AN ASSESSMENT OF INTELLECTUAL DEVELOPMENT IN A GROUP OF BLACK MINEWORKERS.

A THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS IN PSYCHOLOGY,

B Y

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C O N T E N T S

CHAPTER THREE - SELECTION AND PLACEMENT OF BLACK MINING PERSONNEL IN THE SOUTH AFRICAN GOLD MINING INDUSTRY.

CHAPTER FOUR - THE EXPERIMENT.

PREFACE.

Opinions expressed in this text are those of the writer and not officially those of the Chamber of Mines of South Africa, Gold Fields of South Africa Limited or Doornfontein Gold Mining Company Limited.

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ABSTRACT.

The aim of this research is to investigate intellectual development of a group of Black mineworkers on a South African gold mine, in the light of their exposure to a technical industrial environment. The research was conducted within a Piagetian framework and attempts to establish:-

1. A conceptual profile which would highlight the subject's conceptual abilities in relation to job skill requirements.

2. An empirical analysis of combined Behavioural and Explanatory responses to support the hypothesis that experienced Black mineworkers should perform better on the diagnostic battery than novices: the main reason for this being the contention that conceptual development is facilitated by cognitive adaptation to the demands of a selectively different technological environment.

3. Whether the battery of Piagetian conservation tasks could be evaluated for use as conservation scales with sound statistical properties.

A random sample of fifty six Black mineworkers was realised and their performance indicated that:-

a) The concept of Force is not actively developed by mining.

b) There was no significant difference in the performance of Novice and Experienced subjects.

c) The diagnostic battery in its present form is inadequate and would have to undergo some relative modifications.

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d) Conceptual profiles showed that concept areas tapped were not developed past the stage of Concrete operations, and that in some instances subjects did not conserve concepts which are relevant to the occupation they were selected for on the Classification Test Battery.

e) Piagetian methodology could only be selectively applied to the mining industry for purposes of selection and placement.

f) Conservation scales were not realised because of anomalies found in the composition of sub-concepts in the battery.

INTRODUCTION.

A Commission of Inquiry into Labour Legislation was appointed by the State President of South Africa in June, 1977. The Commission's Chairman was Professor N.E. Wiehahn. In view of the importance of the South African mining industry in the contexts of (1) a primary industry, (2) a major employer and (3) a significant contributor to the country's gross national product, it was decided that because of the especially difficult posers the industry provides for labour relations, a separate inquiry be instituted. The Wiehahn Commission of Inquiry into Labour Relations, under the title of 'Industrial Relations in the Mining Industry', was tabled in May, 1979.

The implications of the Commission's recommendations for industrial relations in the mining industry are far reaching. Generally speaking, the Commission attempted to compile a set of recommendations which encompassed the establishment of a single integrated industrial relations system which maintained the preservation of industrial peace. The first principle recommendation of the Wiehahn Commission is one of 'freedom of association'. Briefly this implies full freedom of association, irrespective of race and status as migrants or commuters, with Unions deciding on criteria for membership. The Government responded to this proposal by legislating freedom of association to permanent residents only and the National Manpower Commission would advise it on exemptions.

The second important recommendation was abolition of statutory job reservation as the Mines and Works Act of 1956 makes provision for only Whites and Coloureds to become holders of blasting certificates (Section 12 (2)). Government accepted this proposal and legislated job reservation was to be phased out. These two recommendations pose a great challenge to the mining industry and the formation of a unitary industrial relations system. Black mineworkers are migrant labourers

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and as such are not accorded association rights at present.

According to the Wiehahn Commission (1979) the mining industry was organised on the basis of a small number of highly paid, skilled workers, predominantly White, in administrative, supervisory and other skilled occupations, while a large number of Blacks performed unskilled and semi-skilled work at a rate of pay which was higher than that of the agricultural sector and most industries but low compared to the remuneration of skilled White workers. The industry's labour history reflects the strains brought about by these conventions and the perceived threat, by Whites, to their dominance through the introduction of cheap Black labour. Government came to the rescue of the White mine worker. Unions were organised along craft lines to meet the requirements of the Closed Shop Agreement (1937). Through their constitutions these Unions entrenched a White only membership in order to protect themselves against efforts of employers to introduce Blacks who were prepared to work for low wages.

In 1979 the Chamber of Mines employed 407 570 Blacks on gold and coal mines under its jurisdiction (1). These Black mineworkers originate from various tribal and national areas in Southern Africa. The migrant labour system developed as a result of discriminatory legislation. The system has virtually become traditional for many Blacks who come to the mines from an impoverished, subsistence standard of living. The average duration of a contract Blacks come to the mines for is a year. Because of limited time spent working on the mines, the migrant system mitigates against the acquisition of significant skills by Black mineworkers. The Wiehahn Commission reports that in recent years efforts have been made to 'stabilize' migrant workers. The year-end Review of the Chamber of Mines (1979) stated decreased labour turnover was evidence that Blacks were becoming more career orientated (2).

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(1) Report of the Commission of Inquiry into Labour Legislation - part 6, paragraph 2.6, pp 7.

(2) Report of the Commission of Inquiry into Labour Legislation - part 6, paragraph 2.8, pp 8.

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In the light of the Wiehahn Commission's recommendations and subsequent legislation the mining industry stands on the brink of a significant departure from its traditional labour practices. The single most important aspect which faces the industry is the possible incorporation of Blacks into more skilled occupations, although present employer - Union agreements militates against this. However, Government is committed to dismantling job reservation. A new labour dispensation for the mining industry implies a uniformity in general labour practices, one of them being selection and placement. At present, the Chamber of Mines sanctions the use of an aptitude instrument known as the Classification Test Battery for purpose of selection and placement, of Black mining personnel. The contentious issue remains - Why are Blacks selected for 'trainability' on the strength of their performance on an aptitude battery, while Whites are selected for specific careers based on performance on achievement tests?

The utilization of a Piagetian programme for the assessment of concept levels among Black mineworkers was considered pertinent and objective, as Piagetian methodology is applicable across cultural boundaries. The research aims at breaking into the conceptual system of a specific labour force and examining the impact of exposure to a mining environment in terms of conceptual growth.

The concept of mining may be regarded as one of scientific Western man. Mining in South Africa incorporates few cultural milieu - one of the few being the development of Fanakalo as a means of communication. Adaptability is determined by dynamic equilibrating functions which are interrelated. The organism possesses an epigenetic programme, predetermined by phylogeny which unfolds sequentially in response to interplay with the environment. Unfolding is unidirectional - moving the organism from a state of sensori-motor assimilations to the achievement of formal reasoning, the highest form of which is mathematics.

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Formal reasoning enables the organism to internalise operations in the form of abstractions.

Inherent in this research is the notion the African mineworker originates from an environment which is selectively different in its conceptual demands, by virtue of culture, to that experienced in a Western society. The novice Black mineworker is faced with a tremendous challenge to adjust to Western society when he reports for work on the mines - an adaptation which determines his future as a productive worker and wage earner.

This study attempts to state, with a degree of confidence, that superior performance on a battery of Piagetian conservation tasks by experienced Black miners, when compared to novices, may be attributed to conceptual development resulting from an equilibrating drive to adapt to a technical environment.

Furthermore, in anticipation of projected changes in labour laws affecting the mining industry, as recommended by the Wiehahn Commission (1979), the study makes an assessment of the effectiveness of the instrument currently used for selection and placement. Thirdly, the research may be considered a feeler with regard to utilising Piagetian research methods for industrial training packages.

CHAPTER ONE.

JEAN PIAGET'S THEORY OF GENETIC EPISTEMOLOGY.

1. PIAGET'S THEORY OF GENETIC EPISTEMOLOGY.

1.1 A Question of Origins.

The phase 'genetic epistemology' was coined, not by Piaget, but by the American James Mark Baldwin in 1906. In fact an interest in the evolutionary nature of knowledge was most popular when Darwin's evolutionary theory was most influential. The term 'genetic epistemology' may be defined as the study of the origins of the various kinds of knowledge, beginning with their most elementary forms, tracing their development to later levels, up to and including scientific thought which is regarded by Piaget as the most sophisticated manifestation of knowledge. For Piaget, knowledge is not predetermined in the internal structures of the subject; it is a process of continuous construction. All knowledge involves an aspect of novel elaboration and the important problem for epistemology is the reconciliation of new material with novel items which are linked by necessary relationships as soon as they are elaborated at the level of formal operations and make objectivity possible on the level of reality.

Attempting a construction of non-preformed cognitive structures, the underlying concern is to return to the origins of knowledge, and then constitute a method capable of providing empirical tests. Traditional epistemology concerns itself with only the higher levels of knowledge. Genetic epistemology aims to investigate origins of various kinds of knowledge. The term 'genetic epistemology' implies the need to study origins; however, the study of origins should not eclipse that of the other phases of the continuous construction of knowledge. Piaget writes,

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> "On the contrary, the important lesson learnt from the study of origins is that there never are absolute beginnings. Either one needs to say that everything is a question of origins, including the construction of the most recent theories in contemporary science; or that such origins stretch back indefinitely, for the most elementary phases are themselves preceded by phases in some way organo-genetic".
> (Piaget, 1972, p. 15).

Instigating an inquiry of a genetic nature does not mean some phase is accorded the privileged position of 'absolute beginning'. Essentially it is to note the existence of a construction which is not clearly defined and to emphasise that in order to understand its causes and mechanisms, there should be an understanding of the greatest possible number of its phases. Piaget (1972) explains that by concentrating on the beginnings of knowledge in child psychology and biology, it should not be thought that a privileged significance be attributed to them; but rather that on the whole they seem to have escaped the attention of epistemologists.

Genetic epistemology includes the progress of all scientific knowledge, and is two dimensional:

1) the question of facts (the state of knowledge at a particular stage and the passage from one stage to the next).
2) a question of validity (evaluation of knowledge in terms of advance or regression, which is the formal structure of knowledge).

If one is to examine the as yet unresolved question of the origins of knowledge, two main streams of thought pervade:

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1) Empiricism, which rationalises the idea that all cognitive information has its source in external objects, so that the subject's actions are determined by what is outside him and are in effect reactions rather than actions.

2) The subject is endowed from the start with endogenous structures which it imposes on objects, as is maintained by the 'a priorism' or innatist philosophy.

Taking the variety of positions between these two there is a common postulate of accepted epistemologies, viz. the assumption that there exists at all levels a subject which is aware of its abilities in various degrees (be they merely the perception of objects); that there are objects which exist as such for the subject (even if they constitute 'phenomena'); and most significantly there are intermediaries (perceptions or concepts) which mediate between the subject and objects and vice-versa.

1.2 The Formation of knowledge.

It is Piaget's contention that psychogenetic analysis contradicts the Subject - Object - (Intermediaries) hypothesis, in that, knowledge does not arise from a self-conscious subject, nor from objects so constituted by and impressed on the subject. Knowledge arises at a point between subject and object and so involves both simultaneously. If, at the beginning, there exists neither a subject, object nor invariant intermediaries in the epistemological sense, the initial problem of knowledge will be the construction of such intermediaries. At the point of contact between the body and external things, intermediaries will develop in two complementary directions as given by the internal and external, and elaboration of subject and objects depends on this progressive, dual construction.

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Contrary to the position perception enjoys in empiricist rationale, where it is accorded an initial mediating role, it is action with its greater plasticity which performs this initiating function. For Piaget,

> "Perceptions do play an essential role, but they partly depend on the whole action, and certain perceptual mechanisms which one would have believed to be innate or very primitive (such as Michotte's 'tunnel effect') are only formed at a certain level of the construction of objects".
> (Piaget, 1972, p. 20).

Generally, every perception accords to the perceived elements meanings which are relative to action and therefore it is necessary to start with action as a basis for the development (genetic) of knowledge.

1.2.1 Sensori-motor activity.

Baldwin has demonstrated that the young child does not have a concept of self nor differentiates between internal and external. This 'adualism' remains until the construction of the self in relation and in opposition to others. A structure of reality with neither subjects nor objects provides only one possible link - action - between what is to become differentiated into subject and object. But these actions are of a specific nature and are epistemologically instructive.

Initially the infant relates everything in his spatial and perceptual field to his body, as if he was the centre of the universe - but a centre of which he is unaware. This paradoxical position is established because primi-

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tive action does not differentiate between subjective and objective, and the fundamental centring remains unconscious as a result of the lack of differentiation.

To understand this egocentric state, with its lack of differentiation and centring, it must be remembered that at this stage there is no co-ordination of actions: each action constitutes a tiny isolable whole which directly relates the body itself to the object, eg. sucking, grasping, etc. Piaget writes,

> "From this there follows a lack of differentiation, for the subject only affirms himself at a later stage by freely co-ordinating his actions, and the object will only be constituted as it complies with or resists the co-ordination of movements or of positions in a coherent system". (Piaget, 1972, p. 21).

As long as each action forms an isolable whole the only common and constant reference can be the body, meaning an automatic centring on it which is neither voluntary nor conscious.

The schemes of sensori-motor intelligence are not concepts. They cannot be regarded as reflective thought and are brought to bear at the moment of their practical and material utilization. The child is unaware of the existence of such schemes as he has not as yet developed the semiotic apparatus for designating them and grasping them in consciousness.

In order to develop the semiotic function and progress

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towards the interiorization of mental schemes, the child must give up his central position in his universe. What in effect occurs is a Copernican revolution, whereby through the reflective co-ordination of actions, the child decenters his position relative to objects in his environment, and in so doing the first vestiges of self-awareness in relation to external bodies occur. Initially though, the child in his activity upon objects fails to recognise objects as such with any degree of specificity. Before birth the child has already been equipped with a series of 'reflexes' as part of his genetic make-up. This epigenetic plan is the result of genetic programming through evolutionary development of the organism.

Central to empiricist psychology is the notion of association which is strongly maintained by behaviourists. But the concept of association refers only to an external bonding between associated elements. This notion is in opposition to that of assimilation which implies integration (rather than association) of the given within a prior structure, or the formation of a new structure in the basic form of a scheme. With reference to non-co-ordinated primitive actions, two possibilities may occur. Firstly, the structure pre-exists in so far as it is hereditary as in the case of sucking reflex, and assimilation operates only to incorporate new objects outside of the genetic programme. In the second instance, the situation is not anticipated, as when the child touches an object and the object moves or makes a noise. Such encounters are for the infant novel experiences

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which he attempts to reproduce. Attempts at reproducing novel occurrences may be seen as the beginnings of scheme formation through reproductive assimilation. When encountering other objects in similar positions, the infant assimilates it to the same scheme and in so doing recognises the similarity of action through recognitive assimilation. When he repeats the action in this new situation there is generalizing assimilation. The co-ordination of actions by reciprocal assimilation accounts for the addition of something new in relation to what has gone before, as well as the extension of the same scheme. The same object is assimilated to two new schemes at once (repetition and recognitive) and heralds the start of a reciprocal assimilation. Reciprocal assimilation occurs when the child shakes an object and a sound is produced. This leads the child to look at, and listen to an object simultaneously.

During the period one to two years actions are decentered in relation to the subject which comes to be regarded as an object among objects in a space which contains all of them. The initial vestiges of co-ordination between actions occur. Through this co-ordination the subject begins to be aware of himself as the source of actions and hence knowledge. In order to co-ordinate actions objects are displaced. With the resultant co-ordination of displacements, the 'group of displacements' are progressively elaborated and objects are accorded a determinate position. The object thereby acquires a spatio-temporal permanence which consequently gives rise

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to spatialization and objectification of causal relations.

Differentiation between subject and objects is evidence of a total inversion of perspective which occurs and leads the subject to consider his own body as one object among others, in a spatio-temporal universe and causal universe of which he is an integral part to the extent to which he learns to act effectively on it. Piaget writes:

> "The co-ordination of the subject's actions, inseparable as it is from the spatio-temporal and causal co-ordinations which he attributes to reality, is the origin of both the differentiations between subject and object and of the decentring process on the level of physical acts; and this latter in combination with the semiotic function is going to make possible representation or thought".
> (Piaget, 1972, p. 22).

During the sensori-motor period of cognitive development, which according to Piaget occurs from birth to age two years, there is continuous construction of new combinations by co-ordinating abstractions, derived either from objects themselves, or more importantly, from the schemes of actions applied to objects. The child's recognition of a suspended object as something to be rocked requires an abstraction starting from objects. Differentiation of subject and objects is present in a primitive form during the sensori-motor stage.

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1.2.2 Pre-operational Thought.

During the sensori-motor period, there is no stable differentiation between subjects and objects. Progress made during this period ensures the existence of initial tools of recognition, but these tools occur at the level of actual and effective action. With the occurrence of language and symbolic play there develops a direct interdependence between subject and objects, and to a certain extent, interiorisation of action. Conscious awareness of action is never more than partial, and proceeds by selection and representative schematization which implies conceptualization.

The notion that interiorization of actions in the form of representations or thought involves retracing the course of these actions or imagining them by means of symbols (images and language) as such, and without modifying them, is in fact too simplistic. In reality interiorization is the transformation of schemes into proper concepts, however rudimentary these may be. A scheme is not an object of thought, but an internalised structure of actions. Concepts are manipulated in thought and language. Therefore, the interiorization of actions presupposes their reconstruction on a higher level, and consequently the elaboration of a series of novel aspects which cannot be reduced to lower-level mediating structures. Evidence supporting this notion is to be found in the sensori-motor stage where schemes are inadequate and initially give rise to representation at the level of thought. For Piaget,

> "The essential reason why sensori-motor actions lag behind conceptualized action is

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> that the former constitute, even at the level where there is a co-ordination between several schemes, a sequence of intermediaries between the subject and the object, each member of which remains actual".
> (Piaget, 1972, p. 22).

There may be differentiation between subject and objects but neither are endowed with any other characteristics other than those they are encountered with. Conversely, at the level of conceptualization, the subject of the action (self or object) is thought of with its remem-berable characteristics (be they predicates or relations); objects of the action are similarly regarded. The action itself is conceptualized as one transformation among many others which may be representable from among the terms given or those analogous. In so doing, action, through the mediation of thought, is placed in a larger spatio-temporal context and elevated to a new status as an intermediary between subject and objects.

Proportional to the progress of representational thought, the distance between it and its object becomes greater in Time and Space. In other words, a set of successive physical actions, each given momentarily, is completed by representative systems capable of evoking past or future and present actions as well as spatially distant and near ones, in the form of an almost simultaneous whole.

The development of representational abilities during

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this period occurs in two main directions. Firstly, there is progress towards the internal co-ordinations of the subject and so to future logico-mathematical structures. Secondly, external co-ordinations between objects and so of causality in the broader sense, involving spatial and kinematic structuring, are made more apparent.

The subject is now able to perform rudimentary inferences, classify spatial configurations and set up correspondences. The child's demands for reasons through constantly asking the question 'why' mark the beginnings of causal explanation. This fundamental movement away from the confines of sensori-motor intelligence cannot be attributed to language alone, but to the semiotic function which has its roots in imitative behaviour - the sensori-motor behaviour which is closest to representation, but occurs in the form of acts. Evidence that conceptualization is not solely due to the influences of social life and verbal communication, is to be found in cognition studies on deaf-mutes, who although retarded in relation to hearing children in terms of social stimulation, possess analogous cognitive structures to those found in hearing children.

The transition from sensori-motor intelligence to conceptualization is due to the progress of preverbal intelligence, and to the interiorization of imitation through representation. The move from sensori-motor scheme to concept is not sudden, but the result of a laborious differentiation dependent on assimilative transformation. According to Piaget,

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> "The 'assimilation' characteristics of concepts in their completed state is essentially concerned with the objects subsumed under them and their properties". (Piaget, 1972, p. 28).

Assimilation may be said, for example, to combine all A's into one class because of a common characteristic (A) or it may be asserted that all B's are also A's because in addition to property (A) group A may possess the property (B). The assimilation of objects, to one another, which is the basis of classification, incorporates the first fundamental property of concepts: quantification of 'all' and 'some'.

Structures of sensori-motor intelligence are incapable of representation. They are unable to invoke unperceived situations in the present - judging present situations in terms of direct analogy with properties of earlier situations. It involves perceptual recognition of certain characteristics which invoke the same actions as did the earlier situations. Assimilation at the level of schemes does account for the properties of an object, but only at the time of their perception and in a manner which is undifferentiated, (actions of the subject to which they correspond). As Piaget contends;

> "The important epistemological distinction between the two forms of assimilation by sensori-motor schemes and by concepts is therefore, that the first still inadequately differentiates the properties of the object from those of the actions of the subject

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> relative to those objects; whereas the second concerns only objects, absent as well as present, and thus at once forces the subject from his dependency on the present situation in giving him the ability to classify, serialize and set up correspondences, etc. with much greater flexibility and freedom".
> (Piaget, 1972, p. 30).

In the early stages of the pre-operational stage (2 to 4 years) there exist pre-concepts and pre-relations, which remain midway between action and the concept as they are unable to deal with the present situation with sufficient objectivity.

The second sub-stage (5 to 6 years) marks the beginning of decentring and the discovering of object relationships, Piaget terms as 'constituent functions'. In this period there occurs a recapitulation of decentring by objectification and spatialization as was the case in the sensori-motor stage. The essential difference is that decentring in the sensori-motor sense was linked to the body (without the subject being aware of this), whereas with conceptualization there is a simple assimilation of objects and their powers, by the subject, through the subjective characteristics of action itself (again without the subject's awareness).

Consequently, an analogous centring is reproduced on a higher plane (at pre-concept and pre-relations level) in such a way that structures acquired during the sensori-

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motor stage must be reconstructed on a new plane.

By 'constituent functions' is meant a sense of dependency between the variations of two terms which are related properties of objects but in a qualitative sense. This functional structure is opposed to 'constituted functions' which are at the level of concrete operations, and imply an effective quantification. However, neither constituted nor constituent functions reveal the fundamental characteristics of a function, which is to be a univocally 'straight' application (straight in the direction of application).

The constituent function is not reversible but directed, and as it lacks reversibility it does not give rise to conservation. This directedness and lack of reversibility have epistemological significance in that they show a continuing connection with schemes of action. The constituent function equips the child with a semi-logic that lacks inverse operations, and is not yet an operational structure. This function represents the semi-logical structure most suitable to translate the relations of dependence, as exhibited by action and its schemes, but without these schemes attaining the reversibility and conservation of material quantities which characterise operations.

1.2.3 Concrete Operations.

Piaget found that at age seven to eight years, on average, the children he used as subjects for research showed a decisive turning point in cognitive development. The conceptualized actions which carried the child through

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sensori-motor and pre-operational levels of cognition now acquire the status of operations which, though capable of reversible transformations, modify certain variables and conserve others as invariants. This innovation is due to the progress of co-ordinations, the feature of operations being their formation into systems capable of 'closure'. With the advent of a new conceptual plane, Piaget writes,

> "We have then to account for an innovation which involves essential qualitative change, that is, differs fundamentally from the preceding stage, yet must not be thought of as an absolute beginning but as resulting from more or less continuous transformations. Absolute beginnings are never observed during the course of development and what is new is the result of progressive differentiations or of gradual co-ordinations, or of both at once, as we have been able to demonstrate.
> ..... the fundamental differences separating the behaviour of one stage from that of the preceding ones, must be conceived of as transitions to a limit, the distinctive features of which we need to determine".
> (Piaget, 1972, p. 34).

As in the case of semiotic function, where there is a transition from successive material actions to their simultaneous representation in thought, the knowledge of operations indicates an analogous temporal process; this being the fusion of anticipations and retrospections

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into a single mental activity - the basis of operational reversibility.

Fusion of anticipations and retrospections implies a closure of the system on itself: the internal relationships of the system acquire necessity and are no longer constructed successively without connection to the preceding ones. This necessity is a real transition to a limit and closure may be more or less complete; it is only at the moment of completion that the necessary internal relationships are achieved. These relationships are two inter-connected modes which are common in all operational structures at this plane of cognition: the two modes being conservation and transitivity.

Transitivity is the simultaneous inclusion of a series of elements within a given system; the system being closure. If the system is constructed through trial-and-error, at the level of partial relations where seriations have not yet been co-ordinated into a whole, transitivity only becomes evident through the simultaneous perception of elements A B C. However, once the ability to anticipate inverse relations is developed, transitivity becomes a law of the system (closure) and the position of each element is anticipated because of the method used in the system's construction.

Conservation is closely allied to closure and transitivity. Conservation is the best index of the formation of operational structures. The connection with transitivity is apparent where: A = C because A = B and B = C, some common property is conserved from A to C. If the

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subject acknowledges as necessary, the conservations A = B and B = C, he will infer A = C by using the same argument. At this level the child uses all three types of argument to justify all conservations as all indicate combinations characteristic of a self-enclosed structure (a system whose internal transformations do not go beyond its limits, and does not require any external element for it to occur). In the most common argument the subject states that the same object conserves its quantity when passing from condition A to condition B, because 'nothing has been added or taken away' or 'it is the same'.

In the second type of argument the reason offered for conservation from A to B is that condition B can be restored to condition A through reversibility by inversion. Again this is an operation within a system, where the possible empirical restoration of condition B to condition A was acknowledged at the preceding level, but without there being conservation as such. Similarly, in the third type of argument Piaget writes,

> "..... in cases where the subject says that quantity is because an object has simultaneously lengthened and contracted (or that the collection occupies more space but becomes less dense) and that one of the two modifications compensates the other (reversibility by reciprocity of relations) it is clearer still that the child is thinking in terms of a whole that is systematic and closed upon itself: he does not measure to

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> evaluate the variations and he only judges their compensation 'a priori' and in a purely deductive fashion, which implies the preliminary postulate of the invariance of the whole system".
> (Piaget, 1972, p. 37).

The presence of this deductive ability heralds the start of the concrete operations stage as concerns their logical aspect. But the criteria which constitute the transitions between this stage and that of pre-operations are complex, comprising three interrelated aspects. First, is that of reflective abstraction which derives higher order structures from the lower ordered ones. Lower order structures are only capable of establishing partial bonds found in the make-up of pre-operational concepts. Higher order structures incorporate the existing lower order structures and modify them accordingly so the result is a more developed structure which operates at a higher level of cognition. The second aspect is that of co-ordination which involves the whole system, bringing about its closure by connecting the multitude of partial bonds. Thirdly, there is self-regulation which brings the system's connections into equilibrium in terms of their direct and inverse senses.

Achievement of equilibrium is a major feature of the transition between pre-operational and concrete operations. More specifically, operational reversibility of the higher order systems is in contrast with the lack of such a mechanism in pre-operational systems. In

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concrete operational thought the totality is no longer a series of discontinuous parts, but a whole and continuous object, whose parts are combined and included/excluded according to the 'neighbourhood' principle.

At the level of pre-operations, spatial objects and pre-logical collections are not clearly differentiated. According to Piaget (1972), from ages seven to eight years (for Genevan subjects) these two structures are clearly differentiated, and the term 'logico-arithmetical' operations may be used for those based on discontinuity/similarity or difference. Similarly, Piaget (1972) proposed the term 'infra-logical' operations for those which develop from the continuous and 'neighbourhood' type. The result is two isomorphic 'types' which are non-transitive among themselves; the first combines or serializes objects, while the second divides a continuous object.

With reference to causality, operational thought attributes operations to objects, which are raised to the level of operators whose actions are combined in a more or less rational manner. In handling problems of equilibrium between weights, the concrete operational child thinks in terms of compensations and equivalence, in so doing attributes to objects combinations which are both additive and reversible. At this stage one may speak of the beginnings of operational causality, but operations are not yet formed independently and then attributed to reality. Rather, it is when the child searches for a causal explanation that both operational synthesis and its attribution to objects occurs simultaneously through

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interactions between operational forms which are due to reflective abstraction and information derived from physical experience by simple abstraction - information capable of promoting (or retarding) logical and spatial structuring.

In contradistinction to formal thinking which may be regarded as reasoning by hypotheses, 'concrete' operations are directly involved with physical objects. As in pre-operational thought the subject still acts on objects, excepting that these actions are given an operational structure which makes them combinable in a transitive and reversible manner. This being the case, it is not difficult to understand why certain objects are more or less easily incorporated in such structuring whereas others are not. At the level of concrete operational thought, form is not yet separated from content, and the same concrete operations will apply, with a time-lag, to different content.

Towards nine to ten years of age general equilibrium of the operational stage is manifested. At the onset of this stage (7 - 8 years) operations are formed relative to perspectives and changes of point of view of a 'self-identical' object whose position is modified in relation to the subject. However, at ages nine to ten years (Genevan children) there is co-ordination of points of view relative to a collection of objects; for example, three differently sited houses. At this level spatial measurement in one, two or three dimensions results in the construction of natural co-ordinates relating them to a complete system. Piaget was able

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to postulate from research done on Swiss children that it is only towards nine and ten years that the child is able to predict the horizontality of the water level in a tilted container. Development in this instance is that of interfigural relationships which now accompany interfigural connections evident in the substage, seven to eight years.

Referring to logical operations, Piaget made the following observations:

From ages seven to eight years the child has the ability to construct additive and multiplicative structures. However, such achievements rely on the successful execution of set tasks (arrange the figures in the 'best' way), rather than of a spontaneous recourse to structure. Now the child at the second substage will, according to Piaget, demonstrate an effective operational structuring:

> "..... trying to isolate the functional dependencies in an inductive problem, shows a general capacity for discovering quantitative co-variations, though without the factors involved being separated, as will be the case at the following stage: instead, correspondences are set up between seriated relations or classes".
> (Piaget, 1972, p. 43).

Regarding causality, this substage exhibits a mixture of considerable progress and some regression. Up to this stage the movement of a body together with its velocity is considered as some kind of force or impulse. At age nine to ten years there occurs a differentiation

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and co-ordination, in that movements of objects and changes of velocity need the intervention of an external agent or 'cause'. But at this stage there is no concept of acceleration.

The second level of concrete operations reveals a somewhat paradoxical situation. Starting from a state of undifferentiation between subject and object, there occurs complementary and relatively equivalent progress in two directions: the internal co-ordination of actions and then operations of the subject; secondly, the external co-ordination of psychomorphic actions which become operational and attributed to objects. There has been a level by level, related, development of logico-mathematical operations and of the concept of causality. The former influences the latter with the attribution of form to content, and vice versa, the ease or difficulty with which the content submits to a form. Space is a related aspect of the two, arising both from the infra-logical operations of the subject and the static, kinematic properties of the object, hence its part as a relational agent.

Coupled to this progress, the second substage concrete operations child is restricted by the operational means at his disposal when faced with inquiries into causes and causal explanations, and this may be regarded as regressive. This being the case, it is still important to again draw attention to the uni-directional (overall) and expanding nature of the development of cognition over time. Each new stage is a recapitulation of its predecessor, only on a higher plane, bringing the subject

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more in touch with its environment by enabling it to become a participant in a two-way interaction rather than a passive recipient of stimuli.

1.2.4 Formal operations.

According to Piaget, formal operations have their onset at around eleven to twelve years of age. Formal operations mark the stage when operations are free from their time-dependence, or, from the psychological content of the child's actions where their logical properties also have a causal dimension. It is at this stage that operations finally become extra-temporal.

During the first stage (semiotic function), from one and a half years, imitation is interiorized in image form. With the onset of speech, successive actions may be condensed in the form of simultaneous representations. The second stage is that of concrete operations which co-ordinate anticipations and retrospections, the result of which is reversibility and the subject being able to conserve temporal starting points. But the increasing mastery over Time is at this level still arbitrary as operations remain 'concrete', that is to say, operations which are concerned with objects and actual physical transformations.

'Formal' operations are the third stage of cognitive development.

> "Here knowledge transcends reality itself, relating it within the possible and the necessary; thus dispensing with the concrete as intermediary. The realm of cognitive

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> possibility as exemplified in the infinite series of integers, the power of the continuum or simply the sixteen operations yielded by combinations of the two propositions p and q and their negations, is essentially extra temporal, as opposed to physical displacements which occur in time".
> (Piaget, 1972, p. 47).

The principle feature of formal operations is the capacity to deal hypothetically. This innovation occurs around eleven years according to Piaget's studies on European children.

Hypotheses are propositions and their content consist of inter-propositional operation of classes, relations, etc. which may be verified directly, as can consequences derived from them. But the deductive operation by which the subject proceeds from hypotheses to their conclusions is of an inter-propositional nature, being an operation carried out on operations (or in Piaget's terminology 'a second order operation'). It is this ability to perform operations on operations which enables knowledge to transcend reality, and by means of a combinatorial system make an infinite range of possibilities open to it. Operations now are no longer restricted as they are in concrete operations where they are step-by-step constructions.

For Piaget, a significant novel feature of formal operations is that they enrich prevailing systems by elaborating 'sets of all subsets' or simplexes founded

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on a combinatorial system. The formal operations stage serves to include an important unity among the various novel features of preceding stages. The formal operations stage signifies the use of logico-mathematical operations which are autonomous and differentiated from physical actions and their related causal dimensions. However, logico-mathematical operations are accompanied by a correlative group of features of equal importance in the field of causality. Although the two fields may be differentiated, there exists on two levels at least, co-ordination and even support, in a manner increasingly reminiscent of the procedures of scientific thought.

The first level is that at which, in Piaget's terms, the data of physical experience is 'read off'. For Piaget facts only become available once they have been assimilated by the subject, consequently the notion of 'pure experience' in the empiricist sense is false. Assimilation here utilizes logico-mathematical methods for the construction of relations which structure and order facts and subsequently enrich them. So at this level operational methods elaborated by formal thought ensure the inductive inference of elementary physical regularities.

The second level involves operations attributed to objects, or causal explanation. For Piaget,

> "To the general role of the possible in the latter domain (logico-mathematical operations), there corresponds, on the physical plane, that of the virtual, so that the subject can now understand that

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> forces continue to exist in a stationary state, or that in a system of several forces each conserves its action while combining it with that of others. And linked to these concepts which transcend the boundaries of the observable, we even find the notion of purely 'internal' transmissions without the molar displacement of intermediaries".
> (Piaget, 1972, p. 49).

Though there may be much that is striking about the formal operations stage, it is entirely consistent with the psychogenesis of knowledge. Beginning with a stage of undifferentiated confusion, a series of novel and non-predetermined constructions are slowly co-ordinated, elaborated on a higher level and finally emerges as the subject's operations and the causality of objects. It is the progressive interiorization of logico-mathematical operations, evolving from reflective abstractions which construct operations on operations, that allows a state of extra-temporality to be attained. Such a state is characterised by possible transformations and the subject is no longer impeded cognitively through being bound to real transformations.

The physical world in its spatio-temporal context, which includes the subject, now becomes accessible to an objective 'reading off' of certain laws and most importantly, causal explanations. It is through becoming tied into causal explanations that the mind is

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forced into a process of continuous decentring in order to master objects. It is at the level of formal operations that thought releases itself from physical action and the universe; the latter which is contained in, yet surpassed in thought.

Piaget concluded:

> ".....science has long acquainted us with the surprising convergences between mathematical deduction and experience; but it is a striking thought that at much lower levels than that of formalizing and experimental techniques, a mind which is still very qualitative and scarcely able to employ numerical methods, arrives at analagous correspondences between its attempts at abstractions and its efforts of observation, however unmethodical they may be".
>
> (Piaget, 1972, p. 50).

1.3 Comment.

Traditional epistemology is an attempt at justifying the layman's confidence is his own knowledge. Such an epistemology is, however, a-genetic rather than genetic. Even the epistemologies of the European Rationalist philosophers of the 17th century, and the British Empiricist philosophers of the 17th and 18th centuries, although contending knowledge to originate in the predispositions of the mind or from experience, reflected

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the view of knowledge as a stable possession. There is no hint in traditional epistemologies that knowledge is a process, deriving from a dialectic between a subject and a world of objects (including other subjects). Classical epistemologies are subjective because they take as a starting point the notion of the subject's supposedly 'direct' or 'immediate' observational experience.

According to Popper's theory of knowledge, problem solving is a 'primal activity'; the environment sets out problems which the organism solves at the level of the species. Genetic epistemology may be loosely defined, in the case of Popper, as 'a theory of knowledge given from a genetic point of view'. With reference to the principal protagonists of genetic epistemology, Baldwin and Piaget, there is a shared belief that a progression from a-genetic to genetic explanations of knowledge is acceptable. Developmental theories must contribute to the explanation of human knowledge in the broadest sense, viz. if we want to learn about knowledge we must see how it develops.

An overriding ambition for Piaget in practising genetic epistemology was to try and establish an interdisciplinary field of study with a genetic base and one which he hoped would overcome empirical and philosophical tenets. Piaget was in fact accused of 'incoherence' by Hamlyn (1971) for attempting to establish a theory of knowledge based on empirical and philosophical considerations. Kaplan (1971) went a step further and drew attention to the notion that genetic epistemology is not essentially about cognitive growth in the individual: - "it is the development of scientific knowledge in the human

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community". Although Piaget spent his latter years being more concerned with genetic epistemology and the progress of scientific knowledge than with the course of cognitive growth, it is unfair to suggest that genetic epistemology be regarded as the study of the 'phylogeny' of knowledge. For Piaget:

> "The fundamental hypothesis of genetic epistemology is that there is a parallelism between the progress made in the logical and rational organisation of knowledge and the corresponding formative psychological processes ..... as there are children around us ontogenesis is by far the more accessible study".
> (Piaget, 1970, p. 13).

There are common functions and structures in ontogeny and phylogeny and so Piaget is justified in extending the method of genetic epistemology to the growth of the sciences by focussing on individual development.

On the other hand, Baldwin did not attempt to incorporate the epistemological into the genetic and proceeded as if there was no difference between psychological and philosophical theory. The problem is that more often than not Baldwin's experimentation had little relevance to his genetic theory of knowledge. He did not make any systematic attempt to explore the empirical implications of his system. Although Baldwin's theory does not have the empirical interest of Piaget's, it does give an account of the conceptual system within which the child is developing, and of the dialectic between child and concrete

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world as well as child and the human community. Some authors, (Russell, 1978) regard the functional polarities of assimilation and accommodation, as used by Piaget, as losing their explanatory power after the sensori-motor stage. But as Baldwin is primarily concerned with the self-social world dialectic his theory is ideally adapted to explain the child's intrusion into a world of concepts expressed in language. Also Baldwin's use of assimilation and accommodation is different to that of Piaget; accommodation refers to individual adaptations and assimilation being confined to schematic intelligence.

Baldwin sees the child developing into a ready made, though evolving world and his theory is less active than Piaget's because he is not constructing reality through actions which become interiorized and equilibrated within structural systems. Instead of constructing reality, Baldwin places more emphasis on 'functional interests' (turning the head to suck the nipple, play imitation, proposition, abstraction) and the cognitive plasticity which accompanies them. Although Baldwin claims syndoxic commonness is 'hammered' onto the surface of the child's mind, he says at the same time that reality would remain meaningless unless there was a corresponding functional assimilation on the part of the child. It may be said that without functional interests existing in different forms at each level of development, it would be difficult to make sense of Baldwin's theory. Similarly, the child would have great difficulty in coming to terms with the concrete and social world.

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Baldwin writes,

> "Syndoxic meaning was regarded as only the preliminary to objective knowledge. The child has still to cognise others as judging agents and truth as involving the accord of judgements before he can appreciate that although truth depends on agreement this is not a contingent matter and that certain rules are universal, objective and independent of what other people might judge - synnomic meaning".
> (Russell, 1978, p. 213).

If it is possible to draw out one overriding theme in Baldwin's theory it must be the following: that objective knowledge is preceded by the sharing of experiences (before the child can think for himself he must experience with others); hence the notion that thought is public property.

Baldwin may be regarded as being less of a pragmatist than Piaget. Piaget's system of cognitive growth is founded on a process of equilibration which has its origins in the notion of organismic survival. The implication inherent in Piaget's theory is that knowledge is the result of adaptive mechanism. Baldwin dismissed such a notion as the result of Darwinian influence. For Baldwin, 'the growth of knowledge, by virtue of a system of truths, cannot be explained by a theory in which the survival value, the pragmatic or instrumental utility, the use and consequence of thought are taken to be its entire raison d'etre and justification'. (1906, p. 8).

In a charge against functionalism, which encompasses Baldwin's theory, it may be said that the very nature of such theories stands against them incorporating any reality which is not a

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human product, and which is something more than the systems' functional units. Both Kant and Piaget rejected this 'anthropocentrism' and found it unsatisfactory; they regarded it as a theme which could lead to forms of scepticism, subjectivism and idealism. Baldwin proposed a more ambitious anthropocentrism than did Wittgenstein, who did not intend postulating any meaning beyond the span of language games in the conceptual system. Baldwin's more radical outlook attempted the suggestion that there was a 'reality' which transcended the different 'realities'. According to Russell (1979), it was the primary intention of Baldwin to use the phrase 'genetic epistemology' to refer to what he termed 'real logic' which resulted in a comparison of the different kinds of reality (theoretical, moral, aesthetic); a kind of comparative morphology of meanings. By distantiating oneself as far as possible from this taxonomy the 'realest real' could be encountered, was Baldwin's postulation. This position led him to believe that this immediate reality of contemplation or transcedent reality, reconciled the oppositions which the different realities engendered (a Hegelian contemplation). Such a position does not imply Kantian necessity but is a way in which a transcedent notion of human understanding may be achieved within the confines of a functionalist framework. For Russell,

> "Whether or not one regards Baldwin's actual attempt at reconciliation as more mystical than philosophical, one can at least agree with him that we have access to different realities through a number of different conceptual subsystems whose interrelations are themselves systematic: within these the finest grain

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would be the language game".

(Russell, 1978, p. 275).

Baldwin's functionalism may be regarded as more systematic than that followed by Wittgenstein because he adopted a genetic perspective. For Baldwin the acquisition of knowledge by the child is a systematic procedure and the point at which conceptual and biological systems come together and interact.

Although Piaget adopted a structuralist stance in his theory, he, like Baldwin, proposed a systematic procedure whereby knowledge is acquired. Piaget, like any other theorist, has come in for a fair share of criticism over his theoretical standpoint. This is acceptable as no theory is considered fact. Education programmes based on Piagetian theory have found favour in a number of countries as a more suitable replacement for traditional educational practices and a means by which conceptual growth can be fostered so as to keep children in touch with the rapidly expanding fields such as science and mathematics.

It is relevant in education today to include learning material in curriculae which makes students learn how to use their minds. Piaget refrained from applying his theory, preferring continuing research. So it has been left to others to conduct investigations.

A singularly important feature which has emerged from Piagetian research in various countries throughout the world is that not all individuals possess the same range of conceptual abilities at any set age. Adults don't necessarily think better than children, in terms of correctness, rather adult thought is qualitatively different to that of the child. Similarly,

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qualitative differences in cognition may be found from one culture to the next; again the notion that cognition is superior in, say, Western society as opposed to that found in Aboriginal society, through the use of common measure, is unrealistic. The social environment imposes selectively different demands on individuals and adaptation to such demands may also be governed by various cultural sanctions.

For Piaget there can be no learning without experience and there can only be as much meaning behind a word or object as the individual has had experience with it. A child learns what he is cognitively capable of learning. Behaviourists disagree with this point of view and would propose that mental development will follow if a child learns a series of items in sequence. But the sequence of learning has not yet been sufficiently researched to support such a proposition. In his research, Piaget made the assumption that all children have similar random stimuli inputs. Such an assumption was necessitated in order for him to make general statements about children of different ages. Piaget's concepts of 'readiness' is based on the assumption of randomness which Sund has suggested as:

- All children have had similar experiences.
- Therefore they should develop reasonably (providing there is no cerebral or genetic difference) at about the same rate.
- If this is the case then educators should consider the stage of development (or readiness) before requiring certain tasks. (Adapted from Sund, 1976, p. 65).

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Authors like Jerome Bruner and R. Gagné do not subscribe to the idea of similarity of encounter and therefore do not readily accept Piaget's concept of 'readiness'. Bruner believes that almost any exercise may be taught at any age, provided it is adjusted to the level of competence of the subject and the material is presented in a stimulating and understandable manner. Gagné is of the opinion that a subject can learn related concepts if the correct sequence of learning materials is determined and administered.

The attitude of Piaget is that there is a generalized system in operation involving assimilation and accommodation of information input. The system becomes more sophisticated as the child develops. Piaget acknowledges the possibility of accelerating the learning of concepts but questions the long term effects of what he calls 'the American wish for accelerating mental development'. He proposes that rather than trying to speed up mental growth in children, their environment should be enriched so as to provide stimulating experiences. However, environmental enrichment only becomes relevant once the level of mental competence of a subject has been assessed through evaluative means so as to ensure that stimulation will be directed to what the subject can handle cognitively, and create an optimal learning environment through activity.

Perhaps the most notable and original consequence of Piaget's theory that life is adaptation, (adaptation being a quest for more stable equilibrium), is the connection between biology and mathematics. For Piaget, man can only understand the universe through logic and mathematics which are products of his own thinking; alternatively, man can only understand how he

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constructed mathematical concepts and logic patterns by studying himself psychologically and biologically; in other words, as a function of the universe. Rotman described this connection as:

> "..... the unbroken continuity of pattern from amoeba to nineteenth century mathematics that spans the unfoldings of embryology and the activities of children, portrays mathematics as a form of perfection: the culmination of adaptation to reality, the most perfect instance of biological knowledge whose congruity with the real is absolute".
> (Rotman, 1977, p. 171).

Piaget's circle of the sciences which encapsulates the cyclic dependence of each science on its neighbour, is for Rotman, an intentional frame for an ultimate question. The question being, "whether the mind creates mathematics to understand the universe or does the universe inscribe the language of the mind in mathematics?" Rotman's following questions are, "is mathematics the highest state of adaptation to the real? Is it a perfect form of objective knowledge? Can it be assumed that science is an imperfect form of mathematics? Is rational thought an imperfect science?"

Rotman admits that the history of sciences indicates that they become increasingly dominated by mathematical technique and methodology - a recurring pattern of appropriation at first numerical then statistically and structurally via algebra, geometry, topology and calculus. There are sound reasons why mathematics dominates or has come to dominate the sciences in

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this manner. Mathematics provides the sciences with a language which the logic of their method demands, one which is free of ambiguity and concentrates on the analysis of mechanism. It is at best the study of objects, of determinate entities and well-defined processes as they occur in Time and Space. But the novelty of Piaget's theorising is the manner in which his psychological explanation embraces mathematics. The question in the main that genetic epistemology and Piaget's circular conception of the sciences poses, is not whether science aspires to mathematics, but rather, is rational thought sub-scientific thought? Piaget comes closest to asking whether there exists any form of reason which lies outside the bounds of mathematics and which may be termed 'objective':

> "It must be emphasised that the entire world of reality can be expressed in mathematical terms and, a fortiori in logical terms. There is no known physical phenomenon which has defied expression in mathematical form, and attempts that have been made to prove the contrary, such as Hegel's 'Nature Philosophie', have come to nothing".
> (Piaget, 1971).

Like many other authors, Rotman takes Piaget to task for his naturalist stance on cognitive development; naturalist in the sense that man is viewed as a phenomenon and his thinking is described and understood within its symbolic complexity - in an evolutionary framework. Rotman feels that there is little evidence that this can be done.

Piaget's attempts to give a naturalised theory of mind, or

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alternatively, an evolutionary account of rationality, does for Rotman have some serious shortfalls. Firstly, Rotman argues that Piaget has failed to account for how the individual as a member of the human community and the organism are brought into contact. Piaget's theory of the individual is the isolated organism adapting to its environment, and his paradigm of the world is the ensemble of physical processes and objects in space and time which the organism encounters. For Rotman the major failing of Piaget's theory is what he terms, 'the organism/environment model's refusal to accept the importance of the fact that individuals are immersed in a non-natural world in an environment of ideas, meanings, intentions, history and symbols, within a matrix of social influence and co-operation'.

> "When he identifies social co-operation with the co-ordination of inter-subjective viewpoints whose laws are those of the amalgamation of structure, he neglects the fact that viewpoints are within language and that language is a social relation that constructs an individual's categorisation of the world. And in doing this he replaces human rationality with the logic of objects". (Rotman, 1977, p. 181).

Rotman also criticised Piaget's supposedly inadequate account of the role of language in cognitive development. Rotman supports Piaget's singleminded pursuit to establish mathematics as the highest form of logic in cognitive development.

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In defence of Piaget it must be noted that he did in fact devote an entire volume to the matter of language and thought of the child. Many psycholinguists have been surprised at the off-hand manner in which Piaget deals with language and the role it plays in cognitive development. Piaget by no means discounts language as superfluous to cognitive development, rather he believes the sources of intellectual operations are not found in language, but in the sensori-motor stage which is essentially pre-verbal. According to a psycholinguist who has experienced working at Piaget's Genevan Institute:

> "The co-ordination and decentrations of sensori-motor activity are not limited to this first period of life, but are found, in a different form, at work in the constitution of operational intelligence as well. As Piaget has frequently remarked (1963, p. 72), they are also found in linguistic acts. This may account for a partial isomorphism between languages and logic".
> (H. Sinclair-De-Zwart, 1969, p. 317).

Thought is rooted in action; at the end of the sensori-motor stage and prior to the onset of language or the symbolic function in general, the child must overcome his initial perceptual and motor egocentricity by a range of co-ordinations and decentrations.

The formation of representational thinking is contemporaneous with the acquisition of language, both of which belong to a more general process - the symbolic function. Initial verbalisations are closely linked to symbolic play, deferred imitation and mental images in the form of interiorized imitations. A point

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which is elaborated by Piaget and his principal co-workers (Inhelder in particular) is that intellectual operations are actions that have become interiorized and reversible, but they are still actions. Piaget does not consider language to be a sufficient condition for the constitution of cognition.

Piaget did not propose a theory of language acquisition mainly because he argued (1966, p. 69), "language is a ready made system that is elaborated by society and that contains, for persons that learn it before they contribute to its enrichment, a wealth of cognitive instruments (relations, classifications, etc.) at the service of thought". The knowing individual expresses his 'knowledge' in this code. Language takes the place of symbolization in the knower-symbolizer-known relationship. However, this code is itself an object of knowing and it takes the place of the 'known' in the knower-known relationship; it is this aspect which is stressed by most psycholinguists.

Contemporary linguistics has been concerned with the establishment of systems of elements and procedures for inventory purposes. Linguist Chomsky has titled this type of theory 'taxonomic' linguistics. Taxonomic linguistics in combination with associationist learning theory were produced as theories of language-acquisition that, candidly, left researchers puzzled and did not account satisfactorily for the fundamental fact of language which may concisely be stated as - the ability to verbalise and understand an infinite number of sentences that have not been previously heard. Chomsky produced a non-taxonomic theory of language which was directed at a system of rules rather than a system of elements.

The differences between the theories of Piaget and Chomsky

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are mainly epistemological, with neither subscribing to the empiricist point of view. Both theorists emphasise the creative aspect of language. The Piagetian psycholinguist, according to M. Sinclair-De-Zwart, would always 'try to study language as part of the symbolic function, within the frame of the total cognitive activity of the child rather than an autonomous 'object of knowing' '. (1969, p. 335).

Piagetian theory has evoked a tremendous amount of interest among researchers and has been applied in a multitude of countries and cultures. The theory has possibly had its principle impact in the field of education as it is an excellent pointer of cognitive development through concept conservation. Through implementation of simple tasks which evoke activity response from subjects, the researcher is able to identify cognitive abilities.

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CHAPTER TWO.

CONCEPT AND CONSERVATION.

2.1 INTRODUCTION.

As this research concentrates on the conservation of concepts, some consideration will be given to the matter of clarifying the Piagetian notion of concept as opposed to the notion of discriminative response. It is Piaget's novel method of assessment which sets his idea of concept apart from the mainstream of cognitive theorists.

2.1.1 Environmental Variability.

In psychological terminology, concepts are mechanisms by which the organism attempts to come to terms with the complexity of its environment. Environmental variability is regarded as the starting point for all conceptions of the concept. Elkind (1969) notes two types of environmental variability:

> 'Between things' variability - houses and cars, animals and people all differ from each other by virtue of their spatial discreteness even though they may share common features. The most general feature between these diverse elements is that of similarity and difference, which may occur at the level of whole objects, properties of objects, or at the level of relations between objects.
>
> 'Within things' variability - variations between objects confronts the organism with problems of similarity and difference, whereas variations within things leads to problems of transformations and states.

Piagetian conservation tasks are specifically designed to determine how well a subject copes with variability within things.

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Although psychologists in general have tended to disregard variations within things, Piaget has indicated that from the child's point of view these problems are far from trivial and in fact pose genuine problems of conception. The child, at each stage of cognitive development, is faced with an adaptation of novel forms of within-things variability.

2.1.2 The nature of a concept.

In the discriminative response view of the concept, concept essence may be correlated with the principle of similarity among things. On the other hand, the Piagetian notion contends that it is the principles of identity and conservation which lead to permanence of things in thought and action. The two positions complement one another in that each notion is directly involved with things in terms of their multiplicity as well as their uniqueness.

2.1.3 The function of a concept.

According to Elkind (1969), the discriminative response point of view accords recognition or classification of exemplars as the principle function of the concept. On the contrary, Piaget contends the major function of the concept is discrimination between what is apparent and that which is real. This discrimination may in turn be divided into the differentiation of between- and within-types of variability. Both functions must be included, as a concept serves both purposes.

2.1.4 Content of a concept.

With reference to content of concepts the discriminative response standpoint may be said to be particularly

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concerned with the population of objects to which the concept is applicable. The Piagetian view, however, holds that concept content is essentially intensive and corresponds to the property which remains unchanged through various transformations an object may undergo. For Elkind (1969), 'conservation problems provide a general paradigm for the assessment of intensive content'.

In conclusion to the present digression on Piagetian and discriminatory response definitions of a concept, it is interesting to note a more general and historical schema of conceptual thought. Lewin (1931), provided such a schema on investigating modes of concept formation in science. Lewin refers to an Aristotlian and a Galilean mode of concept formation. The psychologist, who describes mental processes, is in a reflexive position since anything attributed to his subjects must be true of himself and vice versa. Consequently it may be appropriate to compare modes of concept formation as found in the history of science with modes used by the subject in psychology.

Traditional views of the concept held by those inclined to the persuasion of Aristotle differ in three main areas from more contemporary views of the concept held by those influenced by Galileo:

Continuity vs Discontinuity - within the Aristotelian view, properties of objects are considered discontinuous while the Galilean mode regards properties as continuous.

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Elkind writes,

> "What is a discriminative response if not a dichotomizing activity that separates things that are similar from those that are not on an absolute basis. The implication is that the properties in question are dichotomous". (Elkind, 1969, pp. 183).

In contrast to the above, with reference to the essence of a concept in the Piagetian view, more specifically taking principles of identity and conservation, it may be said that such a notion conforms to the Galilean mode of thought. The essence of these principles lies in their acknowledging that dimensions of given objects may differ within themselves. Furthermore, this leads to the quantification of properties which relates to the discovery of conservation in the history of science and mental development of the child.

Heterogeneity vs Homogeneity - a second principle point of departure for Aristotelian and Galilean modes of thought is how the functions of a concept are conceived. The function of an Aristotelian concept is to describe and classify, while the Galilean concept predicts and explains. If the concept is regarded, as in the case of discriminatory response approach, as mainly having a classificatory function, it is confined to superficiality. In contrast, if the Piagetian stance on a concept is taken, whereby the function of the concept is discrimination between what is apparent and what is real, then genotypic laws are

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sanctioned. More explicitly, identity and conservation make possible a prediction and explanation of within-things variations.

Class vs Particular - the Aristotelian view holds a particular object to take its significance from the properties of the class. A Galilean notion contends that the class obtains its significance from the consideration of a particular case.

Aristotelian and Galilean modes of thought on the concept are contrasted, nevertheless they should be retained together in order to complement one another. Taken individually, discriminative response and Piagetian notions of concept are merely a partial understanding. But together, these two accounts provide a more comprehensive overview of concept and conception in the thinking subject and science.

2.2 CONSERVATION.

The notion of 'conservation' is central to Piaget's theory of cognitive development. Conservation may be defined as a subject's cognisance of certain properties (number, quantity, etc) remaining constant, despite apparent transformations. Piaget contends that inherent in the function of conservation is that properties are conserved at different chronological stages according to the level of structural complexity necessary for this to occur.

Researchers at the Geneva Institute (Piaget and Inhelder, 1941) and others (Flavell, 1963) have established that although conservation may be taken for granted at a later stage, until the

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age of six to seven years, children actually believe that properties do change as a result of apparent transformations. The question to be considered is - how do children come to understand that properties do not change when exposed to transformations?

Wallach writes,

> "The question of how conservation is attained is a particularly fascinating one because it is hard to see how experience could possibly provide a basis for conservation; nor yet how conservation could be developed without a basis in experience. The reason it seems so difficult to see how conservation could be based on experience, is that the properties that are conserved typically cannot be observed to remain the same under the transformations in question". (L. Wallach, 1969).

Conservation of properties is a complex concept to analyse. Conservation is a multi-faceted operation which cannot be attributed to the presence or absence of a single factor. What explanation may be offered for the case of a child who witnesses the same amount of liquid, in identical containers, being poured into dissimilar vessels and judges one container to have more liquid than the other because it is 'taller'? Yet should this subject again be exposed to this experiment some years later, he will report that the amount of liquid is the same. There are a number of single factors which may be considered to account for conservation, but a closer inspection indicates conservation can only be accounted for in terms of interdependent variables.

2.2.1 Sensory experience.

Sensory experience allows the subject to familiarise

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itself with different properties through direct manipulation and observation. Could this be a basis for conservation? Not entirely, for though the subject may observe transformations of properties, he does at a certain age fail to conserve, allowing his reasoning to be guided by irrelevant perceptual cues which lead him to make incorrect judgements. The preconservation subject may be entirely conversant with reversibility yet he commits himself to a non-conserving response on observing apparent transformation of properties.

2.2.2 Social learning.

Wallach (1969) and Russell (1978) cite social learning/logic as being critical for learning vocabularies pertinent to conserved properties. Studies by Beilin (1965) and Churchill (1958) set out to teach children about conservation but these efforts had limited success. A pointer which emerged from these studies was how to identify appropriate conditions, conducive to learning conservation, in a child's normal routine.

Furthermore, social learning raises the question of origins. From who was information initially transmitted? Why did anyone begin to think of amount as something which remains the same under transformations of configuration, deformation, etc.? Russell (1978) pointed to the role of the mother as social mediator.

2.2.3 Thinking in certain ways.

Developing an ability to think in certain ways implies firstly, thinking in terms of different yet equivalent units. Secondly, being able to attend to several aspects of a situation at once, and thirdly, an ability

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to conceive operations as being reversible. Each type of thinking may be necessary for the conservation but none account for it in the absence of sensory experience.

An idea of different equivalent units may be essential for an understanding of the 'same amount' but it is not sufficient to account for when different shapes do have the same quantity. Thinking in terms of several dimensions at once does not lead to conservation due to the lack of perception of compensation.

2.2.4 Differentiation.

The preconservation subject does not differentiate the conserved property (eg. amount) from irrelevant transformations (pouring) and irrelevant properties (height of liquid in vessel). A subject who conserves also is able to recognise the conserved property from the irrelevant cues.

Differentiation of the conserved property from irrelevant ones does not provide sufficient basis for recognising that one is conserved - such basis is presupposed. The difficulty lies in finding such a basis which is not provided by sensory experience and consequently, differentiation is not the answer either.

2.2.5 Lowering of immediate stimulus dependency.

Conservation is inhibited by the subject's concentration on dominating perceptual cues. Nothing in the perceived situation indicates that the property in question remains unaltered. Fleischmann, Gilmore and Ginsburg (1966) found that using experimental procedures which did not use misleading cues were not necessarily effective for the

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facilitation of conservation. Alternatively, Bruner (1964) and Wallach, Wall and Anderson (1967) seem to indicate that conservation may be facilitated through use of procedures which reduce misleading cues.

Wallach (1969) cites the change from complete dependence on an immediate stimulus situation to an increase in reliance on memory and other cognitive processes, as being fundamental for recognising conservation. However, that the subject becomes less reliant on perceptual processes, is insufficient to explain conservation. Verbal learning plays a part towards recognition of conservation but learning names only allows the pre-conservation subject to account for dimensions and is inadequate for the total concept.

2.2.6 Inferences from the absence of addition or subtraction. This notion implies the subject's recognition of conservation by infering that quantity remains the same if there is no addition or subtraction of material. As such, this suggestion does appear to account for the necessity of conservation. Studies conducted by Smedslund (1961; 1962) and Wohlwill and Lowe (1962) indicate that an understanding of addition and subtraction precede conservation. However, Smedslund (1964) discounted this. Attempts to induce conservation through procedures involving addition and subtraction (Smedslund 1961, 1963, 1966; L. Wallach, Wall and Anderson 1967) all yield ambiguous results.

Preconservation subjects believe that deformations and re-arrangements constitute a change in amount in the same manner as obvious addition and subtraction of material.

All factors dealt with above do not satisfactorily account for conservation. Nor do they provide a viable alternative to experience. Wallach (1969) contends such factors may possibly play a significant role but only assist an explanation of conservation based on sensory experience.

2.3 REVERSIBILITY.

The possibility of reversibility playing a definitive role in the subject's recognition of conservation was investigated by L. Wallach and Sprott (1964) in an experiment of dolls and beds. First grade children were trained to recognise the reversibility of arrangements which they regarded as implying changes in number. The experiment involved children being shown, repeatedly, that the number of dolls and beds remained the same despite re-arrangement of beds and dolls.

Children may fail to conserve in spite of recognising reversibility. A reason for this may lie in the proposal that subjects do not think about reversibility at the time of making non-conserving assertions. A follow-up study by Wallach, Wall and Anderson (1967) indicated subjects can assert non-conservation while being fully aware of reversibility. Subjects were adamant that the amount of liquid, when poured from identical containers into a container of wider dimensions, was different, even after the liquid was returned to the original containers and assumed former equal levels.

It is not clear how recognition of reversibility may lead to the achievement of conservation. Berlyne (1965) is of the opinion that this was impossible since properties are not conserved, despite reversibility. What is significant is that conservation is not at issue when properties are directly

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perceived. Wallach writes,

> "One speaks of conservation only when there are no appropriate criteria available to the senses. Conservation, in other words, refers to the continuation of something of which there is no adequate sensory evidence at the time". (Wallach, 1969, pp 203).

Given the above, it may lead to a clearer understanding of the relationship between conservation and reversibility. It may be assumed that a property, for which there is no adequate sensory evidence after a reversible transformation, continues unchanged, in that, this would assist in following potentialities (Wallach, Sprott, 1964). However, the problem of bases is brought forward. There is no understanding of how reversibility should lead to conservation. This is coupled to a lack of experimental evidence in support of this idea.

2.4 An experiential basis for conservation.

When speaking of transformations such as pouring, re-arrangement and deformation, with specific reference to quantity conservation, it is implied that transformation does not alter quantity. The stage has now been reached where it is pertinent to examine the notion of 'equality' of quantity. How is the equality of properties determined? A judgment of equality or inequality is based on the perception of sameness or difference of a property. For example, the levels of an equal amount of water in containers of identical or different dimensions.

While there are different sensory methods for determining equality of property, when can it be said that the quantities are equal if the subject cannot perceive properties of which sameness relates to equality? In this case equality of

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property may be arrived at by manipulating both quantities in the same way. Wallach (1969) uses the term 'indicator properties' to describe perceptible properties, the sameness of which is equality and difference inequality. It is then possible to compare properties on the basis of whether indicator properties from the same actions are equal or different. The inference here is that since the same operations affects quantities in the same way, and these quantities have the value of an indicator property, then the quantities must have been equal to start with.

Perceptible properties which are regarded as equal through sameness and unequal through differences are situation linked by a common denominator - the same operational transformation. The situation linkage illustrates an idea that properties are joined by virtue of them starting in a situation where any one of them is the same for two quantities. Identical operations on such properties merely project further situations in which they are the same. Applying the same operations to properties can only result in further sameness. Consequently, further operations on unequal quantities will lead to situations where they are different and never the same.

2.5 A basis for conservation.

Conservation may be explained thus: a subject recognises two quantities as equal when certain perceptible properties they may have are found to be the same, or if one has more than the other the quantities are different. Furthermore, quantities may also be recognised as equal when it is known that they would be the same in respect of one of the properties, if the subject was allowed direct observation

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of the same operations being performed on each quantity. This forms the basis for equality and inequality.

Furthermore, properties indicate equality or inequality when it has been determined that quantities which are the same in these properties are found to be the same in properties already acknowledged as indicators. (A similar rationale applies for quantities which differ).

Wallach notes,

> "Equality comes to be indicated by certain sets of values of difference properties, when it is found that quantities having these values are always the same in properties indicating equality by sameness, when such properties result from performing the same action on each quantity". (Wallach, 1969, pp 213).

If amounts are recognised as equal and if they are the same as regards perceptible properties, it is possible to account for learning that quantity is conserved under a transformation by observing that subsequent to the transformation, a quantity still remains equal to what it was prior to transformation. Linked to this is a criterial notion that indicator properties which are subject to identical operations will always lead to situations in which quantities are the same and never different; alternatively, quantities which are unequal will always be different.

2.6 Realisation of a diagnostic battery.

Piaget contends that cognitive growth may be facilitated provided the structure one wishes to facilitate can be supported

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by more elementary logico-mathematical structures. According to Moore (1980), the implications of this for any facilitatory programme is that one should work within a specific scientific concept which may be reduced to simpler conceptual units. Such reduction to sub-concepts, make it possible to expose pre-operational reasoning, whilst the actual concept may require formal reasoning. This allows a programme to use a specific complex concept and work anywhere from pre-operational reasoning.

The present research makes use of a diagnostic battery of Piagetian conservation tasks compiled by Moore (1980) and works specifically with the concept of force, as it allows the inclusion of simpler concepts whilst at the same time being a formal reasoning concept. According to Moore (1980), force may be reduced to the following component concepts:

a) Force = Mass x Acceleration

b) Acceleration = $\frac{\text{Velocity}}{\text{Time}}$ or $\frac{\text{Distance}}{\text{Time 2}}$

c) Velocity = $\frac{\text{Distance}}{\text{Time}}$

d) Distance requires a relative understanding of the concept of length.

e) Length requires a relative understanding of the concept of space.

f) Space requires a relative understanding of the concept of mass.

g) Mass requires the conservation of weight and substance - which Piaget regards as being intuitive to a degree at the pre-operational level.

For Moore (1980), a profile of conceptual development in a programme designed towards the facilitation of cognitive growth,

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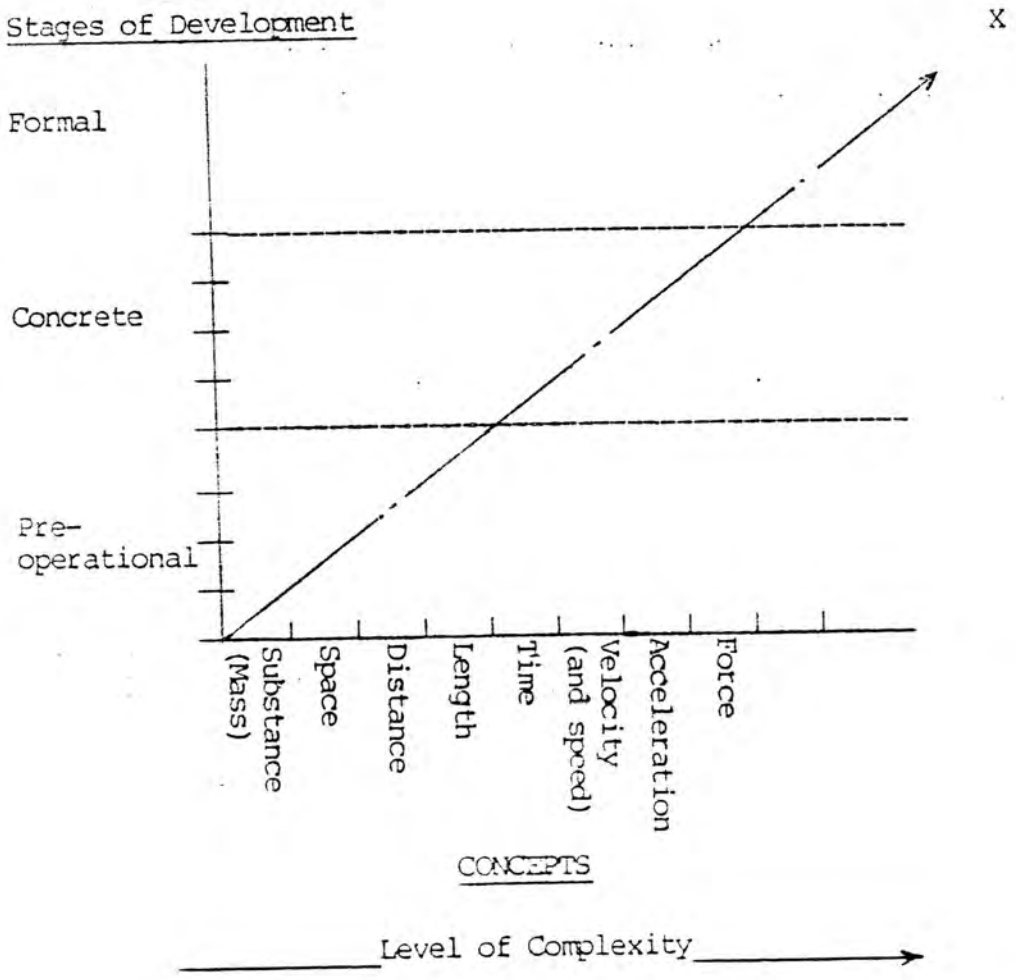
using the concept of force, will look as follows:

PROFILE OF CONCEPTUAL DEVELOPMENT.



Whereas Moore (1980) concentrated on expanding the idea of 'functional interests', the present research deals more specifically with mapping the state of concept development among a certain labour force, as well as attempting to statistically validate a battery of conservation tasks. The experimenter makes a deliberate intervention into the subject's conceptual world and this intervention is illustrated via a

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profile.

By and large, arriving Black mineworkers are an unknown quantity and because of the comparatively short contract period, employers are compelled to use some method of selection which facilitates training expeditiously, in order to return the employee to production. With 'trainability' being used as the selection criterion, to what level should the selection instrument measure an employee's suitability to be trained in a particular occupation? Reference to Stephens may provide some answer, in that:

> "..... to provide a child (employee) with learning opportunities that are commensurate with his level of cognitive development. Commensurate activities may be defined as activities that are far enough in advance of a person's present level of functioning to be motivating but not so much in advance that they will be frustrating. Because tempos of development vary from person to person, individual appraisal of a person's current level of functioning is necessary to determine the individually appropriate level for reasoning activities".
> (B. Stephens, 1977, pp139).

According to Moore (1980), Piagetian theory provides an adequate procedure of intervention when combined with the use of a diagnostic battery. Assessment of abilities is an integral prerequisite to training which may have further implications for productivity and efficiency. It is, therefore, important that some means be established which allows access to the conceptual abilities of a work force in order to select and place workers effectively.

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CHAPTER THREE.

SELECTION AND PLACEMENT OF BLACK MINING PERSONNEL

IN THE SOUTH AFRICAN GOLD MINING INDUSTRY.

3.1 INTRODUCTION.

The mining industry, as represented by the Chamber of Mines of South Africa, has an approximate annual total of 400 000 Black men employed. The majority of these workers are migrants from various parts of Southern Africa, who work on the mines for a contracted period of twelve months before returning home. Not only is the Black labour force heterogeneous in composition, it is also in a state of annual flux. These factors pose complex problems for the various mining houses with regard to adequate selection and placement within the mine.

Each Black mineworker who arrives for work on the mines is allocated to a training section before being released to a production section. Faced with a heterogeneous labour force, which has varied amounts (quality and quantity) of exposure to the industrial environment, coupled with widely differing standards of formal education, the Chamber of Mines uses a measure of 'trainability' as the criterion for selection and placement of Black manpower. Due to a lack of reliable measures of educational and occupational experience, the mining industry is dependant on psychological tests, to assess the capabilities of the labour force.

3.2 THE CLASSIFICATION TEST BATTERY.

The Classification Test Battery (CTB) was developed and validated by Grant in 1970. The battery was designed as a measure of general aptitude aimed at predicting the extent to which recruits could be trained. The CTB replaced the General Adaptability Battery which was introduced after the Second World War. Biesheuvel (1952) reported validity coefficients of 0,58 and 0,55 from training results and ratings

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of job efficiency. According to Hudson (1953), the principle aim in designing the GAB was to allow the mining industry to categorise Black labour and facilitate training for those jobs for which they were best suited.

Grant (1970) reported multiple correlation co-efficients for the battery with theoretical job knowledge (0,60), practical performance (0,63) and a composite criterion (0,65) which gave an overall validation co-efficient of 0,66 (Mauer, 1972; Theunissen, 1979). The validation sample used by Grant was confined to novices with less than six years of formal education. Test scores were correlated with training performance, and according to Theunissen (1979) the co-efficient obtained (0,66) can be considered highly acceptable in psychometric testing.

3.2.1 Composition of the CTB.

The Classification Test Battery consists of three tests, namely:

1) The Pattern Reproduction Test,
2) The Circles Test, and
3) The Form Series Test.

The battery also includes a buffer test, known as the Pegbord test which is intended to reduce test anxiety.

3.2.2 Factors measured by the CTB.

Theunissen (1979) reports that research which led to the development of the CTB was strongly influenced by Thurstone's (1951) conception of primary mental abilities. Grant (1970) notes that the development of the tests was governed by careful attention being given to factors on which the tests are loaded.

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Theunissen (1979) lists the four abilities measured by the CTB as:

1) Perceptual speed - this factor is characterised by the task of finding a given configuration, in a mass of distracting material, which is borne in mind during the searching process.

2) Perceptual analysis - this factor is characterised by the task of breaking down or analysing perceptual material into its component parts. Having analysed the material, the subject is required to discover the similarities and differences which exist among the stimuli.

3) Conceptual reasoning - this factor may be defined as the ability to discover, or apply a rule, by relating concepts to one another. It involves defining the attributes of the given stimuli and distinguishing one stimulis from another.

4) Space - this factor represents the ability to perceive spatial relations accurately and to compare them with one another.

The CTB takes approximately two hours to complete. Testing is supervised by Black aptitude test instructors who have qualified according to requirements laid down by the Chamber of Mines. In order to facilitate an understanding of the testing procedure, instructions are read out in a number of African languages. Testees are also shown a motion picture of testing procedures with Blacks in the various roles as instructor and testee. For a large number of employees, this film is

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their first exposure to such a communications medium.

3.2.3 General psychometric properties of the CTB.

With the increase of levels of formal education amongst Black mineworkers and the increase in scores achieved on the CTB, a study was undertaken by the Chamber of Mines to gauge the feasibility of replacing the CTB. As a consequence, several interesting psychometric factors emerged.

According to Ballantine (1979), it was possible for Grant (1970) to explain 42 percent of the variance of the training criteria used on the basis of a weighted multiple regression formula. Grant did not report the reliability of the total CTB but, on the basis of subtest reliabilities which he provided, it is possible (as done by Kristoff, 1978) to estimate the CTB reliability at 0,94 - an extremely high value. However, this figure does not necessarily hold today, some eleven years later.

Taking the total score distribution, Ballantine (1979) was able to show a slightly bimodal distribution of high variance. Twelve percent of all testees obtained scores in the upper 7 percent of all possible raw scores (range 101 - 107). Ballantine regarded this as problematic in that it prevents any meaningful discrimination between these particular testees. The aim of Ballantine's research was to assess which of the four subtests would be most suitable for incorporation in a new selection test being developed.

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1) Pattern Reproduction Test - the distribution of this test was found to be negatively skewed with 31 percent of all testees obtaining scores in the top 7,7 percent of all possible raw scores (37 - 39). It is clear from the distribution that this test is of little use for classification purposes, as a large percentage of testees are compressed into a small raw score range, making meaningful discrimination extremely difficult.

2) The Circles Test - the distribution for this test was also found to be negatively skewed with 24 percent of all testees falling in the top 12,5 percent of all possible raw scores (29 - 39). This subtest can also be considered as unsuitable for classification purposes.

3) The Form Series Test - the distribution of this particular subtest was found to be bimodal. The FST scores were found to have little skewness and had a large variance. Only 15 percent of all testees scored in the top range (33 -36), which was equivalent to 11 percent of all possible scores. In terms of these findings Ballantine found the FST to be the most suitable for classification purposes; there being only an apparent problem of 'strategy'.

A study by Melamed (1978), was directed at assessing the possibility of testees using various 'response strategies' on the Form Series Test. He found a number of strategies were being used of which only one leads to the answers that Grant (1970) intended. Melamed contended that this problem arose from the use of

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incorrect strategies by testees and this is partially reinforced by completion of practice items prior to taking the test. Melamed found the most common 'alternative strategy' to be what he termed, 'repeat the last two' which, when applied by 40 percent of his sample, resulted in a modal score of '6'. Alternatively those testees who applied the 'correct strategy' (some 38 percent) yielded a modal score of '32'.

Ballantine (1979) concluded that it would be best to retain the Form Series Test if the CTB were to be modified, as the subtest had the most suitable reliability, validity, distribution and variance. Grant (1970) undertook a factor analysis on a number of psychological tests including the three subtests discussed above. The results of which produced a single factor which he labelled 'spatial'. More specifically, the Form Series Test had the lowest loading (h=0,41) on the spatial factor. However, this is not surprising as the FST is basically a test of reasoning ability rather than spatial relations. Ballantine indicates that the FST may be optimally combined with a spatial test in a modified selection battery.

3.3 DISCUSSION.

The CTB has long been regarded as a rather arbitrary means of selecting personnel. However, while it is easy to criticise the relative merits of the battery, let it be said that the selection and placement of so large a body of semi-literate, unskilled, semi-skilled and culturally diverse workers within one industry is no simple matter. The Black mineworker

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provides the labouring element in the industry and as such the training methods which have been developed focussed on ways and means of yielding higher productivity. The Black mineworker is completely removed from planning and decision making yet his work, as labourer and supervisor, is of critical importance.

Principle factors which would hamper any development of a reliable and valid selection battery in the mining industry include:

1) Lack of exposure to an industrial working environment.
2) Standard of formal education.
3) Cultural and linguistic diversity.
4) Unfamiliarity of the abstract demands of aptitude and IQ tests and the consequent scepticism as to their effectiveness.

The selection system is sanctioned by mine management and affects the majority group making up a mine's labour complement - a majority that not only suffers from statutory job reservation - but one which is not represented via trade unions, which could negotiate for more valid selection and placement instruments. The Black mineworker is in a system of which he has little understanding and is being selected for certain jobs on the basis of criteria which principally satisfy the rationale of the whole operation - expediency.

Language difficulties posed by giving instruction at the tribal interface are largely overcome by the use of 'Fanakalo', which is a basic mixture of African, English and Afrikaans words strung together by African pronounciation. Although Fanakalo has proved useful for communication, it is highly restricted especially with regard to technical terminology and industrial

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innovations.

Researchers from the Human Resources Laboratory (Theunissen, Mauer, Melamed, Wolfaardt and Ballantine) have all at some stage referred to the shortcoming of the CTB as a selection instrument. When Grant validated the battery in 1970 he little knew how rapidly his instrument would become dated. Some of the shortfalls of the CTB, identified by certain researchers, will now be highlighted.

3.3.1 A changing labour force.

Theunissen and Wolfaardt (1978) argue that the only factor which influenced performance on the CTB was the testee's level of education. The average level of performance on the three subtests, by subjects, has risen consistently since the introduction of the CTB.

As a result of increased performance on the battery, the reliability and validity of the instrument has reached the level of statistical undesirability, and indicates that the point has been reached where the level of the battery is too low relative to the standard of sophistication of testees. Also, the validity of the CTB for testees with more than six years of formal education is not known.

3.3.2 Retesting.

A study carried out by Verster (1974) attended to the problem of testees being tested more than once on the CTB. Verster concluded that men who are repeatedly retested reveal a positive increase in test performance. These findings were, at first, regarded with some concern but follow-up studies by Melamed (1976) and Theunissen

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and Wolfaardt (1978) found the problem to be less acute than at first thought. Their studies found test scores did increase slightly on retest but declined subsequently. The effect of retesting was considered insignificant.

Although the effect of retesting may be considered to be minor, it is possible in the long term, that the validity of the battery may be affected through over-exposure to the tests. As indicated previously, the normal period before retesting is approximately three months. The CTB takes two and a half hours to administer and the man hours lost through retesting are considerable.

3.3.3 Ambiguities in testing policy.

Black mineworkers are restricted in terms of the Mines and Works Act of 1956 in the types of work they may perform in the mining industry. Although there have been movements recently towards opening certain avenues to facilitate Black advancement, there are in practice very few categories of work in which both Black and Europeans are employed. Generally, aptitude tests are used only for the selection of Blacks and not for Whites. European employees are engaged and placed after completion of training periods, e.g. miners and learner officials. Achievement scores are used for the initial placement of Whites. In contrast to this, Blacks are hardly ever given achievement tests for initial placement. Instead they are limited in their choice of occupation by their performance on an aptitude battery. Melamed (1977) writes,

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> "It is not clear why ability is used as a selection criterion for Whites but not Blacks. Possibly it is thought that Blacks have little experience of technology and therefore there is a greater need to assess their 'potential' rather than their ability. This may hold for novices but not for those with mining experience".
> (Melamed, 1977).

Another difference in selection policy is that Whites are recruited for certain jobs while Blacks are recruited for mining. According to Melamed (1977) aptitude tests, when used for Whites, facilitate selection; tests for Blacks are almost exclusively used for job placement. Melamed proposes the rationale behind such practices is that Blacks have limited experience of specific jobs. Again, this may hold true for novices but certainly not for experienced men.

3.3.4 Implications of testing.

Management may claim to be scientific in its selection policy in that it uses a statistically validated instrument, but it is abuse of the instrument that is problematical. The CTB score labels and virtually channels a Black mineworker's career into a fixed promotional route from which there is virtually no recourse, except by moving on to another mine where he has another opportunity on the CTB. Melamed (1976) drew attention to the hidden cost of a policy where the capable employee is prevented from promotion through low CTB scores. However, as

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Theunissen (1979) correctly points out, the CTB was not intended to label but rather to assist with initial placement of a worker within the industry.

The South African Government has placed restrictions on the use of psychological tests, the most significant being registration of psychologists with the S.A. Medical and Dental Council in order to work as practitioners and be legally recognised as such. This is in contrast with the United States where the courts have enforced a prerequisite which stipulates that psychological tests must have demonstrable validity before they can be used (Fincher, 1973). So in the United States, the test user must demonstrate, for example, that the test intended for use has a significant known relationship with performance on the job. Tests which do not meet legal requirements cannot be put into use in the United States.

According to Melamed (1977), in South Africa the only limitation on what tests may be administered is confined to the choices of certain registered psychologists. There is no legal requirement to demonstrate usefulness of a test and, theoretically, management is free to use any test desired, irrespective of the fact that it may be disadvantageous.

Melamed (1977) contends that workers who are more aware of their rights and assertive in their demands are likely to become more hostile to psychological testing. The situation may become aggravated where testing is conducted in an inflexible manner, as in the mining industry,

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where Black mineworkers are permanently categorised in terms of job capabilities as measured by the CTB. Resistance to the system which permanently channels a man's promotional routing may become especially acute where tests neither predict anything more than 'trainability', nor from the worker's point of view, appear to be doing so.

Management may well become more resistant to the use of psychological tests should testing become a contentious issue.

It must be acknowledged, however, that the utilization of the GAB and CTB in the mining industry has allowed placement of Black personnel, albeit in a very general sense. The contention is, however, that with developments in labour law and recognition of trade unions in the South African situation, it should be apparent to those planning future manpower resource utilization in the mining industry that a more relevant instrument be developed for selection purposes. It is doubtful whether any Black mining trade union (should one ever come into being) would recognise and accept selection methods currently employed by the Chamber of Mines. The Wiehahn Commission (1979) recommended that Blacks be allowed to become scheduled persons - holders of blasting certificates. Should this recommendation be passed through the legislature, it would mean greater competition for mining jobs. The mining industry would, as a result, have to employ more sophisticated instruments so as to ensure selection of the best available candidates irrespective of race.

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The selection system currently used by the Chamber of Mines in conjunction with various mining houses, is relatively cost effective in terms of actual capital outlay. Test scores are monitored at selected centres by trained staff who bring about necessary changes as circumstances warrant them. Test supervision is provided by certificated Black aptitude test supervisors. These supervisors are in turn presided over by White training personnel, who are generally ex-production employees and have little or no formal academic training in psychometric testing. Aptitude testing on the mines is conducted in a mechanical fashion by persons who are thoroughly versed in the routine of test administration but for the most are entirely ignorant of the implications of the instrument they administer. Furthermore, this method of selection saves mining houses the cost of employing academically qualified, registered psychometric testing personnel, whilst relying on the Chamber of Mines to provide suitable staff to act as a monitor.

Should statutory job reservation be done away with, the mining industry will be required to introduce sophisticated selection instruments for all prospective employees, irrespective of race, and to increase the level of standard requirements to be met by applicants. This must not be seen as a discriminatory step against Coloured persons as they would be most disadvantaged because of an inferior education system. Employers would be in the position to select the best candidates available simply because of increased competition for jobs by a larger

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labour resource pool.

Because of its vital position in the South African economy, it is doubtful that Government will allow labour unrest to affect the production of gold. Should Government continue with its present policies and dismantle job reservation, it would be a priority that the new labour dispensation incorporates a system which provides for valid, relevant selection methods and which is acceptable to the respective mining unions.

It is naive to assume that mining positions will always be filled by Whites. As South Africa develops economically so the need for diverse skills increases. In a nutshell, there are simply not enough skilled Whites to fill all skilled positions in an industry which is rapidly expanding. The emotiveness concerning an open job market for all must be replaced by a realistic appraisal of skill requirements.

This study is an attempt to justify the need for better insight into the conceptual abilities of Black mining personnel and consequently structure training accordingly.

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CHAPTER FOUR.

THE EXPERIMENT.

4.1 INTRODUCTION.

The present research is a continuation of that undertaken by Moore (1980). Whereas Moore conducted a pilot study confined to a laboratory setting, the present research is an attempt at applying a battery of Piagetian conservation tasks, as compiled by Moore (1980), in a mining environment.

Subjects were chosen at random to form two main groups, i.e. an Experienced group and a Novice group, and further subdivided into four according to their CTB rating, for example, Blue, Pink, Yellow or White card holders. Subjects chosen for the Experienced group had to have completed at least one contract period on the mines. All novices must complete a period of three months underground working as 'lashers' or manual labourers before they return for further training in the type of occupation deemed most suitable for their dudec rating on the CTB.

A total of fifty six Black mineworkers were tested with the intention of achieving three major objectives:

1) A conceptual profile which would highlight the subject's conceptual abilities in relation to job skill requirements, which for all intents and purposes his performance on the CTB instrument has classified him to be trained for.
2) An empirical analysis of combined Behavioural and Explanatory response to support the hypothesis that more experienced Black mineworkers should perform better on the battery than novices; the reason being conceptual development facilitated by cognitive adaptation to the demands of a selectively different technological environment.

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3) To evaluate a battery of Piagetian conservation tasks in order to construct a conservation scale with sound statistical properties.

Literature on conservation has tended to support some of Piaget's ideas and illustrates some methodological difficulties. Goldschmid and Bentler (1968) write,

> "The lack of consistency in conservation tasks used and the employment of different testing procedures in almost every investigation, make it extremely difficult to compare the many studies and derive some overall conclusions". (Goldschmid and Bentler, 1968, pp 789).

Important psychometric indices such as retest reliability, homogeneity and level of difficulty of different conservation tasks are rarely taken into account. Feigenbaum (1963) and Goldschmid (1967) found that procedural variation (length of a plasticine sausage or comparing a ball with a sausage instead of a pancake) may affect a child's judgement of conservation. By constructing a conservation scale with dependable statistical properties, it is intended to introduce greater consistency and statistical accuracy in conservation studies.

The testing procedure for each task followed the method and design explicitly outlined by Piaget in his descriptions of the tasks and the types of questions put to subjects. A skilled Black interpreter was used and each session was conducted in the home language of the subject.

Descriptions of the conservation tasks and methodology which follow have been selectively adapted from Moore (1980).

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4.2 CONSERVATION OF SUBSTANCE.

Piaget contends that the conservation of substance represents the simplest quantification of qualities and is distinguished from measurement of more complex properties such as weight and volume. Substance is by nature an undifferentiated and global property and may be quantified before its attributes (weight and volume) because it provides the subject with an undifferentiated quality. From this point of undifferentiation the subject can move on to more complex properties which become quantified in the course of their differentiation. The conservation of substance demands an understanding of the invariance of the support of that which makes up the substance of the object. To the conserving subject, transformations in the form of rearrangement, deformation, etc. are neutralised and the quality is regarded as being the same despite misleading perceptual cues.

4.2.1 Method.

The subject is handed two equivalent amounts of plasticine, one being in the shape of a ball. The subject is then requested to make a similar ball of the same dimensions with the lump of plasticine. Once the subject is satisfied that the two balls are identical, the experimenter asks a number of questions (see Appendix 1).

4.2.2 Stages of development.

Stage 1 - The absence of conservation.

This stage is typically dominated by responses indicative of the subject's dependence on perceptual cues as criteria for making judgments. Substance is not judged

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to be the same because observable transformations result in one quantity being 'longer' or 'thinner' or 'bigger' or 'there are more pieces'. Often the subject's only reference for explaining quantities as equal is the colour of material used. Stage 1 subjects do not have the necessary quantifying operations and as a result are unable to conserve substance.

Stage 11 - Towards the conservation of substance.

Stage 11 subjects are able to conserve substance but not weight and volume. Sub-stage 11A is characterised by responses that oscillate between characteristics of Stage 1 and Sub-stage 11B. where the conservation of substance is invoked spontaneously as a logical necessity.

Sub-stage 11A - Intermediate reactions between non-conservation and the conservation of substance.

This stage indicates the conflict situation conservation arouses - a conflict between direct experience and rational operations. Subjects who are dependent on perception give similar responses to Stage 1 subjects. As soon as the reliance on perceptual cues diminishes and is replaced by increasing attention to transformations, the subject is forcibly led towards the conservation of substance. Typically, responses will vascillate between a dependence on perception and transformations. The two key factors involved in conservation of matter are (1) Identification - nothing has been added or taken away in respect of the transformed ball and, (2) Reversibility - the notion that operations which are responsible for the transformations are reversible. Both factors are necessary for the conservation of substance.

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Sub-stage 11B - The conservation of substance.

In Sub-stage 11B the operational mechanism replaces perception and the conservation of substance is acknowledged under all circumstances. But although subjects readily acknowledge the amount of matter as being the same despite transformations, they are as yet unable to conserve weight and volume. The deformed ball may have the same amount of plasticine but its weight and volume increase or decrease according to its size.

Stage 111A - Intermediate responses between non-conservation and conservation of weight.

Another stage of vascillation between dominance by perception and/or logical necessity. There is a lack of true reversibility and the invariance of weight is not discovered. The subject is in a conflict situation governed by a conservation of substance and perceptive intuitions, with regard to the quantification of weight. Subjects respond positively to the behavioural questions and report that the balls weigh the same but cannot give an explanation why this may be the case.

Sub-stage 111B - The conservation of substance and weight..

In this stage, the subject conserves substance and weight, being invoked as a logical necessity. Both balls have the same amount of plasticine and they weigh the same because nothing has been added or taken away despite the transformations. The subject also suggests that should he roll the manipulated material into a ball there will be a return to the position the exercise started out from and where quantities were equal.

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4.3 CONSERVATION OF SPACE.

Piaget distinguishes between conceived space and perceived space. Perceived space is associated with the sensori-motor stage of cognitive development. Initially topological relations are perceived and only later, with the recognition of object permanence and consistency of size and shape, does the child come to recognise euclidean and projective spatial relations.

For the purposes of the diagnostic battery, only euclidean spatial relations are considered as they are more complex than projective or topological spatial relations. The euclidean concept of space is founded on concepts of parallels, angles, proportions and the conservation of distance and measurement. Euclidean space embraces all objects and consists of relations of order which are applied simultaneously to three dimensions. Objects are loaded into a three-dimensional reference system of vertical and horizontal co-ordinates. This frame of reference is not simply confined to relations of order between objects, but is also applicable to the positions objects occupy, which in turn allows relations between objects to be maintained as invariant in spite of any potential displacement of the objects.

Piaget alludes to such a frame of reference constituting euclidean space as similar to a 'container' which is relatively independent of the active objects 'contained' in it.

4.3.1 Method - horizontal and vertical axes.

The simplest reference frame of the physical world is provided by vertical and horizontal axes. The subject is required to make reference to these axes in order to

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assess his conceptual frame of reference.

Concept of the horizontal.

The subject is shown a frame housing two identical glass bottles which may be tilted to any degree around a central point. One bottle is half filled with a red-coloured viscous liquid. The second bottle contains a piece of cardboard, representing the liquid in the other bottle, identical in colour to, and quantity of, the liquid. The card may, in turn, be tilted around a central point in such a manner that it can parallel any angle of the liquid in the other bottle when it is tilted.

The subject is shown both bottles and his attention is drawn to the red card as being fully representative of the red liquid in the other bottle. Furthermore, the subject is shown how to manoeuvre the card. The bottle containing the liquid is covered so that the subject is unable to see it, and the demonstrator tilts both bottles in the same direction and at the same angle. The subject is requested to move the card to show the position of the liquid in the other bottle. The bottle containing liquid is then uncovered and the level of the card compared with it.

The experimenter then tilts the covered bottle containing the liquid to various angles in full view of the subject who must then move the card in the other bottle to indicate the position of the liquid. After completing the prescribed number of manoeuvres, the subject is required to pencil in the position of the

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liquid in outline drawings of a bottle tilted at various angles. Each diagram illustrates a line, representing the horizontal, so as to provide a horizontal axis.

Concept of the vertical.

The subject is shown a plasticine mountain and asked to build a fence over the perceived extrusion. The subject is then requested to draw a fence over a hill in an illustration and then to draw two houses and two trees on the slopes of an outline drawing.

4.3.2 Stages of development.

Stage 1 - Inability to distinguish surface or planes, in the case of liquid or solid.

Subjects at this stage regard fluid in purely topological terms - something contained in a bottle - and not according to euclidean concepts such as straight lines, planes or dimensions. Liquid levels are not delineated by lines but are merely drawn as a blot contained within the bottle. Fence posts are drawn lying down and in proximity to the mountain slope. Houses are attached by their side walls. Irrespective of arrangement, objects are never placed vertically.

Responses of this nature indicate a complete absence of conceptualizing horizontal and vertical co-ordinates, which is initially due to a disregard for orientation of objects, because as yet the subject does not grasp relations applying to empty space.

Sub-stage 11A - water level shown parallel with the base of the bottle and trees perpendicular to the mountain side.

Here the subject still fails to grasp the orientation

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of liquid in a tilted bottle or posts on an inclined slope. When tilted it is assumed that the liquid expands towards the neck of the bottle while the surface remains parallel to the base. However, subjects of this stage do initiate the use of straight lines and planes under certain conditions. Trees and posts are drawn perpendicular to the slope and the concept of right angles starts to emerge to supplement concepts of the plane and the parallel.

Sub-stage 11B - intermediate responses.

Responses typical of this stage center around the subject's belief that liquid in a tilted bottle is not confined to the vessel's base but moves according to the direction of tilt and is related to opposite corners of the bottle. Subjects still have no reference system on which to base their conception of the liquid when it is no longer parallel to the base of the bottle, nor how to determine the angle between the level of the liquid and the side of the bottle.

When the bottle is inverted subjects record a correct response because the liquid assumes its position parallel to the base.

As regards the concept of the vertical, subjects tend to place fence posts vertical on the plasticine mountain, but on the drawings figures are drawn perpendicular to the slope or a position between the perpendicular and the vertical. The subject is also able to enact the concept of the vertical in an inconsistent manner in different situations because his judgments are based on different reference systems without his realisation of this

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anomally. At this stage the concept of the vertical and horizontal is still pre-operational, with the subject's judgment being dominated by intuition.

Stage 111 - the discovery of the vertical and the horizontal.

At this stage the subject starts making use of a reference system to construct and co-ordinate axes which embraces the entire spatial field.

Sub-stage 111A.

This stage is dominated by the subject's trial-and-error constructions of horizontal and vertical axes. The horizontal is discovered when the bottle is on its side and there is a partial discovery of the vertical. Repeated attempts are necessary before the subject is able to recognise the horizontal and the vertical. These concepts are constructed during the actual course of this stage when the necessary operations have been organised into a system.

Sub-stage 111B.

Here the subject utilizes references from parts of the object. The construction of the horizontal and the vertical is translated in operational terms and applied directly to all situations.

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4.4 CONSERVATION OF DISTANCE.

Piaget contends that the concepts of distance and length are psychologically different and should be analysed separately. Piaget refers to distance as 'the linear separation of objects - to empty spaces; and length being the linear size of objects'. Logically the two concepts are interdependent, with distance defined as the length of an interval between objects, and length being the distance taken up by an object.

For Piaget the reconstruction of distance is a problem that is separate from both perceptual estimates and measurement; it is a condition of measurement in itself. Distance is not isotropic to perceptual space in that it represents a deduction that follows from knowledge of the order of points and an understanding of the intervals between the points in relation to the order of the points.

4.4.1 Method.

Two figures (trees) identical in appearance and dimensions, are set out on a table approximately 50 cm apart. The subject is asked whether the trees are 'near one another' or 'far apart'. Care is taken not to refer to movement or distance travelled. The trees remain in the same position throughout the exercise.

Once the subject has answered the first question a wooden screen, which is slightly higher than the trees, is placed between the two figures. Again the question is asked whether the trees are 'far apart' or 'near' depending on previous reply, and he is requested to substantiate his answer. The screen is removed and replaced with other objects such as a screen with its centre removed to give a 'window' effect; a large cube

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which is much taller than the trees; and a carpet of wooden bricks which are lower than the trees and form a pathway.

The question of symmetry was raised by asking, 'is it near or as far (depending on the subject's formulation) from here to there (AB - tree to object) as it is from here to there (BA - object back to same tree)'? The experimenter is required to run his finger along the distance AB and BA to avoid misunderstanding. The subject is then presented with two figures (tree A and cube B) where B is twice as high as A. The same questions are then asked concerning the distance separating the two objects.

Finally, the subject is presented with two figures (trees) where one is raised 50 cm above the other so that they are on different levels. The subject is again asked if AB equals BA, with care taken not to mention climbing up or down.

4.4.2 Stages of development.

Stage 1 - absence of overall distance.

Subjects are unable to co-ordinate the two distances AS and BS (A and B are trees and S is the screen/mediating object) such that the distance relation between A and B has no meaning when the object is interposed. Furthermore, the distance relationship is asymmetrical (AB,BA) when figures A and B are on different horizontal planes and occasionally even when on the same plane.

Subjects are unable to combine the intervals AS and SB to obtain an overall distance because of the impositions of intuition and an inability to reverse operations. The subject may, repeatedly, respond by breaking the

two distances AS and SB and regarding them as separate but equal entities. The subject's attention is focussed on the intrusion of object S and the space it occupies seems to distort his prior conception of the empty distance AB. The object S becomes, for the subject, an obstacle - 'its in the way' - this much is gained from the explanation given to substantiate his response.

With respect to the symmetrical property of distance (AB equals BA), two situations may be distinguished. Firstly, where A and B are on the same horizontal plane, subjects are unable to comprehend whether the distance from A to B is the same as distance B to A because their conceptions of order is not reversible. Secondly, where one of the objects is higher than the other (taller or situated higher), distances seem greater in an upward than in a downward direction. Judging by explanations given by subjects, it would appear that because an upward climb is more strenuous than the downward, the former is perceived as being longer and hence further.

Stage 11.

This stage presents the core of the problem in the conservation of distance. Subjects are able to compare reciprocal distances between A and B with the interposed objects. However, they maintain that the overall distance (AS + BS) varies with the thickness of S. Also, a difference in height between A and B commands the belief that distance between the objects is asymmetrical.

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Sub-stage 11A - non-conservation of overall distance, distance relations asymmetrical.

Subjects lack a co-ordinate system with which they can refer to objects which take up empty space. In order to develop such a system, the subject must recognise that although solid objects may be placed in various positions, each of them must occupy a particular 'site' which remains constant. Furthermore, a simultaneous grouping of relations of order and change of positions is necessary before subjects are able to compare length and distance.

At this stage subjects judge the length of an object in terms of its dimensions and assess distance in terms of intuitive intervals between objects. However, unlike Stage 1 respondents, subjects start to construct an overall relation of the distance between A and B instead of being confined to relations of each figure (A and B) and the object S. This does not imply an operation because subjects are still convinced that the introduction of S alters the distance between A and B. Subjects believe that the distance AB is reduced by an amount which is equivalent to the width of S. In addition, the distance between AB and BA is regarded as asymmetrical.

Sub-stage 11B (Type A) - non-conservation of overall distance. Distance relations symmetrical.

Although subjects still consider distance and length to be heterogeneous, and consequently there is non-conservation of distance, they do recognise the symmetrical character of the interval and the equality of distance AB and BA.

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Sub-stage 11B (Type B) - conservation of overall distance. Distance relations symmetrical.

Type A subjects discover the symmetry of distances AB and BA prior to the conservation of distance. Type B subjects make these discoveries in the reverse order, in that the distance AB and BA are recognised as symmetrical when S is interposed, but when A and B are on different planes the distance is not recognised as symmetrical.

Stage 111 - conservation of distance.

Responses at this stage show the conservation of distance between two fixed objects (A and B) irrespective of the nature of objects interposed as S. Distance is acknowledged as identical from A to B and B to A. Furthermore, subjects recognise that dimensions of solid objects are part of the distance.

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4.5 CONSERVATION OF LENGTH.

Central to measurement is the notion that objects remain constant in size in spite of changes in position relative to one another. As in the conservation of euclidean space and distance, where the subject is required to construct a system of 'sites' that can be filled with objects, conservation of length can only be achieved if the 'site' of an object remains constant in size when it is left empty and when it is occupied by an object. There must be established a stable system of relations between objects, and in addition, a system which hold the length of objects constant when they are moved.

4.5.1 Method.

The subject is presented with two identical sticks, straight and 5 cm long, with their extremities facing one another. The subject is requested to confirm that the sticks are of equal dimensions. One stick is moved 2 cm and the subject is asked which one of the sticks is longer or whether they are of the same length. At all levels the sticks are judged equal before being staggered.

4.5.2 Stages of development.

Stage 1.

In this stage, subjects confine their attention to the extremities of the sticks. Both ends of alternate sticks are not taken into account simultaneously, which implies that subjects are not concerned with intervals of length between the end-points. Changes of position as perceived at this stage lead to non-conservation of length. The path of movement is regarded in terms of

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point of arrival, without reference to point of departure and the interval between the departure and arrival points being made. The lengths of the objects change as a function of their end points.

Sub-stage 11A.

This stage is intermediate between stage 1 and 11B. Subjects maintain that the object which has been moved forward is longer, thinking only in terms of the further extremities.

Sub-stage 11B.

This indicates what Piaget terms 'intuitive regulation' taking place. Intuitive regulation relates to the decentration of attention with subjects taking into account all extremities of the sticks rather than only the leading extremities. Subjects respond that the sticks are equal when in alignment with one another, but this equality is denied when one stick is positioned at an angle of 45 degrees from the mid-point of the other. Subjects who were unable to offer any explanation for their responses were incorporated in this stage. Attempts at conservation of length are dominated by intuition and not founded in logical necessity.

Sub-stage 111 - comparison of length. Two straight lines staggered. Operational conservation.

A reference system of stationary sites and moving objects is constructed and the conservation of length becomes a logical necessity in all instances.

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4.6 CONSERVATION OF TIME.

To determine time, there must be a reference to causality, i.e. linking causes and effects by explaining the latter in terms of the former. Time may be regarded as the co-ordination of motions at different velocities. The construction of time begins with a correlation of velocities. Operational time logically requires that the relations between simultaneity, succession and duration must first be constructed.

4.6.1 Method - the equalization of synchronous durations and the transivity of equal time relations.

For the purposes of the diagnostic battery, the relations of simultaneity and duration will be analysed. Piaget shows that even when a child acknowledges that two bodies start and stop simultaneously he does not, of necessity, conclude that their motions are of equal duration. In order to analyse this, a large reservoir is allowed to empty through a tapering tube that yields two identical jets of water. The flow is collected by vessels of different shapes and sizes. Both jets of water are controlled by a single tap so that the water may be clearly seen to start and stop running at the same time. Questions asked during this task are concerned with synchronisation of water flow, the equality of the durations of the flow, and relations between time and the amount of water run out.

4.6.2 Stages of development.

Stage 1 - failure to grasp simultaneity and synchronisation, and failure to quantify flow.

Responses indicate a primitive inability to grasp

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simultaneity, synchronization and quantification of flow. Subjects at this stage, although aware of the starting/stopping of the flow of water, do not accept the simultaneity of the end of the flow. Piaget indicates that failure to grasp simultaneity may be correlated with an inability to synchronise durations, because the subject thinks of time as belonging to each action separately. Furthermore, actions can only be co-ordinated by their results (i.e. the work done). Because results are not quantified they cannot provide objective criteria by which the subject can judge time durations and intervals, etc. These results do not depend on the interval between the starting and stopping point, but are concentrated on the finishing point alone.

Sub-stage 11A - inverse relations between time and velocity and correct prediction of the filling rate as a function of the size of the bottle; simultaneity but neither synchronisation of durations nor correct quantification of the flow of the liquid.

Subjects at this stage usually succeed in answering the first two questions (see Appendix 1) correctly, but none of the others. It may therefore be inferred that subjects recognise simultaneity and by divorcing time from velocity, predict intuitively, that the larger of the two bottles will be filled more slowly over a longer period of time. They fail to synchronise durations with simultaneous starting and stopping points, or to quantify the amount of water run out. Whereas in stage 1, subjects deny simultaneity because their attention is concentrated on the rising water level and not cessation

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of the flow, in stage 11A this simultaneous stopping of the twin flows is taken into account as well as the rise in water levels. This decentration leads subjects directly to grasping simultaneity.

However, subjects are still unable to establish the equality of the durations until they have developed a conception of quantity that would enable them to realise the equality of the two amounts of water that were run out.

Sub-stage 11B - the empirical discovery of synchronisation.

After a number of attempts subjects are able to grasp the equality of synchronous durations and of the quantities of liquid run out. But this ability is still not fully operational and is to some extent intuitive and empirical.

Stage 111 - immediate synchronisation and quantification.

This stage indicates the operation construction of the relations of time, and demonstrates that the greater the grasp of synchronisation, the better the quantification of the work done. Subjects must construct relations of time operationally before they can appreciate that the equations X = Y and X = Z are transitive.

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4.7 THE CONSERVATION OF SPEED.

According to Piaget, the simplest intuition of speed and movement is founded on an intuition of order. A moving object is judged to move faster than another when it overtakes it on a path parallel to its own, when it was originally behind or side by side the other object according to the direction of travel, and is afterwards ahead of it.

4.7.1 Method - the speed of two movements where only the starting and stopping points are visible.

This task involves the subject judging the respective speeds of two moving objects when the starting and stopping points alone are visible. The paths traversed are unequal in length, but parallel, and run in the same direction. For the most part, two tunnels ensure the travelling objects remain out of sight for the subject. In order to conserve speed the subject must respond correctly by reasoning: if the two objects start and stop at the same time, and if they are in motion for the same amount of time; do not travel the same distance; that one of the objects is travelling faster than the other.

4.7.2 Stages of development.

Stage 1 - failure in comparison of speeds.

The subject is unable to solve the problem even after witnessing the exercise without the tunnels and seeing the cars travel the unequal distance. Intuitive solution to the problem is demonstrated by the fact that subjects have no difficulty in recognising that one of the cars travels faster than the other when the tunnels are removed. This holds only when the cars are

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set off simultaneously from the same point and travel in the same direction. Intuitive judgments are based on visible 'overtaking'.

Piaget points out that subjects observing the simultaneous stopping of the cars, tend to judge the speeds as equal even if one car is set off after the other from the same starting point. Some subjects contend that the car travelling the farther distance takes a longer time, even though they have seen the simultaneousness of starting and stopping.

Generally, subjects at this stage judge the speeds to be equal by centrating on the simultaneousness of starting and stopping.

Stage 11 - intermediate responses.

Subjects initially judge speeds to be equal and then gradually move towards a correlation of time and distance travelled. When the plastic tunnels are returned, subjects have no difficulty in grasping from the length of the longer tunnel that a hidden overtaking takes place and deduce that one object is travelling faster. But this deduction is not operationally based in that they think in terms of real overtaking and do not correlate the time and space traversed.

Stage 111 - operational solution to the problem.

At this stage subjects are able to establish the difference in speeds by immediately correlating the given factors of time and space traversed. In taking cognisance of the equality of the synchronous durations, overtaking becomes the relationship of the space traversed and the intervals of time. Consequently there

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is no further need to imagine any overtaking inside the tunnels. The distance travelled and the time taken are directly correlated into speed.

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4.8 UNIFORMLY ACCELERATED MOVEMENT.

According to Piaget, once a subject is able to conserve speed the way is open for acquisition of the concept of acceleration. Conservation of acceleration requires the co-ordination of relations of speed, distance and time. A simple method of studying acceleration is to observe uniformly accelerated movement on an incline plane.

4.8.1 Method.

Subjects are shown a straight track, half of which may be inclined to various heights, and presents a downhill and a horizontal situation. A scale model car is also presented. Once the subject has discovered that the speed of the toy car changes as it rolls, a second parallel track may be marked with flags at equal distances (four intervals). The subject must discover that the speed of the car differs with each interval.(1) A third condition concerns a decrease in times over equal distances and the fourth condition deals with an increase in distance covered in equal time. (2)

4.8.2 Stages of development.

Stage 1 - no acceleration as a function of descent.

Piaget indicates that most subjects begin this task already having an intuition of acceleration, although some may have no notion of acceleration at all. In the latter case, subjects are unable to conceive an object as moving 'faster and faster' or even just 'faster'. They only entertain the idea that an object is moving at speed which remain constant.

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1. See Appendix 1.
2. See Appendix 1.

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At this stage, questions of acceleration are meaningless to the subject.

Stage 11 - intuitive acceleration.

This stage is characterised by an empirical intuition of acceleration as a function of the incline. Piaget claims that this intuition is incomplete as acceleration is not conceived as regular or continuous - there is no correlation of time with the distance covered. At this stage the subject either believes that times taken for each interval are equal because the distances are, or he correlates an increase in speed with an increase in time.

Stage 111 - articulated intuition of acceleration and gradual success in correlating times and distances successively traversed.

Subjects initially commit the same errors as those in stage 11 (correlation of equal distances with equal times and vice versa, etc.), but then correct their responses spontaneously. It is this correction which indicates that subjects have not yet fully succeeded in construing acceleration operationally. Their thinking remains a simple representational imagination.

Stage 1V - immediate solution of the problem by formal operations.

In the previous stage the subject's reasoning is governed by the concrete - what is physically present - whilst at the formal stage subjects are able to solve the problem by hypothetico-deductive reasoning. Subjects of this stage immediately respond that time taken for equal distance decreases and with each new equal time distance increases.

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4.9 THE CONSERVATION OF FORCE.

Moore (1980) selected a task which incorporated Newton's third law of motion to deal with the concept of force as part of a diagnostic battery.

4.9.1 Method - the transmission of movements.

This task deals with the immediate and mediate transmission of movements from one object to another. The subject is presented with a number of wooden balls suspended on wire and which may be hung from a horizontal frame. There are six medium size balls, eleven small balls and one large ball. All balls are suspended on wire three inches in length except for two small balls - one is suspended by wire five inches long and another by a short wire one inch long. A short wooden ruler (three inches in length and suspended on wire three inches long) is also provided.

The subject is shown the horizontal bar with a small ball and a silver ball attached to its extremities and is asked to move the silver ball by not touching it, but by using the ball already attached and any of the other objects provided. Care is taken to impress upon the subject that neither of the two balls originally placed may be removed from their positions.

The operational solution is achieved when the subject is able to align balls of the same size and the same length of suspension as those originally placed, and they are able to explain how force is transmitted when the ball at one extremity is drawn back and allowed to strike the following ball.

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4.9.2 Stages of development.

Sub-stage 1A - centration on immediate transmission.

Subjects of this stage attempt immediate transmission by implementing direct contact between the two balls. These subjects do not think of using other balls as intermedia and have no conception of mediate transmission. Piaget indicates that in this stage when the subject collides one ball with another, he forgets which ball started the process - indicating a difficulty in realising the order of succession.

Sub-stage 1B - the discovery of quasi-mediate transmission.

Quasi-mediate transmission refers to the idea of a chain of immediate transmissions as opposed to the idea of a force that traverses a number of moving objects. It is a stage of transition from the absence of mediate transmission to the discovery of chain reactions. Subjects of this stage hook up other balls or the ruler as intermedia and follow the chain reaction of one object striking the next, and so on. This seems to indicate that before subjects are able to conceive mediate transmission, they must grasp the order of a succession of events. Subjects discover that by using objects as mediators, they are substituting an action of the object for an action of their own.

Stage 11 - an appeal to mediate transmission.

Subjects appeal almost directly to mediate transmission, but they still believe that large balls should be used to augment the force of impact. The deliberate selection of large balls suggests a failure to grasp the conservation of transmitted motion, and consequently,

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an operational construction of force as mass acceleration.

Stage 111 - operational solution of the problem.

Subjects of this stage hook up intermediate balls of equal sizes (and same length of wire) to the small ball, as an immediate solution to the problem. The most effective solution being to hook up all similar balls so that they touch one another. Consequently, the minimum amount of force applied to the first ball induces movement from the silver ball. Subjects reason the solution as energy (force) being transmitted through intermediate objects and inducing movement in the target ball. (3)

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3. Further details concerning methodology and apparatus may be found in Moore, R.S. Unpublished Master's thesis. Rhodes University (see References).

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4.10 SCORING.

It was decided that for an applied situation, Behavioural and Explanation scales would be used in conjunction with conceptual profiles. Each subject was asked a set of standard questions (4) which were scored statistically and in the form of a conceptual profile. The use of conservation scales allowed between-groups comparisons and statistical inferences to be drawn. This would not have been possible if profiles alone were scored.

Responses were scored strictly according to Piagetian interpretations. Three principle conceptual areas were covered:

1. Responses based on intuition.
2. Intermediate responses (not fully operational).
3. Conservation responses.

Subjects who scored the maximum on both indices were adjudged to have conserved a particular concept and profiled accordingly. The subject who relied on intuition would have some or all of the Behavioural marks but no Explanation scores. Similarly, intermediate subjects would have a predominance of Behavioural scores with a small number of Explanation scores correct. However, each case was scored individually and allowance made for finer demarcations on the conceptual profiles.

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4. See Appendix 1.

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4.11 Results.

Scores were statistically analysed by computing them on SPSS for OS/360, Version H, Released 8.1, May 20, 1980. Three analyses were used, namely,

- Chi square distribution (using crosstabulation)
- Pearson Correlation Coefficients
- Partial Correlation Coefficients

Cross tabulation was used to determine the level of significant difference in performance between Novices and Experienced workers. The Pearson and Partial Correlation Coefficients were used to determine the level of significant correlation between the variables.

These variables were:

1. Category of worker (Novice/Experienced).
2. Substance.
3. Space.
4. Distance.
5. Length.
6. Time.
7. Speed.
8. Acceleration.
9. Force.
10. Age of Subject.
11. Years of Education.
12. Number of Mining Tours.
13. Total Test Score.

4.11.1 Chi-Square distribution.

Chi-square was used to test for significant difference in the scores of experienced and novice groups, if there was any significant difference. Frequency tables were

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computed for both group's scores on each concept (for example, Substance). In addition, frequency distributions were obtained for variables 10 to 13 to test for significant difference. Each cell on the "Crosstabs" computation yielded the following data for each variable:

		SUBSTANCE			
		VAR001			
	SCORE	NOVICE	EXPER.		ROW TOTAL
		1	2		
VAR002	8	2	3		5
		40,0	60,0		8,9
		7,1	10,7		
		3,6	5,4		

VAR001 is the category of worker.

VAR002 is the concept of substance.

The above cell may be analysed as follows, taking row by row and left to right.

8 is the score. Two novices and three experienced subjects scored 8 and this makes up five subjects of the total group who scored 8.

Second row: 40,0 and 60,0 represent the percentage breakdown of subjects who scored 8, for the cell, while 8,9 refers to the percentage of the total sample who scored 8 on the concept of Substance.

Third row: these scores refer to the percentage of subjects who scored 8 within their job category.

Fourth row: these are percentages of the total sample for both job categories and by adding them together a total group percentage of that particular score is obtained viz. 8,9.

From this data it was possible to determine significance and to compile a frequency distribution. (See Figures 1 - 8).

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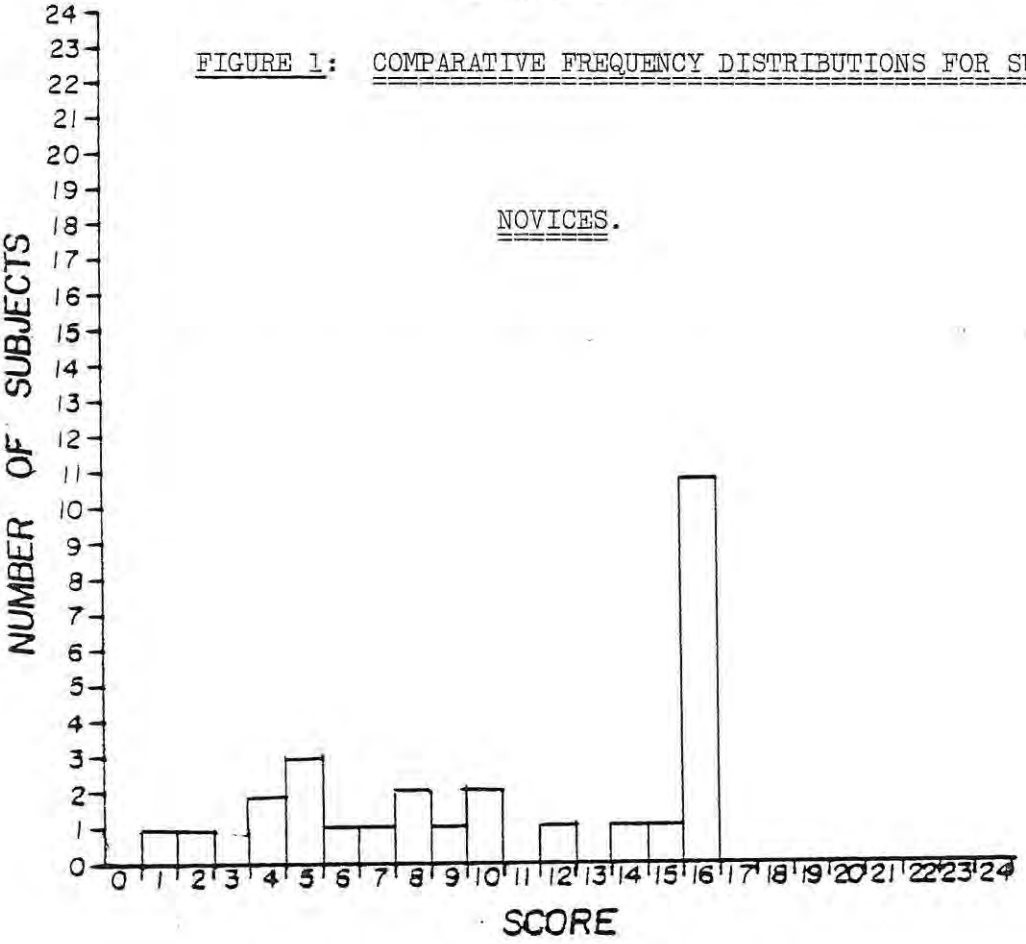
TABLE 1. TESTING FOR SIGNIFICANT DIFFERENCE ON ALL VARIABLES USING CHI-SQUARE.

VARIABLE.	CHI-SQUARE.	DEG. OF FREEDOM	SIGNIFICANCE	OUTCOME
SUBSTANCE	9.20000	15	0.8668	NSD
SPACE	10.89177	11	0.4524	NSD
DISTANCE	15.34286	9	0.0819	NSD
LENGTH	4.32000	5	0.5043	NSD
TIME	9.14035	13	0.7623	NSD
SPEED	10.60168	6	0.1015	NSD
ACCELERATION	8.53333	11	0.6649	NSD
FORCE	5.78056	2	0.0556	NSD
TOTAL TEST SCORE	30.66678	32	0.5340	NSD

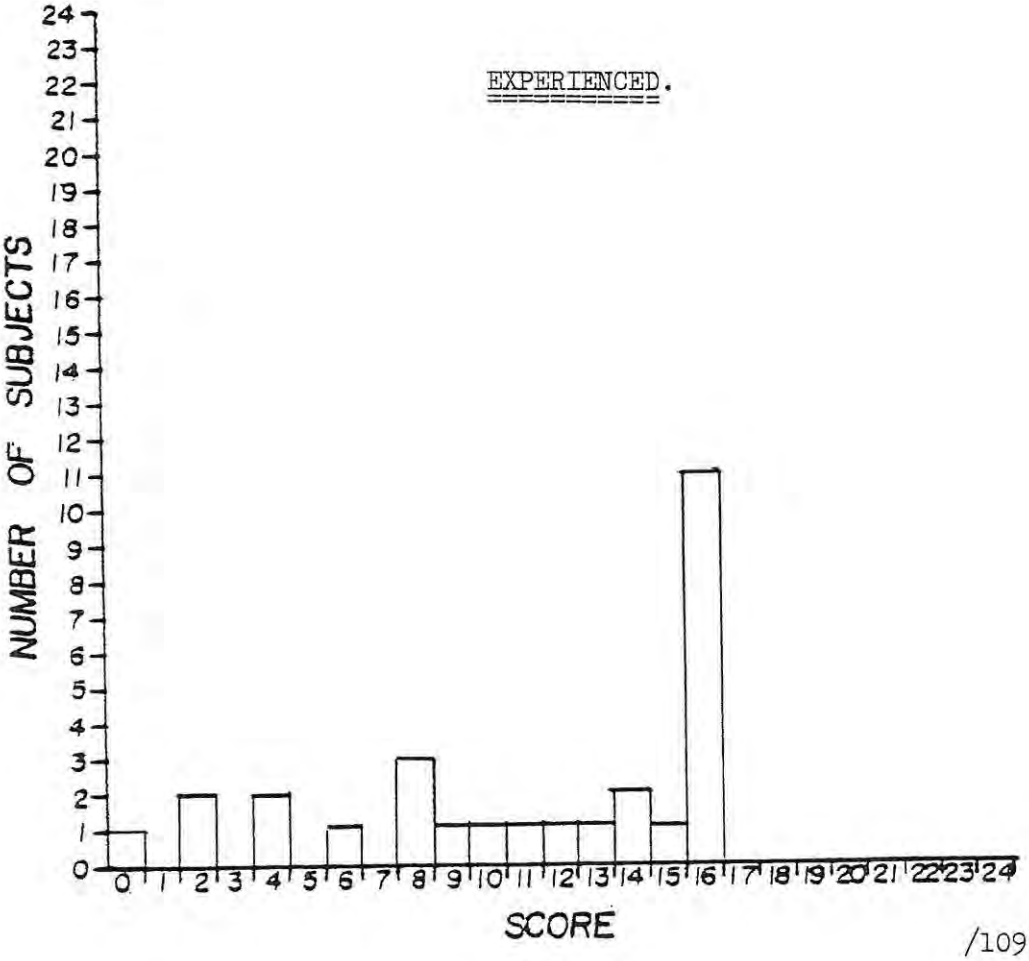
/108.....

FIGURE 1: COMPARATIVE FREQUENCY DISTRIBUTIONS FOR SUBSTANCE.

NOVICES.



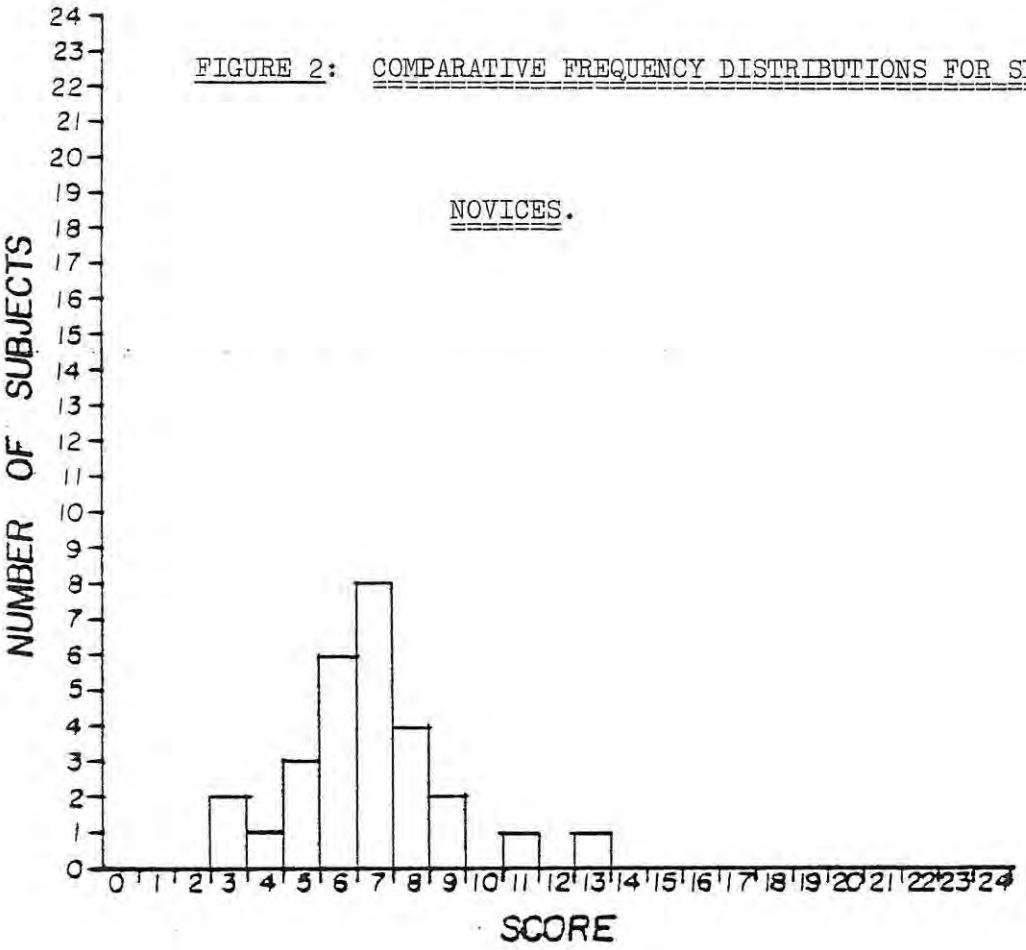
EXPERIENCED.



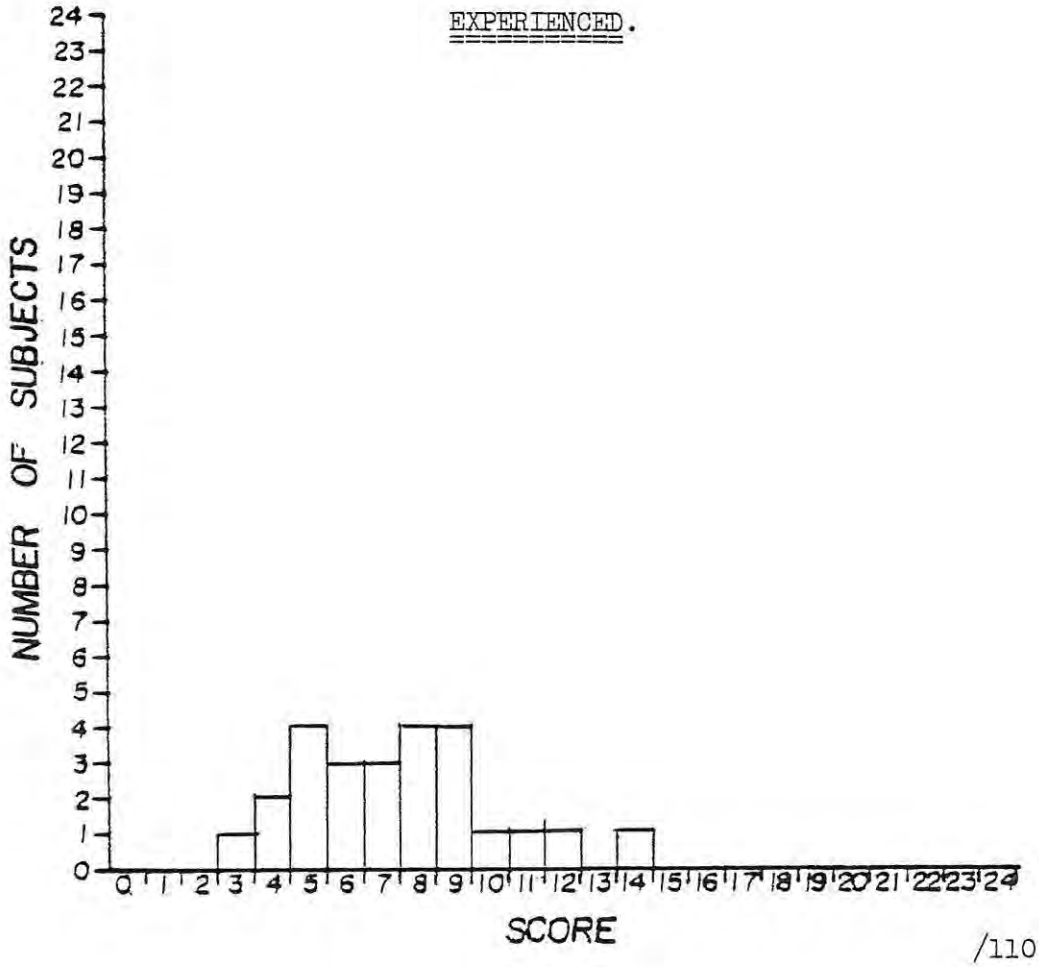
/109.....

FIGURE 2: COMPARATIVE FREQUENCY DISTRIBUTIONS FOR SPACE.

NOVICES.



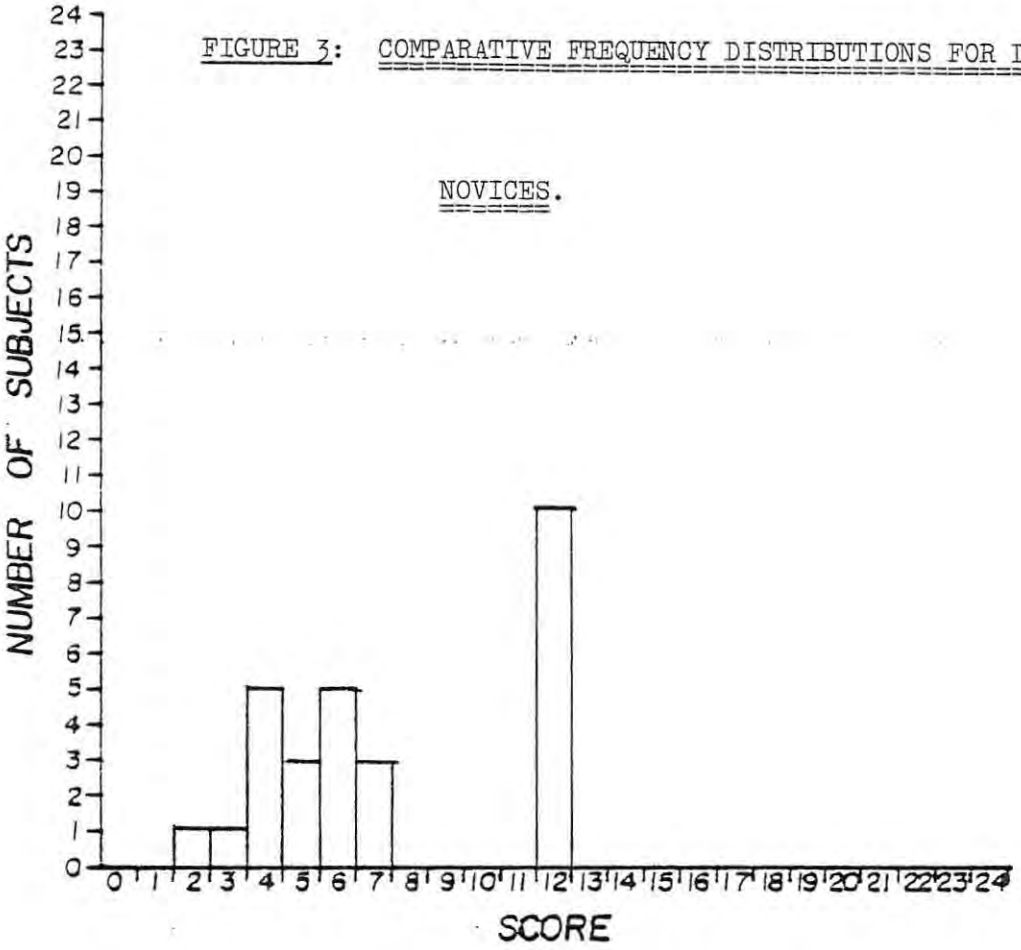
EXPERIENCED.



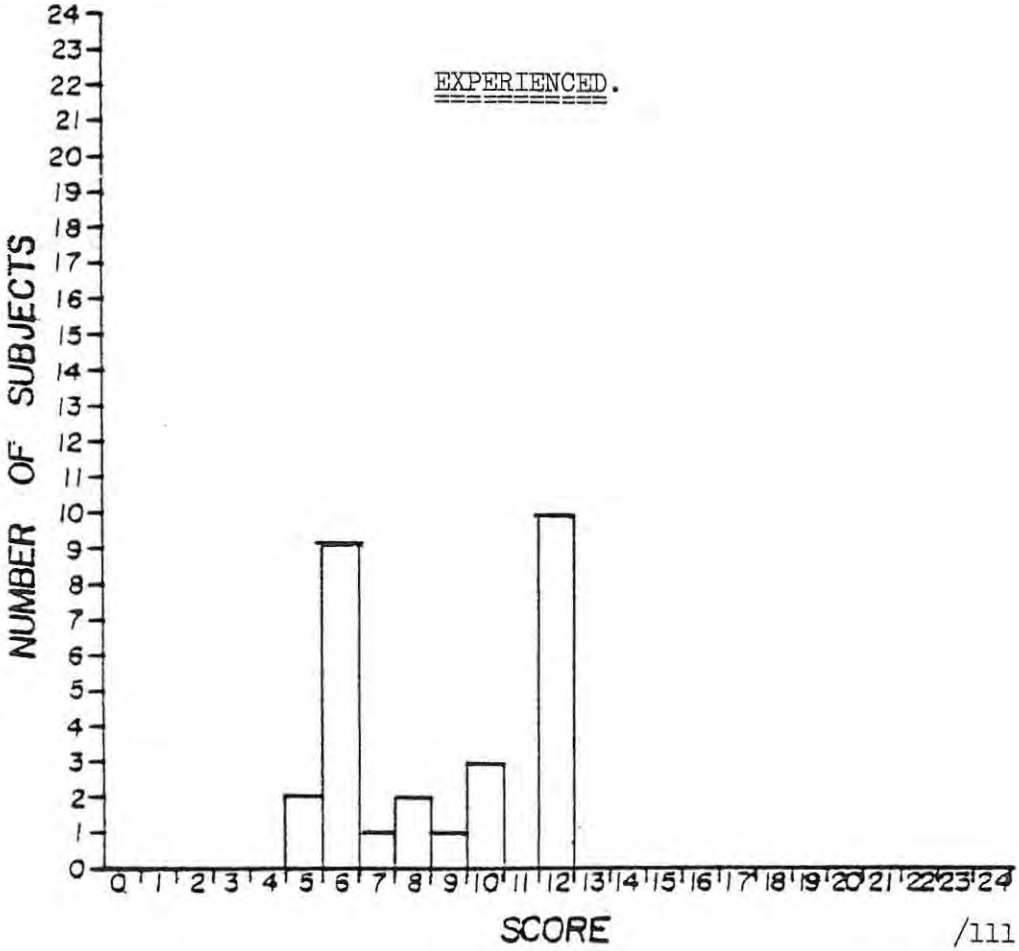
/110.....

FIGURE 3: COMPARATIVE FREQUENCY DISTRIBUTIONS FOR DISTANCE.

NOVICES.

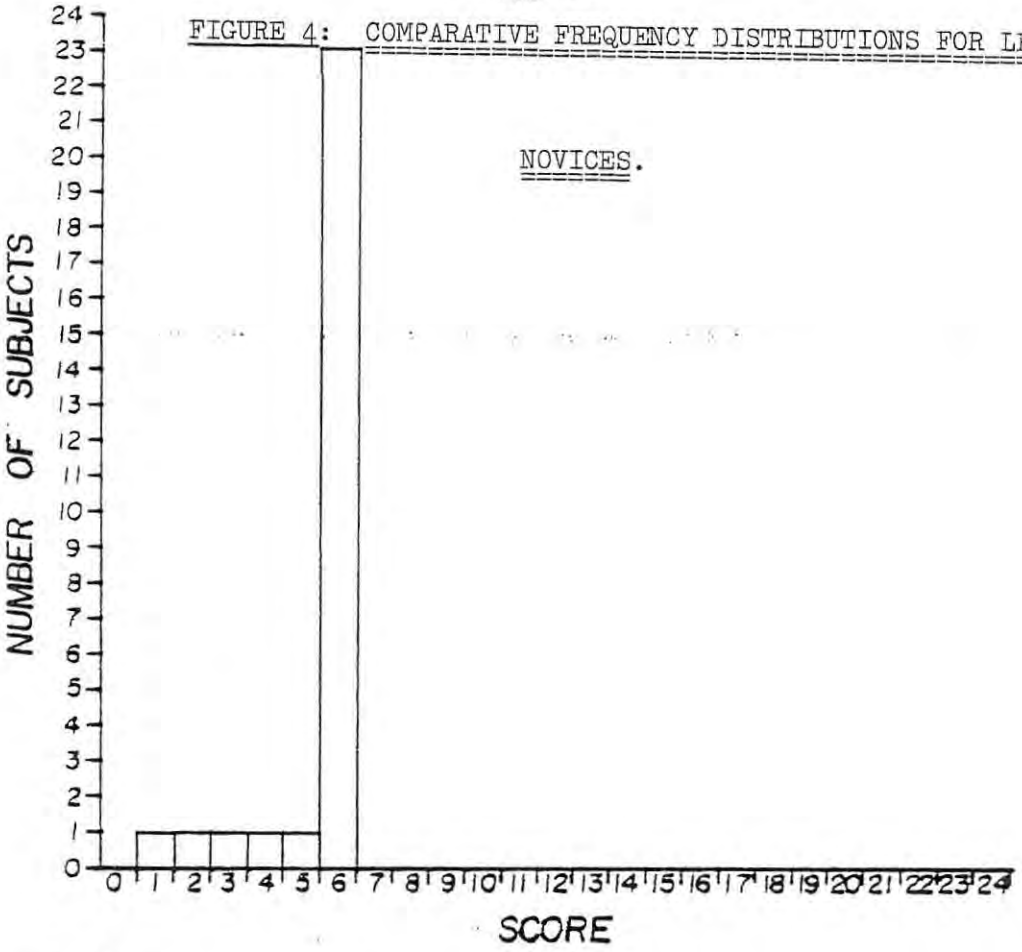


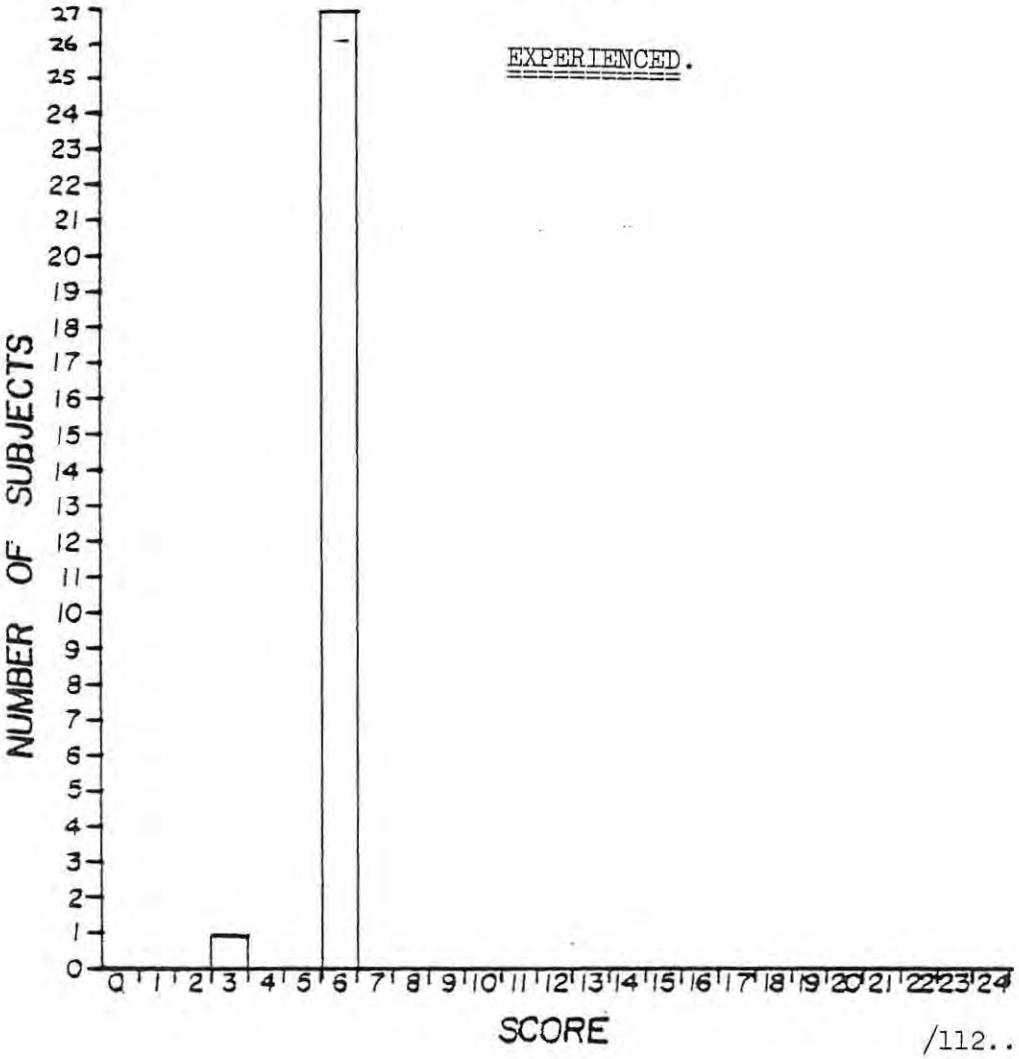
EXPERIENCED.



/111.....

FIGURE 4: COMPARATIVE FREQUENCY DISTRIBUTIONS FOR LENGTH.

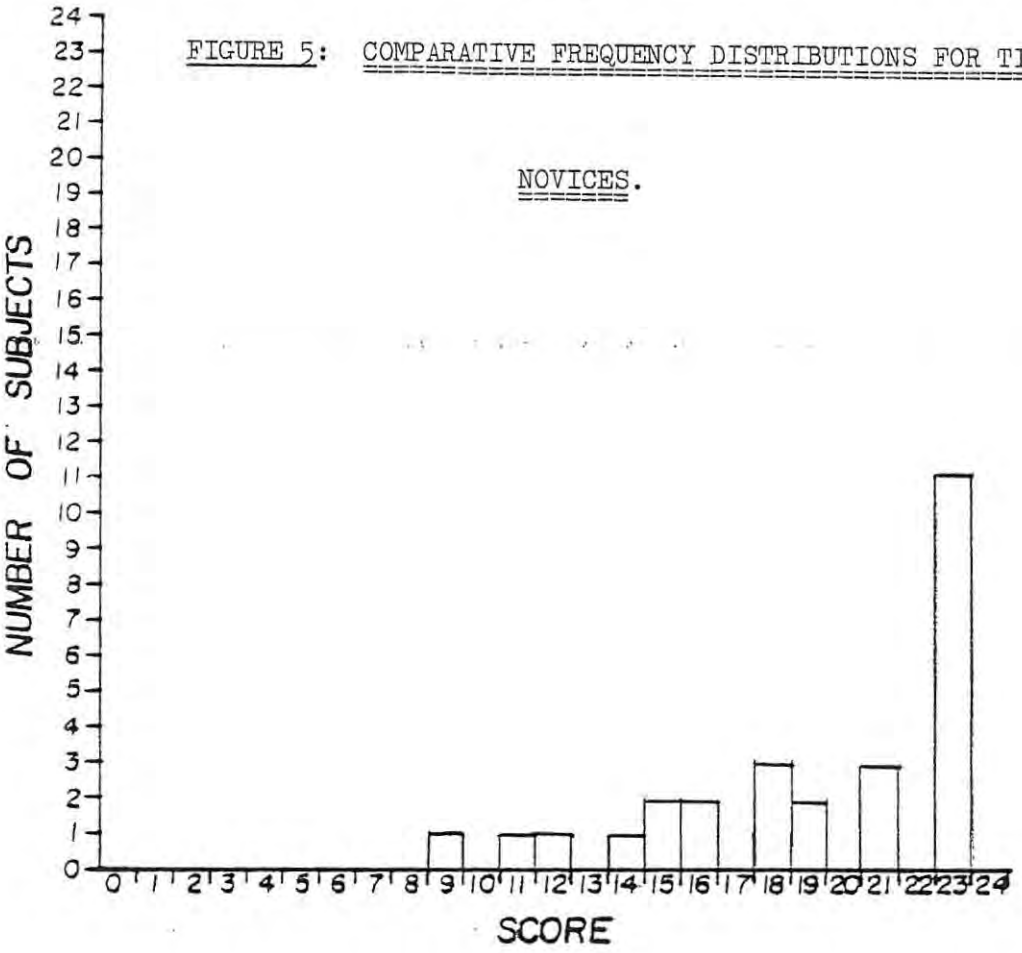




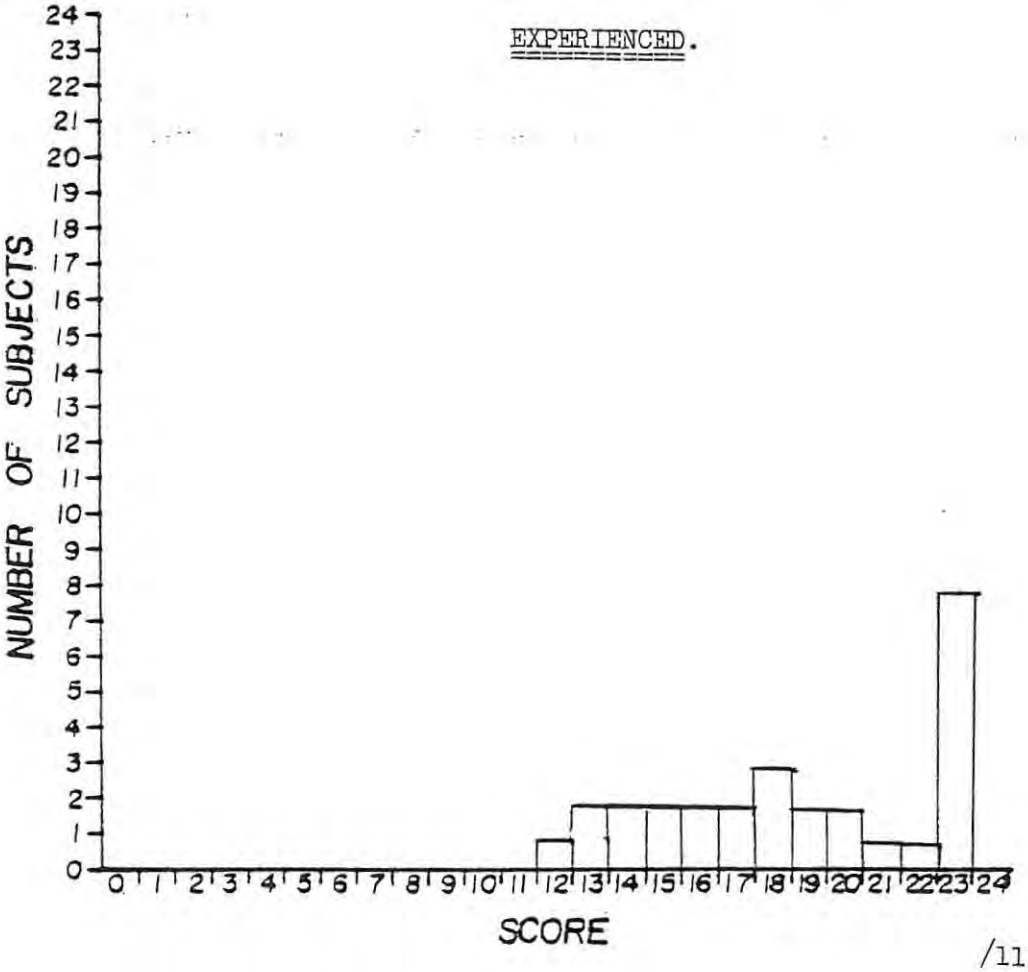
/112.....

FIGURE 5: COMPARATIVE FREQUENCY DISTRIBUTIONS FOR TIME.

NOVICES.



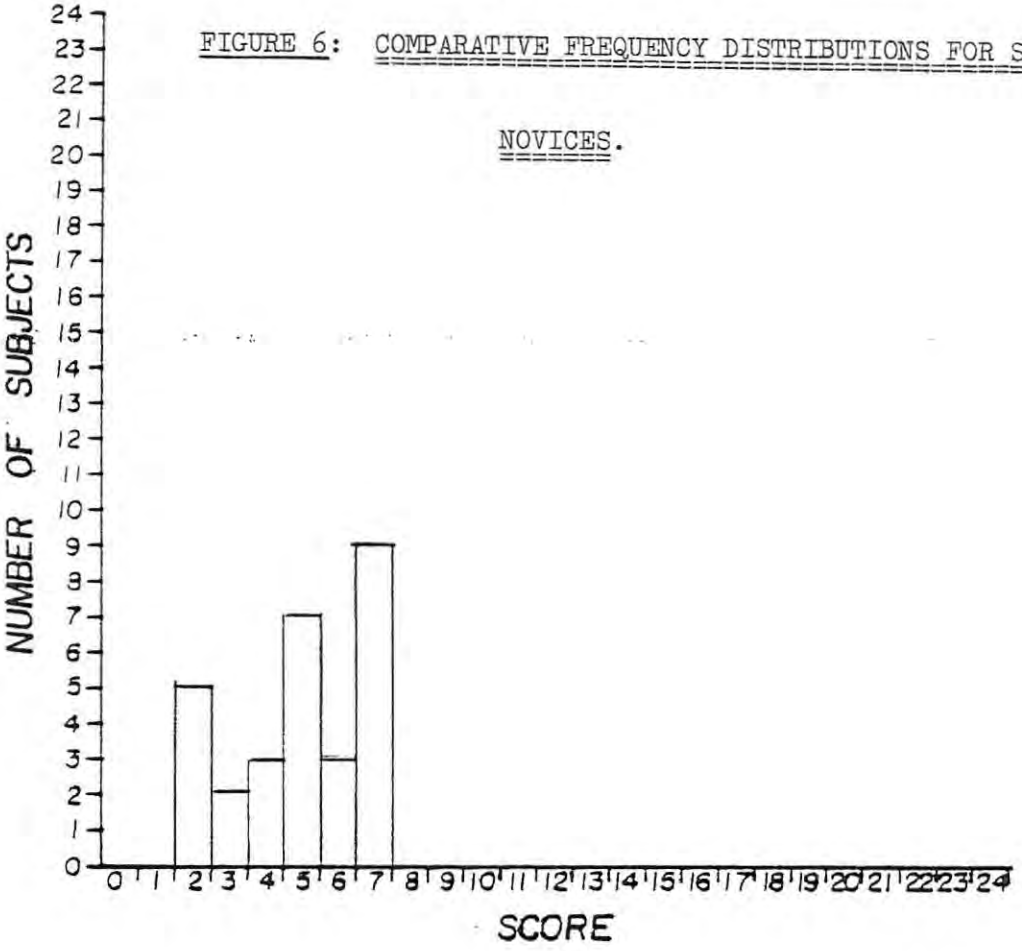
EXPERIENCED.



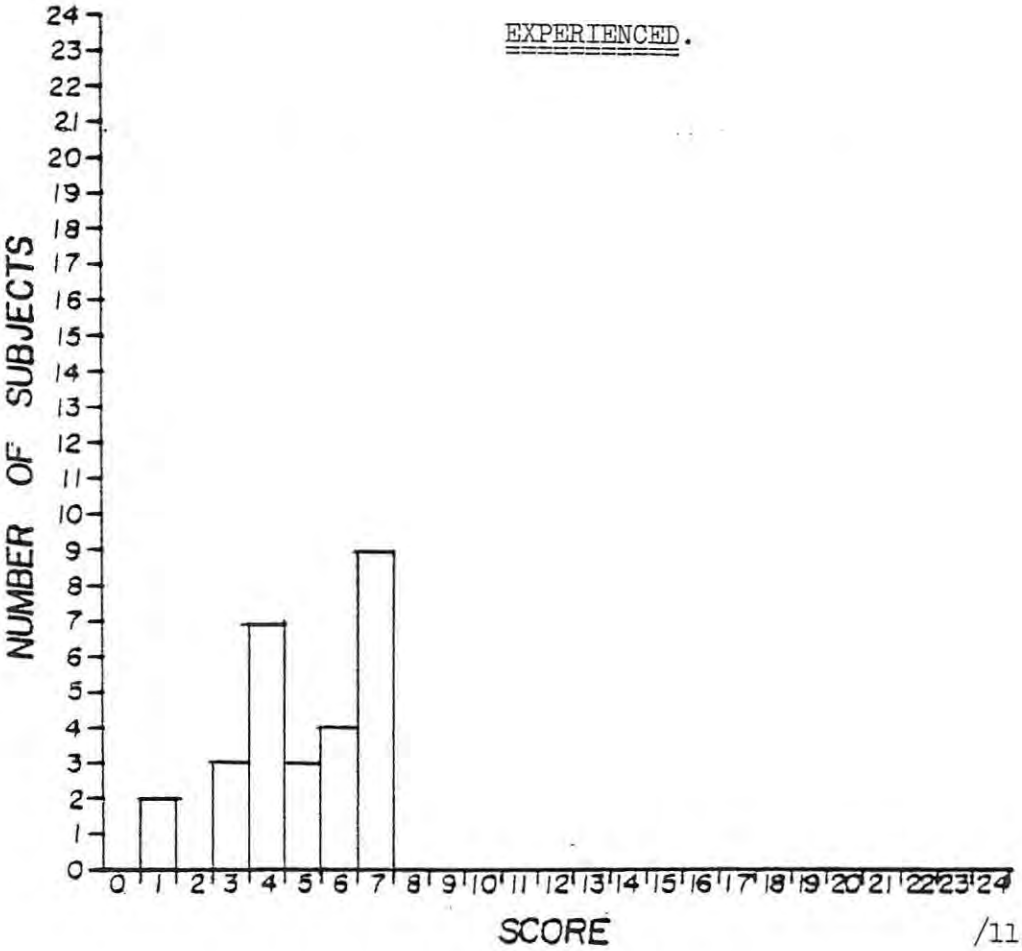
/113.....

FIGURE 6: COMPARATIVE FREQUENCY DISTRIBUTIONS FOR SPEED.

NOVICES.



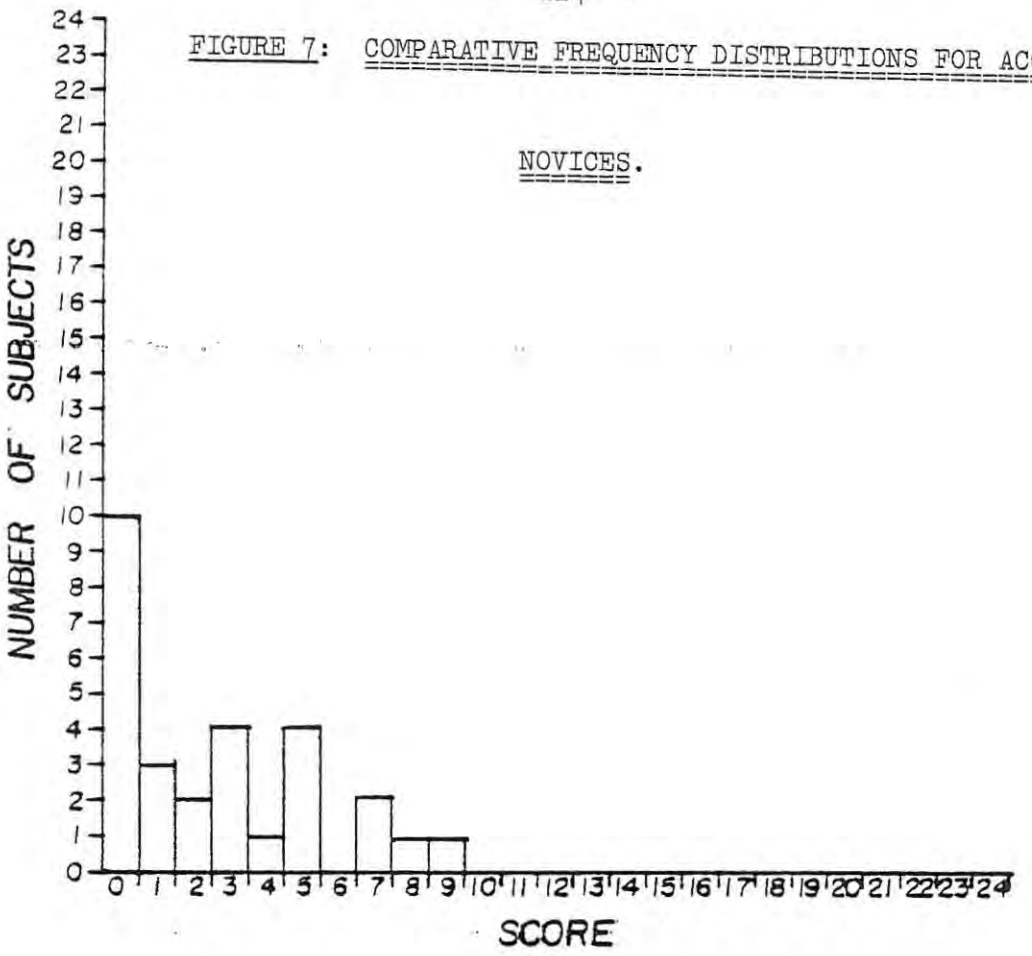
EXPERIENCED.



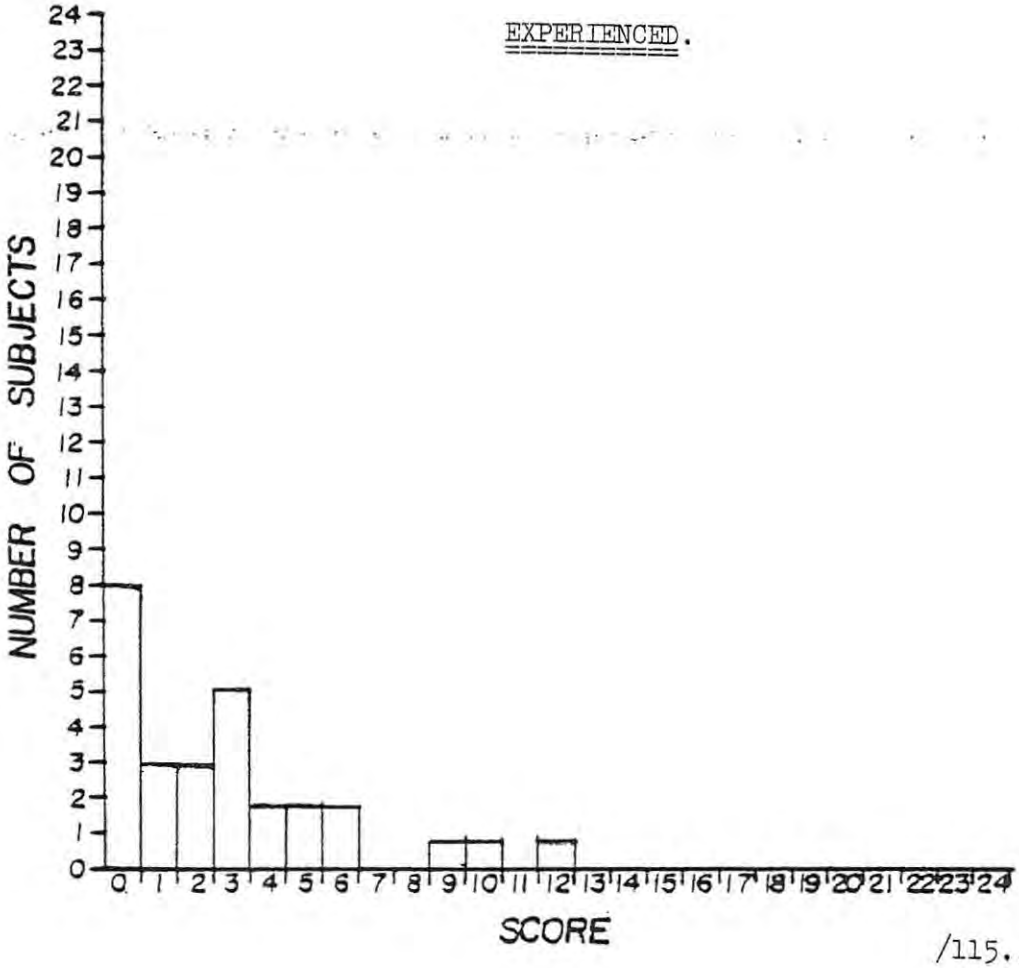
/114.....

FIGURE 7: COMPARATIVE FREQUENCY DISTRIBUTIONS FOR ACCELERATION.

NOVICES.



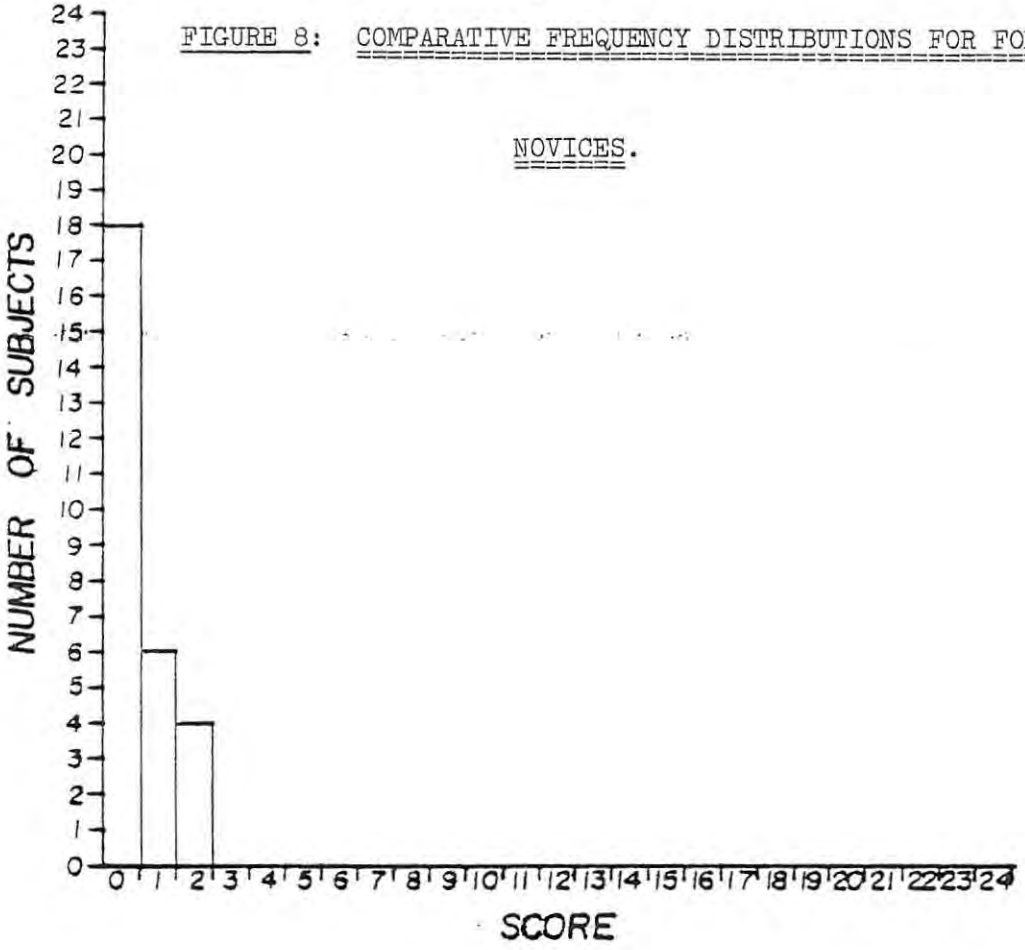
EXPERIENCED.



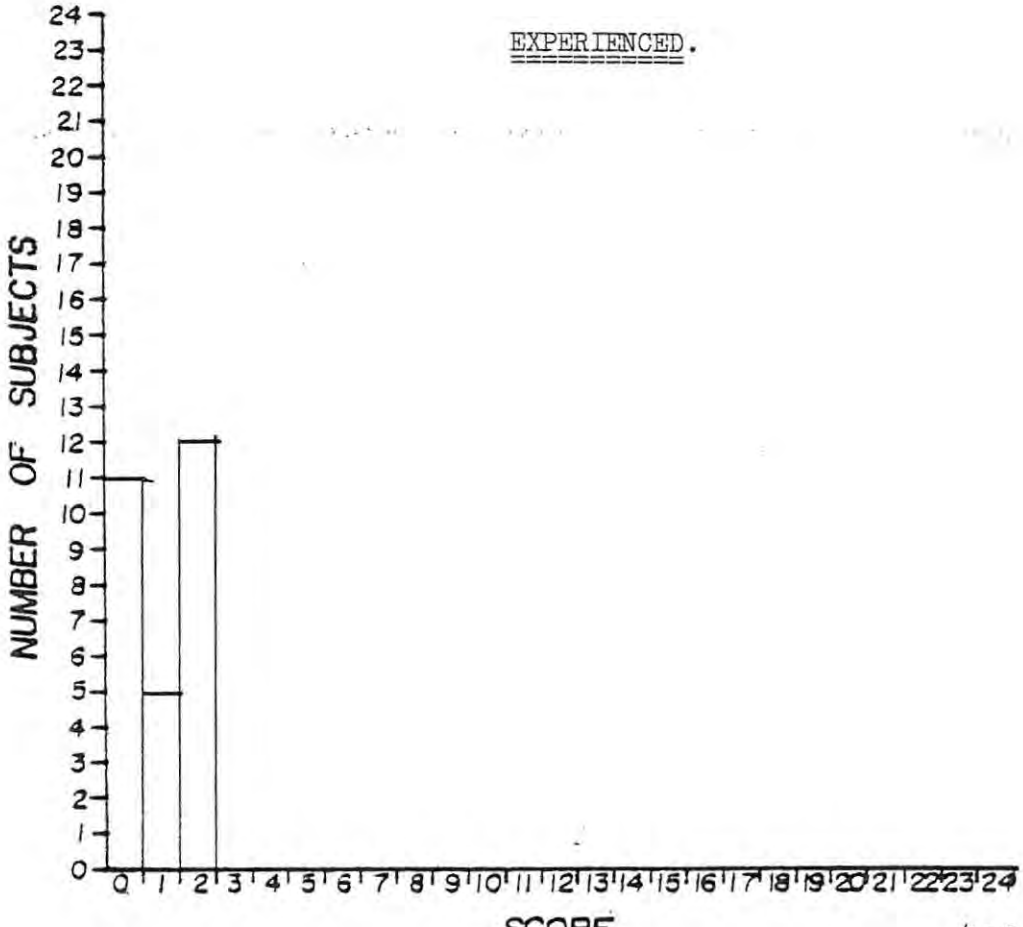
/115.....

FIGURE 8: COMPARATIVE FREQUENCY DISTRIBUTIONS FOR FORCE.

NOVICES.



EXPERIENCED.



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4.11.2 Pearson Correlation Coefficients.

As a back-up to the test for significant difference it was decided to include two measures of correlation, namely, the Pearson correlation and Partial Correlation Coefficients.

Pearson's correlation was used to correlate all the concept variables with the variables of (1) age of the subject (2) years of education and (3) number of mining tours, and (4) total test score, in four separate analyses. For this test the worker category was treated as a single variable and not broken into Novice and Experienced variables.

TABLE 2. RELATION BETWEEN CONCEPT VARIABLES AND AGE OF SUBJECTS USING PEARSON CORRELATION COEFFICIENTS.

(Number of cases - 56)

VARIABLE.	PEARSON CORRELATION COEFFICIENT.	RELATION.
SUBSTANCE	0.057	No significant correlation
SPACE	0.032	Significant correlation
DISTANCE	0.106	No significant correlation
LENGTH	0.124	No significant correlation
TIME	0.307	No significant correlation
SPEED	0.376	No significant correlation
ACCELERATION	0.332	No significant correlation
FORCE	0.034	Significant correlation

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TABLE 3. RELATION BETWEEN CONCEPT VARIABLES AND YEARS OF EDUCATION USING PEARSON CORRELATION COEFFICIENTS.

VARIABLE.	PEARSON CORRELATION COEFFICIENT.	RELATION.
SUBSTANCE	0.436	No significant correlation
SPACE	0.493	No significant correlation
DISTANCE	0.181	No significant correlation
LENGTH	0.354	No significant correlation
TIME	0.348	No significant correlation
SPEED	0.209	No significant correlation
ACCELERATION	0.254	No significant correlation
FORCE	0.280	No significant correlation

Number of cases - 56.

TABLE 4. RELATION BETWEEN CONCEPT VARIABLES AND NUMBER OF MINING TOURS USING PEARSON CORRELATION COEFFICIENTS.

VARIABLE.	PEARSON CORRELATION COEFFICIENTS.	RELATION.
SUBSTANCE	0.089	No significant correlation
SPACE	0.276	No significant correlation
DISTANCE	0.131	No significant correlation
LENGTH	0.139	No significant correlation
TIME	0.393	No significant correlation
SPEED	0.392	No significant correlation
ACCELERATION	0.289	No significant correlation
FORCE	0.161	No significant correlation

Number of cases - 56.

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TABLE 5. RELATION BETWEEN TOTAL TEST SCORE AND AGE OF SUBJECT, YEARS OF EDUCATION AND NUMBER OF MINING TOURS, USING PEARSON CORRELATION COEFFICIENTS.

VARIABLE.	TOTAL TEST SCORE.	RELATION.
AGE OF SUBJECT	P 0.043	Significant correlation
YEARS OF EDUCATION	P 0.281	No significant correlation
NO. OF MINING TOURS	P 0.104	No significant correlation

No. of cases - 56.

4.11.3 Partial Correlation Coefficients.

Partial correlation is a multivariant technique which shows the effect of all variables on each other. Furthermore, select variables may be held constant during the correlation so as not to influence each other.

TABLE 6. PARTIAL CORRELATION COEFFICIENTS FOR CONCEPT VARIABLES / TOTAL TEST SCORE AND AGE WHILE CONTROLLING FOR EDUCATION AND NUMBER OF MINING TOURS.

VARIABLE	TOTAL TEST SCORE.	RELATION.
SUBSTANCE	P 0.188	No significant correlation
SPACE	P 0.000	Significant correlation
DISTANCE	P 0.288	No significant correlation
LENGTH	P 0.351	No significant correlation
TIME	P 0.243	No significant correlation
SPEED	P 0.437	No significant correlation
ACCELERATION	P 0.404	No significant correlation
FORCE	P 0.005	Significant correlation
TOTAL TEST SCORE	P 0.066	No significant correlation

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TABLE 6. PARTIAL CORRELATION COEFFICIENTS MATRIX FOR TOTAL SAMPLE.

	VAR002	VAR003	VAR004	VAR005	VAR006	VAR007	VAR008	VAR009	VAR013	VAR012
VAR002	1.0000	-0.0180	0.4932	0.1903	0.3622	0.1740	0.1255	0.2993	0.6752	0.1826
	(0)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	P=*****	P=0.448	P=0.000	P=0.080	P=0.003	P=0.100	P=0.178	P=0.013	P=0.000	P=0.089
VAR003	-0.0180	1.0000	0.2522	0.2019	0.2891	0.2628	0.2550	0.4011	0.4500	0.0812
	(54)	(0)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	P=0.448	P=*****	P=0.030	P=0.068	P=0.015	P=0.025	P=0.029	P=0.001	P=0.000	P=0.276
VAR004	0.4932	0.2522	1.0000	0.3539	0.4204	0.4822	0.4054	0.2767	0.7808	0.1523
	(54)	(54)	(0)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	P=0.000	P=0.030	P=*****	P=0.004	P.0.001	P=0.000	P=0.001	P=0.019	P=0.000	P=0.131
VAR005	0.1903	0.2019	0.3539	1.0000	0.1916	0.3047	0.2189	0.2189	0.4218	0.1476
	(54)	(54)	(54)	(0)	(54)	(54)	(54)	(54)	(54)	(54)
	P=0.080	P=0.068	P=0.004	P=*****	P=0.079	P=0.011	P=0.053	P=0.053	P=0.001	P=0.139
VAR006	0.3622	0.2891	0.4204	0.1916	1.0000	0.3994	0.4236	0.2937	0.7498	0.0371
	(54)	(54)	(54)	(54)	(0)	(54)	(54)	(54)	(54)	(54)
	P=0.003	P=0.015	P=0.001	P=0.079	P=*****	P=0.001	P=0.001	P=0.014	P=0.000	P=0.393
VAR007	0.1700	0.2628	0.4822	0.3047	0.3994	1.0000	0.3326	0.2235	0.5806	0.0375
	(54)	(54)	(54)	(54)	(54)	(0)	(54)	(54)	(54)	(54)
	P=0.100	P=0.025	P=0.000	P=0.011	P=0.001	P=*****	P=0.006	P=0.049	P=0.000	P=0.392
VAR008	0.1255	0.2550	0.4054	0.2189	0.4236	0.3326	1.0000	0.1383	0.5947	0.0758
	(54)	(54)	(54)	(54)	(54)	(54)	(0)	(54)	(54)	(54)
	P=0.178	P=0.029	P=0.001	P=0.053	P=0.001	P=0.006	P=*****	P=0.155	P=0.000	P=0.289
VAR009	0.2993	0.4011	0.2767	0.2189	0.2937	0.2235	0.1383	1.0000	0.4741	0.1348
	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(0)	(54)	(54)
	P=0.013	P=0.001	P=0.019	P=0.053	P=0.014	P=0.049	P=0.155	P=*****	P=0.000	P=0.161
VAR013	0.6752	0.4500	0.7808	0.4218	0.7498	0.5806	0.5947	0.4741	1.0000	0.1709
	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(0)	(54)
	P=0.000	P=0.000	P=0.000	P=0.001	P=0.000	P=0.000	P=0.000	P=0.000	P=*****	P=0.104
VAR012	0.1826	0.0812	0.1523	0.1476	0.0371	0.0375	0.0758	0.1348	0.1709	1.0000
	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(0)
	P=0.089	P=0.276	P=0.131	P=0.139	P=0.393	P=0.392	P=0.289	P=0.161	P=0.104	P=*****
VAR010	0.2134	0.2500	0.1698	0.1569	0.0689	0.0432	0.0595	0.2454	0.2319	0.9363
	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	P=0.057	P=0.032	P=0.106	P=0.124	P=0.307	P=0.376	P=0.332	P=0.034	P=0.043	P=0.000
VAR011	-0.0221	0.0023	0.1239	0.0512	0.0535	0.1106	0.0904	0.0795	0.0791	-0.2133
	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)	(54)
	P=0.436	P=0.493	P=0.181	P=0.354	P=0.348	P=0.209	P=0.254	P=0.280	P=0.281	P=0.057

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TABLE 8. PARTIAL CORRELATION COEFFICIENTS FOR CONCEPT VARIABLES / TOTAL TEST SCORE WITH YEARS OF EDUCATION WHILE CONTROLLING FOR AGE AND NUMBER OF MINING TOURS.

VARIABLE.	EDUCATION.	RELATION.
SUBSTANCE	P 0.453	No significant correlation
SPACE	P 0.450	No significant correlation
DISTANCE	P 0.121	No significant correlation
LENGTH	P 0.270	No significant correlation
TIME	P 0.328	No significant correlation
SPEED	P 0.191	No significant correlation
ACCELERATION	P 0.215	No significant correlation
FORCE	P 0.203	No significant correlation
TOTAL SCORE	P 0.193	No significant correlation

TABLE 9. PARTIAL CORRELATION COEFFICIENTS FOR CONCEPT VARIABLES / TOTAL TEST SCORE WITH NUMBER OF MINING TOURS WHILE CONTROLLING FOR AGE AND YEARS OF EDUCATION.

VARIABLE.	NO. OF MINING TOURS.	RELATION.
SUBSTANCE	P 0.364	No significant correlation
SPACE	P 0.000	Significant correlation
DISTANCE	P 0.485	No significant correlation
LENGTH	P 0.474	No significant correlation
TIME	P 0.494	No significant correlation
SPEED	P 0.494	No significant correlation
ACCELERATION	P 0.316	No significant correlation
FORCE	P 0.024	Significant correlation
TOTAL SCORE	P 0.183	No significant correlation

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TABLE 10. MEAN AND STANDARD DEVIATION OF VARIABLES 2 TO 13.

VARIABLE.	MEAN.	STANDARD DEV.	CASES.
VAR002	11.0179	5.2310	56
VAR003	7.3571	2.5656	56
VAR004	8.1607	3.2405	56
VAR005	5.6786	1.0288	56
VAR006	18.8214	3.9456	56
VAR007	4.9643	1.8187	56
VAR008	2.8393	2.9956	56
VAR009	0.7679	0,8737	56
VAR010	25.9107	7.3640	56
VAR011	5.1607	2.3800	56
VAR012	4.1250	6.7368	56
VAR013	59.6071	13.8652	56

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4.12 EVIDENCE OF CONCRETE OPERATIONAL THINKING IN EXPERIENCED AND NOVICE SUBJECTS.

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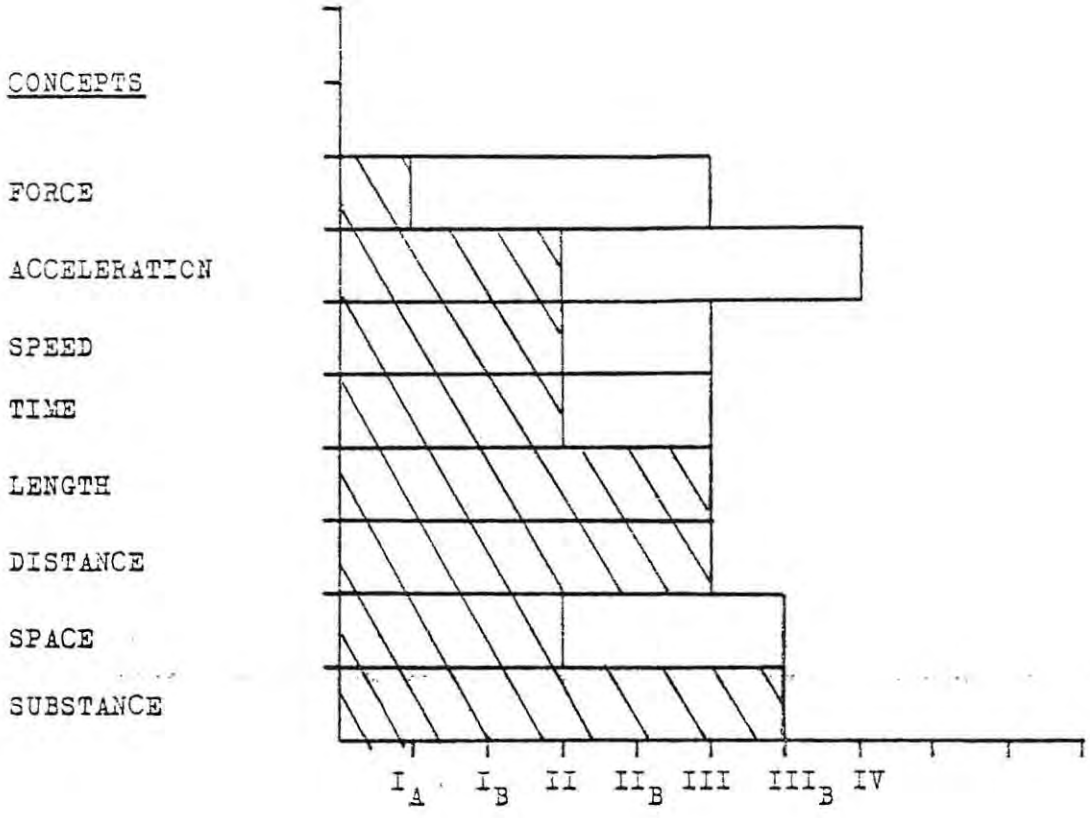
FIGURE 10. Experienced subject.

PROFILE OF CONCEPTUAL DEVELOPMENT.



NAME: .....JCR.....

AGE: .....25.....

OCCUPATION: MONO MINCH. INSTRUCTOR (BLUE CARD)

CONTRACT: .....3.....

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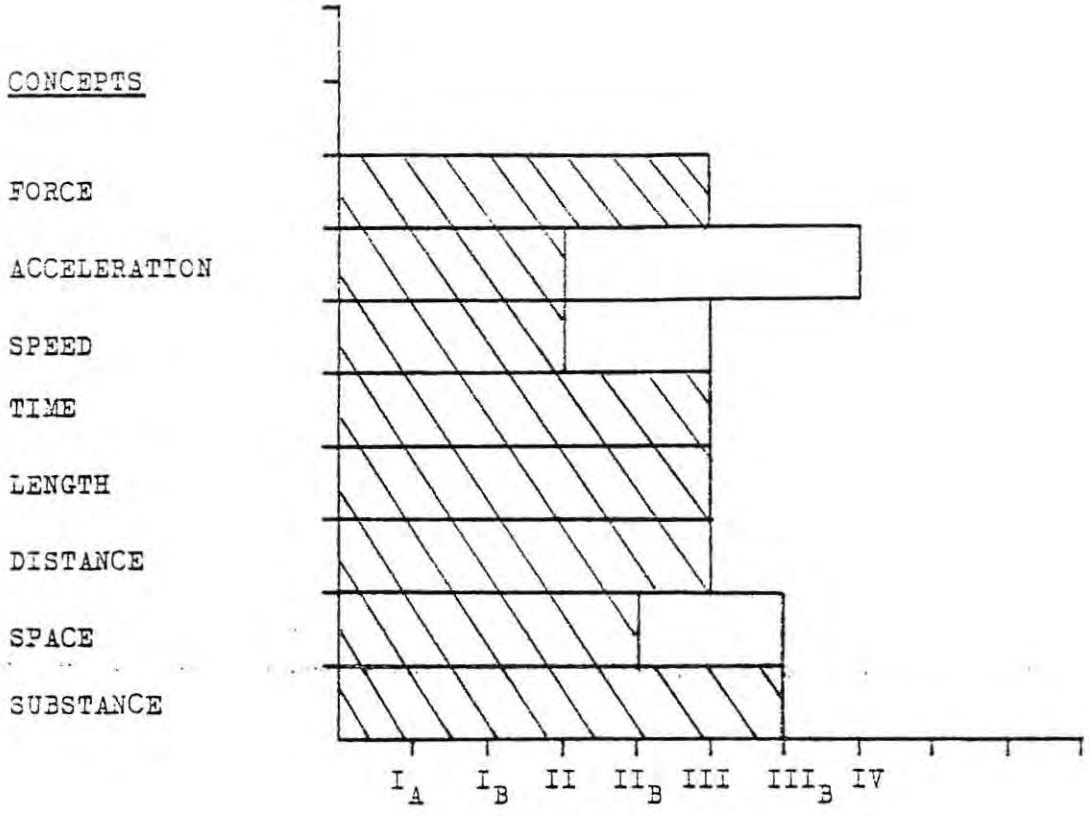
PROFILE OF CONCEPTUAL DEVELOPMENT.



PA1

NAME: .....

25

AGE: .....

APTITUDE TEST SUPERVISOR (PINK CARD)

OCCUPATION: .....

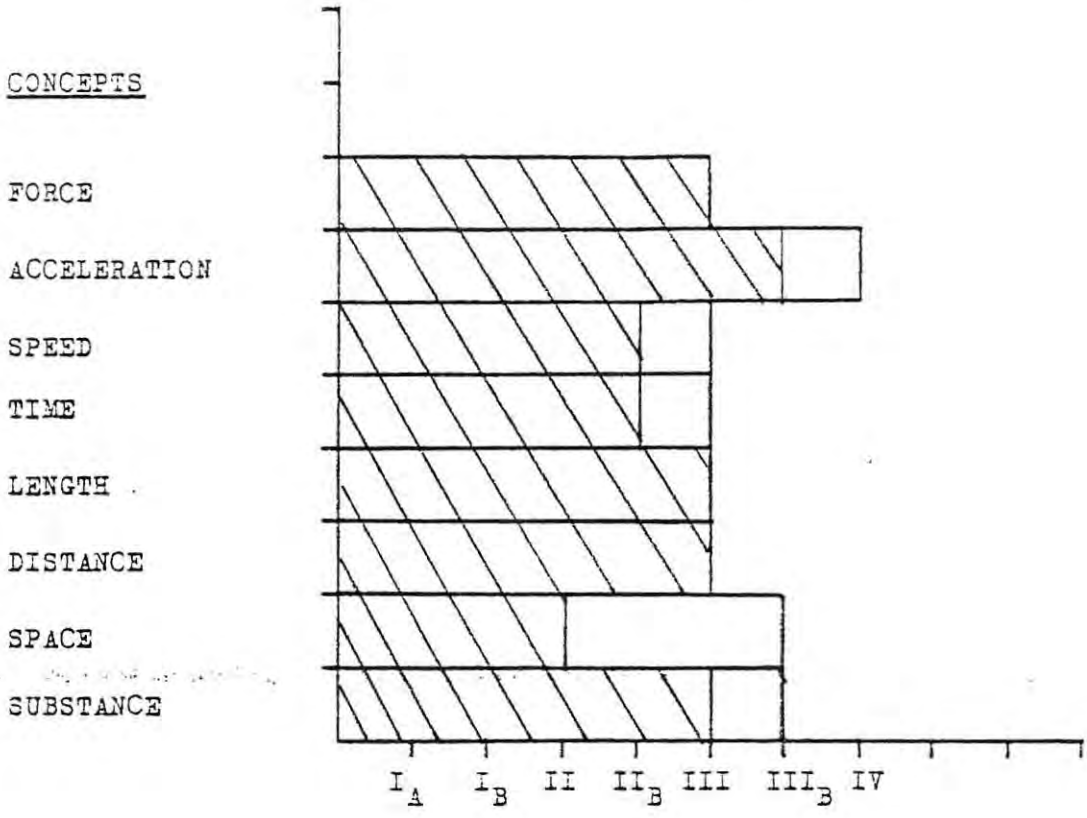
4

CONTRACT: .....

/125.....

FIGURE 12. [illegible]

PROFILE OF CONCEPTUAL DEVELOPMENT.



NAME: .....CAS.....

AGE: .....40.....

OCCUPATION: LOCO.DRIVER.INSTRUCTOR

CONTRACT: .....9.years...

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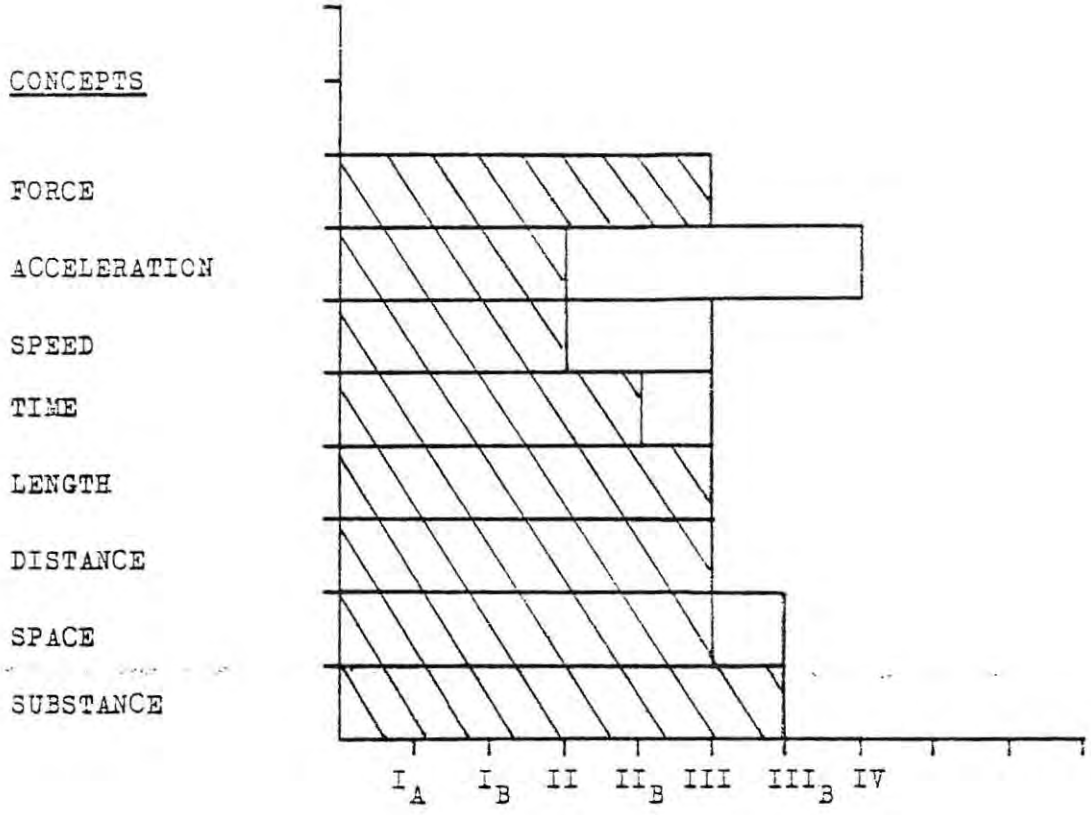
FIGURE 1: Experienced subject.

PROFILE OF CONCEPTUAL DEVELOPMENT.



NAME: .....FRA.....

AGE: .....54.....

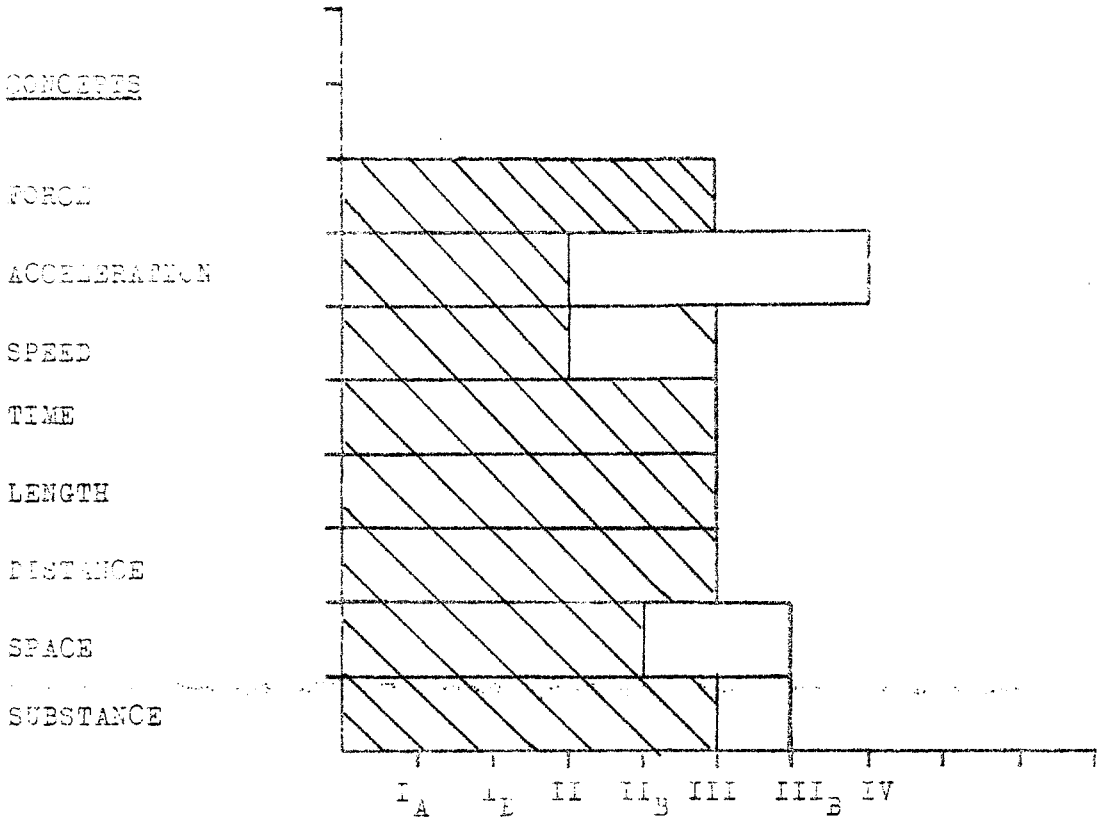
OCCUPATION: ..BUS DRIVER INSTRUCTOR (BLUE CARD)

CONTRACT: .....21.....

/127.....

FIGURE 14. Novice subject.

PROFILE OF [illegible] DEVELOPMENT.



NAME: .....RAY.....

AGE: .....24.....

OCCUPATION: ..CONSTRUCTION..

CONTRACT: .....0.....

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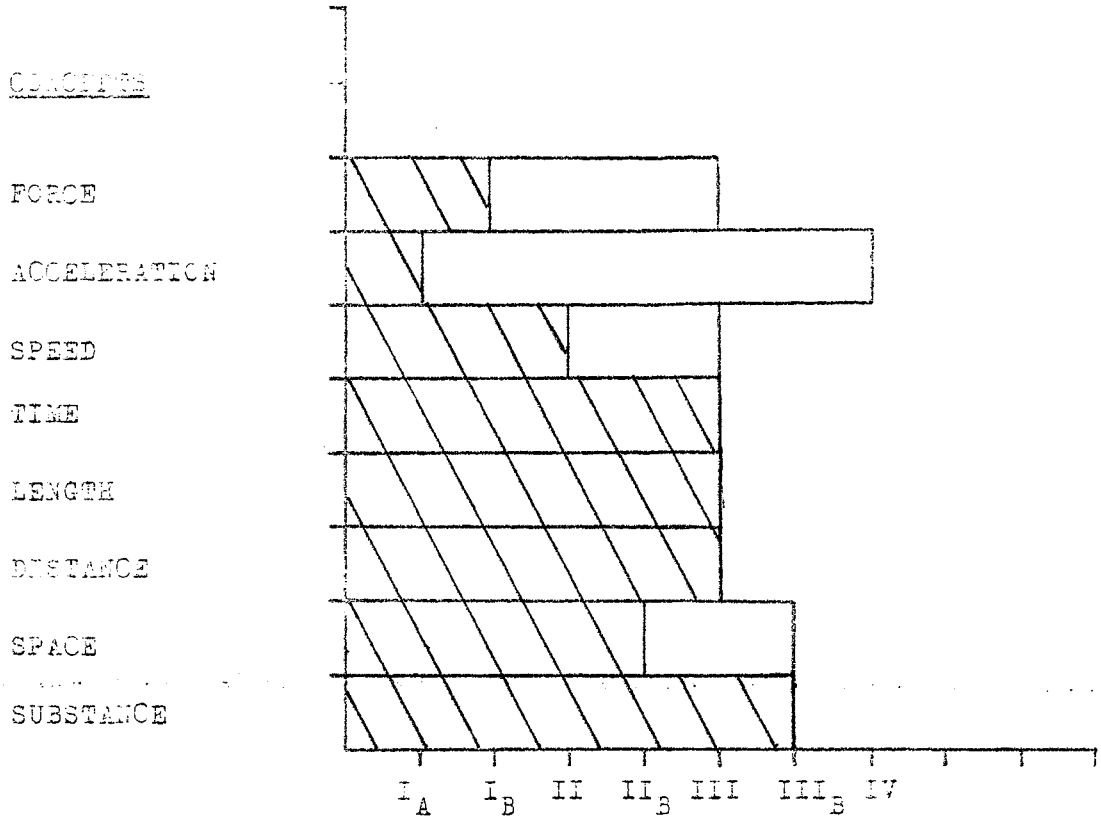
FIGURE 15. Novice subject.

PROFILE OF CONCEPTUAL DEVELOPMENT.



NAME: AND

AGE: 22

OCCUPATION: PINK CARD (LOCO DRIVER)

CONTRACT: 0

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4.13 EVIDENCE OF PRE-OPERATIONAL THINKING ON EXPERIENCED AND NOVICE SUBJECTS.

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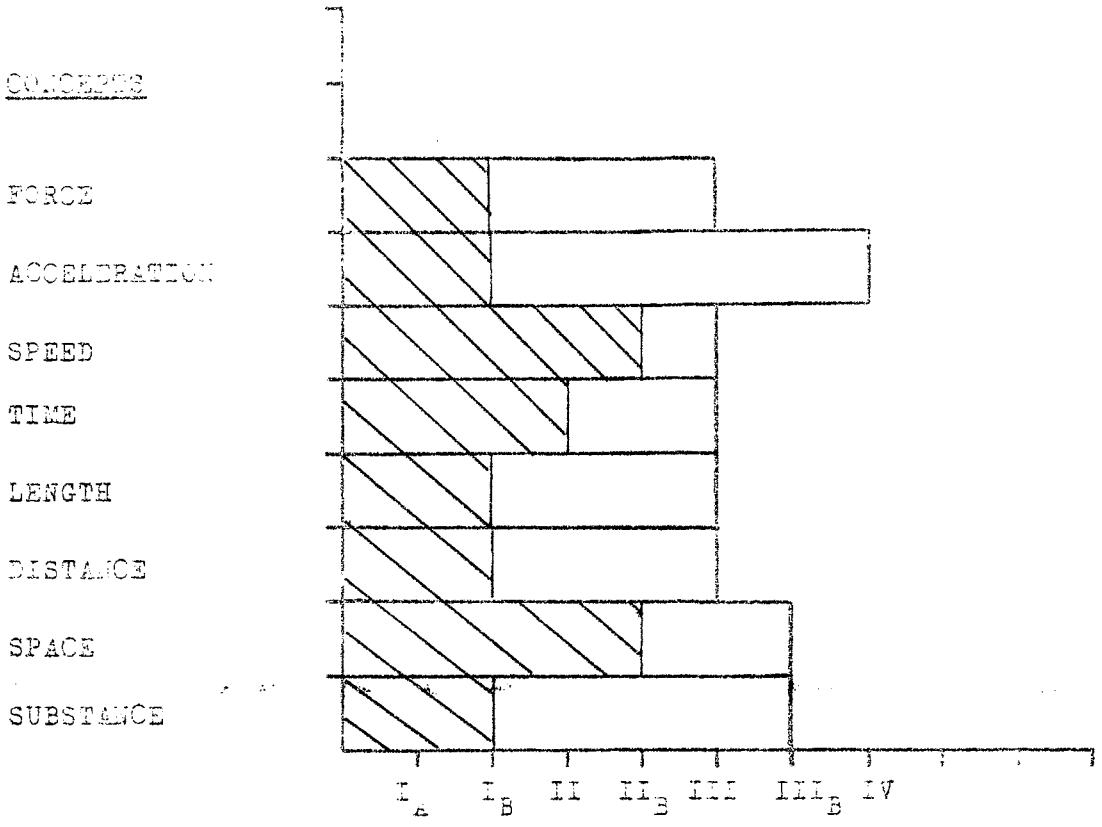
APPENDIX 15 experimental subject.

PROFILE OF CONCEPTUAL DEVELOPMENT.



NAME: ....TEI....

AGE: ....16....

OCCUPATION: WHITE (LASHER)....

CONTRACT: ....4....

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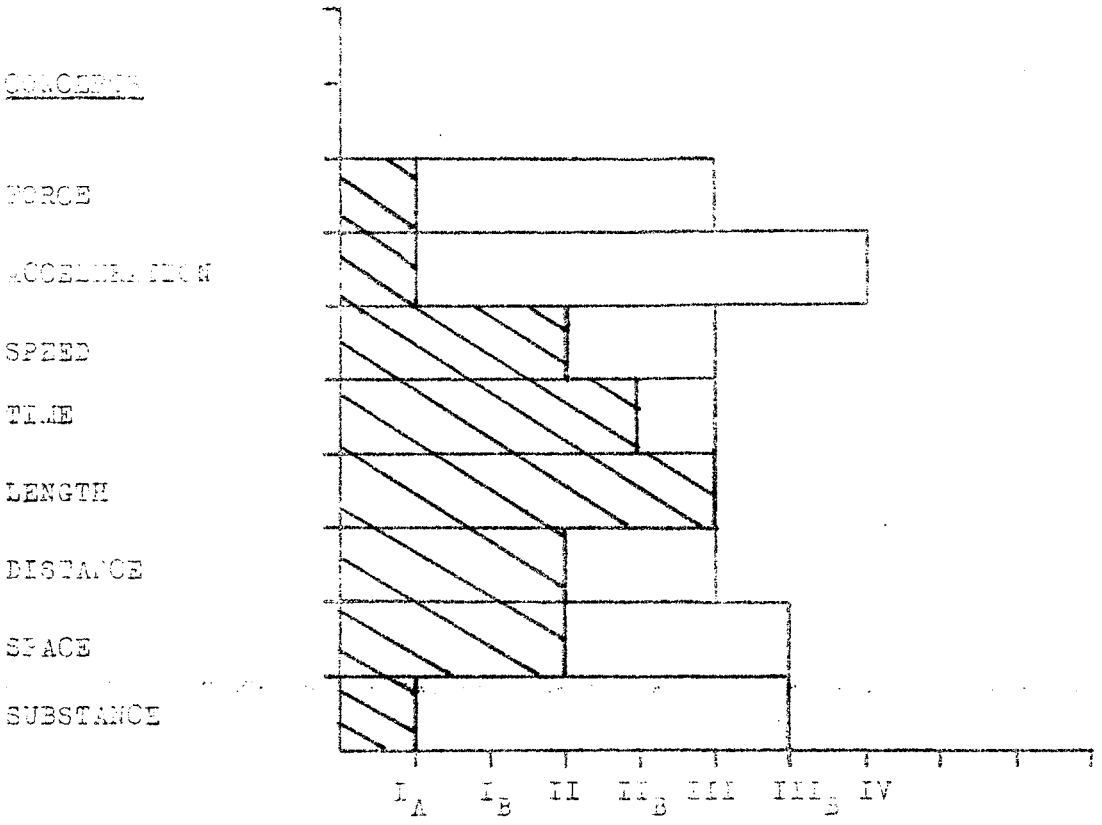
FIGURE 17 EXAMPLES OF PROFILES.

LEVELS OF CONCEPTUAL DEVELOPMENT.



NAME: .....MEG.....

AGE: .....26.....

OCCUPATION: WINCH DRIVER (PINK)

CONTRACT: .....4.....

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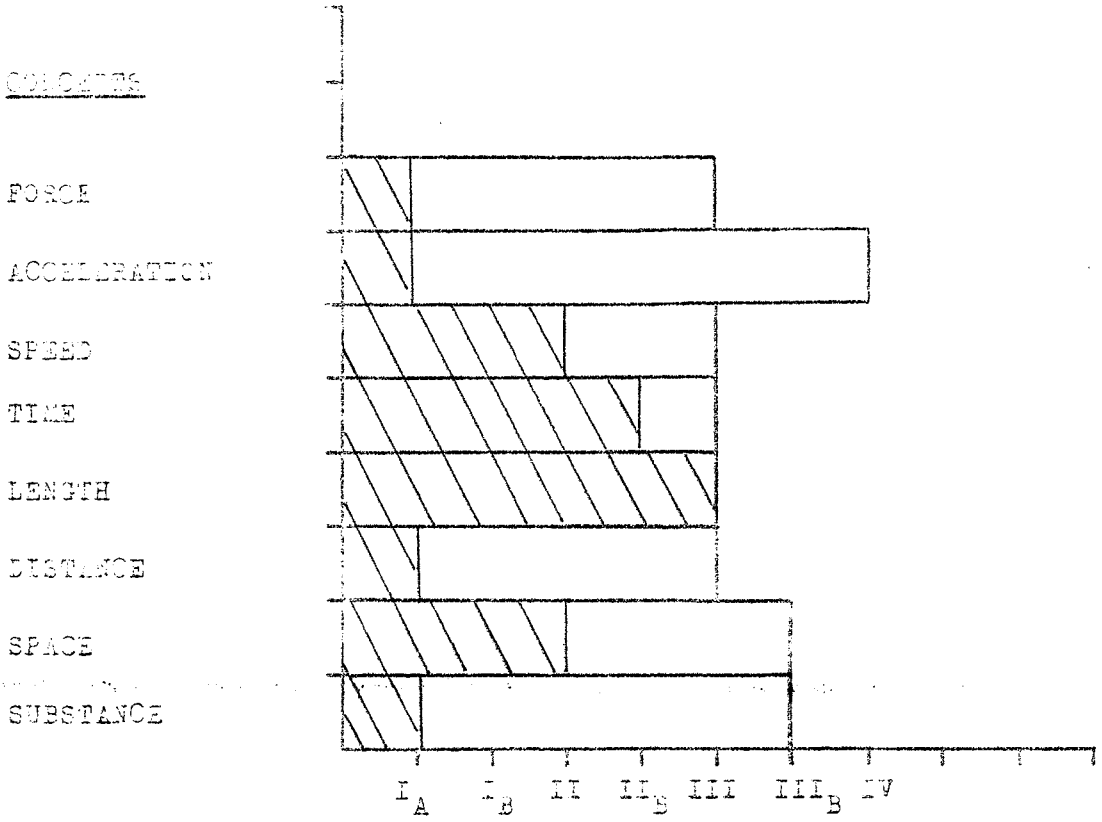
Table 18 Action schedule.

PLOT OF CONCEPTUAL DEVELOPMENT.



NAME: ....ALF.....

AGE: .....6.....

OCCUPATION: .PINK CARD.....

CONTRACT: .....0.....

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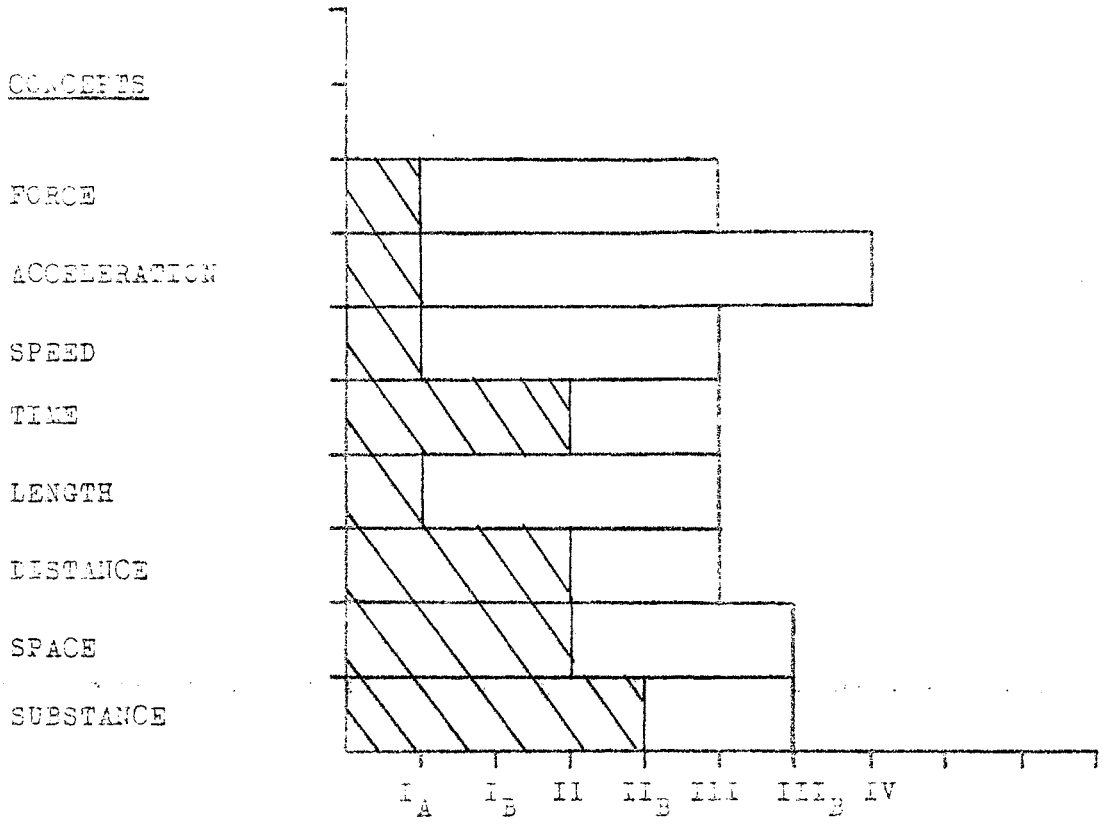
FIGURE 19. Novice subject (Yellow card).

PROFILE OF CONCEPTUAL DEVELOPMENT.



NAME: .....SAM.....

AGE: .....20.....

OCCUPATION: .....LASHER.....

CONTRACT: .....O.....

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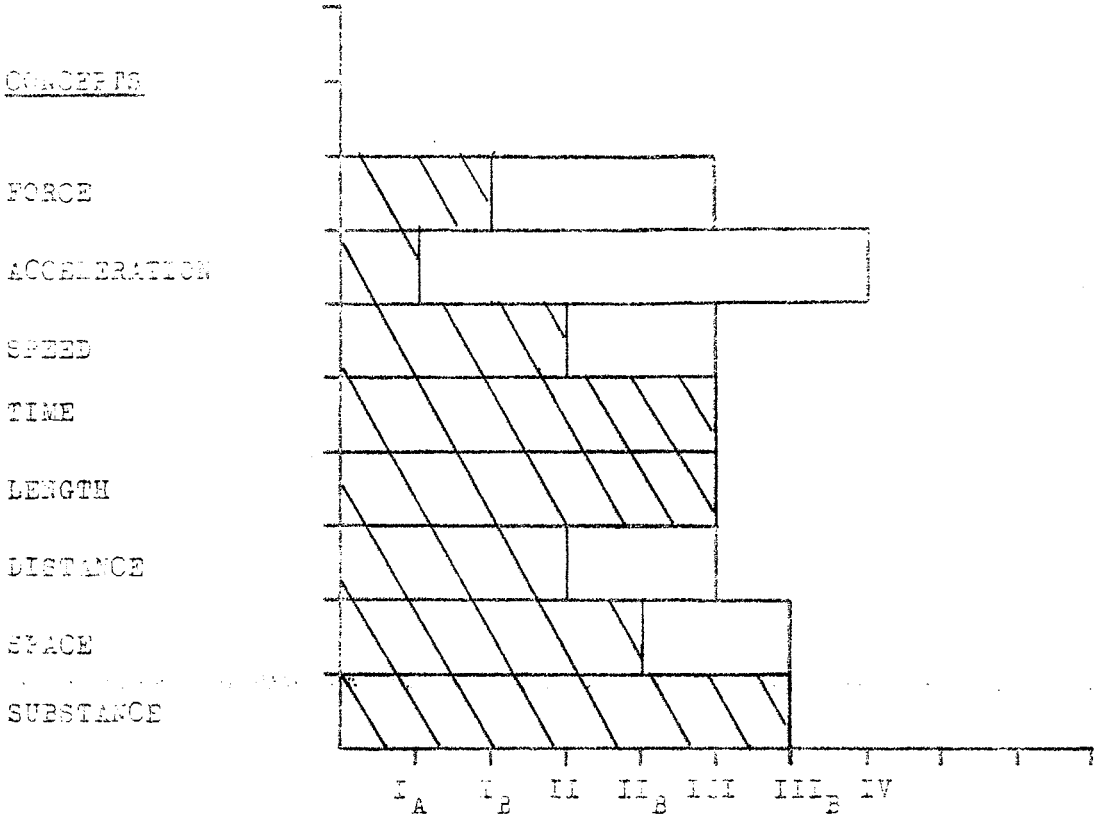
FIGURE 6Q. ADVICE SCHEDULE

PROFILE OF COLONIAL DEVELOPMENT.



STAGES

NAME: .....KON.....

AGE: .....21.....

OCCUPATION: ..WHITE (LASHER)..

CONTRACT: .....0.....

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4.14 DISCUSSION.

The statistical analyses indicate that there was no significant difference in performance between the two sample groups. The partial correlation coefficients seem to indicate that the concept tasks measured by the diagnostic battery are incorrectly ordered or may not be relevant. A good example is the poor correlation between the concepts of Force and Acceleration. The reason may be that apparatus used was ineffective in its measure of the concept.

Conceptual profiles showed that the Experienced group were more Concrete in their thinking and the Novice group more Pre-operational, although there was a fair distribution of both types of thinking in the two worker categories. (See Figures 10 - 20).

It would appear that the adaptation of the diagnostic battery, as compiled by Moore (1980), to the mining industry is not appropriate in its present form and it is pertinent to discuss some of the areas of shortcoming in the present study.

4.14.1 Methodology.

The research showed that the concept of Force was not actively being developed by the experience of mining. No subject achieved formal operations on the battery. This may be because the Black mineworkers tested did not have the need of a fully developed concept of Force to successfully complete their tasks. The test for Acceleration was too difficult for any subjects to complete, in spite of its innocuous simplicity. The two major difficulties encountered by subjects were (1) a toy car (2) having to imagine the workings of a clock. Subjects were unable to equate a unit of time (held constant) with a standard distance (as in Condition 3 of the questionnaire). Consequently they did not integrate the concepts of Distance, Length, Time

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and Speed so as to conserve Acceleration. The test for the concept of Length was completely inappropriate. Subjects were able to conserve Length before they conserved Space or Distance. A reason for this may be that the test for Length was too easy and the concept was conserved by more subjects than the concepts of Space and Distance.

Because of the disparity in the degree of difficulty of the tests for Length and Acceleration the battery lost its continuity. These structural handicaps did not however prevent subjects from giving 'typical' responses on the sub-tests. Pearson's correlation coefficients indicated a significant correlation between the concepts of Force and Space when correlating the concept variables and Age (Table 2). This was again borne out in Table 7 when Partial correlations were computed. These two conceptual areas appear to be developed by mining, whereas the others remain at a Pre-operational or Concrete level of development. The implications of this finding would indicate that mining does not actively foster the development of the concept of Force, as measured, because (1) it is not required to be developed beyond the Concrete level by Black mineworkers, or (2) the diagnostic battery was ineffective in tapping the conceptual abilities of the sample group.

The researcher suggests that perhaps it is a combination of both factors which makes the principle hypothesis unacceptable.

Another interesting finding was the correlation between Force and Age of subjects. This may be explained by the suggestion that all the experience of the subjects, mining and non-mining, may be responsible for this.

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A rather surprising result was the poor correlation of mining tours and education with Force. Theunissen & Wolfaardt (1978) cited education as being the only significant factor which affected performance on the CTB.

It may be suggested that the standard of education acquired by Black migrants is of an appalingly low standard. Better educated candidates scored better on the CTB but this was not necessarily so on the diagnostic battery. Novices who had some eight years of education did not perform significantly better than Experienced subjects who had more than five mining tours, and less than eight years of education.

If the two measures are taken in conjunction then the CTB is shown as a poor discriminator (because education tends to distort cut off areas). The CTB is used by the industry to measure mechanical aptitude. The diagnostic battery measures concept conservation. Where scepticism about the CTB really begins is its inability to provide a profile of a candidate's intellectual abilities. It was surprising that Black miners were found suitable to be trained for driving occupations by the CTB, yet their conceptual profile showed that they were unable to conserve Speed, Acceleration or Force. But this point may be more of academic interest at this stage when the realities of the mining position is considered. Production is being maintained and the industry is safer than it has ever been. Following on this supposition then it must be noted that the training of workers for these occupations must be up to standard. This research does indicate the difficulty of applying Piaget's clinical method in an industrial setting. Piaget's theory, although having its roots in Western intellect is

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useful in that success in a Western technological environment was being measured. The difficulties of wedding Piaget's clinical method to the demands of statistical analyses is a problem that many people in diverse fields of psychology are facing at present.

The small sample size militates against an extensive statistical analysis. But the conceptual profiles obtained remain useful plotting devices to identify areas of conceptual development. The mean of 59 out of a possible 96 indicates subjects were getting more than half the test correct and with a standard deviation of 13.8652 there is evidence that the test was discriminating well between individuals. (See Table 10). Potentially the diagnostic battery is a good discriminator.

Taking into account the present rigidity with which the CTB is applied in the mining industry and the comparatively poor scan of concept development of which it is capable, then it can be tentatively suggested that the use of Piagetian methodology for selection purposes may be a viable proposition. The diagnostic battery has shown it is capable of mapping concept areas, although it was a random application of a methodology which may have had very little to do with mining. The following proposals are put forward in support of limited use of Piagetian methodology in the mining industry:-

1. As the technological demands of operating sophisticated machinery and an overall rise in the demand for job skills occurs, the selection and placement of Black mine personnel will have to be adjusted accordingly.

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The Piagetian diagnostic battery indicated that the CTB was an arbitrary measure of aptitude and that a more sophisticated method of selection was necessary to keep pace with technological advances.

2. The diagnostic battery showed it had the ability to be a useful discriminator although its composition still needed selective improvements. Although the CTB takes some four hours to administer and the diagnostic battery only an hour, the diagnostic cannot, in its present form, be administered en masse as the CTB may. Even though it is a good discriminator, the Piagetian battery can only be administered selectively.

3. This research was pioneering and startling results were not anticipated. Rather than seriously question genetic epistemology and the foundation of Piagetian theory, it is best to admit the methodological shortcomings of the research. The diagnostic battery measured the sample group to be conceptually underdeveloped in relation to the conservation of the tasks. A number of reasons for this have been cited, not the least of which is language.

4. If the original research rationale of disregarding cultural milieu and clinically assessing how the experience of mining has affected intellectual development in a group of Black mineworkers, then it may be confidently stated that the subjects interviewed exhibited evidence of concept conservation at the Preoperational and Concrete operational level. The experience of mining had very little influence on the conservation of Force. Because of the strong evidence

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of Pre-operational and Concrete thinking in the sample group, the suggestion may be made that such findings are proof of the very practical level at which Black mineworkers are required to function intellectually in their occupations. Once the obstacle which job reservation has created is removed, the industry must give serious consideration to the intensive development of the intellectual abilities of Black mineworkers in relation to job skill requirements. This process will be fascilitated by the use of a diagnostic methodology which provides for the trainer some graphic evidence of a candidate's abilities.

4.14.2 LANGUAGE.

A second reason for the inconclusive results may lie with linguistic discrepancies. Although interviews were conducted in the home language of the subject, interpreters did experience some difficulty with direct translation of the questionnaire. An example is the odd scores obtained for the concept of Substance. It follows that to accept the mathematical model of conceptual sequence proposed by Moore (1980), subjects must be able to conserve Substance before there can be any progression towards the conservation of Space. Yet in many instances subjects, on the strength of their responses, did not conserve Substance. The difficulty lay with the words 'amount' and 'same'. (See Condition 1.Q.1.1a of Appendix 1). Subjects were unable to correctly verbalize their explanations and repeatedly referred to perceptual cues such as 'same colour' or 'same size' even when requested to attempt an alternative explanation by the researcher. The interpreter was also inclined to ask leading questions at this stage in an attempt to

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overcome the verbal impasse. Although Piaget does not regard language as a particularly significant facilitator of mental growth, it was of great relevance to employ the Explanatory variable in the questionnaire. In most instances a completely false impression would have been gained from the research had only the Behavioural response been scored.

4.15 CONCLUSION.

Although the principle research hypothesis was rejected, this study did reveal types of thinking and reasoning ability among a select sample of Black miners which could be categorised according to Piaget's theory of cognitive growth. The diagnostic battery used cannot be regarded as sufficiently developed so as to be used with confidence. Much work is still required in this area, but as a beginning the battery did provide a means of breaking into the conceptual world of a group of Black miners. Despite the methodological and apparatus problems encountered, the battery gave evidence of the viability of applying Piagetian method in a cross-cultural setting. Future use of Piagetian methodology for selection in the mining industry is governed by two alternatives:-

1. to introduce cultural milieu into the battery or tasks so as to tap 'pure' Black thinking and align training accordingly. This would appear to be a very fair method in that Black mineworkers could come to terms with increased skill acquisition on the basis of their own experience and intellectual adaptation.
2. design assessment tasks according to the milieu in which they were developed and mould Black thinking towards job requirements by artificially boosting concept conservation.

With modification and adaptation the diagnostic battery could be

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usefully employed in the industry, but not as a primary selector. The research did not show significant difference or correlation. Rather it identified types of thinking used by a group of Black miners in attempting to solve conservation tasks.

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CHAPTER FIVE

PERSONAL IMPRESSIONS BY THE RESEARCHER.

5.1 Original Idea of the Research.

The original idea which motivated this research may be traced to the researcher's awareness of the serious handicap job reservation posed for the Black mineworker. The mining industry is labour intensive and although much has been done by the Chamber of Mines to reduce the wage gap between White and Black mineworkers, there still remain fundamental differences in terms of skill acquisition and career prospects. The Black mineworker finds himself confined to a specific job categorisation which prevents him from acquiring new skills and advancement. The researcher considered it prudent to examine the extent to which the conceptual abilities of Black mineworkers were really being measured by the standard measure of 'trainability' used by the Chamber of Mines, namely the CTB.

The research in no way is an attempt to discredit the method of assessment currently used by the Chamber of Mines. It should rather be seen in the light of being a probe into the possibility of using a more individual centered method of selecting candidates for specific occupations.

Publication and circulation of the report of the Commission of Inquiry into Labour Legislation Part 6 (1980), gave further impetus to the original research idea. The report indicated that a move away from traditional labour practices in the mining industry was a definite need. Furthermore, the report suggested that mine employees other than Whites and Coloureds be made eligible to become holders of blasting certificates on a merit basis. The fears of White mineworkers concerning the implementation of such a proposal are based on two intrinsic beliefs. The first is the belief that the Black mineworker is an inferior because of his race and 'primitive' culture. There is a very great fear that

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Blacks may supercede Whites employed in the industry on the basis of 'cosmetic' advancement. It basically comes down to a lack of faith and confidence in the abilities of Black miners to perform skilled tasks. This is an attitude which is inherent in the White mining labour force.

The second belief is that Whites qualify to perform skilled and scheduled occupations on the mines by virtue of their allegiance to a trade union which encompasses their class of work. The most militant example is the Mine Worker's Union which constitutionally excludes Blacks from becoming members. Again the belief in racial superiority and the protection of their class of work, rather than a spirit of competitiveness for various employment, has moulded this attitude. It is an attitude which developed out of fear, on the part of White miners, that mining companies would replace them with Black workers who were prepared to work for much lower rates of pay. However this fear may be discounted today because of the prevailing ethic of equal pay for equal work. Yet White miners are still unable to reconcile the idea of competing with Blacks for mining jobs on a merit basis.

The researcher acknowledges that a great number of Black miners may be found to be out of their depth should they be suddenly allowed to become integrated into more sophisticated aspects of mining and many reasons may be cited for this. But these are not justified by continually excluding Black miners from being allowed the opportunity of training for skilled jobs. Consequently it was reasoned that the current means of assessing Black mineworker aptitude would be grossly inefficient for the purposes of selecting and placing Blacks in skilled positions which may require intensive formal training. What is greatly needed is to raise the level of

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sophistication of selection of Black mineworkers and establish a uniform code of practice as regards selection and placement of all mining personnel. However, this remains speculative until the industry decides to shift away, in a more positive manner, from present entrenched discriminatory labour practices.

5.2 Attitudes of White personnel to the research.

The most common attitude of White mine personnel who were consulted, either for assistance or opinion, was one of 'interesting implications'. But training staff who became more closely associated with the research regarded it as an exercise which reinforced, and gave positive 'proof' of the inferiority of the Black mineworkers mentality. The actual battery was regarded as nothing more than a collection of children's games which Black subjects had difficulty in mastering and to the White observer was a sign of an equality between White children and Black adults in terms of mental ability. Some went even further and suggested that White children were superior to Black adults in reasoning abilities. It goes without saying that White mine personnel are very sceptical about Black advancement and the wisdom of advocating intensive training for Blacks on the mines, as it is felt that the return on such input in the short to medium terms will be minimal.

While it may be understandable that racially biased views are held by White mining staff, in the training centre where this research was conducted, there was a frightening lack of comprehension, on the part of White training instructors, of the intellectual difficulties faced by Black miners in a technological work environment.

5.3 Impressions of the subjects on the research.

The overall impression gained by the researcher was that subjects, both novice and experienced, responded very positively to the

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research and no problems, such as refusing to continue answering questions, were encountered. One of the most interesting aspects to emerge was the archetypical responses associated with Piagetian research on conservation. This tended to support the universal application of Piagetian methodology, in that, Black African mine-workers were giving similar responses to Genevan children on standardised conservation tasks and so could be identified as Pre-operational, etc. The application of this battery on a cross-cultural basis was a success. Reactions to the battery and test situation did vary slightly between novice and experienced groups.

5.3.1 Novices.

The novice group showed signs of pre-test nervousness but this was easily dissipated by the reassurances from the interpreter and researcher. Subjects did appear to appreciate that their responses were not counted as being 'right' or 'wrong'. As the exercise progressed they became more absorbed in the tasks and accepted being shown solutions of tasks they were unable to master. As a class, novices struggled to verbalise explanations as required, but this was more pronounced in subjects who had very little formal education, for example standard one to standard three. Novices did account for the highest number of unanswered questions on the explanatory variable.

5.3.2 Experienced.

This group was able to verbalise more lucidly than the novices and education did not play as important a role in determining participation in explanatory responses. However, subjects who had little formal education tended to be dogmatic in their responses, but appreciative when shown task solutions.

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It was found that the more senior Blacks, especially aptitude test supervisors and administrators, showed a tendency to be hyperaware of making 'right' or 'wrong' responses despite a reassurance that such criteria were not being measured.

Experienced subjects responded more spontaneously to questions and, unlike the novices, questions rarely had to be repeated. As a group they were far more confident than novices in their general approach to the battery. Novices seemed a little overawed by the testing situation and were inclined to be reserved when explanations were sought. The experienced subjects approached solutions for the tasks in a methodical manner and did not become involved in guessing. Also, when using examples, the experienced subjects tended to keep these within the context of the apparatus used. Alternatively, novices were apt to use external figures such as horses and stones and other unrelated objects in their explanations.

5.3.3 Interpreters views on the battery and research implications.

Two Black interpreters were used and both held supervisory positions in the mine training centre. The first interpreter, Mr. Tokozwayo, was an aptitude test supervisor and initially some difficulty was experienced by the researcher in convincing him that 'right' and 'wrong' responses were not required. This may be a carry-over from his experience with the CTB. However, this man remained slightly sceptical in that he suspected the outcome of the research would show up Black miners as having poor intellectual capabilities. The second interpreter, Mr. Mganga, was an administrative clerk in the

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training centre who processed aptitude test results. Mr. Mganga was found to be very suitable as an interpreter as he was more objective and did not try and steer subjects into making 'right' answers.

Both interpreters declared that the subjects felt very positively about the battery and found it to be a rewarding exercise. Some tasks were said to be more interesting than others, for example, Speed; Acceleration and Force were the most popular.

The interpreters felt that the battery was a radical departure from the CTB and allowed subjects to relate to the test material. The CTB was said to be an abstract medium which Black miners could not relate to and this generated a tremendous amount of anxiety. The Piagetian battery, on the other hand, was composed of articles such as trees, cars, balls, glass containers and water, all easily identifiable by the subjects. Because subjects could relate to these familiar objects no anxiety was apparent in their conduct during the test.

5.3.4 Conclusions.

It may be stated, with confidence, that the battery of Piagetian conservation tasks used in the research was accepted, without exception, by all subjects who stated that the exercise was a challenging, interesting and enjoyable experience.

The most rewarding aspect of the test programme for the researcher was to witness the subject's gradual coming to terms with the intellectual demands of each task. Subjects

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displayed an ability to approach tasks in a systematic and logical manner, irrespective of the conceptual level at which task solutions were effected (intuitive, pre-operational, concrete or formal). That a collection of such apparently simple objects could evoke responses so diverse and intricate in their logic, was for the researcher, an insightful and gratifying experience.

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APPENDIX 1.

QUESTIONNAIRE.

QUESTIONNAIRE.

Modified and adapted by Liddle (1982) from original by Moore (1980).

==========

This is an investigation of how you approach various objects. You will be asked questions about objects presented to you. Please attempt to answer the questions as well as you can. You must explain how you reached the answer. Remember there are no right or wrong answers.

1. SUBSTANCE.

Condition 1.		Make another clay ball that is as big and as heavy as the one on the red card. Put your clay ball on the white card.
(Q. 1.1a)	B	Does the ball of clay on the red card have the same amount of clay as the ball of clay on the white card or do they have different amounts of clay?
	E	How do you know this?
(Q. 1.1b)	B	Does the ball of clay on the red card weigh the same as the ball of clay on white card or do they have different weights?
	E	How do you know this?
Condition 2.		Experimenter changes the ball of clay on red card into sausage shape.
(Q. 1.2a)	B	Does the clay sausage on the red card have the same amount of clay as the ball of clay on the white card, or do they have different amounts of clay?
	E	How do you know this?
(Q. 1.2b)	B	Does the clay sausage have the same weight as the clay ball, or do they have different weights?
	E	How do you know this?
Condition 3.		Experimenter rolls sausage on red card back into ball and then rolls ball on white card into a coil.
(Q. 1.3a)	B	Does the clay ball on the red card have the same amount of clay as the coil on the white card, or do they have different amounts?
	E	How do you know this?

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(Q. 1.3b) B Does the clay ball weigh the same as the clay coil, or do they have different weights?

E How do you know this?

Condition 4. Experimenter rolls coil on white card into a ball and breaks ball on red card into six pieces.

(Q. 1.4a) B Is there more clay altogether on the red card than there is in the ball on the white card, or is there the same amount of clay?

E How do you know this?

(Q. 1.4b) B Do all the pieces on the red card together weigh more than the clay ball on the white card, or do they weigh the same?

E How do you know this?

TOTAL B8 E8 T. (16)

2. SPACE.

Condition 1. Concept of horizontal - (moving bottles).

Look at bottle No. 1. Look what happens to the red water when the bottle is moved.

Look at bottle No. 2. See how you can move the red water around the bottle.

Move bottle No. 2 to the same position as bottle No. 1. Move the coloured red water in bottle No. 2 to be the same as the red water in bottle No. 1.

Experimenter: Cover bottle No. 1 and move bottle to position 1. Move bottle No. 2 to same position as bottle No. 1.

(Q. 2.1a) Move the red coloured water to where you think it should be.

B

Experimenter: Move bottle No. 1 (still covered) and bottle No. 2 to position No. 2.

(Q. 2.1b) Move the red coloured water to where you think it should be.

B

/iii.....

Experimenter: Move bottle No. 1 and bottle No. 2 to position No. 3.

(Q. 2.1c) Move the red coloured water to where you think it should be.

B

Experimenter: Same for all six positions.

(Q. 2.1d) Position 4.

B

(Q. 2.1e) Position 5.

B

(Q. 2.1f) Position 6.

B

Condition 2. Present diagram. (6 B)

(Q. 2.2a) Here are some drawings of the bottle. The lines underneath them represents the table on which the bottle stands. With the red pen draw in where you think the red water should be:

6 B

Condition 3. (Concept of vertical).

Experimenter: This clay is a mountain and these sticks are fence posts.

(Q. 2.3a) Which one of these fence posts is 'straight up' and which one is 'sloping'?

Experimenter: Put these fence posts into the mountain side such that they are standing 'straight up'.

B

Condition 4. Present diagram.

Experimenter: Here are two diagrams of a mountain.

(Q. 2.4a) On the first drawing, draw some fence posts on the sides of the mountain standing 'straight up'.

(Q. 2.4b) On the second drawing, draw in two houses and some trees on the sides of the mountain.

B

T (15B)

/iv.....

3. DISTANCE.

Condition 1. (Two trees 50 cms apart).

(Q. 3.1a) Are these trees near one another or far apart?

(Place screen between trees).

(Q. 3.1b) Are these trees still as near one another (or as far apart) as they were before?

B

How do you know this?

E

(Screen with window).

(Q. 3.1c) Are these trees still as near one another (or as far apart) as they were before?

B

How do you know this?

E

(Large cube in between).

(Q. 3.1d) Are these trees still as near one another (or as far apart) as they were before?

B

How do you know this?

E

(Carpet of bricks).

(Q. 3.1e) Are these trees still as near one another (or as far apart) as they were before?

B

How do you know this?

E

Condition 2. (One tree and cube).

(Q. 3.2a) Is it as near or as far from there to there (AB - tree to object) as it is from there to there (object back to same tree).

/v.....

(Experimenter to run finger along distances AB and BA to avoid misunderstanding).

B

How do you know this?

E

Condition 3. (Hillside).

This is the side of a hill and here are two trees.

(Q. 3.3a) Is it as near or as far from this tree (tree at bottom of hill) to this tree (tree at top of hill) as it is from this tree (top of hill) to this tree (bottom of hill) or are the distances different?

B

How do you know this?

E

TOTAL 6B 6E T (12)

4. LENGTH. (Two straight bars parallel to each other and extremities facing each other).

Condition 1.

(Q. 4.1a) Are these two bars of equal length or are they different?

Condition 2. (Stagger one bar forward 1 - 2 cm).

(Q. 4.2a) Are these two bars of equal length or are they of different lengths?

B

How do you know this?

E

Condition 3. (Move one bar at 45° to mid-point of other).

(Q. 4.3a) Are these bars of different length or are they equal in length?

B

How do you know this?

E

Condition 4. (Stagger again (parallel) but in opposite direction to sloping).

(Q. 4.3a) Are these two bars equal in length or is one longer?

B

How do you know this?

E

TOTAL B3 E3 T (6)

5. TIME.

Experimenter: Here is a bowl of water. If I open this tap the water will begin to flow out of these two tubes at the same time. If I close this tap the water will stop flowing from each tube at the same time: Watch carefully.

Demonstrate.

Condition 1. (Present bottle A and bottle B).

(Q. 5.1a) Which of these two bottles would be filled more quickly, A or B?

B

How do you know this?

E

Will it take more or less time to fill bottle A than bottle B with water?

B

How do you know this?

E

Condition 2. (Water allowed to flow into A & B).

(Q. 5.2a) Did the water start and stop flowing into bottles A and B at the same time?

B

(Q. 5.2b) Did it take more time, the same time or less time for the water to go from here to here (A_o - A_1) as it did from here (B_o - B_1) to here?

B

How do you know this?

E

/vii.....

(Q. 5.2c) Is there the same amount of water in here ($A_o - A_1$) as there is in here ($B_o - B_1$) or is there more water in one of the bottles?

B

How do you know this?

E

Condition 3. (Put bottle B_1 next to bottle B).

Experimenter: This bottle B_1 is the same as this bottle B.

(Q. 5.3a) If this water (bottle A) is poured into this bottle (B_1) how high would the water rise?

B

How do you know this?

E

(Put bottle A_1 next to bottle A).

Experimenter: This bottle (A_1) is the same as this bottle (A).

(Q. 5.3b) If this water (bottle B) is poured into this bottle (A_1) how high would the water rise?

B

How do you know this?

E

Condition 4. These two bottles (L and L^1) are the same.

(Q. 5.4a) If this water (A) is poured into here (L) (pour A into L), it rises to this level. If that water (B) is poured into here (L^1) how high would the water rise? Will the water rise higher, lower or to the same height as the water in this bottle (L)?

B

How do you know this?

E

Condition 5. (Using X, Y + Z just fill X & Y).

/viii.....

(Q. 5.1a) Did this bottle (X) take the same time to fill as this bottle (Y)?

B

How do you know this?

E

(Throw away water Y and then fill Y + Z together).

(Q. 5.1b) Did this bottle (Y) take the same time to fill as this bottle (Z)?

B

How do you know this?

E

(Put X, Y + Z together).

(Q. 5.1c) Did these bottles all take the same time to fill, or did they take different times?

B

How do you know this?

E

(Q. 5.1d) Which bottle holds the most water, or do they all hold the same amount of water?

B

How do you know this?

E

TOTAL 12B 11E T (23)

6. SPEED.

Condition 1. This is a short tunnel and this is a long tunnel. Tell me when you are ready and I will start the motor cars moving. Watch the motor cars carefully.

(Q. 6.1a) Did the motor cars start moving and stop moving at the same time?

B

How do you know this?

E

/ix.....

(Q. 6.1b) Did the cars travel the same distance or did one travel further than the other?

B

How do you know this?

E

(Q. 6.1c) Did the cars travel the same length of time or did one car take longer than the other?

B

How do you know this?

E

(Q. 6.1d) Did the cars travel at the same speed or did one car travel faster than the other?

B

How do you know this?

E

NOTE: If the subject clearly fails to solve the questions of condition 1, the tunnels are removed and the questions of condition 1 (i.e. 1a, 1b, 1c, 1d) are asked for condition 2.

Conditions 2 and 3 are only to be interpreted as qualitative analysis).

Condition 2. Remove tunnels and demonstrate car movement. Proceed with questions in condition 1.

(Q. 6.2a)

(Q. 6.2b) How do you know this?

(Q. 6.2c) How do you know this?

(Q. 6.2d) How do you know this?

If condition 2 is used, condition 3 must be followed.

Condition 3. Replace the tunnels on the apparatus and again demonstrate car movement. Proceed with the same questions as in condition 1.

/x.....

(Q. 6.3a)

(Q. 6.3b) How do you know this?

(Q. 6.3c) How do you know this?

(Q. 6.3d) How do you know this?

TOTAL 4B 3E. T (7)

7. ACCELERATION. This is a motor car and this is a road down a hillside.

Condition 1.

(Q. 7.1a) What will happen to this car if I let it go down the hill slope?

(let the car run down the slope).

(Q. 7.1b) At which part of the slope was the car going the fastest?

B

(Q. 7.1c) Where was the car going the slowest?

B

Condition 2. (Put up flags at equal intervals).

These flags are all the same distance apart. Let us say they are all one mile long. This is interval No. 1, No. 2, No. 3 and No. 4.

(Q. 7.2a) What time does the car take to cover each interval?

B

Does the car take the same time to cover each interval or are the times longer or shorter for each interval?

B

How do you know this?

E

(Q. 7.2b) On which interval will the car be going the fastest?

B

How do you know this?

E

Condition 3. Imagine there is a driver inside the motor car. He has a watch and at every minute he shouts 'hey' as he goes down the hill. Every time he shouts 'hey' we will put a flag at the side of the road.

(Q. 7.3a) Point to where you think we should put each of the flags down the road (put the flags up where the subject points).

B

(Q. 7.3b) Are the distances between these flags equal, or are some longer and some shorter than others?

How do you know this?

E

(Q. 7.3c) Which interval is the longest and which is the shortest?

B

How do you know this?

E

(Q. 7.3d) Tell me the order of the intervals, ranging from the shortest to the longest?

B

Experimenter: Use numbers i.e. 1st, 2nd, 3rd, 4th.

How do you know this?

E

TOTAL 8B 5E. T (13)

8. FORCE - TRANSMISSION OF MOVEMENTS.

Condition 1. Show the subject the apparatus with a silver ball hanging on the left and a small ball hanging on the right.

Condition 1. "You must start from this end (right) and you should not move this object any closer to the silver ball. You may use any of these other objects to help you.

(Q. 8.1a) Show me the best way of making the

/xii.....

silver ball move, without touching the silver ball with your hands.

B

(Q. 8.1b) What causes the silver ball to move?

E

TOTAL 1B 1E T (2)

TOTAL SCORE = B 57

E 37

T 94

APPENDIX 11

SCORE SHEETS.

INDIVIDUAL SCORE SHEET

	B	E
1. Substance.	1	1
	1	1
Stage 1	1	1
11a	1	1
11b	1	1
111a	1	1
111b	1	1
	1	1
	1	1
B M 8 S	1	1
E M 8 S		
2. Space.	1	1
	1	1
Stage 1	1	1
11a	1	1
11b	1	1
111a	1	1
111b	1	1
	1	1
	1	1
B M 15 S	1	
E M 0 S		
3. Distance.	1	1
	1	1
Stage 1	1	1
11a	1	1
11b	1	1
111	1	1
	1	1
B M 6 S		
E M 6 S		

NAME: _____

COY. NO. _____

AGE: _____

EDUCATION: _____

TRIBE: _____

DUDEC _____

NO. OF CONTRACTS _____

OCCUPATION _____

	B	E
4. Length.		
Stage 1	1	1
11a		
11b	1	1
111		
	1	1

	M	S		M	S
B	3		E	3	

	B		E	
5. Time.	1	1	1	1
	1	1	1	1
Stage 1	1	1	1	1
11a	1	1	1	1
11b	1	1	1	1
111			1	
	1		1	

	M	S		M	S
B	12		E	11	

	B	E
6. Speed.	1	1
Stage 1		
11a	1	1
11b		
111	1	1
	1	

	M	S		M	S
B	4		E	3	

		B	E
7. Acceleration.		1	1
Stage	1	1	1
	11a	1	1
	11b	1	1
	111a	1	1
	111b	1	
	1V	1	
		1	
8. Force.		1	1
Stage	1		
	11a		
	11b		
	111		

	B M	B S	E M	E S
7. Acceleration.	8		5	
8. Force.	1		1	

TOTAL

	M	S
B	57	
E	37	

DIAGRAMS FOR CONCEPT OF THE HORIZONTAL.

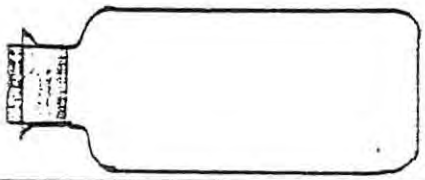
CONDITION 2.

QUESTION 2.2a.

SUBJECT _____

1.

4.



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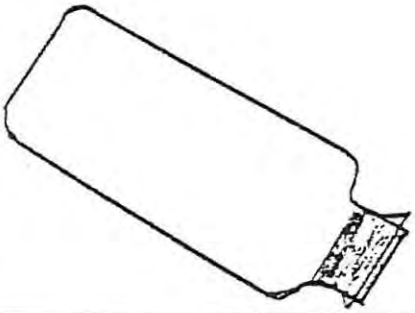

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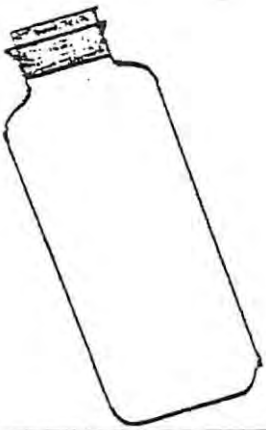

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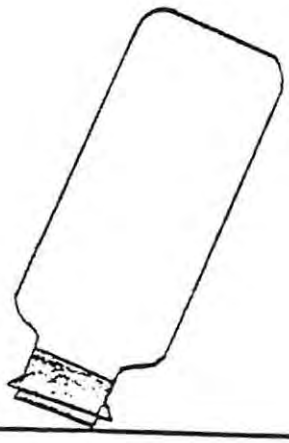

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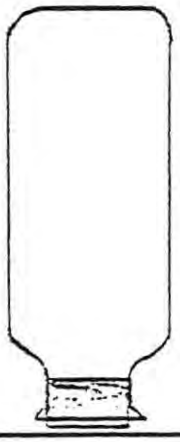
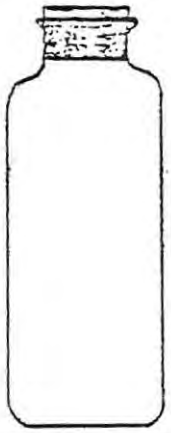


xvii.

SUBJECT _____

1.



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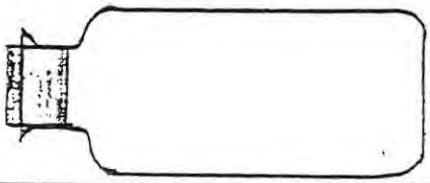

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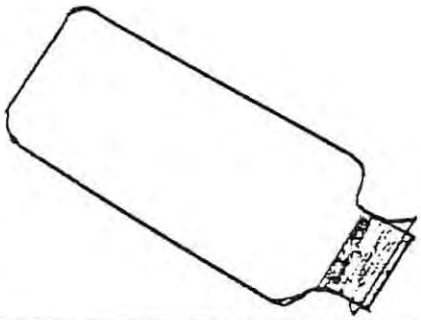

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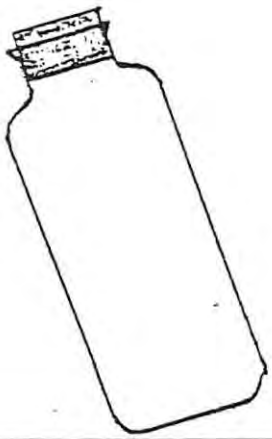

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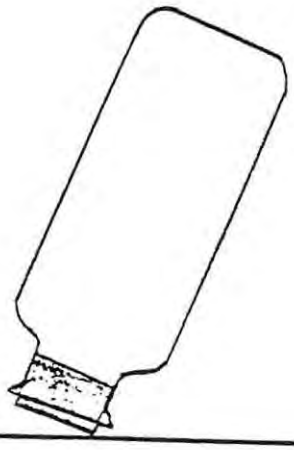

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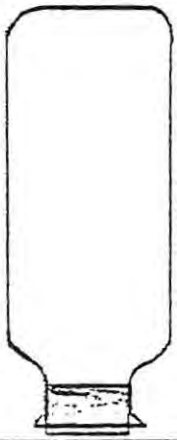
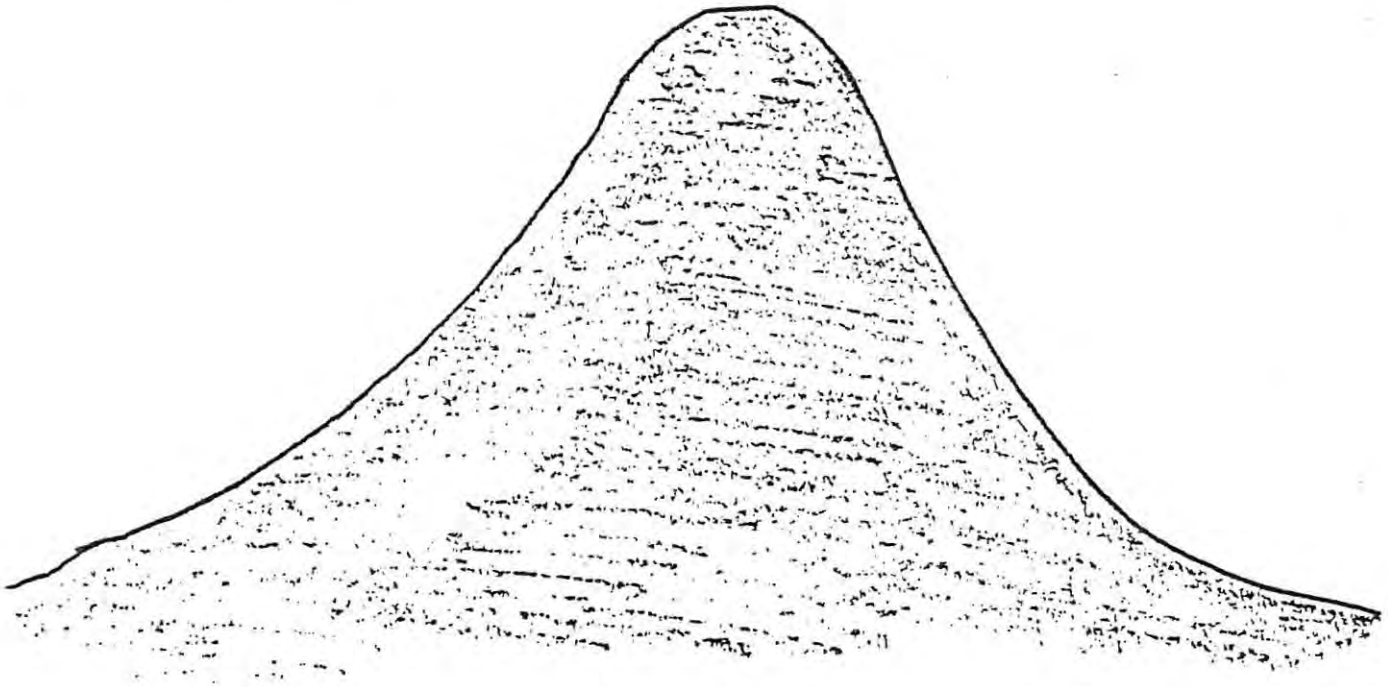


1. DIAGRAM FOR THE CONCEPT OF THE VERTICAL.

SUBJECT _____

CONDITION 4.

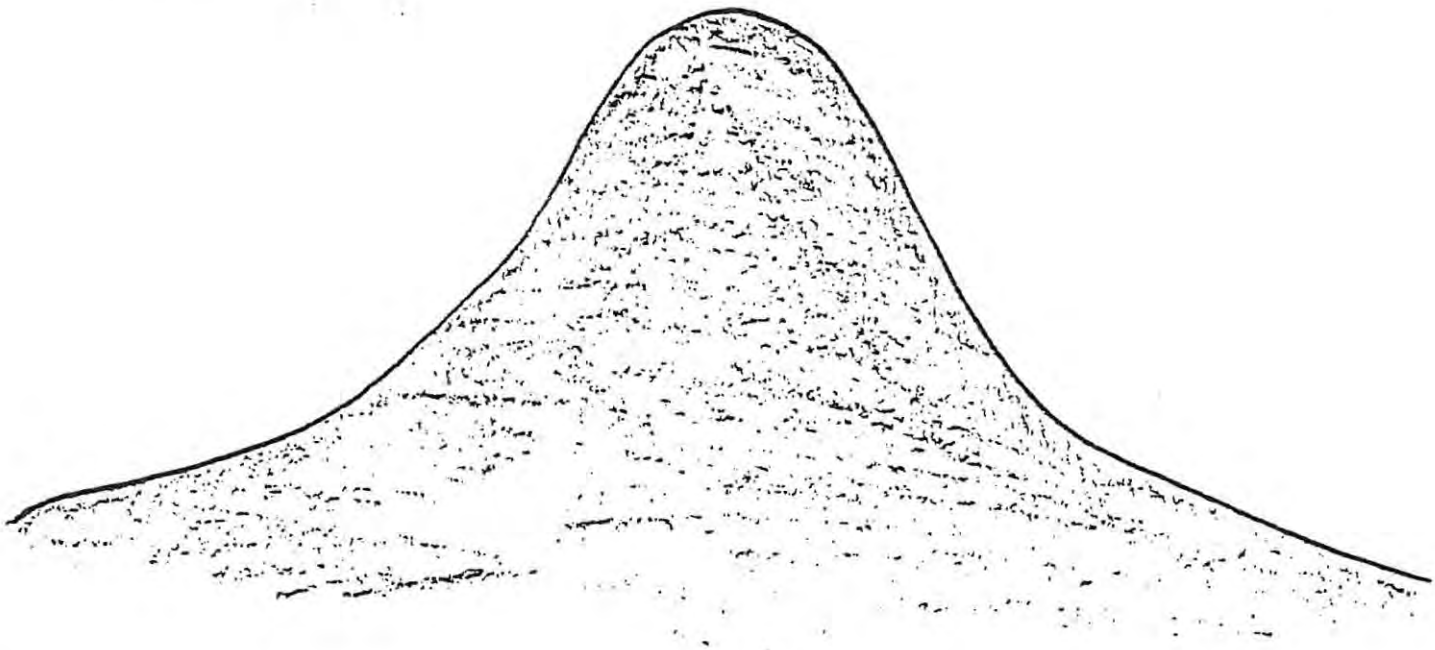
QUESTION 2.4a.



2. DIAGRAM FOR THE CONCEPT OF THE VERTICAL.

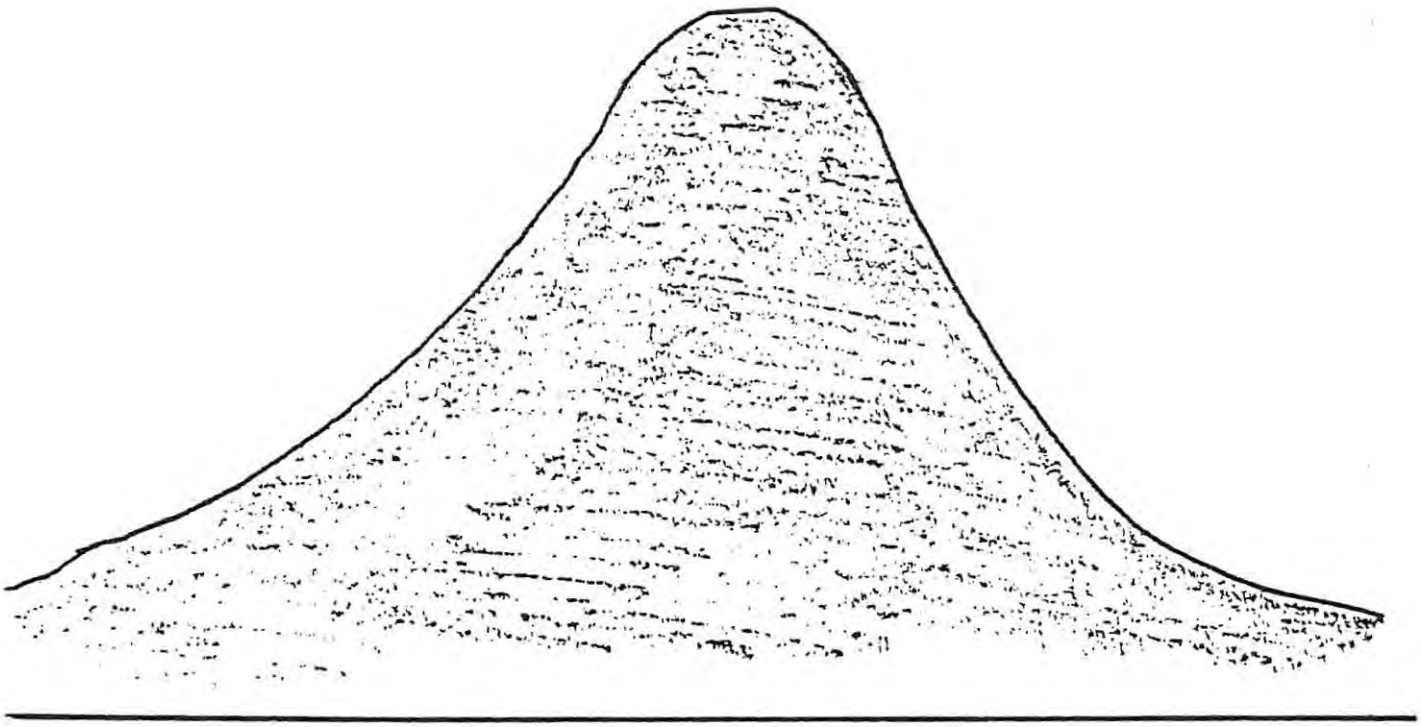
CONDITION 4.

QUESTION 2.4b.



SUBJECT _____

1.



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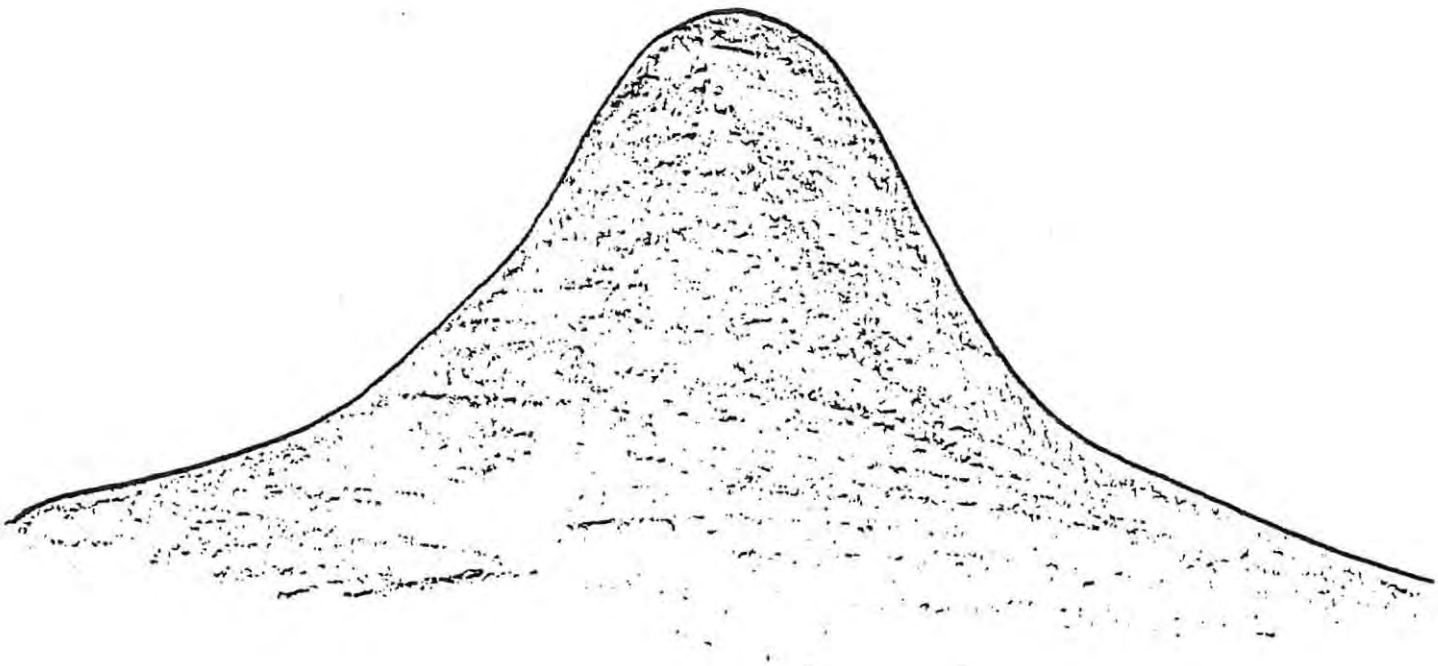


CRITERION GROUPING SCORE SHEET (PART 1).

CATEGORY: (EXPERIENCED/NOVICE AND CARD COLOUR).

NUMBER	NO. OF CONTRACTS	AGE	YEARS EDUCATION	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
TOTAL				
MEAN				

CRITERION GROUPING SCORE SHEET (PART 2).

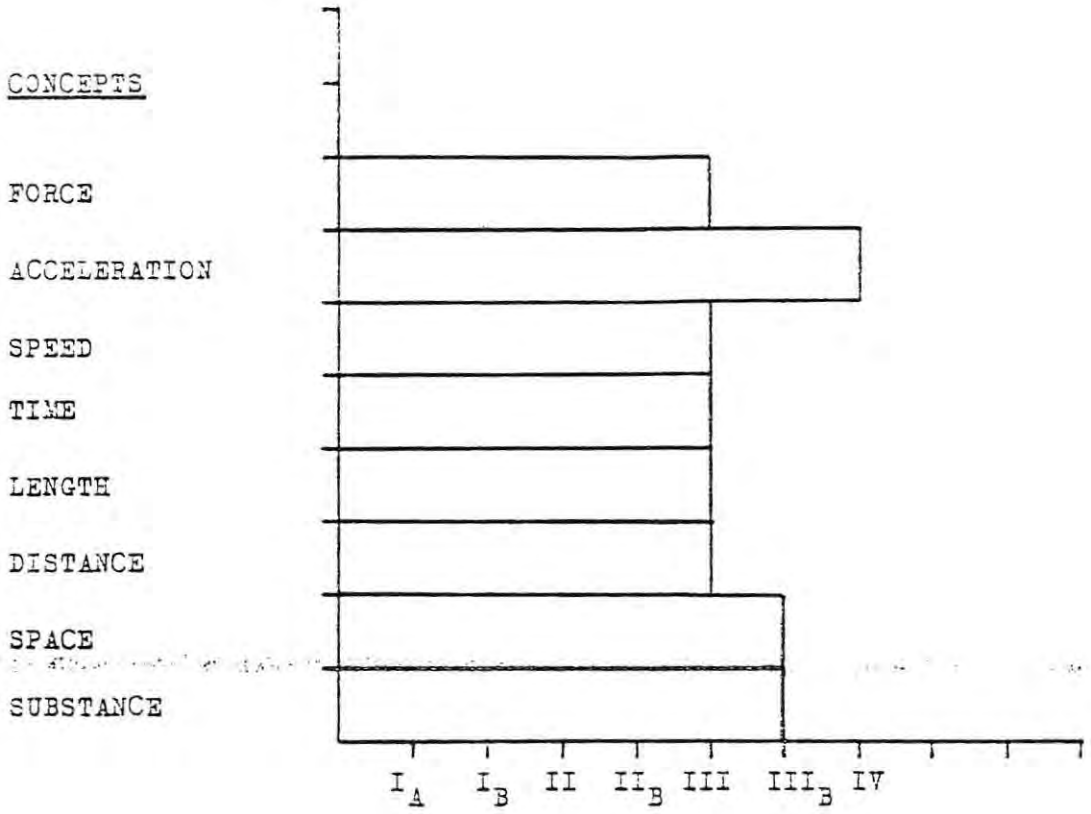
CATEGORY: (EXPERIENCED/NOVICE AND CARD COLOUR).

CONCEPT.

NUMBER	SUBSTANCE		SPACE		DISTANCE		LENGTH		TIME		SPEED		ACCEL		FORCE	
	B	E	B	E	B	E	B	E	B	E	B	E	B	E	B	E
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
13																
14																
15																
TOTALS																
MEAN																

NUMBER OF SUBJECTS: _____

PROFILE OF CONCEPTUAL DEVELOPMENT.



NAME: .....

AGE: .....

OCCUPATION: .....

CONTRACT: .....