suggested that both the left and right hemispheres contribute to the maintenance of multiple world meanings in highly creative subjects, while less creative subjects show sustained subordinate priming only in the right hemisphere or no sustained subordinate priming. These results supported an interactive collaborative theory of creativity and suggested that there are important individual
differences that expand on the basic time course model of hemispheric processing.

In view of the contradictory evidences cited earlier for a balanced polymorphism (rs + -) in right shift (rs +) gene, Annett’s model needs empirical validation. Present investigation is proposed to test the advantages of balanced polymorphism (rs + -) in right shift (rs +) gene for cognitive abilities. The problem of the study is entitled as:-

“Handedness and Cognitive Abilities : A test of Balanced Polymorphism Advantage Model.”

**Objectives of the study :**

In the light of theoretical framework provided earlier following are the major objectives of the present study:

(i) Empirical validation of ‘Annett’s Model of Balance Polymorphism’ (rs + -) in the right shift (rs) gene with an heterozygous advantage for intellectual ability and creativity.

(ii) To study the interaction of sex with handedness groups on measures of cognitive ability.

(iii) In view of the objections raised by Mc Manus, Shergill and Bryden (1993) with regard to Annett’s method of selecting subjects in four groups, another objective of the investigation is to test the Model by selecting the groups on the basis of Mc Manus et. al. (1993) method i.e. testing differences within right handed groups excluding left handers.

(iv) An additional objective of the study is to test the cross-cultural generality of Annett’s Model.
**Hypotheses:**

Attendant upon and congruent with the aforesaid objectives, the following hypotheses are proposed regarding handedness and cognitive abilities:

(i) \( H_1: \) The rs + - heterozygotes would manifest increased cognitive ability than rs ++ and rs -- homozygotes on non-verbal and verbal measures of intelligence.

(ii) \( H_2: \) Though empirical evidence lacks for heterozygote advantage on measures of creativity in Annett’s model, however, Annett has postulated superiority of rs + - heterozygotes over rs -- and rs + + homozygotes on measures of cognitive ability. Therefore, it is hypothesized that the rs + - heterozygotes would score higher than rs -- and rs + + homozygotes on measures of creativity.

(iii) \( H_3: \) The interaction of sex and handedness groups on measures of non-verbal intelligence, verbal intelligence and creativity would be significant.

(iv) \( H_4: \) To fulfill the objective of testing the Annett’s Model by selecting groups on the basis of Mc Manus, Shergill & Brydens, (1993) method i.e. testing differences within right-handed groups it is hypothesized that the R1 & R2 groups (rs + -) would significantly score higher than R3 group (rs ++) on measures of non-verbal, verbal intelligence & creativity.