Chapter 11

Genetic Method

In twentieth century the increased interest in genetic and developmental psychology is 'related to the rapid progress of biology. Genetic methods were, in early years, purely biological and were applied to physical and anatomical development. Another factor which prompted genetic approach in psychology and education includes: recognition of the importance of the child as an individual, formulation and development of evolutionary theories, observational and questionnaire studies of the growth of infants and young children, certain psychological moments, and the invention and the use of measuring and recording instruments, especially mental tests, in growth studies.

The basic concept of development fundamentally biological and has been commonly associated with the organization of living structures and life process but in broader terms of word 'development' is associated not only with physical changes but also with physical systems, cultures, social institutions, or system of ideas. It is the concept of development, which is applied to behavioural sciences, viz: education, sociology, psychology, anthropology, history, economics, political sciences, etc. The genetic approach could be applied more readily in tracing the developments of the insane, criminal and maladjusted. The techniques of genetic research have to be adopted to the age and nature of the subjects. For example, in studying infants and pre-school children, it may be necessary to use direct measurements and observations and for older children, pencil and paper tests might be used.

MEANING OF GENETIC RESEARCH

Genetic study is ideally long-term investigation of origin direction, trend, rate pattern, limit and decline of growth. Genetic research should identify causes, inter-relationship and patterns of development among such factors as experimental background, including both formal and informal teaching and learning, physiological age, mental age, degree of social maturity or social age, interests, needs, socio-economic status, motivation, attitude, methods of instruction, material of instruction, length and intensity of instruction, learning procedures, modifiability of nature ability, aims and objectives reading ability, habits and procedures . of thinking and in problem solving of the material to be learned.

The relationship between pattern of development for mentality, emotional stability and physical growth is far more significant than separate consideration of data for each phase of growth. This conception is much broader than that of many earlier investigators who considered growth data valuable without practical applications.

PURPOSE OF GENETIC METHOD

The purpose of genetic studies is to discover origin, direction, trends, rate pattern, limit and decline of growth with a more recent interest in cause and interrelationships as factors affecting growth for example the relationships and pattern of development for mentality, emotional stability and physical growth are more meaningful than separate analysis of each aspect of growth. Adequate interpretation of behaviour includes consideration of children ‘of growth rate and optimal development direction indicates whether the child is moving forward, or stationary or regressing rate and indicates whether progress is slow or rapid. It is particularly important in the instruction of gifted children to know whether the level attained represents optimal development in relation to ability.

Investigation of development problem have been extended beyond the classroom, laboratory, nursery, school and child clinic to the church school, home child care agency, camp, playground and discussion group with interest going beyond the earlier physical and anatomical studies to phases of mental, social and personality development. The genetic approach could be applied more readily in tracing the development of the insane criminal and maladjusted, if suitable methods were available for identifying the several types of abnormality or maladjustment an early age as has been done for the gifted, so as to permit a forward movement of observation through the several stages of growth or development the longitudinal approach in most studies of abnormality or maladjustment, it has been necessary to work backward to origin or cause through case or clinical method or the life history since these cases usually reach some critical studies before coming to attention of person equipped with the nature of the case.

TYPES OF GENETIC RESEARCH

There are two types of approaches of solving the problems by genetic method:

1. Cross-sectional Technique, and
2. Longitudinal Technique.

1. Cross-sectional Technique

The Cross-sectional technique requires at least a single measurement for each individual within the particular groups represented as when height is measured for each pupil in the first six grades of a public school system the central tendency for each of the six grades can be calculated and the result represents the ‘norms’ of growth in height or growth trends from grade to grade or year to year, although these central tendencies are not appropriate ‘norms’ of growth in height for an individual child.

Advantages

The following are advantages of this technique:

1. The cross-sectional technique has the advantage of gathering the data promptly, as in measuring at one time the height of the children in the first six grades, rather than waiting for the pupils in the first grade to grow in height through a period of six years (a longitudinal technique).
2. It is economical in respect of time because all the samples are available at a time.
3. Relatively large number of subjects are involved in cross-sectional studies, in contrast to much smaller number followed over a period of time in longitudinal studies. If more people have opportunity to be selected as sample.
4. It is economical in respect of energy because all the samples are available at a time.
5. It would be helpful to have norm for such every day activities as dressing habits, ordinary major performance and virtually all practical skills.

Limitations

The following are the limitations of this technique:

1. Cross-sectional approach does not represent the developmental stage of an individual or child.
2. Mostly no prediction can be made.
3. This type of genetic research represents special difficulties in sampling and in statistical procedures.
4. Large and many groups of samples are required.
5. We can not use it for clinical purpose of a particular individual.

2. Longitudinal Technique

The longitudinal approach is considered a sound method than cross-sectional technique. This type of genetic method is used in the repeated observations or measurements of the same child or the same group of children over a period of years. In following the same child, the investigation becomes extended case study. The longitudinal approach to an investigation of the weight of school children is to follow a particular group of people or the same individual year after year through repeated measurements. The resulting series of measurements, therefore, represents growth sequence for the same group of children or same individual.

Advantages

The following are major advantages of this technique:

1. It deals with inter-relation of many variables in growth through the cooperation of socialist in a variety of field.
2. It represents the cross-sectional of development stages of an individual child.
3. Prediction can be made for a subject.
4. Real development may be studied by this method.
5. This method is less difficult in sampling and statistical technique in comparison to cross-sectional method.
6. Small sample is selected.
7. It can be used for the clinical purpose for a particular pupil.

Disadvantages

This technique suffers from the following limitations:

1. It is not helpful in providing the norms for every day activities.
2. Uniform sampling criteria, as employed in cross-sectional studies, cannot be set up and applied for longitudinal data, since unpredictable and uncontrollable selective elimination almost inevitably occurs because of the causalities of death, illness, moving of families and changes in the co-operation of parents with the investigator.
3. It is time consuming.

Although wider use of the longitudinal method has been recommended, rather specific precautions are necessary in dealing with certain difficulties some of which are common to cross-sectional studies.

1. Difficulties in population sampling, such as the selective elimination of many of the original subjects during the course of a long term investigation.

2. Maintenance of satisfactory working relationships among subjects, parents, schools and investigators particularly as personnel changes takes place with the passing of time.
3. Motivation of children to demonstrate full rather than perfunctory performance. A real challenge in the case of repeated testing over a period of month of years.
4. Systematic errors of measurement in the administration or scoring of tests mental or physical.
5. Non-comparability or uncertainty of uncertain psychological equivalence of test used at different age level, especially when the time span is from early childhood to adolescence.
6. Unequal experience of groups in terms of factors affecting the results of the measurement used, but not affecting the trait itself: for example, variation in previous experiences with standardized tests.
7. Recording and collection of data for example work of graduate students probably not as accurate and efficient as a highly trained permanent staff or skilled punch ‘operators and statistical clerks.
8. Mistakes or interpretation resulting from failure to take into account the principle of regression, particularly in its effects of measurement of gain or loss.

PROBLEM OF GENETIC RESEARCH

The research of genetic problem is not limit to classroom, laboratory nursery school and child clinic, but may be carried forward in the church school, home child care agency, playground and discussion group. As the scope of problems to the earlier in physical and anatomical growth is newly added phases of mental, social and personality development as profitable areas for research. The breadth of the field is indicated by the content of treatise and we trace the development of psychological processes in animal ranging from unicellular organism to man. As further evidence of the breadth of genetic approach, investigation of mental and physical growth has enough answers to the following problems:

1. Individual, age, maturity, sex and ethnic differences in growth.
2. The general nature of growth curves their inception, shape and point of cessation.
3. The nature cause and results of abnormal growth.
4. The nature of growth curves of various structures.
5. Relationship between mental and physical growth.
6. The relationship of physical growth to abnormalities of behaviour.
7. The relation of growth to environmental changes.
8. The study of effectiveness of methods and techniques for obtaining the above information.

There are certain fields to which the genetic method could be applied more rapidly to the gifted, criminal and maladjusted in general as to secure a faithful record of past biological events in the developmental history of individual or group to discover cause and effects relationship, principle of development, common likeness and differences in the development history of individual or groups of persons to determine change in interest, capabilities and abilities from the one age level to another for either individuals or groups of persons to secure age grade norms of development for group of children.

SOURCES OF GENETIC DATA

Among the sources for study of child development are the following:

1. The present behaviour of the child, including verbal output, as based on observations, measurement and records or experimental situations, or on direct observation of behaviour in play and social settings.
2. Products of the child in the form of permanent records including drawings, letters, and compositions.
3. Records on file at home, school and in a variety of agencies covering school achievement, birth certificates and health records.
4. Introspections of the child.
5. Memories of the child, or the adult of his own earlier life, as based on the recording of conscious memories or of getting at more deeply buried memories by a free association process or projective methods.
6. Memories of the child's life as retained by those who have been associated with him.
7. Measures of the parents, siblings, and other relatives of child or of the environment, culture or background in which he develops-a source that actually does not provide direct information concerning with the child.
8. Historical and biographical materials-both genetic and historical studies deal with the sequence and unfolding events, but genetic approach centres attention on events relating to individual growth or past roots. The historical approach employs the entire range of human events.
9. Survey instruments: Genetic research makes extensive use of the varied data-collecting and recording tools of normative- survey methods (testing, questionnaire, scales, interview and records).
10. Experimental technique; Genetic approach is frequently used in combination with experimental inquiry, as when employing parallel groups to study the effect on growth of variation in a nutritional factors.

DESIGN FOR GENETIC RESEARCH

The genetic method includes at least three possibilities of designs:

1. Experimentation through the technique of the control group and co-twins control.
2. The behaviour survey.
3. The Individual case study: Studies of different phases of growth: intellectual, emotional and physical. Projective techniques are used for emotional has emphasized longitudinal studies of the same children over a period of time.

(*a*) Developmental Evaluation

1. **Developmental Examination:** Naturalistic observations, organisation and consistency of performance of simple tools, standardized psychometric tests, subjective techniques.
2. **Visual Examination:** Case history, visual analysis, visual skill.
3. **Physical Growth Evaluation:** Observations of sequence to situation, standard physical growth measures standardicated physique photographs.

(*b*) Subject Interview

Topic covering emotion sense of self, inter-personal relationship activities and interest self-care and routine, action system, school ethical sense philosophical outlook.

(*c*) Teacher Interview

Survey Instruments

Genetic investigation makes extensive use of the varied data collecting and recording tools or normative survey method including developmental examinations, growth schedules, behaviour records tests, anecdotal journals, anthropometric measuring instruments standard, rating scales, checklist, questionnaire interviews and direct observation. The types of sociological, psychological, educational, economic and medical phases of growth.

ANALYSIS AND INTERPRETATION OF GENETIC DATA

There are certain principles for analysis and interpretation of genetic data. These are as follows:

(*a*) Principles of Child Development

Certain principles of child development which many be classified under the following abbreviated headings are helpful as background for discussion of the several aspects of human growth and development.

1. Developmental objectives.
2. Levels of maturity.
3. Differential rates of maturing.
4. Variability in rate of maturing.
5. Differential developmental pre-eminence at various stages of growth.
6. Whole heartedness and gradation in emotional development.
7. Variabilities in differential rate of maturing.
8. Indigenous motivation or spontaneous use as a feature of growing ability.
9. The principle of anticipation.
10. "Laying By" or sheding as a feature of developing. Developmental revision of habits.
11. Differentiation and integration.
    (*a*) Individualization.
    (*b*) Progression from generalised to more localized response.
    (*c*) In corporation of separately practised operation into the larger activity system.
13. Priority of "larger" over "small" nuclear activities in certain sections of the body.
14. Interaction between various aspects of growth.
15. Various extensions of experience.
16. Early establishment of some of the basic features of personality structure.
17. The play of complementary and potentially conflicting force.
    (*a*) Dependence or independence
    (*b*) Self-centered and out-going tendencies.

(*b*) Initial Stage

Interpreting growth and development, certain stages and processes are significant, as reported in the classic studies of genetic and the beginning of development is important in genetic research. The initial stages of certain types of behaviour in infancy are commonly as follows:

1. In the first quarter or the 1st year he gains control of the muscles that moves his legs.

2. The second quarter reach out for thing.
3. Third quarter, sits.
4. Fourth quarter stands upright.

Second year walks and runs, and articulate words and phrases and in the third year, speaks in sentences, using words as tools of thought.

(*c*) Qualitative and Quantitative Changes

Growth or development is both quantitative and qualitative. Growth In vocabulary involves both the total number of words used for qualitative changes and the effectiveness of usage in speaking or writing a relatively qualitative phase of development. Qualitative changes in growth commonly are expressed descriptive terms for example of different stages of development in infant commonly responds to the minor situation as follows as 40 weeks smiles at his mirror image; at 52 weeks, approaches his mirror image socially and even vocalizes; and at 56 weeks, brings his face close to his image, sometimes kissing it.

(*d*) Rate of Growth in Terms of Trends and Patterns

A basic continuity characterize human psychological development in the sense that pattern of personality and adjustment once established tend to persist over long periods of time, although environmental or constitutional factors or circumstances, under certain conditions might alter the growth trend of particular individual. The interrelation of development trends is noted in the positive correlation of desirable traits and in a certain unity of growth. Although in physical and social interaction and possibly in intelligence, some alteration in direction or rate of growth is associated with presence, anything approaching recognization of personality has not been demonstrated. The characteristics of any age group such as adolescents must be evaluated in the perspective of what has gone before and what follows:

(*e*) Stages of Growth and Integration

Reasonable unity or integration development prevails at a particular stage of growth although there are many exceptions. The normal boys reach similar stages of development intellectually, educationally, socially and physically. On the other hand an exceptional boy may be small in physical size but will answer questions in a quiz-show at the college level in science and mathematics. Another exception to the concept of integrated growth at a particular stage is the adolescent boy who may be 6 feet in height but quite immature socially and emotionally. The vestibules of the ear is of adult size at birth but the heart has not fully completed it's growth. At the age of 20, as a general rule the several aspects of development lend to cluster around a centre of gravity of growth for the individual.

(*f*) Individuality of Growth

Although there are stages of maturation and behaviour that reveal basic or common trends in development, not even identical twins grow up in exactly the same way individuality of behaviour in motor activity relates to such item as output of energy, bodily activity and fatigue ability and postural demeanour with the latter noted to determine whether it is relaxed, poised, steady or variable, adaptive behaviour varies in terms of insight inquisitiveness originality, decisiveness and initiative language is characterized by individual differences in articulation flow of speech inflections, inhibitions, conversational support and expressiveness. Personal social behaviour reflects variations in emotional vitality motivation reaction to success failure and fatigue reaction to novelty and surprise and sense of humour.

(g) Limit of Growth and Old Age

The upper limit of physical growth or performance can be determined with considerable precision as in height or speed of running but little is known concerning maximum mental development or performance. It may be that quantitative growth of intelligence continues until 10 or 19 years or even later although qualitative and functional development of intelligence in terms vocabulary, information and insight or power in contrast to speed of reaction probably continues well beyond the age of 20. In term of physical and psychological development adulthood is reached soon after the age of 20 followed by a few years at the peaks of physical efficiency and then some physical deterioration actually beginning as early as the late 20's as is well known in the atheletic sports of physical maturity and physiological equilibrium are lost in part only a few years after attainment. Fortunately the relatively early deterioration of the anatomical and physiological functions may be offset by creative imagination, enriched experience and good judgement thus permitting the intellect to operate In a socially effective manner changes in test performance of a quantitative sort during maturity and old age may be offset by qualitative aspects of intellectual performance. It is well known that disease may produce marked changes in behaviour and even disintegration of personality.

DIAGNOSIS AND PROGNOSIS

Interest in the development diagnosis and causation come later than the investigations limited to determination the growth of norms or sequences. A common error in identifying causation in failure or to recognize the combined effects of two or more casual factors that are interrelated functionally as illustrated by the differently or separating the influence of nature from nature on achievement as casual factor that effects growth, and development includes race, age, sex, heredity parental conditions of birth, order, maternal age at pregnancy; nutritional factors, health factors disease and infections, seasonal conditional atmosphere conditions temperature humidity and pressure national, racial culture socio-economic status, educational agencies, social pressure, family and neighbourhood acquaintances and friends intelligence, knowledge, experience, exercise and training, interest and motivation and emotional adjustments.

The factor which affecting physical and mental growth suggest the difficulties of developmental progresses and prediction. Prediction in such area as constancy of I.Q., height, time of maturity and age at which growth will cease is possible. Only to the extent that valid technique and instrument of measurement are available, that early development provides a stable base from which subsequent proceeds, and that later development is affected by the same casual factors as operated in the earlier stages of growth. It is much simpler to predict in the area of physical growth and performance than in the field of mentally and personality development.

NEEDED RESEARCH

While available sources have enumerated detailed series of problems in child development that touch the interests of education, psychology and sociology, only a selected list of major problems for genetic investigation can be presented.

1. Increased observation of development and behaviour changes in relation to classroom activities, nursery school, play ground, camp and even adult behaviour.

2. In addition to growth investigation of individual and of relatively broad sample, study of developmental aspects of homogeneous groups and even adult behaviour.
3. Developmental study of experimental modification or alteration of behaviour.
4. Invention of improved instruments suitable for measuring mental development in the late teens and early twenties.
5. Further emphasis on developmental studies that seek to secure a reasonable picture of the "total child" for example to identify interrelationship between mental, physical and social emotional factors.
6. A complete description of how individual children acquire certain social attitude, ideals, interests and modes of behaviour.
7. Comparative sociological studies of children growing up under clearly defined social levels and backgrounds of different types.
8. Evaluation of the effectiveness of social and institutional programmes for child welfare in terms of wholesome development of children.
9. Appraisal of the effects of periods of depression and war on the development of children.

CONCLUDING STATEMENT

The interest of genetic research has now extended for beyond the early emphasis on physical and anatomical growth to mental, social and personality development and also includes study of casual factors as well as growth norms and developmental sequence. The scope of generic research for human individuals includes growth and developmental processes from conception to senescence.

EXERCISES

1. What do you mean by Genetic Research? Enumerate the purpose and importance of Genetic Research in Education.
2. Distinguish among Historical, Case study and Genetic method of research though all these methods are based on time sense approach.
3. "Genetic Researches employ both the research approaches: longitudinal and cross-sectional". Comment on this statement.
4. Enumerate the steps of Genetic method, which are used for conducting such study.
5. Describe the design of Genetic method and illustrate your answer with examples.
6. "Genetic researches concern with growth and development, therefore it requires both quantitative and qualitative analysis and interpretation." Elaborate this statement.
7. "Genetic research employs diagnostic and prognostic functions". Indicate the limitations of Genetic method research in the field of Education and enumerate some problems of Genetic research in Education.

Chapter 12

Design of Experiments

Experimental method is the most sophisticated way of research, particularly in sciences. In this way we study some variables by controlling some variables affecting the previous one. When certain variables can be controlled or manipulated directly in research problem by the investigator, the research procedure is often described as an experiment.

Thus, in an experiment we observe and measure the effect of treatment given to few variables by controlling other variables affecting our observations. The term "treatment" refers to a particular experimental condition. The material to which the treatment is applied and on which the variable under study is measured, is known as experimental unit. Since all variables cannot be controlled, it may cause the error in our observations. It is the experimental error. The whole experiment is conducted according to some plan which is called the design of experiment or experimental design.

Thus, an experimental design is a plan or strategy of investigation conceived so as to solve the research problem.

NEEDS AND PURPOSE OF EXPERIMENTAL DESIGN

Generally in an experiment we take observation and infer that the hypothesized relation exists on the basis of the observation taken, but it is obvious that we can not rely on this inference. It is due to the numerous variables which are affecting our experiment and which we have not controlled. Thus in the inference drawn by observation, the influences of these uncontrolled variables will also be included and we firmly can't say that the inference is due to 'treatment given', i.e. 'hypothesis made' or by some another factor. So, experimental design is the need for precision of our experiment. Precision means the degree to which extent we can rely on our observations and inferences due to treatment given. This precision depends upon the success with which the affecting variables have been controlled. The absolute precision, of course, is not possible.

Moreover, we want our inferences as valid, objective, accurate and economically as possible.

For all these causes an adequately planned and executed design help greatly in permitting us to rely on and to obtain both our observations and inferences. Mainly an experimental design serves two purposes (*i*) to provide answers to research questions and (*ii*) to control the variance due to various factors.

IMPORTANCE OF EXPERIMENTAL DESIGNS

Without a design, research study is just like the building construction without any plan or map. The design enables us to answer research questions as validly, objectively, precisely and economically as possible.

An experimental design sets up a framework for adequate tests of the relations among variables. Design tells us in a sense “what observations to make”, “how to make them”, and how to analyze the quantitative representations of the observations. Strictly speaking, design does not tell us precisely what to do, but rather “suggests” the directions of observations making and analysis. A design suggests which variables are active and which are assigned. We can then act to manipulate the active variables and to control the assigned variables.

A design also suggests, what type of statistical analysis to use and what may be the inferences by a particular technique applied.

The results obtained in a study dealing with human behaviour can never be considered absolutely accurate due to numerous variables. A design tells us “how far we have been able to control the experimental errors”. Most technical function of an experimental design is to control the error variances.

THE NEED FOR PRECISION

The precision of any experiment may be defined as the degree to which the observed differences in results, from group to group are due to the only differences which have been deliberately introduced into ‘treatments the precision of the experiment” will then depend upon the success with which all factors which might otherwise affect the result other than the deliberate variations in “treatment” have been controlled or equalized from group to group and upon the extent to which the criterion measures really measure the things which they are interested to measure.

Absolute precision is, of course, impossible, in other words it is always possible that any observed difference in results is due not to the treatment differences but to uncontrolled and unmeasured variations in factors extraneous to the purpose of the experiment. It is impossible to determine the magnitude and direction of these errors, we only can calculate or determine the possibility that the errors arising from certain sources will exceed a given magnitude and estimate the maximum error that it is reasonable to suppose might arise from these sources.

THE ESSENTIAL CHARACTERISTICS OF A GOOD EXPERIMENTAL DESIGN

The essential characteristics of a good experimental design may be summarized as follows:

1. It will ensure that the observed treatment effects are unbiased estimates of the true effects.
2. It will permit a quantitative description of the observed treatment effects regarded as estimates of the “true” effects. It will ensure that the observed treatment effects will have whatever degree of precision is required by the broader purpose of the experiment.
3. It will make possible an objective test of a specified hypothesis concerning the true effects, that is, it will permit the computation of the relative frequency with which the observed discrepancy between observation and hypothesis would be exceeded if the hypotheses were true.
4. It will be efficient, that is, it will satisfy these requirements at the minimum “cost” broadly conceived.

These are not only essential characteristics of a good experiment. The usefulness or worthwhileness of an experimental is primarily depend upon many other factors.

The important decisions to be made in planning the experiment are considered with:

1. The definition of the “treatments.”

2. The selection or exact definition of the population to be investigated.
3. The selection of a criterion.
4. The identification of the factors to be controlled and the level or levels at which each is to be controlled.
5. The final restatement of the problem, and
6. The selection of a specific experimental design.

These decisions are independent. A decision made a particular stage in the planning may require modifications in previous tentative decisions, which may in turn affect other previous decisions etc. The selection of the experimental design is usually the last step taken, but as already noted, even it may suggest desirable modifications in other decisions previously made.

VARIOUS TYPES OF ERRORS

Generally in an experimental study errors may be of two kinds: (1) Chance error and (2) Systematic error.

1. Chance Error: This error is due to the individual differences, e.g., if we are studying the superiority of programmed method over traditional method, then the differences in intelligence, learning ability, socio-economic status, established habit of study, etc. may affect our study.

In chance error two categories may be according to the sources of errors.

(*a*) **Sampling Error:** The error is due to the differences within the sample chosen for study is known as sampling error, e.g., in the above study habit of study, intelligence etc.

(*b*) **Measurement Error:** It is due to inability of measuring instruments to produce accurate results.

2. Systematic Error: Inspite of precautions taken, other factors than those involved in study, may affect our experiment during study. It causes results to vary in a particular direction. Systematic error causes bias in study and it is far more likely to catch the researcher by surprise than does chance error, e.g., in the above study the differences in circumstances attending the administration of methods, poor or well ventilation of classroom, teacher's performance etc. A rather famous source of systematic error in research studies is the "Hawthorne effect". Whenever a new method or treatment is studied the persons, using it, try to prove it better, no matter which is actually superior. Generally the researcher wants to prove his hypothesis this way or that way. This kind of effect cannot be controlled completely.

Every researcher tries to control these errors through experimental designs. Kerlinger has pointed out that a researcher attempts in three ways for error variance control.

1. Maximizing the Variance of Desired Variables

The experimenter's most obvious concern is to maximize the experimental variance. It simply refers to the variance presumably introduced into dependent variable by the independent variables being manipulated or controlled. It is variance of the independent variables of the substantive hypothesis. If the independent variable does not vary substantially, there is little chance of separating its effect from the total variance of the dependent variable, so much of which is often due to chance. It is necessary to give the independent variables a chance to show their variances, to separate themselves from total variance which is a composite of variances due to various variables. Remembering this Maximincon Principle we can write a research percept as – design, plan and conduct research so that the experimental conditions are as different as possible.

2. Controlling the Variance of Extraneous Variables

It means that the influences of independent variables extraneous to the purposes of study are minimized, or isolated. In other words the variance of such undesired variables is in effect reduced to zero or near zero. It is done in the following ways:

(*a*) To eliminate the variance as variable e.g. if we are studying achievement and racial membership is a possible contributing factor to the variance of achievement, it can be eliminated by using only members of one race.

(*b*) Second way is through randomization. If we do randomization then the experimental groups can be considered statistically equal in all possible ways. Group can be unequal by chance, but the probability of their being equal is much greater, with proper randomization, than the probability of their not being equal.

(*c*) Third way is to build it right into the design as an independent variable, e.g., sex was to be controlled in any experiment and it was not possible to assign subjects to groups at random. One could add another independent variable sex, to the design.

(*d*) Fourth is to match the subjects. The basic principle behind it is to split a variable into two or more parts and randomize within each level.

3. Minimizing the Error or Random Variance

Error variance is the variability of measures generated by random fluctuations whose basic characteristics is that they are selfcompensating varying this way or that way. Random errors tend to balance each other but the error variance is unpredictable, which is due to the factors associated with individual differences, variation of responses from trial to trial. So we try to reduce the errors of measurement through controlled conditions and by increasing reliability of measures. Reason to reduce error variance is to give systematic variances a chance to show their significance if they are significant.

The sampling error is reduced by controlling extraneous variables and applying the Maximinicon Principle.

The error of measurement controlled by minimizing the error variances and using reliable instruments.

The systematic error may be reduced with proper care by investigator to some extent.

The degree of error to which we were able to eliminate or control depend upon the experimental design used. These experimental designs are based on some principles.

Each design has its own assumptions, lay-out and technique of analysis.

BASIC PRINCIPLES OF EXPERIMENTAL DESIGN

The three principles of experimental design namely the indispensability of replication and randomisation, and the desirability of local control are developed by R.A. Fisher. From these the modern experimental designs have been evolved.

1. Randomization

The principle of randomization, as advocated by Fisher, is essential for a valid estimate of the experimental error and also to minimise bias in results. Cochran and Cox stated:

"Randomization is analogous to insurance in that it is a precaution against disturbances that may or may not occur, and that may or may not be serious if they do occur."

Also, designs we frequently use analysis of variance which holds the assumption of independence of variances, randomisation is a device to achieve this independence of variances, randomisation is a device to achieve this independence of errors. Randomisation by itself is not sufficient for the validity of the experiment. It only forms the basis for validity.

Randomization may be done by any technique by lottery or Fisher bowl technique or random number tables.

2. Replication

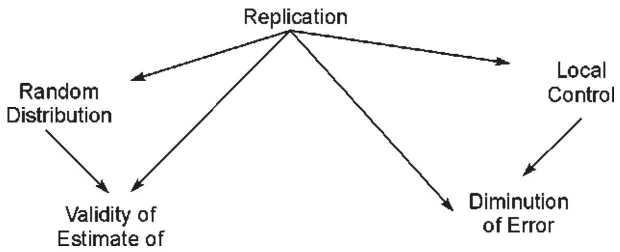
A treatment is repeated a number of times in order to obtain a more reliable estimate than is possible from a single observation. It is apparent from Fisher's diagram that the function of replication is two-fold: (1) along with randomisatin, it provides an estimate of the error to which comparisons are subjected, and (2) alongwith local control it reduces the experimental error. The most effective way to increase the precision of an experiment is to repeat the experiment.

Since $S.E_M = \sigma / \sqrt{n}$ or Standard Error of Mean

Standard error ($S.E_M$) decreases when N, the size of sample increases. But replication beyond the limit may be impractical because it also depends on experimental unit, time, cost, experimenter's ability, etc. Replication broadens the scope of experiment.

3. Local Control

The third principle is called local or error control. As already mentioned replication with local control reduces the experimental error. In simplest case, experimental units are divided into homogenous groups. The variation among these groups is eliminated from the error and thereby efficiency is increased. The choice of size and shape of experimental units, environmental conditions etc. have also some effect on experiment, causing errors. It may be controlled by using analysis of co-variance also.



Fisher Diagram

Local control helps in controlling the systematic error or general factors or say "*G*" error, Randomization controls the sampling error or "*S*" error and also a little "*G*" error replication, mainly controls the variations in treatment effects from replication to replication due neither to "*S*" nor "*G*" type of errors. Let us call it "*R*" error. Measurement error is controlled by replication. Replication with randomisation would be able to control all the three errors and with local control, the "*G*" error and measurement error. So replication is a very important principle.

TYPES OF BASIC EXPERIMENTAL DESIGNS

These basic principles are applied to all experimental designs, therefore, these designs are also known as Basic Experimental Designs. Now let us discuss various experimental designs which are being summarized by E.F. Lindquist as follows:

1. Simple Random Design,
2. Treatment X Level Design,
3. Subject X Treatment Design,
4. Random Replication Design,
5. Group Within Treatment Design, and
6. Factorial Design.

E.F. Lindquist (1956) has given these six basic experimental designs. These are known as basic designs because, their focus is to eliminate three basic types of errors: Type '*S*' erros, Type '*R*' errors and Type '*G*' errors.

Type '*S*' Errors: That part of an observed treatment effect which is due solely to the assignment of subjects to treatment groups is called as a Type '*S*' errors.

Type '*R*' Errors: Variations in treatment effects from replication to replication, due neither to Type '*S*' nor Type '*G*' errors, but genuinely characteristics of the individual replications or sub-populations are referred to as Type '*R*' errors.

Type '*G*' Errors: Are those due to the operation of extraneous factors which tend to have the same effect on all members of any given treatment groups, but different effects on different treatment groups in any simple replication.

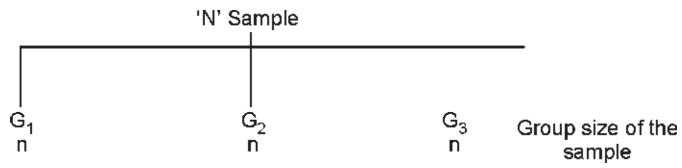
Lindquist has developed these six models of basic experimental designs which are oriented to control the effect of these three basic types of errors. The first three models of basic designs concentrate on type '*S*' error only and do not consider the effect of remaining two types of errors. The third design attempt to eliminate the influence of Type '*S*' and '*R*' errors. The fourth design tries to eliminate the confounding or contamination effect. The last design attempts to control the effect of all three basic types of errors. The description and model of these designs have been given in the following paras:

1. Simple Random Design

Simple randomized designs are those in which each treatment is independently administered to different sample of subjects all samples are independently drawn at random from the same parent population. These selected subjects are divided randomly into desired number of treatments and these groups were assigned to the treatments randomly so the randomization is done at every stage of experimentation. This randomization is done because the main focus of this design to eliminate *S*-error. This design is based on simple random sampling technique.

Layout of Design

Subjects are drawn randomly from population. These are divided into three groups randomly and assigned to three treatments randomly.



The three groups are assigned randomly to the treatments.

Treatments

A_1	A_2	A_3	
X_1	Y_1	Z_1	
X_2	Y_2	Z_2	Scores on criterion test
X_3	Y_3	Z_3	
–	–	–	
–	–	–	
–	–	–	
X_n	Y_n	Z_n	

A random sample is selected from the population. The sample N is divided into 3 groups randomly and each group is assigned to these different methods randomly. After this experiment criterion test is administered to all in the groups and then we get three sets scores.

Treatment or Analysis of Data: Analysis of variance technique is used for calculating *SSt i SSb*, and SSw and we prepare analysis table.

Analysis Variance Table

Source	*df.*	*SS*	*MS*	*F*
Between	K–1	SSb	$MSb = \frac{SSb}{K-1}$	$F = \frac{MSb}{MSw}$
Within	N–K	SSw	$MSw = \frac{SSw}{N-K}$	df. (K–1), (N–K)
Total	N–1	SST		

One way analysis of variance technique can be used to obtain the '*F*' value. If *F* is significant '*t*' test is followed to locate difference among the methods available, if the same criterion test would be administered before the treatment. The more precise result may be obtained with the help of pretest. It eliminates the following errors too:

1. It will give the initial learning of the group.
2. By this we can eliminate '*S* error too.

Advantages

The following are the main advantages of this design:.

1. It allows to study the treatment effects of the experimental variable.
2. It attempts to eliminate the '*S*' error through randomization.
3. Simple one way analysis of variance is applied for studying the main effect of treatments.
4. Effect of more than two treatments can be studied simultaneously.
5. It is very simple and easy experimental design.

Disadvantage

The following are the limitations of this design:

1. Though it attempts to eliminate '*S*' error, but we can not ensure that *S*-error is completely minimized.
2. Only the main effect of one variable can be studied.
3. It concentrates only to *S* error: other basic type of errors Le., '*G*'error and '*R*'errors are not considered.
4. This design is not applicable in educational research, because no principal or parent or teacher will allow to select subjects randomly and to keep in experimental and controlled situations, and
5. Neither the subjects will cooperate.

Suggestions

The following precautions, may be taken in using this design:

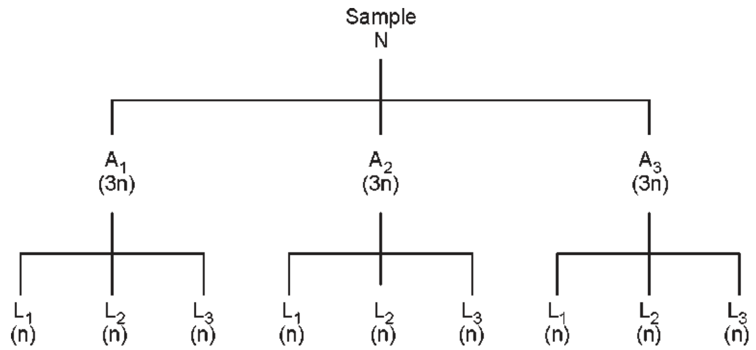
1. Randomization should be done rigorously at every step.
2. Pre-test and post-test should be administered for analysing the effect of treatment and analysis of covariance technique should be employed for analysing the data, so that net gain may be tested and more precise results may be obtained.

2. Levels X Treatments Design

This design is a direct improvement over simple random design in the sense that in this design '*S*'error is minimized and we guarantee that sampling error has been controlled. It provides a direct control for intra subjects variations. The main focus of design is to control '*S*' error. It does not consider '*G*' and '*R*' errors. In this design stratified sampling technique is used. It means the population is classified on the basis of some relevant criterion. Thus, the strata are formed on the basis of criterion subjects from each stratum is assigned to each treatment and each treatment is assigned to every level of subject; these treatments should be assigned independently. The purpose of assigning treatment to each level of subjects is to eliminate the '*S*'error.

Layout of the Design

In this design levels are introduced only to equate the groups for studying in main effects. The 'N' size of sample is selected from the population. It is stratified into three levels. An equal number of subjects are taken from each level. The subjects of each level are assigned to each treatment as shown below:



Treatments

Levels	A_1	A_2	A_3
L_1	n	n	n
Criterion			
L_2	n	n	n
Intelligence			
L_3	n	n	n
Experimental Variables is administered.			
Criterion Test Scores	X_1	Y_1	Z_1
	X_2	Y_2	Z_2
	X_3	Y_3	Z_3
	–	–	–
	–	–	–
	X_n	Yn	Z_n
Total	$\sum x$	$\sum y$	$\sum z = \sum i$

Analysis of Data

Simple one way analysis of variance technique may be used for analysis. The main effect of treatment is analyzed as follows:

Analysis Variance Table

Source	*df.*	*SS*	*MS*	*F*
Between	$(K–1)$	SSb	MSb	$F = \dfrac{MSb}{MSw}$
Within	$N–K$	SSw	MSw	$df \rightarrow (K–1), (N–K)$
Total	$N–1$	SSt		

The significance of F value with $(K–1)$, $(N–K)$ degrees of freedom is ascertained with the help of Table and interpretation of the result is done. The conclusions are drawn about effectiveness of treatments. There are three treatments, which therefore, 't', must be followed if 'F' is significant.

Advantages

The following are the advantages of this design:

1. It is the direct improvement over simple randomised design.
2. It eliminates 'S' error by selecting subjects from each level.
3. This design yields relatively more dependable and accurate results than earlier one.

Disadvantages

The following are the limitations of this design:

1. This design has less difference than the simple randomized design because type '*G*' and '*R*' errors are not considered in this design.
2. The levels are formed only on the basis of one criterion. Thus, the groups are equated quantitatively but not qualitatively. So the intra subjects variation is not controlled.
3. It is a difficult job to consider the criterion for stratifying the sample. In an investigation a number of criterion seem to be equally relevant in that situation, it is difficult for investigator to choose the most relevant criterion for stratification.
4. This design generally confused with the factorial design.
5. The design is not practicable in teaching-learning situation.

Suggestions

The following precautions should be taken in using the design:

1. Other improved designs may be used.
2. Pre-test and post -test should be administered and we should prefer analysis of covariance technique.
3. The levels and treatments effect may be considered for obtaining accurate results

3. Treatments X Subjects Design

Treatment X Subjects designs are those in which all treatments are successively given to the same subjects. The choice of this design is conditioned by the fact that treatments are such that all can be administered in a sequence to the same subjects and the effects of each treatment are influenced by the fact that other treatments have previously been administered to the same subjects. Thus, it is possible to eliminate entirely the influence of inter-subjects differences upon the treatments effect. Since exactly the same subjects are assigned in all the treatments, no part of the difference in the treatment means can be attributed to differences among subjects. This design eliminates entirely the 'S'error. Although the chance error of measurement might still favour one treatment or the other inter subjects differences are usually a major source of error in educational and psychological experiments. This design is more precise then simple randomized design and treatments X Levels design.

Model or Layout of Design

The same subjects are assigned to each treatment successively as shown below:

Treatments

	T_1	T_2	T_3
Subjects	A	B	C
	C	A	B
	B	C	A
	–	–	–
Treatment	M_1	M_2	M_3 Main effects

Analysis of Data

The analysis of variance technique is used to analyze the main effects of treatment.

Analysis Variance Table

Source	*df.*	*S S*	*MS*	*F*
Treatment	$a–1$	SS_A	MS_A	$F = \frac{MS_A}{MS_{AS}}$
Subjects S	$s–a$	SS_S	MSA	
Treatment & Subject As	$(a–1)(s–1)$	SS_{AS}	MS_{AS}	$df(a–1), (S–1)$
Total	$N–1$	SSr		

The significance of F is examined for the result.

Advantages

The following are the main advantages of this design:

1. The treatments *X* Subjects design is usually for more precise than the simple randomized or treatments *X* levels design, granting that a fairly reliable criterion measure is employed.
2. This design is a useful design so far concerned with the sampling error. It eliminates entirely the '*S*' error.

Disadvantages

The following are the limitations of this design:

1. The effect of given treatment is usually not independent or unaffected by the previous administration of another treatment to the same subjects.
2. The use of this design usually requires that equivalent forms of a criterion test be available, so as to eliminate or render negligible the practice effect of taking the same test more than once.
3. The design does not take into consideration type '*G*' and type '*R*' errors.
4. The same subjects are assigned to the same treatments, it causes, '*R*' errors because the subjects are the replicates. It means that intervening variables may influence the treatment effect.

4. Random Replication Design

Random replication designs are those in which the same basic experiment (or simple-randomized type) is "replicated" (repeated) with independent samples of subjects. The purpose of random replication design is to control type *S* error and type *R* error. The experiment is designed in different types of institutions by using simple random design. The subjects for the various "replication" may be drawn from the same population or the experiment as a whole may be concerned with a population or the experiment of a large number of sub-population and the subjects for each replication may be drawn at random from a different and randomly selected sub-population.

Random replication design in general differs from simple random design. The experiment is repeated by selecting random sample from different types of institutions. It means the simple random replication design is the repetition of the experiment on sub- population. Each replication is performed for a different subpopulation selected at random from the total population.

The only errors which are not taken into consideration in test of significance employ for the design are those which have not been randomized independently in each replication or which are constant for all replication.

Layout of Design

The following is the layout of the replication design for two treatments.

	A_1	A_2	*Difference*
Replication 1	MA_1R_1	MA_2R_1	$D_1 = MA_1R_1 - MA_2R_1$
Replication 2	MA_1R_2	MA_2R_2	D_2
Replication 3	MA_1R_3	MA_2R_3	D_3
Replication 4	MA_1R_4	MA_2R_4	D_4
Replication 5	MA_1R_5	MA_2R_5	D_5
Mean	MA_1	MA_2	$D = MA_1 - MA_2$

$$t = \frac{MA_1 - MA_{A2}}{es'd\sigma D}$$

Layout

The following is the layout of replication design for three treatments. Three schools are replication.

Treatments

		T_1	T_2	T_3
Institutions	S_1	n	n	n
	S_2	n	n	n
	S_3	n	n	n
		–	–	–
		M_1	M_2	M_3

The two way analysis of variance technique is used to analyse the data. The following is the statistical model.

Treatments

Source	*df.*	*SS*	*MS*	*F*
Treatment A	a–1	SS_A	MS_A	For treatment effect
Schools	$i = k$	SS_i	MS_i	$F_A = \frac{MS_a}{MSai}$
Replication				For school effect
X School	(i–k) (a–1)	SS_{ai}	MS_{ai}	$F_i = \frac{MS_i}{MSai}$ df (i–1), (a–1) (i–K)
Total	N–1	SSr		

The main effect of treatment is tested through F_A value.

It also studies the effect of institutions and then this design becomes factorial design. The significance of values F is ascertained for interpreting the results.

Advantages

The following are the advantages of the design:

1. It takes into consideration all the three type G, type S and type R errors.
2. Since type S and type R errors may be relatively very important in many educational and psychology experiment, it is apparent that the random replication design represents a very marked improvement over the earlier designs.
3. Effect of institutions may also be studied simultaneously.
4. It is most frequently used in educational studies.

Limitations

The following are the limitations of this design:

The only G-errors which are not taken into consideration in this test are those which have not been randomized independently in each replication or 'G' are constant for all replications.

Types of Effects in Factorial Design

The difference between Treatments X levels design and factorial design is that the interest conceivable might be greater in the interaction effect that in the main effect of the treatments, and two or more experimental variables may be studied in a single experiment.

The Treatment X levels design has the focus to study the main effect of treatments whereas factorial design attempts to study the interaction effect of two or more experimental variables. These effects have been illustrated here:

Treatments A

Levels B	B_1	M_{11}	M_{12}	MB_1
	B_2	M_{21}	M_{22}	MB_2
		MA_1	MA_2	

This example has two main effects, two simple effects and two interaction.

Main Effect of Treatment $A = (MA_1 - MA_2) = D_1$

Main Effect of levels $B = (MB_1 - MB_2) = D_2$

Simple Effect of Treatment at B_1 level = $(M_{12} - M_{12}) = d_1$

Simple Effect of Treatment at B_2 level = $(M_{21} - M_{22}) = d_2$

Interaction Effect = $(d_1 - d_2)$

Simple Effect of level at A_1 Treatment = $(M_{11} - M_{21}) = d_3$

Simple Effect of level at A_2 Treatment = $(M_{12} - M_{22}) = d_4$

Interaction Effect = $(d_3 - d_4)$

Thus, the interaction effect is the difference of simple effects or it is joint effect of two or more variables.

5. Factorial Designs

Factorial designs are those in which there are two or more cross classification of treatments (variables), or in which the main effects and interaction effects of two or more variables are simultaneously studied. It is a design in which two or more experimental variables may be studied simultaneously in the same experiment or in which comparison may be made simultaneously within each of number of cross-classification of treatments.

This design is an improvement over the earlier designs in the following ways:

1. In this design the main effect of two or more variables is studied simultaneously by conducting an experiment whereas in earlier design we study the main effect of one variable only.
2. In this design joint effect or interaction effect of two and more variables is studied whereas the question of interaction in earlier designs does not arise.

Layout of the Factorial Design: 3 × 2 × 2 factorial design.

Treatments A

Personality B	*Sex C*	A_1	A_2	A_3
$B1$ Extrovert	C_1 Boys	*n*	*n*	*n*
	C_2 Girls	*n*	*n*	*n*
$B2$ Introvert	C_1 Boys	*n*	*n*	*n*
	C_2 Girls	*n*	*n*	*n*

In each cell n subjects have been assigned. After the experiment the same criterion test is administered to each group. The obtained scores are analysed in the following manner.

Statistical Model

The following statistical model is used for three variables interaction effect.

The significance of F value is ascertained for interpreting the results and 't' test may be followed for specification of results.

Factorial design and method of analysis are appropriate to it which is due to R.A. Fisher is considered to be the most important contribution to the experimental technique in the present time. The factorial design involves several factors or variables or treatment classification and the number of the subjects may differ from one level to another of the same factor. In this case the analysis is considered to be more complex for specification of the results the simple *t*-test must be followed when *F* is significant.

Comparison Between Factorial and Treatments X Treatments Levels Designs

When compared with treatments *X* levels design this design indicates that the treatments *X* levels and factorial designs have many features in common, and that, it is sometimes difficult to decide under which of this type a particular design should be classified. One variable or factor is introduced into the design basically to make possible a more precise estimate of main effect of the other factor and if the interaction effect is or only identical or secondary interest, the design may be clearly classified as a treatments *X* levels design.

In this case it is presumably known in advance that the control variable is related to the criterion variable. Hence there would be no point in testing the significance of the main effect of the control factor or variable. On the other hand, if the second variable is introduced basically in order to study and evaluate its main effect along with that of first factor and to study the interaction effect between the two then the design is clearly a factorial design. In this case it is not knowing in advance whether the second factor is related to criterion variable or not. Hence, the purpose of introducing second factor is not to increase the precision of the experiment, so far as the evaluation of first factor is concerned. It is some situations of the purpose of experiment are so mixed that one cannot readily decide how to classify the design. This is of little practical consequence so long as results are properly analyzed and interpreted, hence it is very essential on the part of researcher or experimenter to decide the design appropriately so that appropriate analysis can be done.

Analysis Variance Table

Source	*df*	*SS*	*MS*	*F*	*df*
A Treatment	$a–1$	SS_A	MS_A	$F_A = \frac{MS_A}{MS_w}$	$(a–1)$, diff.
B Variable	$b–1$	SS_B	MS_B	$F_B = \frac{MS_B}{MS_W}$	$(b–1)$, diff.
C Variable	$c–1$	SS_C	MS_C	$F_C = \frac{MS_C}{MS_W}$	$(c–1)$, diff.
$A \times B$	$(a–1)(b–1)$	SS_{AB}	MS_{AB}	$F_{AB} = \frac{MS_{AB}}{MS_W}$	$(a–1)(b–1)$, diff.
$A \times C$	$(a–1)(c–1)$	SS_{AC}	MS_{AC}	$F_{AC} = \frac{MS_{AC}}{MS_W}$	$(a–1)(c–1)$, diff.
$B \times C$	$(b–1)(c–1)$	SS_{BC}	MS_{BC}	$F_{BC} = \frac{MS_{BC}}{MS_W}$	$(b–1)(c–1)$, diff.
$A \times B \times C$	$(a–1)(b–1)(c–1)$	SS_{ABC}	MS_{ABC}	$F_{ABC} = \frac{MS_{ABC}}{MS_W}$	$(a–1)(b–1)(c–1)$, diff.
Between cells Within	$(abc–1)$ diff.	SS_B SS_W	MS_B MS_W		diff. = $(N–abc)$
Total		SS_T			

6. Group Within Treatment Design

Group within treatment designs are those in which the population to be investigated consists of a large number of finite groups and in which each treatment is administered to an independent random sample of intact group. When the purpose at an experiment is to establish generalizations about a population consisting of a large number of sub-population, this design is much less precise than other designs using the same number of subjects. But since it eliminates any possibility of contamination of one treatment by other. It is sometimes preferable to other design inspite of its lack of precision. The purpose is to study the main effect of treatment.

Treatments A

	A_1	A_2	A_3
1st Experiment	G_{11}	G_{12}	G_{13}
2nd Experiments	G_{21}	G_{22}	G_{23}
	M_1	M_2	

This design is most frequently used in education. There are three treatments which are administered in six groups of different institutions so that contamination of the treatment may not influence the main effect of the treatments. Two treatments should not be given in the same institutions. The data are analysed in the following manner:

When, $F_G = MS_G / MS_W$, is significant df– (G–a). (N–G)

Then, $F_A = MS_A / MS_G$) df – (a = 1), (G–a)

Analysis Variance Table

Source	*df.*	*S S*	*MS*	*F*
Treatment A Group within	a–1	SS_A	MS_A	$F_A = \frac{MS_A}{MS_W}$
Treatment G	G–a	SSG	MSG	$F_G = \frac{MS_G}{MS_W}$
Within Subjects	N–G	SSW	MSW	
Total	N–1	SST		

If F_G is not significant.

$$F_A = \frac{MS_A}{MS_W}\ df - (a-1),\ (N-G)$$

Then,

If F_A is significant 't' must be followed to specify the results.

In group within treatment design. group variation is tested at the analysis stage. Before testing main effect of treatment, significance of group variation (*SSG*) is to be tested: If group variation is significant then main effect of treatment is tested by dividing by mean group variation. If it is not then by mean subjects variation (*SSw*) as shown above.

Advantages

The following are the main advantages:

1. This design is highly applicable in educational experiments because in educational situation the more chances of more contamination effects are these because subjects are human beings.
2. Other experimental designs can control only basic type of errors but not the contamination effect. The contamination effect is eliminated by this design only.
3. In this design '*G*' -error has greater scope. This error can be eliminated by repeating the experiment or more over the group variation (*S*-error) is eliminated at analysis stage.

LATIN SQUARE DESIGNS

"The Simple Latin Square Experimental Design is one in which a different independent random sample of n subjects corresponds to each cell of the table." This type of design is known as a Simple Latin Square Design.

– E.F. Lindquist

In derives its name from an ancient puzzle, that of determining in how many different ways Latin letters may be arranged in a square table so that each letter appears once but only once in each row and each column. The following are the examples of Latin Square Designs:

A	*B*	*C*
C	*A*	*B*
B	*C*	*A*

B	*C*	*A*
C	*A*	*B*
A	*B*	*C*

There are two different ways of arranging the three letters *A, B, C.* It may be indicated 3 × 3 squares, it involves 12 different ways.

Example: Suppose that we wish in a single experiment to compare the effects on reading rate of three styles. (*A*), three size of type (*B*) and three widths of column (*C*). In a complete factorial design of this type, would require the printing of 27 different editions of the rate of reading test, each with a different combinations of size, style and widths of columns.

If we printed only nine editions, combining each style of type once with each size and only once with each width of column. We should then administer the nine editions simultaneously, each to one of nine different randomly selected groups of subjects. The main effect of styles would then be independent of the main effects of size and width, and similarly for the main effect of size or of width. This is a defective design unless one can assume that there are no interaction of the factors involved.

It is evident, then that there is no possibility of identifying or testing! individual interactions in the Latin Square. Also the use of ‘residual’ means square as an error term for testing main effects would be open to exactly the same objections as the use of a pooled error term in a complete design.

Confounding in Latin Square Designs

The comparison of overall treatment means in any classification would appear or would seem to be completely balanced with reference to the other factors. Actually the comparisons are truly balanced. Consider the 2 × 2 Latin Square.

	A_1	A_1	Column I	Column II
B_1	C_1	C_2	$A_1\ B_1\ C_1$	$B_1\ A_2\ C_2$
B_2	C_2	C_1	$A_1\ B_2\ C_2$	$A_2\ B_2\ C_1$

Hence the sum of squares for columns on which the estimate of the main effect of A will be based, depends on the difference between the sums of the means of the pairs of cells.

It is clear that any interaction of *A* and *C* or of *A* and *B* would also be equalized or counter balanced. The *AC* interaction effects are illustrated as follows:

		C		Column I	Column II
		*C*1	*C*2		
A	*A*1	+7	–7	+7	+7
	*A*2	–7	+7	$A_1C_1B_1$	$A_2C_2B_2$
				–7	–7
				$A_1C_1B_1$	$A_2C_2B_2$
				7 – 7 = 0	7 – 7 = 0

The effects would be completely confounding with the A effect in the column differences. The confounding means inextricably Intermingled. The full effect of these interaction would be included in the column difference as follows.

	C_1	C_2
B_1	+5	–5
B_2	–5	+5

Column I	Column II
+5	–5
$A_1C_1B_1$	$A_2B_2C_2$
+5	–5
$A_1A_2C_3$	$A_2B_2C_1$
+5+5 = 10	–5–5 = –10

	B_1	B_2
A_1	+4	–4
A_2	–4	+4

Treatments A_1 and A_2 were equally effective at each level of *B* or separately.

In general, then the *BC* interaction effect, but only this effect, is completely confounded with the *A* effect in the column difference. Similarly *AC* interaction effect is confounded with the B effect and the *AB* interaction effect is confounded with the *C* effect.

ANALYSIS OF VARIANCE FOR A LATIN SQUARE DESIGN

Suppose, for example, that one of the four subjects is tested each day at 1, 2, 3 and 4 '0' clock. The variation between the hours might be controlled by randomization that each treatment occurs not only once on each day arrangement of the treatments shown in the following 4 x 4 Latin Square. Design

4 × 4 Latin Square Design

Hours/days	*1*	*2*	*3*	*4*
1	*A*	*B*	*C*	*D*
2	*B*	*A*	*D*	*C*
3	*C*	*D*	*B*	*A*
4	*D*	*C*	*A*	*B*

After experimentation, the following observations corresponding to the cell entries are those shown as follows:

Observations Obtained with
4 × 4 Latin Square Design

Hours/days	*2*	*2*	*3*	*4*	Σ
1	4	3	8	2	17
2	6	1	2	4	13
3	2	4	3	1	10
4	3	2	2	3	10
Σ	15	10	15	10	50

The total sum of squares is based on the variations of the cell entries of this table-

Total = $4^2 + 3^2 + 8^2 + \quad 2^2 + 3^2 - (50^2/16) = 49.75$

The hour (column) sum of squares will be given by

Hour = $(15^2/4) + (10^2/4) + (15^2/4) + (10^2/4) + (50^2/16) = 6.25$

The day (row) sum of squares will be

Day = $(17^2/4) + (13^2/4) + (10^2/4) + (10^2/4) + (50^2/16) = 8.25$

The treatment sums are obtained by adding the cell entries for each treatment. Thus, we have-

$A = 4 + 1 + 1 + 2 = 8$

$B = 3 + 6 + 3 + 3 = 15$

$C = 8 + 4 + 2 + 2 = 16$

$D = 2 + 2 + 3 + 4 = 11$

Then the treatment sum of squares will be equal to

Treatment = $(8^2/4) + (15^2/4) + (16^2/4) + (11^2/4) + (50^2/16) = 10.25$

We subtract the sum of squares for days (rows), hours (columns) and treatments, each with 3 d.f., from the total sum of squares. We obtain a residual sum of squares with 6 df. This residual sum of squares is the error sum of squares for the Latin square design. Thus

Errors = Total – (row + column + treatment)

= 49.75 – (6.25 + 8.25 + 10.25) = 25.00

These results have been summarized to obtain the significance of treatment effects in the Latin square design.

Analysis Variance Table

Source of value	*df*	*Sum of Square*	*Mean Square*	*F*
Treatment	3	10.25	3.42	0.82
Days	3	8.25	2.75	
Hours	3	6.25	2.08	
Error	6	25.00	4.16	
Total	15	49.75		

The *F* value was obtained 0.82 with d.f. (3,6) it was not significant at any level of significance. The null hypothesis was not rejected. It may be interpreted that all the four treatments are equally effective.

DISADVANTAGES OF LATIN SQUARE DESIGN

It has the following limitations:

1. In this design the main effect of the treatments can only be studied. The interaction effects of the treatments can not be identified or it is counter balanced.
2. The main effect of the treatment design is great influenced by the confounding of the factors included in the experiment. The simple Latin Square Design has the little use in education and psychology.
3. The type of *G* errors are completely randomized with reference to cells.
4. It assumes that both intrinsic and extrinsic interaction may be negligible.

SOME COMMON ERRORS IN EXPERIMENTAL DESIGNS

Norton and E.F. Lindquist (1951) have pointed out some common errors in experimental designs

1. There is a usual failure to comply with the basic conditions of control.
2. It is generally overlooked the confounding or contamination effect on the criterion or dependent variable.
3. The criterion test is not validated in experimental settings, it is a common error.
4. There is a failure to take into account the assumptions underlying the procedure of experimentation.

5. In the analysis or treatment of data is inappropriate and inadequate statistical techniques are employed. The assumptions of the statistics are not observed.
6. The population of the study is not defined carefully to which the results are to be applied and generalized.
7. It is a common error that inappropriate and inadequate experimental designs are used to achieve the objectives of the study.
8. The researcher is not conscious enough regarding the intervening variables of the study which usually influence the criterion variable.

A researcher should attempt to minimize these common errors designing and conducting an experiment.

EXERCISES

1. Define the term 'Experiment'. Differentiate between Research Design and Experimental design.
2. Indicate the need of experimental designs in Education and Psychology. Distinguish between experimental methods and experimental designs.
3. Enumerate the essential characteristics of a good experimental design and purpose in research studies.
4. Describe the Basic Principles of Experimental Designs. Mention Basic types errors of experiment.
5. There are six Basic Experimental Designs according to E.F. Lindquist. Why these designs are known as Basic designs?
6. Differentiate between Levels X treatments designs and factorial designs and their uses in educational research studies.
7. "Group within Treatment Design is less precise design but more useful in educational studies". Justify this statement.
8. Describe the model, uses and disadvantages of Latin Square Design.