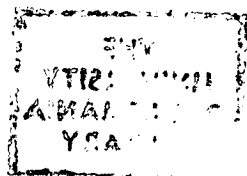UNIVERSITY OF TASMANIA

THE BEHAVIOURAL CONTRACT:-

A neo-Piagetian view of the collaboration between
individuals and their environments, based on the form and
synchrony between an EEG cognitive competence profile and
cognitive performance profiles.

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A dissertation submitted to the Centre For Education in
partial fulfilment of the requirements for the Degree of Master
of Educational Studies.

December,1985.

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ABSTRACT

This paper adopts a competence-performance view of
cognitive development (Flavell and Wohlwill 1969; Fischer
1980; Bertenthal, cited Fischer 1981; Bullock, cited Fischer
1981; Fischer and Silvern 1985) where cognitive competence
reflects the structure of the individuals' minds and
cognitive performance is a variable derived from a
collaboration between individuals and their environments
(Fischer and Bullock 1984). It is hypothesised that
cognitive performance profiles reflect the cognitive
competence component of the collaboration when the learning
environment is manipulated to induce an individual's best
performance.

It is argued that EEG data suggests the location of
powerful alpha wave generators located in the
occipital-parietal region of the brain. Energy from these
appear to be an adequate index of cognitive competence.
Cross-sectional EEG data (Matousek and Petersen 1973) and
other neuro-physiological data are interpreted in terms of a
discontinuous function of the natural logarithm of age, which
maps skill levels defined by Fischer (1980) and presents as a
normative profile of cognitive development.

Patterns of cognitive performances extracted from the
developmental literature provide evidence of profiles of
similar form and synchrony to that derived
neuro-physiologically and this supports the hypothesis.

Educational considerations implicit in the
developmental profile suggests a view that decrements in
cognitive performance can be predicted to occur throughout
cognitive development. These should be considered as
corresponding to periods of structural reorganization within
the brain. The outcome of which is a more effective level of
cognitive competence which increases that components ability
to act in future collaborations with the environment, so
increasing the expectation of the quality of cognitive
performance outcomes.

It is suggested that while SOLO levels (Biggs and
Collis 1982) confound Skill Theory levels the SOLO taxonomy
provides an appropriate and relatively simple technique for
evaluating qualitative changes in performance. First, in
establishing that a new level of competence is attained, and
secondly, in observing any environmentally induced decline
from optimal performance.

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INTRODUCTION:

In general, this paper draws a cognitive developmental perspective in the tradition of Piaget and focuses on his view of how the intellect grows:

> "at any point in its development, it may be described as a set of organized structures or schemes; as the individual encounters his world, he assimilates objects and events to these structures (thus they function and expand without structural change); when this is not possible the existing structures are inadequate, they modify themselves or accommodate (thus they undergo structural changes).... only occasionally do they result in fundamental changes in such structures."
>
> Grubber and Voneche (1977, xxvii)

In particular, the paper adopts a competence-performance view of cognitive development where it is assumed that cognitive competence reflects the physiological structures of the human mind (Flavell and Wohlwill 1969; Fischer 1980; Bertenthal, cited Fischer 1981; Bullock, cited Fischer 1981; Fischer & Silvern 1985, 624). Included among these structures are the myelination of nerve fibres, changes to neural pathways and the modification of the number and organization of synapses. In effect, cognitive competence is seen as placing an upper limit, or optimal level, on a person's ability to process information (see also, Fischer and Pipp 1984, 3). Performance, on the other hand, represents a person's cognitive behaviour in a specific environment or context. In this regard, performance is assumed to reflect a collaborative role between the individual's cognitive competence and his environment (Fischer and Bullock 1981, 1984). The term "collaboration" is used to convey the existence of a mutual harmony or resonance (Shepard 1984, 436) at work between an individual's cognitive competence and a particular environment.

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It is also used as a rejection of the view that either cognitive competence or environmental factors dominate to the exclusion of the other in the determination of behaviour. Through adopting a collaborative approach to cognition the fear of preformism often associated with structural theories (Flanagan 1984) can be lessened. In addition, it provides a mechanism to counter some of the inadequacies of structural approaches that lead to purely behaviouristic theories of learning.

In general, the broadest possible meaning can be attributed to the term "environment". In view of the suggested collaborative nature of behaviour many of its aspects, such as emotion, attention and motivation can not be effectively thought of in isolation as belonging solely to either the individual or to his environment. Fischer (1980,484) proposes that the environment for a particular test may consist of a piece of physical apparatus. In this paper learning environments more appropriate to the collection of performance data are considered. Fischer and Pipp (1984,10) suggest that the most important environmental considerations leading to improved performances are _practice_ and _instruction_, as well as _support_ through the immediate context of cues, that indicate the kind of performances that are expected of individuals. Fischer and Bullock (1981,11) support the theory that there is an upper bound on performance complexity. In this respect optimal performance seems to be a function of both cognitive capacity and the optimal, or best environmental conditions conducive to the performance.

Patterns of change in performance observed over periods of time produce developmental performance profiles. These profiles are suggestive of a behavioural contract existing between individuals and their environments. In view of the possibility of such a contract it is hypothesized that performance profiles will reflect the cognitive competence component of a collaboration between an individual and his environment, providing the learning environment is manipulated and maintained to induce optimal performance.

While investigating the idea of behavioural contracts, this paper is not committed beforehand to any theoretical paradigm beyond the basic collaborative notion. It draws ideas, however, from a variety of disciplines; including the works of Andersen & Andersson, Bever, Cotman & Neito-Sampedro, Epstein, Fischer, Hebb, Lorenz, Luria, Matousek & Petersen, and Strauss, among others, wherever they put forward insights that seemed valuable, irrespective of the way in which they were developed.

The work of K.W.Fischer constitutes a dominant theme throughout this paper. The reason for this is that Fischer's theory of cognitive development has as an underpinning, the active integration of the individual with his environment, whereas Piaget (1971) for example, makes fewer concessions in this direction. Another reason is that Fischer's mathematically defined levels appear more finely tuned than Piaget's stages. Viewed from a different perspective, levels have both qualitative and quantitative aspects which permit their use as a scale for investigating developmental change in performances. Furthermore, there are several dichotomies which

have hindered progress towards a comprehensive theory of cognitive development. Werner (1957) and Kagan (1985) identify some of these dichotomies as: constancy and variation, biology and experience, connectedness and discontinuity and, qualities and quantities. In Fischer's approach, however, he seldom treats the branches of these dichotomies as being opposed to each other. Thus new perspectives open out and old data can be re-evaluated.

It is accepted that momentary fluctuations in physiological or environmental variables result in transitory behavioural changes. However, this paper does not focus upon these transitory fluctuations, but rather, upon the long term qualitative changes which occur in the central nervous system of the human organism and which substantially change its competence to act in any further interaction it has with its environment. The competence-performance view of cognitive development views "competence" as a variable reflecting the structure of the organism's mind. It must not be forgotten, however, that although the central nervous system may be the dominant physiological variable in cognitive development its interaction with other systems, such as the endocrine system, should not be underrated. The question becomes what does one use an index of cognitive competence.

If learning takes place at the synapse within the neurological system as some writers suggest (Hebb 1949; Lorenz 1977,88; Cotman & Nieto-Sampedro 1982; Kagan 1985), then it seems appropriate to seek some physical quantity associated with synaptic activity as an index of the changes taking place there.

Hebb (1949) for example, assumes as a working hypothesis that the electroencephalogram (EEG) represents the total synaptic activity of the brain when it is poised ready to commence processing information. The use of EEG data as an indicator of cognitive development has often been suggested (Walter 1963; Epstein 1980; Fischer 1983,16), but seldom with convincing demonstration. This paper adopts John's (1977) use of EEG energy calculations based on Matousek and Petersen's (1973) cross-sectional EEG analysis of five hundred and sixty-one Swedish children and adolescents. However, it takes a different perspective of EEG energy data, in that the data is considered as representing a discontinuous function, rather than a continuous one. This means that while the percentage of EEG alpha energy generally increases there are times when it also decreases, thus suggesting some kind of regression in the structural development of the brain consistent with the views of Werner (1957), Bearison (1974) and Lorenz (1977). In this way a rather distinctive pattern, suggestive of changes in cognitive competence can be obtained.

The aim of this paper is to attempt to show that the same pattern is reflected in performance data when environmental conditions are suitably arranged. It is suggested that the pattern of EEG data can be interpreted in terms of the mathematical structures reported by Fischer (1980) as representing a hierarchy of levels in cognitive development. It is also suggested that the changing pattern of EEG energy output is focussed on the occipital-parietal region of the brain. This offers the possibility that the structural changes indexed by EEG energies may be viewed in terms of the

simultaneous processing of information which takes place in that region of the brain, as suggested by Luria (1976).

The main concern in this paper is to contribute to a more efficient and effective approach to the learning process. If we view learning from a competence-performance perspective, when provided with a greater knowledge of the limits of competence, then the advantage may be in a better predictive power of learning outcomes. Furthermore, it might provide a better understanding for any intervention in the learning process aimed at achieving optimal cognitive outcomes. In this way, individuals might be catered for by changing environments to accommodate differences among children rather than changing children to fit environments (Plomin 1983).

It is stressed that the correlations to which attention is drawn throughout the paper are aimed at encouraging further thought and empirical research into the relationships that exist between individuals and their environments. Unfortunately, much of the data used in this paper is cross-sectional and normative, and the correlations should be viewed at the most, as normative of populations and not prescriptive of any individual. In particular, the need to follow up significant correlations with longitudinal studies is required to determine if they might be relevant to individuals or only groups of people.

FISCHER'S THEORETICAL MODEL OF COGNITIVE DEVELOPMENT:

As pointed out in the introduction Fischer's work in cognitive development is important with respect to this paper's attempt to investigate a relationship between competence and performance profiles. Because of this, several of Fischer's ideas will be treated in detail.

Fischer's (1980) main work is <u>Skill Theory</u> which is a mathematical model whereby he reconceptualizes cognitive development as a transaction, or a series of transactions, that takes place between individuals and their environments. Through his model Fischer (1980,525) achieves a union of behavioural and developmental ideas expressed in the concept of "skills", which he defines as "units of behaviour". These skills are also characterised by a "standard structural description" expressed in terms of simple set theory.

The structures by their very nature invite an investigation to see if they fit an interval scale, as this quality is of significance in investigating both competence and performance as developmental functions. The structures therefore are not simply important because they can be interpreted in terms of a collaboration between individuals and their environments. Although Fischer uses skills as a scale for cognitive development he specifically makes no claims that they form an equal interval scale (Fischer and Bullock 1981,11). By this he means that the temporal distance between adjacent levels is not necessarily constant.

Skill Theory provides a symbolic language which enables convenient communication of developmental ideas and permits the

defining of developmental sequences and synchronies. As well, it enables the description, prediction and explanation of actual cognitive skills. Through Skill Theory, Fischer attempts to resolve the following questions:

(i)   What is the structure of an individual's cognitive skills at any point in development?
(ii) Which skills develop into which new skills as the child moves step by step from infancy to adulthood?
(iii) What is the process by which present skills develop into new skills?
(iv) How do present skills relate to the skills that they have developed from?
(v)   Why is cognitive development so often uneven in different domains?

In terms of Skill Theory a set is a "behaviour class" over which the individual has control of the source of variation in his thoughts and actions. The optimal level of skill complexity that an individual can control at any one time, is limited by the individual's "single central processing capacity" (Fischer & Bullock 1981,11). At its simplest, this is a control over a single set, at level 1.(^{1}L), or with more complexity, control over many sets and the relationships between them to provide mastery of higher level skills (Fischer 1980,482).

Skills at one level build upon skills from preceding levels in a step wise fashion, where each level is characterised by fairly well defined structures corresponding to the kinds of behaviours controlled at that level (ibid 479). The theory proposes a series of ten hierarchical levels divided into three tiers corresponding to significantly different skills:

(i)   sensory motor;

(ii)   representational; and

(iii)   abstract.

One of the main arguments advanced by Fischer is that progression through each tier to the next is via a cycle of four levels, each represented by specific structures and each defined in terms of set theory. The highest obtainable level of one tier, a "system of systems", becomes the "single-set" or the lowest level of the next. On moving to a new level an individual displays a spurt of development as many skills move to the new optimal level and an unevenness is observed in performance. The length of the interval for which this is observed to occur, Fischer suggests, depends on such factors as practice, task, content and environmental support (ibid 521). It should be noted that according to Skill Theory a new cognitive level does not suddenly emerge at maximum capacity for all people once they attain a specific age. (Fischer,1980; Fischer & Bullock,1981; Fischer & Pipp,1984b). In order to be able to measure the occurrence of a spurt, in particular one that reflects optimal performance, many physiological and environmental factors need to be either considered or controlled.

At its simplest, the "single-set" in the sensory motor tier corresponds to an infant's control of say, grasping or looking or hearing. According to the theory, infants do not become stuck on one set, but drift to others and are eventually lead to explore the relationships between them.

A relationship between single sets results in higher order skills at level two ($^=L$). This is described in the

theory as "mapping"; a structure relating the two sets is defined as a collection of ordered pairs in which the first member of each pair is from one set e.g. W. and the second member is from another set e.g. X. The first set is said to be mapped onto the second, i.e. $\left[{^{=}W} - {^{=}X} \right]$, under these conditions, an infant is able to control and understand the relationship between two sets of variations (ibid 486).

At level three ($^{=}L$), the infant is able to control one sensory motor system e.g. at a time. This is achieved when two aspects of each action are related to build skills that co-ordinate and differentiate types of variations in some means and ends situation. In other words one sub-set can be processed while the other is kept in mind, so that fine variations can be controlled.

At level four (^{4}L), the infant develops the ability to understand objects and the complexity of actions on objects independently of his own actions. This he achieves by co-ordinating two or more sensory motor systems to form a single representational set which it should be noted, is different from memory recall or symbolization. The newly acquired skill is also defined structually and not functionally:

$$\begin{bmatrix} {^{4}A} \longleftrightarrow {^{4}B} \\ {^{4}C} \longleftrightarrow {^{4}D} \end{bmatrix} \equiv \begin{bmatrix} {^{4}R} \end{bmatrix}$$

As indicated previously ^{4}L is not only the culmination of the sensory motor tier, but it is also the generator of the first set in the representational tier. Thus, four successive levels of change and consolidation have taken place in the first two years of an infant's life.

Fischer has relied heavily on the research of Emde, Gaensbauer & Harmon (1976), Kagan (1979), McCall, Eichorn & Hogarty (1977), and Uzgiris (1976) for support in the adoption of these four levels of cognition.

Level five (^5L) of the representational tier is achieved when one representational set is mapped onto a second.

Although children at this level are able to carry out many different mappings, their understanding of a particular problem is still disjointed because of their inability to consider two aspects of each set simultaneously. This is achieved at level six (^6L), when two sub-sets of one representation (concrete variable) are related to two sub-sets of another representation. Examples of cognition cum behaviour, at this level, are most of the Piagetian individual conservations. Skills are still limited because objects cannot be understood independently of their overt characteristics i.e. objects cannot be thought of in the abstract.

Level seven (^7L) culminates concrete thought and generates the new "abstract tier". Here again the recurring cycle of four levels is observed. In this instance ^7L has the characteristic structures of a representational system of systems and also that of a single abstract set; symbolically represented:

$$\left[\begin{array}{c} {^7R} \longleftrightarrow {^7A} \\ \updownarrow \\ {^7B} \longleftrightarrow {^7C} \end{array} \right] \cong \left[\; {^7M} \; \right]$$

This implies that a person of about fifteen years should be able to control the relationship between two representational systems and that they would be able to understand how all the changes co-vary. As such this provides

them with the skill to be able to control an abstract set. Whereas, at ^{4}L students' skills enabled them to control individual conservations, at ^{7}L they can understand and control abstract conservations (ibid 495), which can then be generalized to other tasks. At this level students' skills include most analogies (Lunzer 1965), political concepts like law and society (Adelson 1972) and a few of Piaget's simple formal operational tasks (Inhelder & Piaget 1955,1958).

Little research has been carried out on cognitive development beyond the onset of adolescence. However, for this tier Fischer proposes sequential levels of development in such areas as personal identity, moral judgements and professional skills (ibid 496).

Skill Theory is enhanced by the simplicity of five transformation rules which specify how a skill is transformed into a more advanced skill. The rules, like levels, are defined structually and symbolically in terms of set theory. They allow for changes in the organization of behaviour during a learning or problem solving experience. These rules are not claimed by Fischer to be exhaustive, however, they do provide mechanisms for predicting specific sequences of development.

In effect, the rules provide the theoretical link that synthesizes individuals with their environments. In order for a transition to occur at all, via one of the transformation rules, two skills at the same level of control must have been mastered. Then the environment must first ensure that the transformation will work, and secondly, provide the opportunity for exploration of the relationship between the juxtaposed skills (ibid 497,498).

Given a careful task analysis the levels and transformation rules enable direct predictions about developmental sequences and synchronies within a task domain. These must be assessed subject to environmental experiences which play a central role in determining synchronies. Fischer, Pipp and Bullock (1984), emphasize that optimal performance will only be reflected in data when children have had the opportunity to practice a task in a supportive environment, otherwise, their performances will be functioning below their optimal capacity. Examples of the kind of environments likely to produce optimal performance were given on page two of this paper.

In the broad view, Skill Theory predicts that different individuals will follow different developmental paths within the same domain. It also predicts that they will develop preferentially in different skill domains due to their varying environmental experiences. Although the paths may differ, the theory predicts that the end products of those paths are skills that are equivalent for most purposes (ibid 514).

Several of the above aspects of Fischer's work give an insight to his middle path through the dichotomies of constancy and variation, as well as, biology and experience. These of course are in addition to the underlying mathematical structures of skills having both quantitative and qualitative properties.

Another dichotomy that Fischer and his colleagues investigate and report in some detail is connectedness and discontinuity. Their middle path through this complex problem, simply put, is that there is no necessity to treat continuous

and discontinuous functions as being opposed. For cognitive development this means that at times cognitive performances will reflect a pattern of continuous cognitive behaviour, while at other times, it will reflect a pattern of discontinuous cognitive behaviour. Fischer draws attention to an outcome from this view and suggests that at times cognitive performances will reflect qualitative changes. This of course enters into another dichotomy that exists between qualitative and quantitative changes in cognitive performances.

With regard to measuring qualitative changes the problem is exacerbated because statistics and Western philosophy, favour continuity. Mathematically, an outcome of this is that "classical methods of reliability are not appropriate for qualitative data because the variable in question is not continuously distributed for either true score or error" (Appelbaum & McCall, 1983).

The question arises as to how a qualitative changes in performance can be recognized and measured, while overcoming the obstacle to simple mathematical treatment of data. Fischer and his colleagues (Fischer 1983, Fischer and Bullock 1981, Fischer and Kenny (in press), and Fischer, Pipp and Bullock 1984) discuss two methods for detecting and measuring developmental discontinuities. They draw attention to the fact that this criterion has not often been used in cognitive developmental research (Fischer & Silvern 1985,630).

In the first method, Fischer and Bullock (1981), Fischer and Bullock (1984), Fischer, Pipp and Bullock (1984) emphasize the important attributes of the Strong Scalogram method for testing developmental sequences. This technique involves the

designing of separate tasks to measure each step in a sequence to be studied. Students progress through the tasks passing all items until a point is reached when they commence to fail all subsequent items. To control for developmental unevenness Fischer and Bullock (1984,12) stress that all test items need to use the same stimuli and procedures. Under such adequately controlled conditions it is only the assessed complexity or organization of behaviour that varies and hence the complexity of behaviour can be measured. In this way the separateness and sequentiality of steps in development can be demonstrated. While this permits a direct test of developmental spurts it also allows for an estimation of the upper limits associated with hypothesized cognitive developmental levels (ibid 13).

This latter aspect of the scalogram technique results from a clustering of children at certain steps in a developmental sequence and is revealed on analysis as a bimodal distribution, when the number of tasks passed is plotted against the number of children passing those tasks.

The second method of detecting developmental discontinuities is the method of Multiple Tasks (Fischer, Pipp & Bullock 1984,104), which incorporates a different kind of continuous scale. Instead of seeking micro-sequences within levels a number of items are simply grouped according to the capacity demands defined by the level. Scoring is effected by noting the number of correct responses to tasks given by each individual, for each level, as a function of age. The general characteristics of this method are similar to the strong scalogram method in that the number of tasks an individual passes at a lower level is greater than, or equal to, the

number passed at the next higher level.

This method will be taken up in some detail when cognitive performance profiles, derived from test items designed by Russell and Fischer (in press), and reported by Fischer, Pipp and Bullock (1984) are discussed and compared with changes in EEG energy.

Throughout his work, Fischer places particular importance to the patterns of data which are observed during cognitive development and are reflected in both brain changes and optimal performance. Fischer and Bullock (1981,15) suggest that cognitive development can be reconceptualised when the patterns of data are viewed in terms of developmental sequences, synchronies, and formal developmental constraints. However, of specific interest to this paper, Fischer (1983), Fischer and Bullock (1984), Fischer and Pipp (1984), and Epstein (1979) drew attention to the existence of EEG studies, that reflected developmental spurts during age periods for which developmental performance spurts were also predicted to occur.

Although this paper gives a different interpretation to the same EEG data derived (John,1977) from Matousek and Petersen's (1973) work. It is acknowledged that Fischer's analysis of EEG data constituted the catalyst that initiated this paper's attempt to interpret EEG data as an index of cognitive competence. It is therefore fundamental to this paper's attempt to compare the patterns of change in both cognitive competence and cognitive performance, when environmental conditions are supportive of individuals' best efforts.

EEG AS AN INDEX OF COGNITIVE COMPETENCE:

Throughout the works of Hebb (1949), Lorenz (1977), Cotman and Neito-Sampedro (1982), and Kagan (1985), are references that associate EEG data with the total synaptic activity of the brain. These people often assume a working hypothesis that learning takes place at the synapse. In other words, learning is associated with events or modifications to the chemical or electrical transmissions across the junctions between neurons.

EEG frequencies are reported to change as a developmental function of age (Smith 1938; Lindsley 1939; Henry 1944; Surwillo 1971, cited Epstein 1979). This paper, however, is more concerned with "energies" within specified EEG frequency bands, rather than frequencies per se. Energies have been calculated and reported by John (1977). These were derived from a consideration of the magnitude of electrode potentials at particular ages and the spindle shapes of alpha waves using the Matousek and Petersen (1973) data.

An assumption is made in this paper that EEG frequency bands appear to reflect a qualitative aspect of synaptic activity. In addition, it is assumed that energy within selected frequency bands might represent a quantitative index of synaptic activity at particular points in time. Consequently, in order to build up a cognitive competence profile it appears necessary to obtain a quantitative measure of synaptic activity as a function of age. In this regard, the most likely candidate as an adequate index of functional change in activity is energy.

Unfortunately, there is little experimental evidence available to explain specifically the overall picture of how EEG electrical potentials are generated, maintained, or even distributed in the human brain. However, if EEG data is to be used as an index of cognitive competence, then it is necessary to inquire further, to see that a reasonable connection between the two can be made.

Lairy (1976) for example, points out, that most of what is known about EEG is based on the assumption that the underlying processes are similar in man and in experimental animals. Andersen and Andersson (1968; see also Garey 1976; Storm Van Leeuwen & Kamp 1980) postulated a mechanism by which the thalamus acts as a pacemaker and the primary driving force for EEG alpha waves. Alpha waves are rhythmical wave patterns recorded by an EEG when electrodes are attached to a person's scalp. However, in order for the pattern to be maintained, the person must be resting quietly, and not attending closely to any stimulus. Under these conditions the brain achieves a state of tone, that by analogy can be thought of in terms similar to muscle tone which maintains body posture in a state for ready action.

Andersen and Andersson's view of EEG activity also suggests a mechanism by which the small amounts of current flow produced by single neurons can become functionally coupled populations. In this way, their synchronized output seems sufficient to account for the magnitude of EEG potentials, measured from the scalp. In addition to this, Furukawa and Furshpan (1963) draw attention to the possibility of electric field effects caused by large populations of synchronously

active neurons. They suggest that fields produced by individual neurones, orientated parallel to each other, can summate to produce gross population potentials. It is important to note, that in summation these potentials can result in reinforcement or cancellation effects depending on their location and orientation (Creutzfeldt 1974,2C-41). With this in mind, and looking at the degree of convolution of the cerebral cortex, it would not be unreasonable to suggest that a very large part of the induced electric fields and potentials will cancel out. If this argument is accepted, then there is an indication from the pattern of Matousek and Petersen's (1973) EEG data that a dominant alpha generator is located in the occipital-parietal region of the brain.

Hori, Hayasaka, Sato, Harada and Iwata (1969) suggest a similar view from their research into phase relationships in human alpha activity for different regions of the brain. From the shape of EEG alpha patterns, with regard to their spatio-temporal characteristics, they suggest that alpha generators might consist of four oscillating charges. These appear to consist of two independent alpha generators, orientated at right angles to each other and located in the posterior regions of the head. Interestingly, Walter, Rhodes, Brown and Adey (1966), from a comprehensive spectral analysis of human EEG generators, also suggest that dominant alpha generators appear to be located in the posterior regions of the brain.

The implications of this are two fold: first, the possibility of two alpha generators in each hemisphere opens the way for consideration that they may separately relate to

concrete and abstract neuro-physiological structures, and secondly, the location of the generators in the O-P region of the brain invites consideration of their function in terms of the simultaneous processing of information, as elaborated by Luria (1976).

In many instances (Hagne 1968; Persson 1972; Matousek & Petersen 1973), however, normative EEG data is presented for interpretation and application, simply as empirical fact.

The facts are, that minute electrical currents are generated in the brain, which can be measured from the brain surface. The patterns of data are different for the separate states of excitement, relaxation (tone), drowsiness, sleep, deep sleep and coma, as well as for brain abnormalities like tumours and lesions. In this paper only patterns for the brain in tone will be considered, because only under these conditions do EEG frequencies and energies present as developmental functions with age. Alpha waves, with frequencies between 7.5 Hz and 12.5 Hz, which this paper proposes to use as indicators of changes in cognitive competence, significantly disappear or are blocked when the eyes are opened and attention is focussed. Under these conditions, or when the brain is processing information, alpha waves are replaced by low voltage, rapid irregular waves.

In the normal brain, rhythmic oscillating waves are observed at frequencies of about 0.5 Hertz (Hz) at birth. These developmentally increase to about 13 Hz at the age of eight to twelve years, when adult patterns start to appear. Beta energies at higher frequencies also exist, but they are usually low in energy and they do not change greatly, either as

a function of age, or of electrode position on the scalp. Stewart (1961,27; see also Encyclopaedia Britannica 1978,III,836) suggests that they correspond more with the sensory motor regions of the brain, while Hill and Parr (1963,86) suggest that their changes are in phase with changes taking place at alpha frequencies. Matousek & Petersen (1973) suggest that at about twenty-two years of age some seventy percent of all EEG energy detected at the scalp is at the alpha frequency.

This paper follows Matousek and Petersen's (1973) division of continuous EEG frequencies into qualitatively distinct wave bands, noting that their sample has an age range from one through twenty-two years: delta = 1.5 - 3.5 Hz, theta = 3.5 - 7.5 Hz, alpha-1 = 7.5 - 9.5 Hz, alpha-2 = 9.5 - 12.5 Hz, beta-1 = 12.5 - 17.5 Hz, and beta-2 = 17.5 - 25 Hz. The treatment of the data in this way is similar to our qualitative understanding of colours from their continuous wave lengths in the range of 400 to 700 nanometres. In effect, it appears to overcome some of the dichotomies mentioned previously of qualitative change being opposed to quantitative, and continuity being opposed to discontinuity. Even though some sensitivity may be sacrificed by considering frequencies in broad bands, it enhances the psychological and physiological interpretation of EEG data. For this reason the reanalysed data in this paper particularly supports Matousek and Petersen's (1973) division of the alpha frequency band, into separate alpha-1 and alpha-2 bands, and gives developmental significance to these bands in terms of concrete and abstract development.

The over-all picture of alpha generation as a developmental function is not quite that simple, because amplitudes (property of a wave proportional to its energy) observed as scalp potentials may result from increases in the intensity or density of synaptic input to the neuronal populations involved. On the other hand, the changes could be a consequence of increases in the size of the neuronal populations themselves. These matters must be considered before confidence can be placed in the idea that EEG data may be a reasonable index of cognitive competence.

In selecting an EEG data base, Matousek and Petersen's (1973) published results appeared to be an obvious choice, for several reasons:

i)   the sample has an extensive age range; one year to twenty-two years
ii)   they claim sufficiency for obtaining statistically normative data, in terms of size, physiological and psychological criteria
iii) their results are reported in both absolute and relative quantities
iv)   the alpha frequency band is analysed as two contiguous bands, and
v)   electrode potentials have been converted to energies (John 1977).

Most other sources of available EEG data (Smith 1938; Lindsley 1939; Henry 1944, Surwillo 1971; cited Epstein 1979) report frequency as a function over a limited age range. In other cases, data has been obtained from combinations of electrode positions which prevent meaningful comparison among studies.

Matousek and Petersen (1973) reported EEG data obtained from objective measurements and analysis of broad-band frequencies, for normal children (218 females & 183 males) and adolescents (85 females & 75 males). Eight channels of the

electroencephalograph were used for EEG data collection, while
the other two channels were used for recording eye movements.
In this way, it could be ensured that the visually selected
sections of wave data from a thirty minute period represented
the patterns for a brain in tone. From this mass of data six
sections each of ten seconds duration were analysed and
averaged for age intervals of a year. EEG recordings were
obtained from seven pairs of leads (F7-T3, F8-T4, T3-T5, T4-T6,
P3-O1, P4-O2 and CO-C4) attached to specific locations on the
scalp. Data from electrodes were processed by means of a
broad-band analog frequency analyser into the six frequency
bands listed on page 21. Throughout their data collection
Matousek and Petersen reported that explicit controls of
filters and integrators were maintained. In addition to this,
regular calibrations and analyses of EEG signals were carried
out to avoid extraneous effects imposing on the data (ibid.77).
 Averages and standard deviations for individual age groups
were given and a correlation matrix with labeled significance
limits for the whole material, as well as for each EEG
electrode position were computed and reported.

      Matousek and Petersen's (1973,82) data analysis reflects
the predominance of delta, theta and alpha frequency bands
during specific ages. Delta activity predominates from birth
and tends to decline most rapidly in the course of growth while
continuing to be present in early adulthood. Theta activity
increases from birth and predominates during infancy. It then
declines, but continues to have a presence throughout the
sample tested. Alpha activity slowly increases from birth and
rapidly gains predominance during early childhood. It then

becomes a permanent phenomenon throughout the entire lifetime of the adult. Matousek and Petersen's findings concur with those reported by Walter (1953, cited Lairy 1975) and Stevens (1968, cited Lairy 1975). Stevens (ibid.), however, goes further, and draws parallels between increased brain weight, the rate of increase in EEG frequencies and the stages of intellectual development elaborated by Piaget. In addition to the above, Matousek and Petersen (1973,93) draw attention to the existence of fundamental differences in alpha patterns for children and adolescents. In view of this, they divided the alpha frequency band into two discrete contiguous bands, alpha-1 and alpha-2, which reflect age dependent changes. For adolescents sixteen through twenty-two years, changes are slowing down and EEG parameters reflect logarithmic dependency on age, which contrasts with a linear dependency observed for children.

From their data Matousek and Petersen derived an empiric expression: THETA/(ALPHA + 8), which gave them the best correlation (r=-.742, for children and r=-.248, for adolescents) between EEG potentials, derived from various positions on the scalp and age. However, it is suggested that the transformation of data into this expression has the effect of substantially reducing its discontinuous nature, in regard to its relationship with age.

In general, and for most electrode positions, it can be seen from Matousek and Petersen's data that theta potentials correlate negatively with age. Furthermore, alpha potentials which predominate throughout most of Matousek and Petersen's study correlate positively with age, as might be predicted from

previous studies.   However, their transformation of data from these two frequency bands results in a <u>negative</u> correlation.

Further to this, and as mentioned previously, Hill & Parr (1963,94) can be interpreted to suggest, that the pattern of theta data presents as a spatial, causal harmonic of alpha data during its period of predominance.   In other words any peaks or troughs occurring in one set of data are likely to be in phase with peaks and troughs occurring in the other.   Hence, when this is considered in the transformation, THETA/(ALPHA + 8), the result is a smoothing of the appearance of the data which is reflected in an improved correlation coefficient.   Weighting the denominator of the expression tends presumably to enhance the smoothing effect as well.   Overall, it is suggested that the transformation forces the data to appear as a continuous function, whereas it might be better represented by a discontinuous function.

Part of the difficulty of interpretation of Matousek and Petersen's work arises from their forcing data to fit a continuous function.   Another part arises from a lack of an adequate interpretation of the fact that absolute EEG alpha energy may decrease significantly with age, whereas alpha energy expressed as a percentage of the total energy recorded from the brain (relative alpha energy) increases significantly with age.   In effect Matousek and Petersen present their data, in both absolute and relative terms and leave the decision to the users to decide which is more suitable for their particular purposes.   FIGURE 1. shows absolute alpha energy as a function of age.   It also shows how the energy is distributed between the alpha-1 and alpha-2 frequency bands, as a function of age.
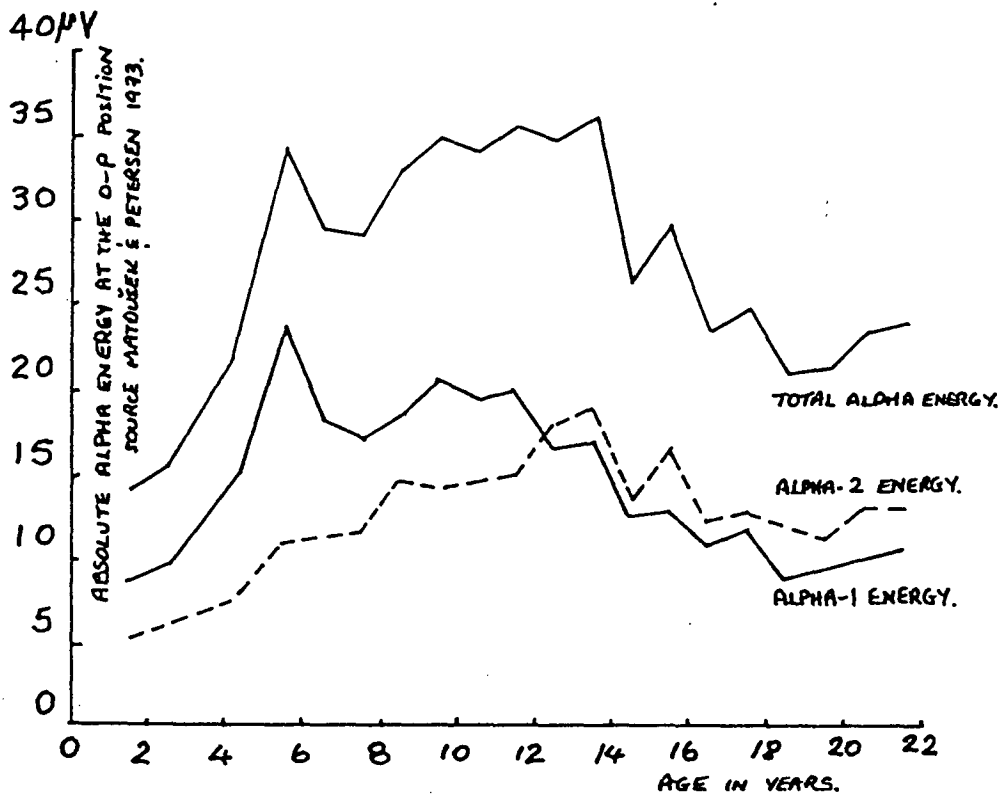
FIGURE 1. ABSOLUTE ALPHA ENERGY AS A FUNCTION OF AGE.

A REINTERPRETATION
OF EEG DATA:

The suitability of EEG as an index of cognitive competence appears to depend on a successful reinterpretation of available data, particularly in terms of the differences between absolute and relative energies, mentioned in the previous chapter. In this regard, data calculated by John (1977) from Matousek and Petersen (1973) were graphed. This is shown in FIGURE 1. The graph of total alpha energy is complex and presents uniquely when compared with curves for other frequency bands. Generally, these tend to decline logarithmically during the period of alpha predominance, but appear to increase from time to time in phase with major events occurring in the alpha band. This paper suggests that the very nature of the bimodal curve of total alpha energy (FIG.1) invites the investigation of alpha as two contiguous frequency bands. In fact Matousek and Petersen did just this.

Relative alpha energy from the O-P region of the scalp, is presented in FIGURE 2. It was obtained by plotting energies (John 1977) for mid interval ages, but it has not been drawn point to point, as the points are not sufficient to give a picture of the variation of the function. Rather, a more reasonable course of smoothing curves through the points to give a clearer, simpler representation of the possible behaviour of the function has been given (see also McQueen 1982).
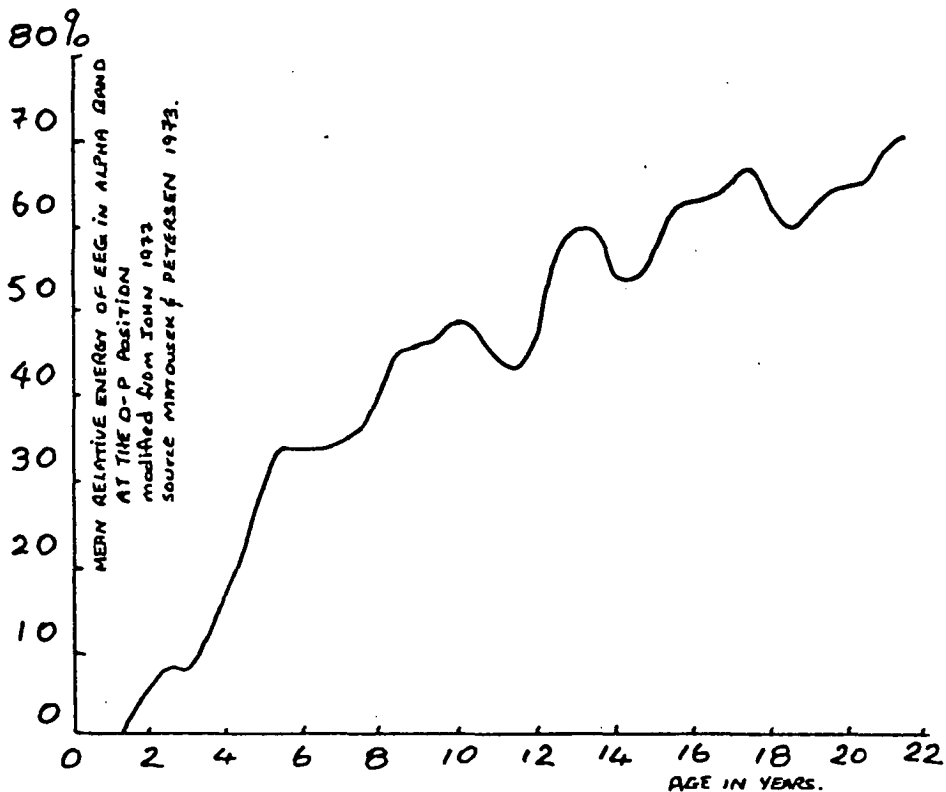
FIGURE 2. RELATIVE ALPHA ENERGY AS A FUNCTION OF AGE.

The significant feature to note in FIGURE 2. is that relative alpha energy, that is, alpha energy as a percentage of total EEG energy output, generally increases developmentally, at least to twenty-two years of age. Prima facie, it presents as a developmental function worthy of further investigation. It should also be noted that the line is not smooth. It displays the form of a complex sinusoidal curve and its apparent discontinuous form leads one to an interpretation that the relative alpha energy not only increases, but from time to time declines. This decline can perhaps be interpreted as a decline in the total synaptic output of the alpha generators.

It should also be noted that the absolute energy curve (FIG.1) is fundamentally different from the relative alpha energy curve (FIG.2). For both graphs the electrodes are located for maximum energy output at the occipital-parietal

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position on the scalp.   In neither case, absolute or relative,
have the differences between these curves been adequately
interpreted in the literature.

A synthetic curve, FIGURE 3. represents the equation
$y = Ln(x) + n.sin(x) + n.cos(x) - n/2.sin(2x) - n/2.cos(2x)$,
(where $n = .018$).
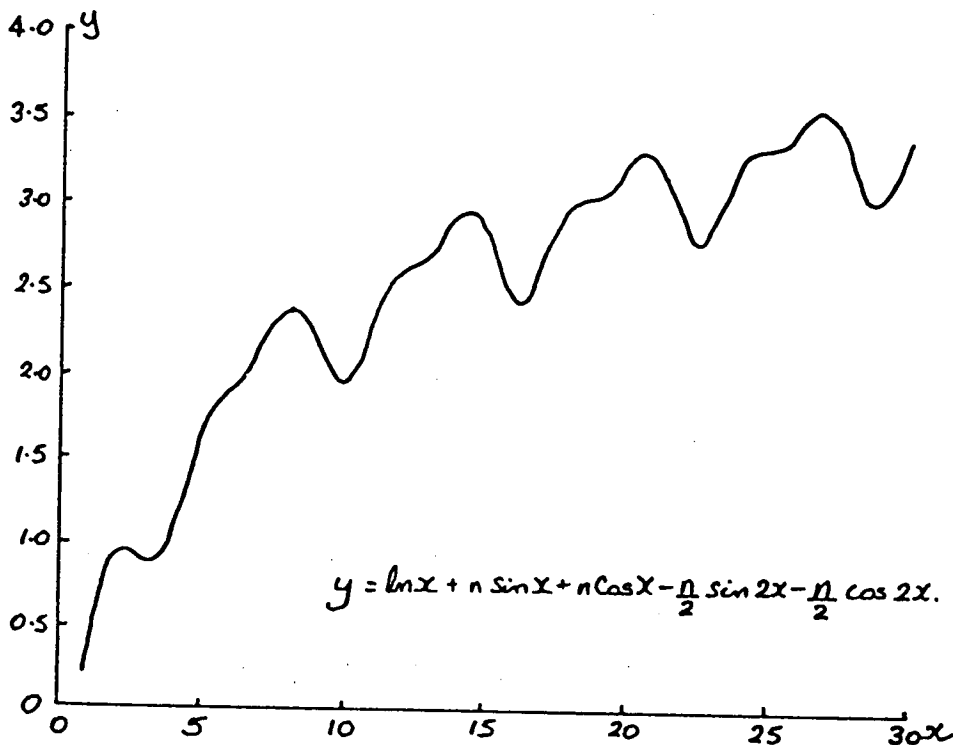
FIGURE 3.   A SYNTHETICALLY PRODUCED CURVE.

This curve was produced by using a modification to the L3-GRA
function option, of the Graphs and Charts software package
(Harding/Acornsoft Ltd. 1982).   A guided discovery approach was
used and the curve was found to consist of three fundamental
components, a natural logarithmic curve and two oscillating
curves.   A Fourier series was then considered and as more

harmonic terms of the series were included the approximation became better. The curve FIGURE 3. represents the summation of the first four harmonic terms of the series, integrated with a natural logarithmic function. A comparison of this curve with the relative energy curve FIGURE 2. suggests that they appear to have many characteristics in common.

This paper suggests that the natural logarithmic aspect of the curve is a manifestation of "growth", in that the rate of increase of relative alpha energy, in the long term, is proportional to relative alpha energy itself. In this respect it is common with many other biologically determined, natural logarithmic functions. The two oscillating components of the curve can be interpreted as supportive of the division of alpha frequencies into the two separate contiguous bands. They also add support for the concept of two dominant alpha generators being located in each hemisphere in the O-P region of the brain. The curve in FIGURE 3. is less complex than the one for relative alpha energy at O-P (FIG.2). This is because the variable in each of the components continues to increase. However, inspection of the relative energy curve reveals a change in the pattern in the region of the peak at thirteen years. This corresponds to the time when relative alpha-2 energy surges and becomes predominant, while relative alpha-1 energy momentarily declines. This is taken as an indication that alpha-1 and alpha-2 are not harmonically related and are at least partially independent of each other.

The assumed independence of these two hypothetical generators has a major bearing on the interpretation of absolute energies in terms of neuro-physiological structural

changes and cognitive competence.

From the above reinterpretation of relative alpha energy data (John 1977) it appears a reasonable hypothesis that EEG data can be adequately represented as a discontinuous function of age. The same data has been analysed from a point to point perspective and graphically presented by Epstein (1980) and again by Fischer(1983) and Fischer and Pipp (1984) to present a series of developmental spurts in the EEG. However, Fischer and Pipp's analysis and presentation is slightly different from Epstein's, in that they calculate annual, rather than biennial, increases in relative alpha energy. FIGURE 4. presents the data for annual increases in relative alpha energy plotted for mid interval ages.
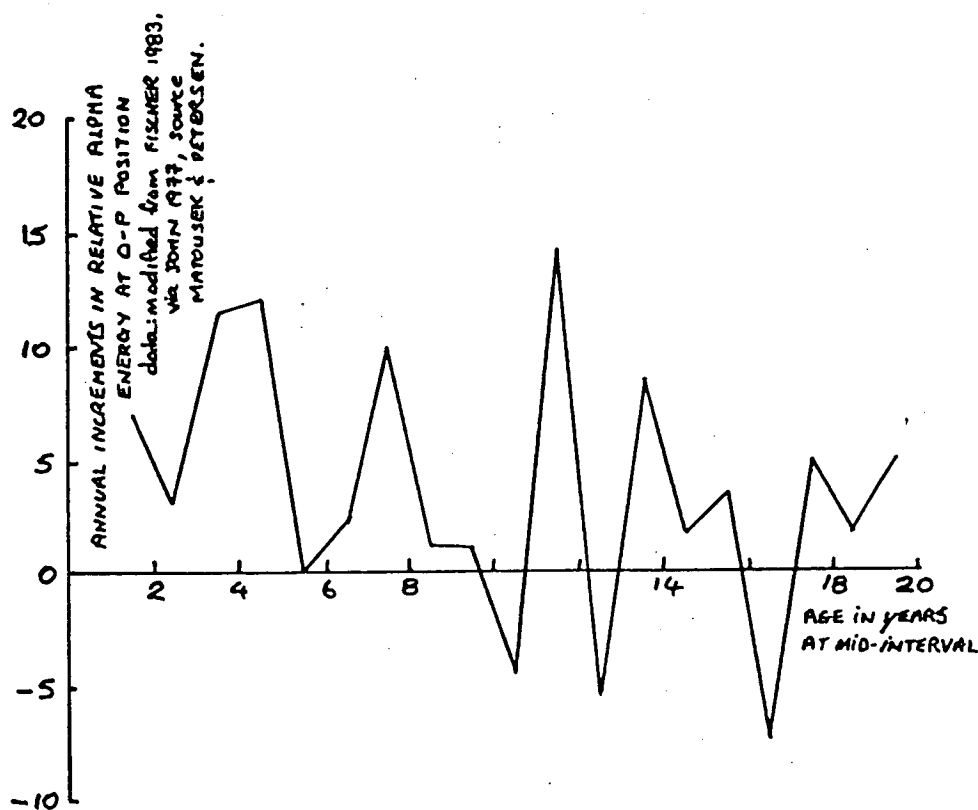
FIGURE 4. A SERIES OF DEVELOPMENTAL SPURTS IN THE EEG

Fischer (1983,16) suggests that the "data (FIG.4) show an impressive correlation between the modal ages for the developmental levels and ages of spurts in brain wave changes". Fischer interprets the peaks (FIG.4) as the time when spurts in brain wave change are initiated, while Epstein (1979) also attempts to correlate these with spurts in brain growth.

If we take an over-view of the relative alpha energy curve (FIG.2) as a discontinuous function of age then these hypothesized growth spurts (Epstein 1979) are likely to be located in the troughs. In other words maximum brain growth would be associated with the troughs, while minimum growth would be associated with the peaks, (in the next chapter it will be argued that evidence for a correlation between brain growth spurts and EEG energies does not exist), however, it is not "growth" per se, but functional change in EEG generators that must be considered, relevant to a competence profile. In this regard the troughs, (FIG.2) while indicative of developmental spurts (Fischer 1983) are associated with lower EEG values. This presumably means that spurts in cognitive development and EEG energy which are predicted to concur are different, in the regard that maximum cognitive developmental change appears to correlate with lower EEG energies, while minimum cognitive developmental change appears to correlate with higher EEG energies.

It is argued that when absolute alpha energies are considered the troughs (FIG.2) are far more complicated in terms of neuro-physiological structural changes than the peaks. In this view, many of the anomalies to which Fischer (1983,16) draws attention and which are associated with the peaks in

FIGURE 4. may be lessened, if instead attention is focussed on the troughs.

Many theories of cognitive development focus on the ages of "emergence" of new cognitive stages or levels and there is some agreement among some theories on the modal ages for these spurts. In view of the above, it is proposed to define a level of cognitive development, not in terms of the age of its emergence, but rather in terms of the age of maximum EEG alpha energy associated with a developmental spurt. In other words if levels exist and they are associated with structural changes indicated by the energy of synaptic output, then peak EEG energies are assumed to define levels (peaks in FIGURE 2, and troughs in FIGURE 4).
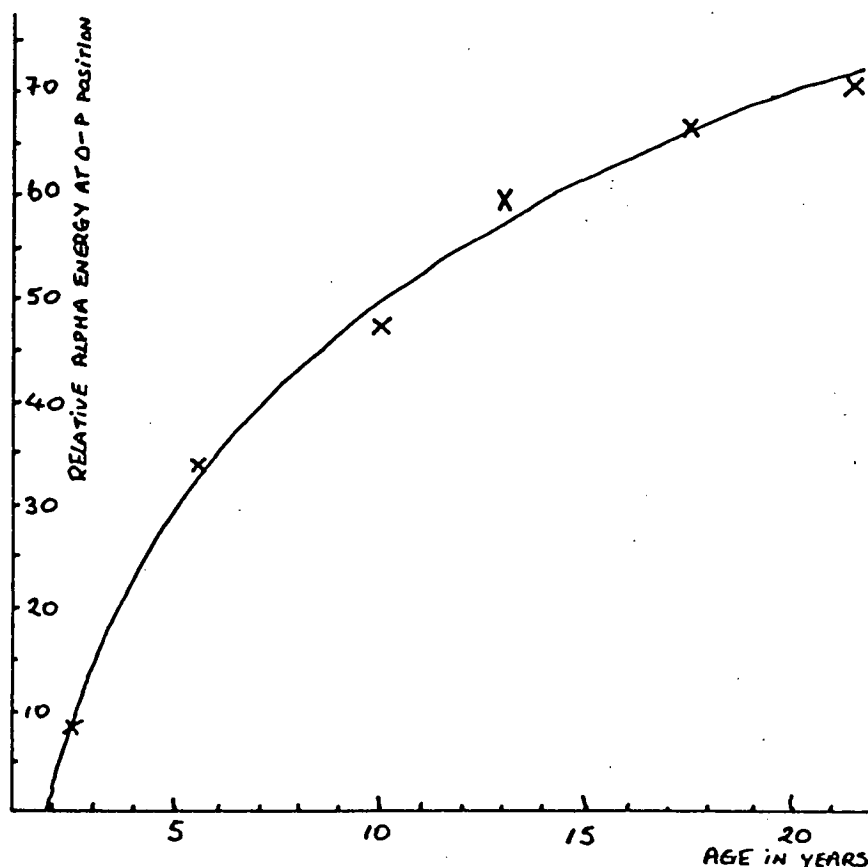
FIGURE 5. ENERGY OF ALPHA PEAKS AS DISCONTINUOUS FUNCTION OF GROWTH.

It is shown in FIGURE 5. (for the period of alpha predominance, following the sensory motor period) that when the relative alpha energies for the peaks alone are plotted as a function of age, the points regress to a natural logarithmic curve. This curve relates only to peak alpha energies, therefore energy may be interpreted as a discontinuous function of age. On further analysis the data can be presented in linear form as shown in FIGURE 6.
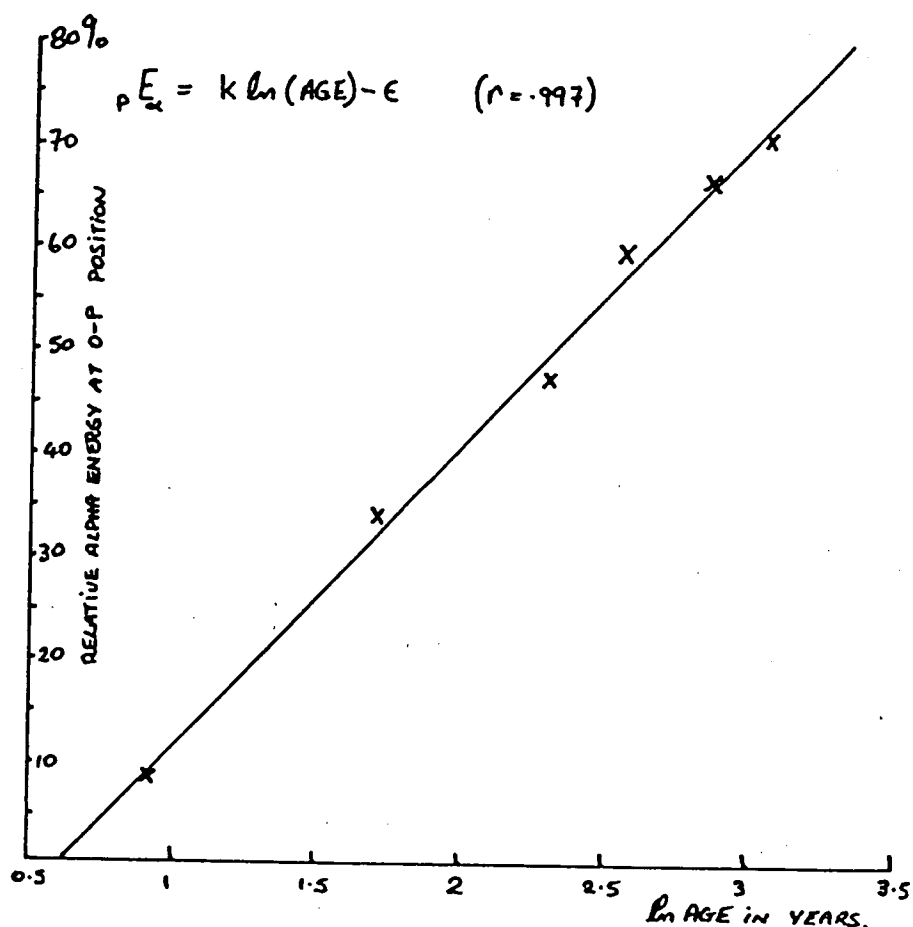
FIGURE 6. RELATIVE ALPHA ENERGY AS A DISCONTINUOUS FUNCTION OF THE NATURAL LOGARITHM OF AGE.

The following equation can be written to represent the straight line in FIGURE 6:

$$pE_{(\alpha-alpha)} = k.\ln(AGE) - c \quad (r=.997)$$

where both k and c are constants and the left hand side of the

equation is relative peak alpha energy. The values of the

constants have little meaning because of the discontinuous

nature of the relationship. The function, however, clearly

relates relative peak alpha energies to specific ages during

development. In as much that these ages are logarithmic this

paper suggests that peak alpha energies appear as a function of

natural growth. If their appearance can be shown to occur at

particular ages for the human species, as a whole, then there

is a basis to suggest that they might be genetically embedded.

Immediately the spectre of preformism arises. It is suggested,

that such a spectre need only cause concern if the function had

been continuous. As it is not, it questions, what is happening

to the brain during the trough periods between alpha peaks. It

seems that this may be the period during which the environment

has the opportunity to play a major role in collaborating with

existing competence structures.

In view of the way levels have been defined and given a

reasonable interpretation of FIGURE 4. as perhaps indicating

modal ages for cognitive developmental spurts, it is tempting

to make an <u>a priori</u> assumption to equate peak alpha energies

with Skill levels, as defined by Fischer (1980):

$$^{4+\text{n}}PE_{(\%-ALPHA)} = {}^{4+\text{n}}L, \quad (L = \text{Fischer's skill levels}).$$

This can be viewed as an attempt to observe the effect of

assuming that Skill levels might constitute an equal distance

interval scale. As alpha energy rises abruptly following the

sensory motor period of cognitive development, the first alpha

peak is equated to skill level four, the next alpha peak to

level five, and so on.

In FIGURE 7. Skill level plotted as a function of age is presented.

From this graph the following equation is obtained:

Level = .2575 Age + 3.4869   (r=.999);
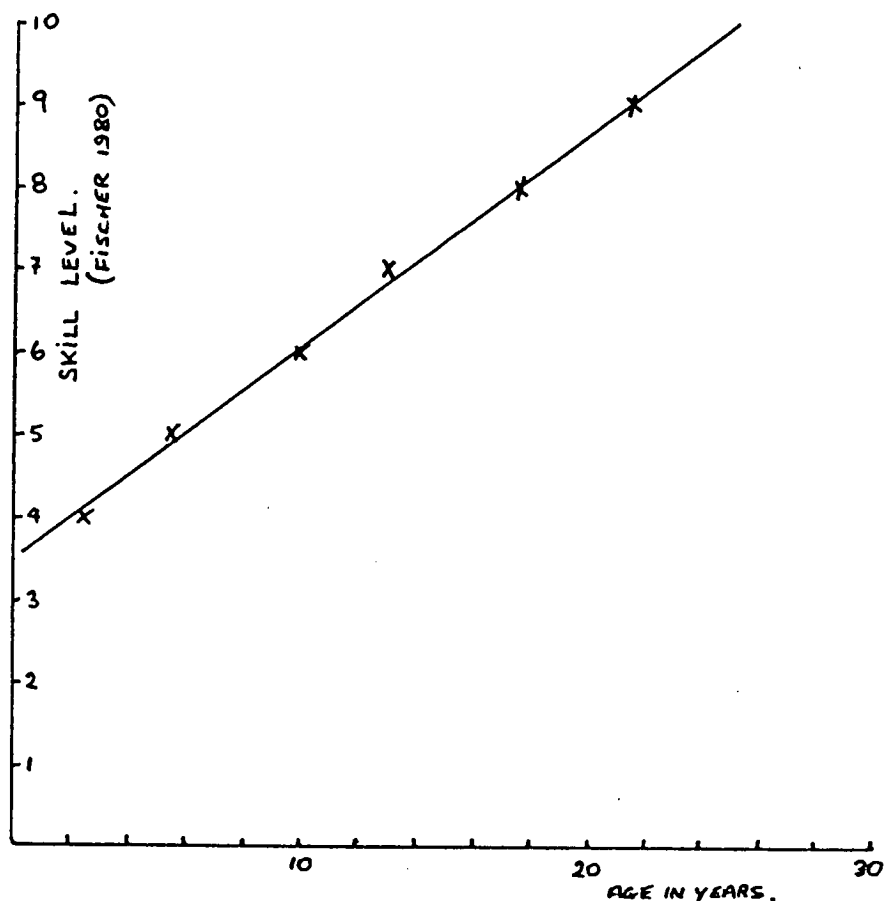
From a different perspective, FIGURE 7. can be considered as a collapsing of the ordinate axis of the graph in FIGURE 2. Previously this axis expressed relative alpha energy on a continuous scale. In FIGURE 7. the ordinate scale represented qualitative skill levels which were structurally defined by Fischer (1980), and mathematically separated by one unit in a hierarchy of set theory structures. In view of the logarithmic nature of the relationships expressed in FIGURES 5. & 6., the linear function expressed in FIGURE 7. clearly correlates (not necessarily functionally) Skill levels and peak alpha energies.

The linear function, therefore, appears to support the a priori assumption that Skill levels might form an equal interval scale. On further investigation it is found that:

$$rE_{(\%-alpha)} = -92.9 + 76.55 \ln(L) \quad (r=.986);$$

The data can be regressed marginally better to a parabolic function, but for practical purposes the above linear equation is a reasonable representation of the relationship.

Keeping in mind two things, first, that this function is based on relative alpha energy and secondly, that alpha-1 and alpha-2 energies display individual developmental patterns. Then the above equation can also be interpreted to suggest that cognitive development may reflect an integration of both alpha-1 and alpha-2 energies. The data also suggest that their influence during their individual periods of predominance may, in part, reflect the other non-predominant component. If this is so, then it may well account for some anomalies which are observed to occur in performances. In particular, when children give isolated demonstrations of behaviour a level or so in advance of the structures they can control.

To change the focus of reinterpretation from relative energy to absolute energies, absolute EEG values (as mean amplitudes in micro volts) for each frequency band are presented graphically for the occipital-parietal, temporal, central and fronto-temporal regions of the brain (Matousek & Petersen 1973). These data are shown in FIGURES 8. through 11. Several features are noticeable when the separate regions of the brain are compared. First, the degree of complexity is greatest in O-P regions. Complexity decreases via the temporal (FIGURE 9.) and central (FIGURE 10.) regions, to the

fronto-temporal region (FIGURE 11.). Unfortunately data is not available for the frontal and prefrontal lobes alone, where the pattern of data reflect similar features to those displayed in the relative alpha energy curve (FIGURE 2.), in terms of the location of peaks and troughs.
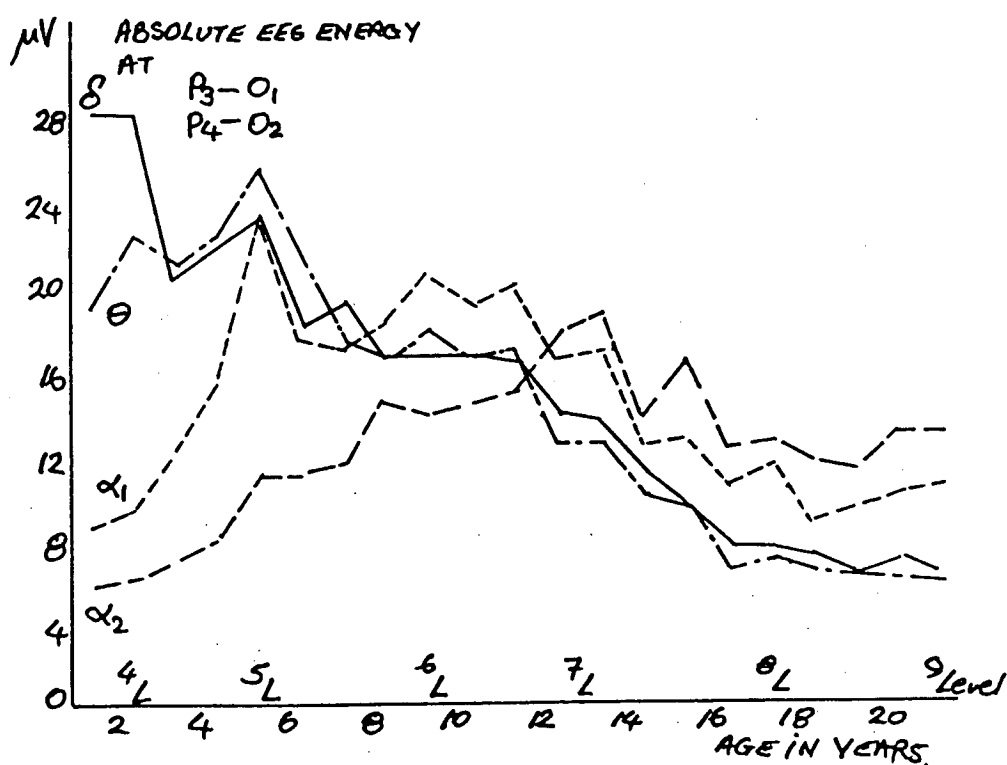
FIGURE 8. DISTRIBUTION OF ABSOLUTE EEG ENERGY AT O-P.
FOR DELTA, THETA & ALPHA-1, ALPHA-2 BANDS.
DATA: MATOUSEK AND PETERSEN 1973.
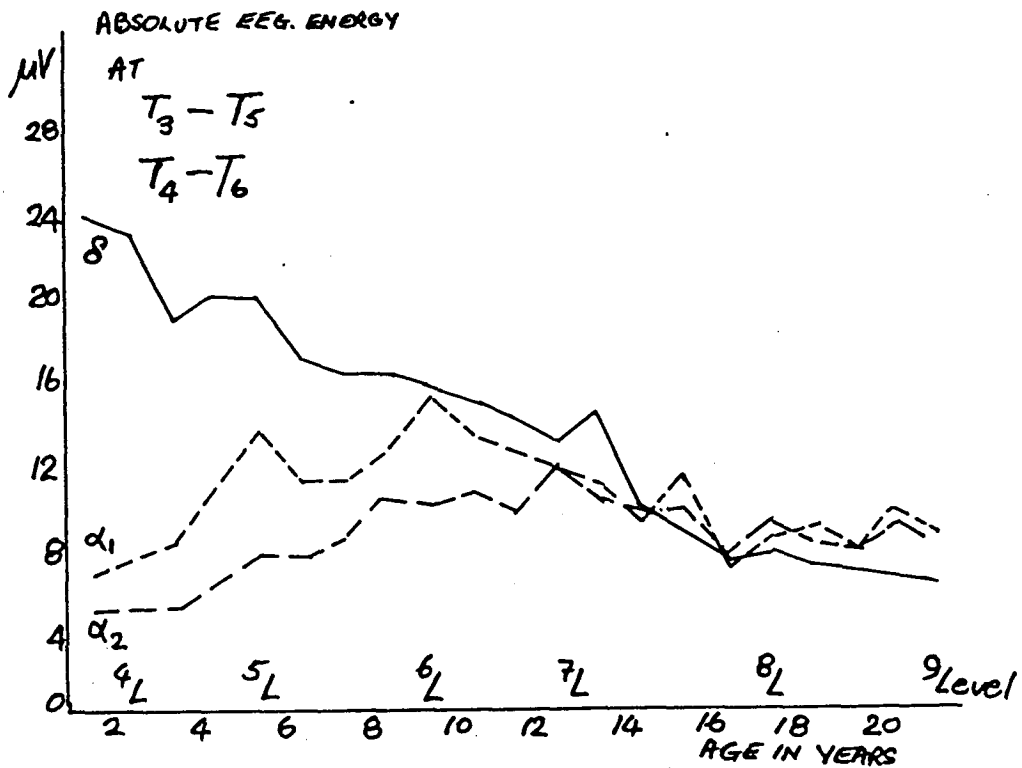
FIGURE 9. DISTRIBUTION OF ABSOLUTE EEG ENERGY AT TEMPORAL POSITION
FOR DELTA, ALPHA-1 & ALPHA-2 BANDS.
DATA: MATOUSEK AND PETERSEN 1973.
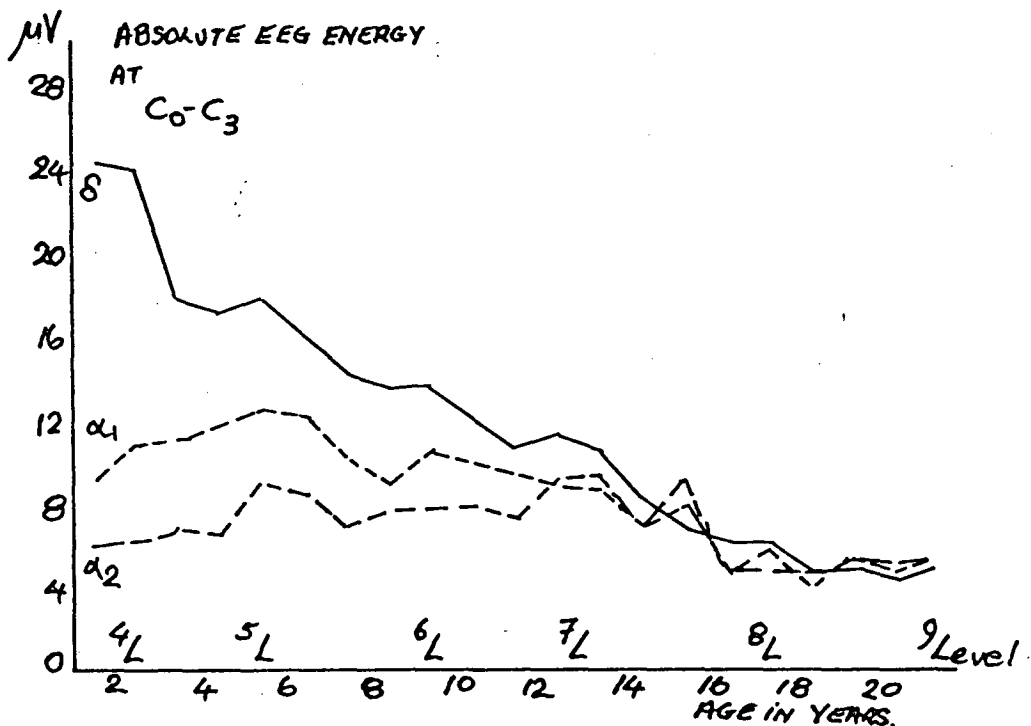
FIGURE 10. DISTRIBUTION OF ABSOLUTE EEG ENERGY AT CENTRAL POSITION
FOR DELTA, ALPHA-1 & ALPHA-2 BANDS.
DATA: MATOUSEK AND PETERSEN 1973.
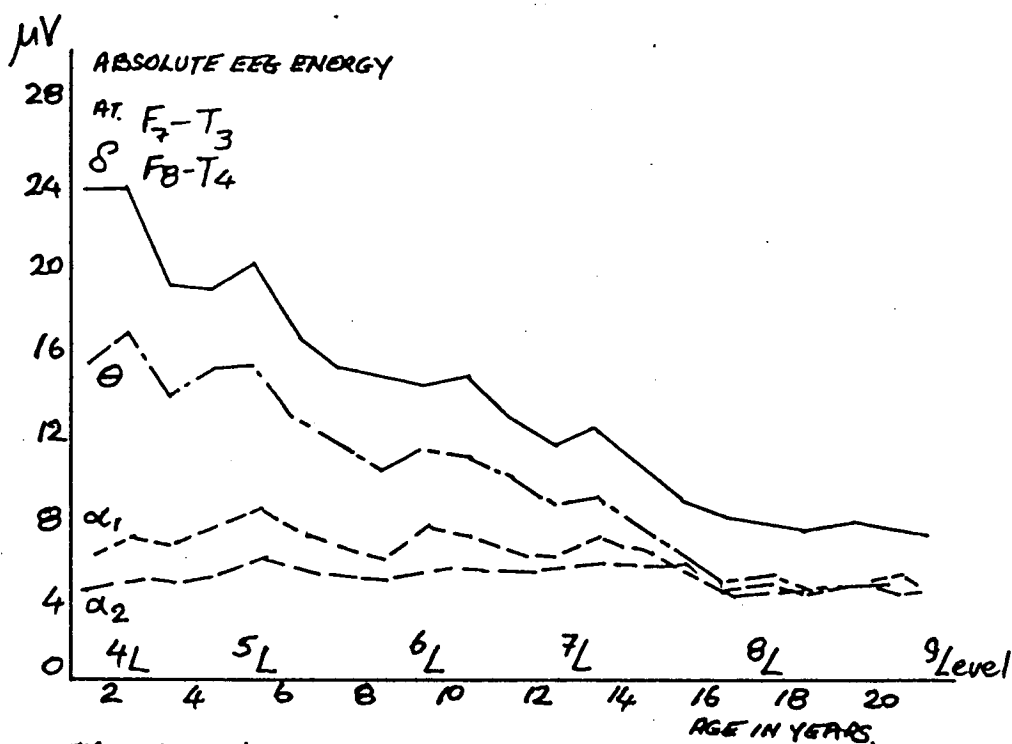
FIGURE 11. DISTRIBUTION OF ABSOLUTE EEG ENERGY AT FRONTO-TEMPORAL.
FOR DELTA, THETA, ALPHA-1 & ALPHA-2 BANDS
DATA: MATOUSEK AND PETERSEN 1973.

In the fronto-temporal lobe, FIGURE 11. the absolute

energy in each band appears to logarithmically decrease as a

developmental function of age. It also appears that the peaks

for separate frequency bands are in phase with each other (see

also, Chatrain & Lairy 1975; Hill & Parr 1963,94). These

peaks, it appears, can be progressively traced back through the

central (FIGURE 10) and temporal (FIGURE 9) regions of the

brain to major events taking place at alpha frequencies in the

O-P region. This focuses attention on the O-P region of the

brain as the site of alpha activity and adds support to the

alpha generators being located there.

The order of dominance of frequency bands at any point in

time in the F-T region of the brain is the same as the order of

frequency predominance as a function of age, with alpha

energies being respectively the lowest and latest. In the F-T
region of the brain the bands are clearly separate. It is
tempting to suggest that their order reflects their
evolutionary history and their fundamental importance to the
survival of the species (see Turko, Giurintano, Giurintano &
Andy 1974). If the pattern follows, then it might be
conjectured that delta energies index reflex action levels
during fetal development. In other words energies at this
frequency may reflect developmental peaks and troughs,
indicating changes in development. Hagne (1968), Hagne,
Person, Magnusson and Petersen (1973), and Kagan (1982) report
EEG changes at theta frequencies which they suggest reflect
developmental levels in sensory motor actions. In a similar
way, it is suggested, that perhaps at alpha-1 frequencies,
energies index the preoperational and concrete levels of
cognitive development. Furthermore, at alpha-2 frequencies,
energies might index abstract levels of cognitive development.
If it could be shown that theta, alpha-1 and alpha-2 energies
correlate with periods of sensory motor, concrete and abstract
cognitive development, then this would appear supportive of the
stages of cognitive development elaborated by Piaget.

The absolute energy data as a whole focuses attention on
the O-P region of the brain (FIG.8) as the region of complex
EEG generation for the period of alpha predominance. There is
a significant increase in alpha-1 energy at the end of the
sensory motor period which is also the commencement of the
concrete operational period (level 4, Fischer 1980). It is
suggested that the end of the sensory motor period can be
recognized in FIGURE 8, by a theta energy peak at approximately

two and a half years of age. This energy rise is the most

significant increase for any frequency band in any electrode

position for the human EEG. It presents as a unique, dominant

peak in O-P and corresponds in time with the obscure Piagetian

stage (lacking structure d'ensemble) of pre-operationalism as

well as with Fischer's (1980) $^{\varpi}$L. If it is accepted that

energies at delta and theta frequencies react in phase with

changes in alpha energies then it is suggested that the maximum

theta peak observed to occur at this time in O-P, is perhaps a

manifestation of alpha. Thus, the "real" theta peak, which is

predicted to occur at the end of the sensory motor period is

more correctly located, at $^{\triangle}$L, where it occurs in F-T data,

FIGURE 11.

From level five, alpha-1 energy declines and then peaks

again at about nine and a half to ten years. It is suggested

that this corresponds to Fischer's $^{\diamond}$L.

The curve (FIG.8) declines from $^{\diamond}$L to peak again at about

eleven and a half years of age. The following idea is

hypothesized to account for this sequence of events. In the

over-all view of the logarithmic nature of EEG development (see

for e.g. FIG.3), the processes underlying it are commencing to

slow down. This can be seen graphically as a flattening out of

the curve to the extent that many of the changes that may have

been obscured during the period of rapid change in alpha

energy, can now be seen. This paper suggests that the decline

and subsequent rise in the EEG curve corresponds to a period of

structural reorganization within the neurons of the O-P region

of the brain. It is suggested that $^{\diamond}$L is first attained at

about ten years of age and during neural reorganization the

level is temporarily lost, to be regained again at about eleven

and a half years of age. This can be interpreted as "a

regression in the cause of development" and is reflected as a

disequilibrium between accommodation and assimilation.

The interpretation this paper assumes for a level,

indexed by an EEG peak, is that an equilibrium exists between

the structures of accommodation (acm) and the structures of

assimilation (asm). Fischer (manuscript in preparation),

describes the processes of accommodation and assimilation as:

> "an interaction between the schemes that a person
> applies to a situation and the adjustments that the
> situation requires in the schemes. Assimilation
> refers to an organism's active attempts to apply
> particular schemes to things and events in the world,
> and accommodation refers to the adjustment of those
> schemes to the characteristics of the thing to be
> known. Thus the contribution of the scheme to
> knowing is called assimilation, and the contribution
> of the situation or object is called accommodation".

For example at the ^6L peak, an equilibrium is assumed to be

achieved: $\left[^6L_{ACM} \longleftrightarrow ^6L_{ASM} \right]$, which on reorganization is

lost. The resultant disequilibrium can be thought of in terms

of temporarily weakened assimilative structures:

$\left[^6L_{ACM} \leftarrow\!-\!-\!\rightarrow ^6L_{ASM} \right]$ such that,

$\left[^6L_{ACM} > ^6L_{ASM} \right]$. When the peak at eleven and a half

years is achieved, level six equilibrium is once again

attained. Given a supportive environment (see page 2), these

structures should thereafter be available to be called upon and

displayed in behavioural performances. It is suggested that

this pattern continues for levels through to ten.

At about twelve years of age alpha-1 energy has declined

(FIG.8) to be superseded by energy at the alpha-2 frequency

band. This peaks at about thirteen years of age, and

corresponds in time with Fischer's (1980) ⁷L. This peak can be

seen as the dominant right peak in FIGURE 1. It not only

signals the end of concrete operations, but heralds the

commencement of the period of abstract operations. In

Fischer's (1980) structural terms this peak corresponds to

concrete control over a system of systems and also constitutes

the first element of an abstract set.

Having peaked, alpha-2 energy abruptly declines and

equally abruptly re-peaks at fifteen and a half years of age

(FIGS.1 & 8). This appears to be one of the most dramatic

reorganizations that takes place through-out EEG development

and can be detected as a trough in FIG.4. Level seven

equilibrium is first achieved at thirteen years, regresses, and

is finally regained and controlled at fifteen and a half years

of age. While this reorganization takes place, it is suggested

that level eight structures commence to emerge. The over-all

effect of this, particularly in a non-supportive environment,

is likely to be a period of confused behaviour, with some level

six, but mostly levels seven and eight performances being

demonstrated from thirteen through fifteen and a half years.

The pattern continues for levels eight and nine (FIG.8),

where upon the energy levels decline to a point where data

cannot be reliably interpreted. However, after level nine,

alpha energy levels continue to increase. It is hypothesized

that the pattern will continue, and therefore accord with

Fischer's level ten. In like manner, it is hypothesized that

the three energy peaks detected at theta frequencies by

Hagne(1968) and Hagne, Person, Magnusson and Petersen's (1973)

and given cognitive developmental significance by Kagan (1982),

might correspond to the first three Skill levels defined by Fischer (1980).

It should be noted that the degree of phase dependence of delta and theta on alpha is not observed for alpha-1 on alpha-2 or vice versa. In view of this it is suggested that alpha-1 and alpha-2 develop relatively independently of each other. However, the data can be interpreted as suggesting that their effect is to some degree compounded, especially during the period corresponding to mid-to-late concrete operations, where both alpha-1 and alpha-2 energy levels are high.

It was previously suggested that stages or levels of development that focussed on the "emergence" of a spurt, did so on the periods of cognitive development that seemed, from EEG data, to be the most complicated. The degree of complication can now be expressed as possibly the reorganization of some structures, the emergence of others, and a compounding of these with structures already existing. It needs to be shown, however, that reasonable neuro-physiological explanations are available to support this view.

In view of the observed decrements in EEG energies, the complexities surrounding the emergence of a new level also need to be considered in terms of the reorganization of structures, to the "equivalence" of the previously controlled level. Neuro-physiologically the new structures are going to be different to those from which they evolved. However, it needs to be considered whether, at a point rising from a trough (FIG.2), the structures for mathematical and practical purposes are likely to resemble earlier structures. For example in FIG.8, it seems reasonable that the mathematical structure

Fischer (1980) attributed to level seven will for practical purposes in analysing behaviour, suffice for the EEG peak observed at thirteen, as well as the peak at fifteen and a half years of age. To assess this, it will be necessary to consider the underlying structure of performances controlled at these times.

It is suggested that an integration of the above ideas involving both relative and absolute EEG-alpha energies might provide an index from which a profile of cognitive competence can be derived. From EEG data, FIGURE 12. suggests what a profile of cognitive competence may look like.
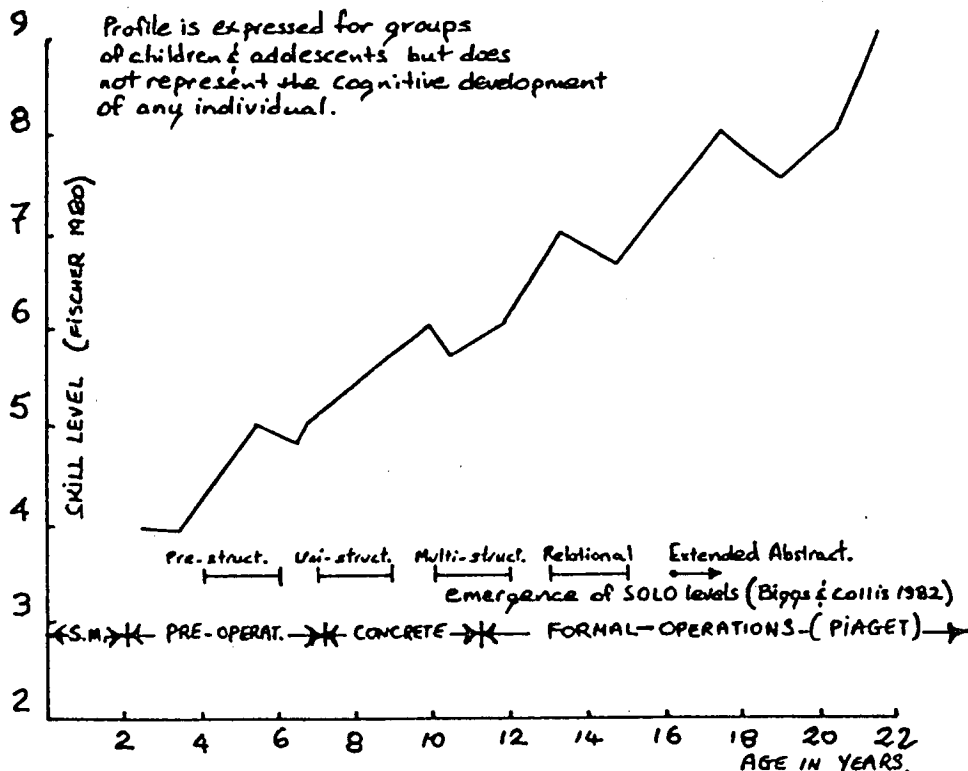
FIGURE 12. ORGANISMIC PROFILE OF COGNITIVE DEVELOPMENT FROM EEG
— THE DEVELOPMENTAL PROFILE —

It is assumed that cognitive competence places an upper limit on cognitive performance. If this is so, then the profile should be reflected in the patterns of cognitive performance. Providing environmental conditions are suitable.

The profile immediately suggests the question, what is happening to the brain that results in decreased EEG energy out-put. For the profile to be meaningful a reasonable explanation must be found.

EVIDENCE CONSISTENT WITH A PROFILE OF DISCONTINUOUS COGNITIVE COMPETENCE:

Physiological structures of the brain are assumed to be reflected in cognitive competence. Thus, cognitive competence is viewed as placing an upper limit on the maximum possible level of performance an individual can produce in collaboration with his environment.

In the previous chapter it was suggested that EEG alpha energy may have potential to index cognitive competence. From Matousek and Petersen's (1973) data a profile of alpha energy was presented as a possible profile of cognitive competence. However, the profile is discontinuous in the respect that the general increase is from time to time interrupted, corresponding to periods of alpha energy decline. It needs to be seen that such decreases in the profile can be reasonably justified from a consideration of what is known, or suggested, might be occurring to brain structures during their development.

Rousseau (1712-1778), opens his work "The Social Contract" with the words: "man was born free, and he is everywhere in chains". With regard to a behavioural contract the emphasis is reversed, for it is more appropriate to suggest that "man is conceived in chains, and he is everywhere free". The chains of his conception are the double helices of the DNA molecule. Daunting as this may sound, it is at a very early stage of cell division that the environment collaborates in cell differentiation. Lorenz (1982,257) suggests that the genetic program stakes out the limit of what is possible and an "open program" (Mayr 1942, cited Lorenz 1982,258) enables the

organism to gain mastery over various changes in an unstable environment. This appears to be a reasonable suggestion both in terms of the results of embryological experiments (Lorenz 1982,295) and from what is known to occur in post natal neural development, where changes appear to be both environment dependent and environment expectant (Reinis and Goldman 1980,308).

Both EEG and neuro-physiological considerations focus attention concerning competence on the O-P region of the brain. In this respect, Blauenstein et al.(1977), Meyer et al.(1978), and Gur et al.(1980) show from in vivo human cerebral blood flow measurements that the sub-dominant hemisphere of the brain and the parietal lobes of both hemispheres reflect lower ratios of grey to white matter, compared to the rest of the cortex. These same regions correspond with higher out-puts of EEG alpha energies (Matousek & Petersen 1973). Consequently, although grey matter is traditionally associated with EEG energies, this paper suggests that both grey and white matter are required to produce the kind of powerful alpha generators envisaged for the O-P region of the brain (see also Hill & Parr 1963,19). Oscillating waves like those exhibited for alpha spindles could be produced if a large synaptic effect (grey matter) functions as a capacitor when positioned in series with uniformly orientated bundles of myelinated fibres (white matter). In effect, the fibres would function as an induction coil. Under these conditions, it is suggested that the synaptic effect would build up to maximum firing potential. During this time, the electric field strength would decline. On firing, the synaptic potential would drop to zero while the field strength

increased to its maximum before declining again. A repetition of this would produce a series of oscillating signals.

The connection between the synapse and EEG has often been demonstrated. It is simply not possible to obtain _in vivo_ developmental data from human brains that will in any way be representative of a normative sample. It is necessary to extrapolate from animal studies. Kandel (1970,60) reports that in all tests involving the plasticity of synaptic pathways a change in synaptic energy has been detected. However, the connection between the modification of synapses and learning, which as mentioned above, was often assumed as a working hypothesis, lacks a wealth of empirical support. Some evidence does exist (Glaser 1963), and in particular Kandel (1970,57) discusses a combination of cellular and behavioural techniques which he used to relate synaptic modifications in certain nerve cells of an invertebrate to short-term modification of behaviour. In another example, Tsukahara et al.(1981, cited Cotman & Nieto-Sampedro 1982) showed that classical conditioning of cats produced synaptic growths on specific cortical neurons. Cotman and Nieto-Sampedro (1982) acknowledge the elusiveness of synaptic modification, but they suggest that the available data show that behavioural plasticity has neural counterparts. This applies particularly to the ability of the nervous system to modify its circuitry. It therefore remains a reasonable hypothesis that EEG alpha energy might index synaptic modification in the O-P region of the brain. Consequently, it appears reasonable to correlate EEG alpha energy with qualitative levels of competence.

The need now arises to account for decreases in energy

that are assumed to occur from time to time in the energy of
synaptic output. It is suggested that these times correspond
to periods of structural reorganizations among neurons, in
particular, to the synaptic terminals of their dendrites. From
the research of Brown, Jansen and Van Essen (1976), Lichtman
(1977), Purves and Lichtman (1980), Cotman and Nieto-Sampedro
(1982), and Patterson and Purves (1982), the elimination of
synapses and the rearrangement of synaptic connections in early
brain development is now accepted as fact. The mechanism seems
to be that there is an initial overproduction of synaptic
connections (Purves & Lichtman 1980), to the point where they
overtax the spatial synaptic geometry of the cell (op.cit.;
Hume & Purves 1981, cited, Patterson & Purves 1982). Their
elimination does not appear to be a random process, as some
sort of competition exists among them to determine which
survive (Brown, Jansen & Van Essen 1976). It is assumed that
synaptic cells secrete chemical agents that contribute to the
formation and maintenance of synaptic endings (Purves &
Lichtman 1980). When an imbalance of activity occurs among
competing inputs it determines which synapses are not
maintained and therefore, which are eliminated.
The plasticity of such a process, leading to individual
differences, can be appreciated. In particular this provides a
mechanism by which environmental variation and use will
strengthen specific neural pathways and selectively enhance
their survival. While there is strong evidence for this
process in the neonate, Cotman and Nieto-Sampedro (1982,372)
report that evidence is now available that suggests synaptic
growth and renewal are part of the normal operation and

maintenance of brain circuits throughout their development.

In support of this, Cotman and Nieto-Sampedro (1982,379) cited an instance where an enriched environment significantly increased the dendritic weight and complexity of the occipital cortex of rats during an eighty day test period. They suggested (op.cit.383), that experience gained with age, or age itself, maybe a stimulus for increased synapse number and probably synapse renewal. It also appears that this kind of developmental plasticity is adversely affected by inactivity, however, Cotman and Nieto-Sampedro (1982) suggest that once initiated, synaptic contacts can be formed in less than twenty-four hours. Apart from repeated stimuli, oscillations and resonances within neural networks are obvious mechanisms by which afferent signals can be maintained for a sufficiently long time to permit a restructuring of the networks.

There are two other issues of particular importance to an understanding of the cognitive competence profile based on EEG energies. First, Purves and Lichtman (1980,156), and Patterson and Purves (1982,521) report that the synchronous activity of cortical neurons somehow impedes their competitive interaction compared to those whose inputs fire out of step with each other. Secondly, Purves and Lichtman (1980) raise the matter of critical periods. They suggest that cellular geometry plays a significant role in the selective elimination of synapses and that dendritic networks tend to establish relatively distinct spatial domains to minimize or preclude competition among synaptic endings. A critical period exists when competition reaches a maximum and ends when the process of synapse elimination has progressed to the point where few, if any,

synapses are still capable of competitive interaction.

If the effects of synchronous synaptic activity, critical periods and synaptic plasticity are combined, then a mechanism exists that can account for the discontinuous profile of EEG data. It is suggested that the highly synchronous activity of alpha generators located in the O-P afferent <u>processing</u> region of the brain precludes the kinds of dynamic synaptic restructurings likely to occur in say schema <u>storage</u> regions. It is further suggested that over a period of several months, specific brain structures are not so much turned on (Davidson, cited Plomin 1983), but rather selectively accelerated to an ultimately higher <u>qualitative</u> level. During this period of acceleration, it is suggested that a <u>quantitative</u> synaptic addition is made to the generators. This is accompanied by a corresponding increase in EEG alpha energy output. The addition of synapses is envisaged to continue until a critical point is reached, recognized as a new alpha energy peak. At this point in time, it is imagined that the spatial geometry of the generators becomes unstable and forces a reorganization. Such a reorganization is envisaged as an elimination of synaptic connections, antecedent to a more effective and efficient synaptic structuring. These periods of reorganization are viewed as times during which de-differentiation of neural structures ensues and which are accompanied by a temporary regression. Lorenz (1977,198), Werner (1957,139) and Prechtl (1982,104) consider such a fundamental restructuring to be biologically sound and essential to a developing system. In Lorenz's words, "one must regress in order to progress".

The reduction in the number of synapses, and the associated reduction in energy output are predicted to result in reduced EEG potentials measured at the O-P position on the scalp. Again, due to the synchronous nature of the generators, any changes to them would be expected to take a considerable period of time. Consequently, through a repetition of these events a profile of EEG alpha energy can be derived which seems to be supported physiologically and seems to represent qualitative changes in something that might constitute alpha generators.

In the long-view, the ten qualitative changes (Fischer 1980) envisaged for the period of human cognitive development represents a remarkable degree of stability in the O-P region of the brain. A stability that seems essential for a measure of constancy in the human ability to process information (Cotman & Nieto-Sampedro 1982,389).

It was suggested previously that changes to EEG values might result in ways that prevent their use as an index of competence. These need to be briefly considered. Kandel (1970,65) proposed that the intensity of synaptic potentials may be altered in two ways. First, by a direct change in the synaptic current produced, and secondly, by a change in the electrical resistance of the cell fibres. Keeping in mind the above discussion concerning the dynamics of synaptic reorganization, the proposed functional integration of synchronized synapses with cell fibres to produce the alpha generators and the sampling techniques of Matousek and Petersen (1973), it is suggested that the functional model outlined above copes adequately with this potential difficulty. This is

because of the synchronistic nature and dominance of the alpha generators. If single neurons or small localized populations only were being considered, then it is suggested that they would be more susceptive to change and reflective of fluctuations in these variables.

It seems reasonable that the generators might also recruit new neural populations, and hence increase their EEG output during development. However, the pattern of EEG data then requires an explanation as to why, from time to time, populations are abandoned, and why the recruitment program generally is logarithmic. These explanations are not forthcoming. If neurons were incorporated into the functional model of a generator, as outlined above, then the model is in no way threatened providing they remain synchronous and partake in synaptic reorganization during the critical periods.

Of more concern to the viability of the EEG profile as an index of cognitive competence is the possibility of changing electric field strengths due to different rates of growth between the skull and brain. Extensive brain growth data is not available and with few exceptions (Dobbing and Sands 1973; Boyd 1962) does not differentiate for growth with respect to cerebral region, chemical component or sex.

Epstein (1974a, 1974b, 1979, 1980) processed a combination of brain and skull data that suggested spurts in growth that approximated to those observed in EEG alpha data, from the O-P region of the brain. However, McQueen (1982) disputed the accuracy of the processing and McCall, Meyers, Hartman and Roche (1983) attempted to replicate Epstein's findings using eighty subjects from the Fels longitudinal study. Using linear

extrapolations and quantitative statistics they failed to find the kind of relationships Epstein reported. This paper suggests that the difficulty arises due to a lack of consideration of sexual dimorphism, in the brain growth data.

Brain growth data is generally logarithmic and that reported by Brierley (1976) reflected a loss of brain weight corresponding to each of the regressions observed in the EEG data. This data is similar to that reported by Coppoletta and Wolbach (1933) and almost identical to that reported by Donaldson (1895) and Boyd (1962), when data for males and females are averaged. The point of this, however, is that both the Donaldson and Boyd data reflect extensive sexual dimorphism, which negates the apparent correlation with EEG data determined from the Brierely undifferentiated data and negates Epstein's findings.

In a similar way, the most comprehensive data on growth in head circumference (Nellhaus 1968) also reflected extensive sexual dimorphism, which does not map the patterns found for brain growth. When brain and skull growth are mapped the patterns reveal considerable fluctuations which can be interpreted as density changes. FIGURES 13 and 14 manifest sexual dimorphism in density changes. Because EEG alpha data from the O-P region of the scalp do not reflect sexually dimorphic patterns (Matousek & Petersen 1973), it is argued that the different rates of growth that exist between the brain and the skull do not significantly impose on the EEG data. This may be due to the fact that potentials measured at the scalp are from positions on electric lines of force, of non-propagated fields (Holmes & Houchin 1967), emanating from

presumably powerful alpha generators located in the O-P region
of the brain.

Although the arguments have been briefly discussed here,
there is a wealth of neuro-physiological evidence that supports
a discontinuous profile of EEG activity. This paper suggests
that cognitive competence can be indexed by EEG energies. When
the structures deemed to represent levels are thought of as
being associated with alpha generators located in the O-P
region of the brain, and when thought of in terms of set theory
structures, this invites a discussion concerning their possible
relationship with information processing. This appears
warranted as simultaneous information processing is associated
with this region of the brain (Luria 1976).

FIGURE 13. MANIFESTATIONS OF SEXUAL DIMORPHISM IN BRAIN & SKULL GROWTH.
— SUGGESTIVE OF BRAIN DENSITY CHANGES IN THE FEMALE.
DATA: DONALDSON 1895, BOYD 1962, & NELLHAUS 1968.
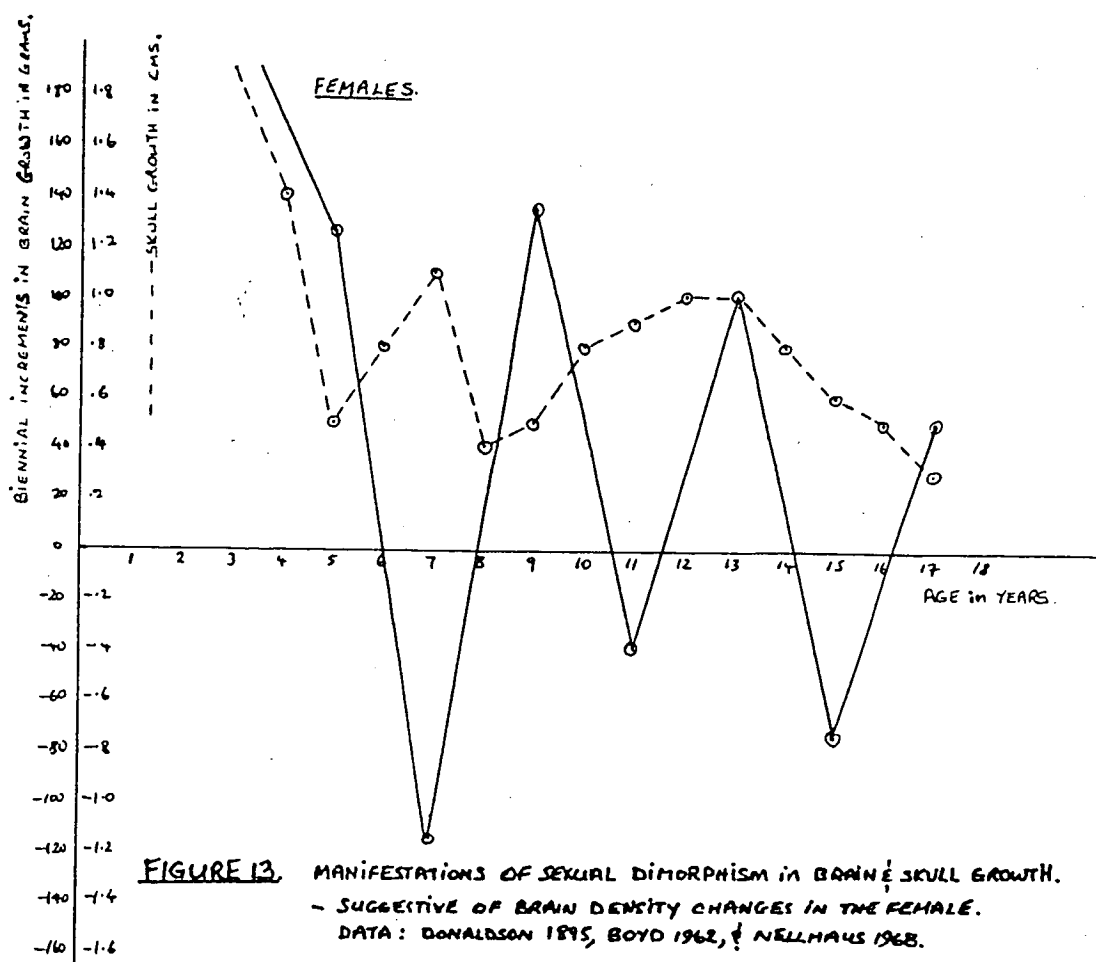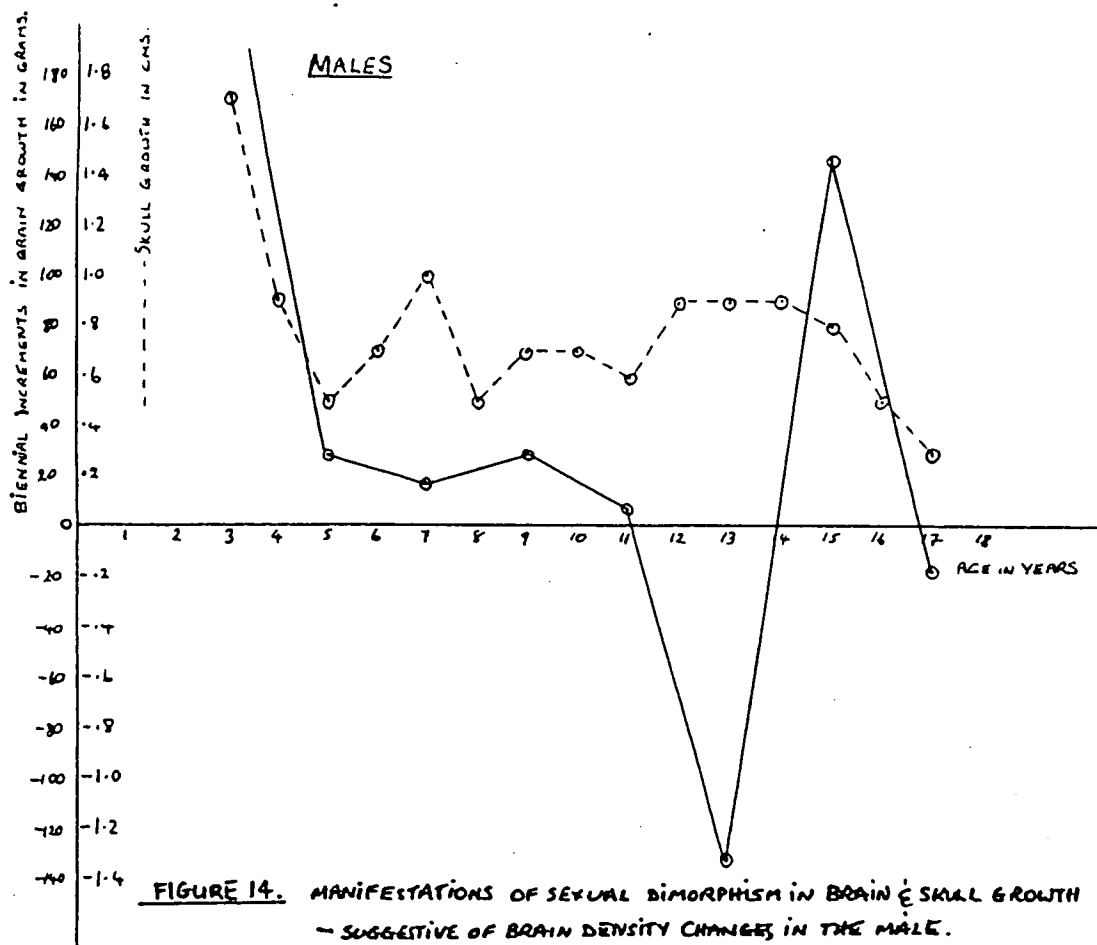
FIGURE 14. MANIFESTATIONS OF SEXUAL DIMORPHISM IN BRAIN & SKULL GROWTH — SUGGESTIVE OF BRAIN DENSITY CHANGES IN THE MALE.
DATA: DONALDSON 1895, BOYD 1962 & NELLHAUS 1968.

THE COMPETENCE PROFILE
VIEWED IN TERMS OF
A LURIAN MODEL
OF INFORMATION PROCESSING:

It has been suggested in the previous chapters that EEG data may be a suitable index of brain changes and hence of cognitive competence. When viewed over the long term it is suggested that changes in EEG can be considered to constitute a profile of cognitive competence.

It has also been suggested above, that the focus of EEG alpha activity centres on the occipital-parietal region of the brain. This region of the brain has long been associated with intelligence. In particular both Weinstein and Teuber (1957) and Ingvar (1976, both cited Epstein 1979,126) suggested that the inferior parietal lobe of the brain was developmentally correlated with intelligence, while Luria (1966,1976) incorporated this region of the brain into a functional model of information processing.

With regard to the connection of the O-P region of the brain to EEG energies, Andersen and Andersson (1968) proposed that alpha energy is characterised by attention and problem solving, as well as in more efficient perception and performance. John (1977), in his review of functional brain measures considered EEG energies from various parts of the cortex and suggested that the posterior cortical formations of the brain engaged in the most complex integrations of simultaneous visual, auditory and somatesthetic activity. From a structural point of view, Walter (cited Lairy 1975,6B 73) assumed that from about the age of nine years, alpha energy is represented as <u>a search for pattern</u>. From a totally different

perspective Fouts (1983,67) suggested in his theory of cognition that the distribution of cognitive processing of the organism should be represented in its neurology. From his studies he suggested that cerebral white matter is associated with simultaneous cognitive processing, while grey matter is associated with sequential processing of information. This needs to be viewed in terms of the previous chapter, where it was suggested that the O-P region of the brain has higher concentrations of white matter (Gur et al.1980), which in turn correlated with higher EEG energy outputs.

There are, however, three aspects of alpha generators which warrant consideration with respect to a Lurian model of information processing. First, the connection between the discontinuance of alpha wave production and attention. Secondly, the proposed location of alpha generators, occipital-parietally, in both hemispheres and thirdly, that the proposed ten levels of cognitive operation (Fischer 1980) can be structurally and mathematically viewed as a hierarchy of more complex integrations of simultaneous visual, auditory and somatesthetic activity.

Luria (1976) developed a functional systems approach to cognition which is concerned with the processing of information within cerebral hemispheres. His work is based on extensive psychological testing of brain damaged patients and was primarily directed towards the prediction and location of brain lesions. The success of his predictions, based on repeated observations, led him to a unique view of the functioning of the human mind. He visualized three interrelated, but psychologically separate blocks which can be described

functionally as: arousal, coding and planning.

Block 1 consists of that physiological section of the brain concerned with arousal which includes the brain stem, the reticular formations and the hippocampus. The function of this block is the regulation of the tone and waking state of the cortex. When low levels of cortical arousal are experienced the functioning of the higher level blocks, two and three, may also be adversely affected.

Block 2 is situated in the posterior parts of the cortex, specifically in the occipital, temporal and parietal lobes. This block functions in the obtaining, processing and storage of information. Like the other blocks, it is hierarchically arranged into designated areas: primary projection, secondary associated and tertiary or over-lapping areas. The tertiary areas are of importance as they receive information from all other modalities and Luria suggests that they are the basis of symbolic behaviour. In particular, the tertiary areas of Block 2 engage in two sorts of information processing: simultaneous and successive. These concepts in themselves are not unique, as each has a firm basis in Kantian philosophy and Einsteinian physics, but the psychological connection Luria makes is most original. Kirby and Biggs (1980,133) describe simultaneous processing as the integration of information into a quasi-spatial gestalt, where all parts of the information are immediately surveyable and relatable, thus combining details into one simultaneous whole. This simultaneous processing is assumed to take place in both cerebral hemispheres, in the occipital-parietal areas, and involves both verbal and non-verbal tasks. Successive processing of information, is

assumed also to take place in both hemispheres, specifically in the fronto-temporal regions of the brain. These areas effect the integration of unrelated information into a temporal sequence, such, that meaning is achieved only in terms of the result of the whole sequence.

Block 3 is located in the prefrontal lobes of both hemispheres where it assumes an executive role and appears responsible for the planning and programming of behaviour. In addition to this inputs from other blocks are received. Block 3 appears responsible for the setting of goals, the planning of process strategies and actions and it also appears to determine if goals have been successfully achieved. For instance, in answering a question, the occipital lobe is the receptive area for visualizing words, while the frontal lobe directs activities making possible the expression of an answer.

There is also close interaction or feed back between Blocks 1 and 3. This is important, for while the former is fundamental for arousal, the latter regulates that same arousal (Kirby & Biggs 1980,134). In effect Luria (1976) has demonstrated a combination of all three functional units of the brain and their involvement in cognitive performances, such as perception, attention, memory, speech and thinking.

With regard to a Lurian model, the connection between Blocks one and three is manifest in the EEG data. This is because alpha wave activity is associated only with a brain in tone. When the eyes are open and attention is concentrated, or the individual is excited or engaged in information processing, then the alpha waves are replaced by low-voltage, rapid, irregular waves. More fundamentally, however, interruptions to

the normal functioning of information processing is observed when lesions occur in the O-P region of the cortex, especially to the dominant left hemisphere. Such lesions lead specifically to a disturbance of the simultaneous organization of stimuli (Das, Kirby & Jarman 1975; Luria 1966). From an electroclinical point of view, Lairy (1975 6B-78) cites EEG abnormalities, such as focal spikes or paroxysmal discharges, especially in the occipital, parietal and temporal areas of patients, whose common factor is the existance of <u>relational</u> difficulties of adjustment and adaptation.

Finally, the kinds of structures Fischer (1980) proposes for levels, expressed in terms of increasingly more complex control of relationships between elements in sets, and ultimately to more complex sets and the relationships among them, suggests a form of simultaneous processing. It is suggested that the set theory structures defined by Fischer (1980), as representing the qualitative levels of cognitive operation, when analysed, constitute a crude mathematical approximation of the logic implicit to the simultaneous processing of information.

In view of the above assumptions, it is reasonable to assume that a centre for simultaneously processing information is located in the occipital-parietal region of the brain, as suggested by Luria (1976). But this paper goes further and suggests that it is also a reasonable assumption that the simultaneous processing of information might be indexed by EEG alpha energy. In this way the competence profile might be interpreted in terms of the structures underlying the simultaneous processing of information.

THE PERFORMANCE PROFILE -
A CRITICAL REVIEW
OF FISCHER'S DATA:

As Fischer, Pipp and Bullock (1984,105) pointed out, two components are necessary in an attempt to detect developmental spurts. The first component involves the use of an appropriate method that reveals any discontinuity or break in an otherwise continuing pattern of data; suitable techniques to achieve this, were discussed on page 14. The second component requires a careful consideration of the environmental conditions under which developmental discontinuities are likely to be observed. Because these two conditions have not been simultaneously incorporated into research paradigms the literature is scarce in reporting developmental discontinuities.

Fischer and his colleagues are engaged in a series of cross-sectional experiments (Fischer,Hand & Russell 1984; Fischer & Kenny, in press) using the method of multiple tasks, previously described, to test a hypothesis (Fischer & Pipp, 1984) about environmental conditions for discontinuities.

> "According to the hypothesis, when individuals develop a new cognitive level, their abilities do show discontinuous change. The spurt is evident, however, only in optimal performance. With familiar materials, the opportunity for practice, and the provision of environmental support for high-level skills, performance becomes optimal, and development shows a spurt as a new level emerges"
> (Fischer, Pipp & Bullock 1984,105).

A new emerging level will be manifest in a broad range of domains (Fischer & Pipp 1984), providing appropriate environments are available. Fischer's research area includes the cognitive, social and emotional domains. Although, only the cognitive domain as represented by arithmetic will be considered here. This domain was selected by Fischer, because

it is a standard topic of instruction in schools (op.cit.), but it might also have been chosen because the structures inherent in the arithmetic tasks can be more easily analysed and checked against the set theory structures of the skill levels being investigated.

Fischer's sample consisted of ninety-six subjects, four of each sex, for each year, from nine through twenty years of age. All of the subjects came from the white middle-class student population of Denver, Colorado.

Tasks for level eight abstract mappings consisted of "eight problems requiring explanation of the relation between two similar arithmetic operations (addition-subtraction, addition-multiplication, multiplication-division, or division-subtraction) and the application of that explanation to two concrete computational problems (such as 7+3=10 and 10-3=7 for addition and subtraction)" (Fischer, Pipp & Bullock 1984). For level seven, single abstraction tasks consisted of "six problems requiring the definition of one of the arithmetic operations (addition, subtraction or multiplication) and the application of that definition to a concrete computational problem, such as 7+3=10 for addition." (op.cit.106). The tasks for the level six representational system have not been fully analysed or reported as yet, and they are a little more difficult to interpret. This is because six tasks involving the operations of addition, subtraction and multiplication were required of students in grades three through six, while another two division items were required of students in grades seven through fourteen. This data will be discussed in two parts.

Fischer's study in progress investigates students'
performances on the above tasks under four environmental
conditions which vary in degree and which were designed to
ultimately effect optimal performance. Optimal performance is
a theoretical concept which is assumed to correspond with the
best possible level of performance an individual can produce.
Whereas Fischer et al. discuss only the two most extreme
environmental conditions from their study (Fischer, Pipp &
Bullock 1984; Fischer & Pipp 1984), this paper considers, as
well, the intermediate conditions which are available for level
eight. The data is interpreted in regard to it constituting
performance profiles which reveal patterns of change in
performance as a function of age.

The first data collection session consisted of two parts.
Initially, students were given the arithmetic tasks for the
selected Skill level without any assistance or opportunity to
practice or prepare for the test. This environmental condition
was called the <u>spontaneous</u> condition. Later in the first
session, students were shown an appropriate response for each
of the test items. They were then environmentally assisted by
instruction, task practice, and supportive feedback prior to
retesting. This environmental condition was termed the
<u>practice and support</u> condition. At the end of the first
session, students were encouraged to practice the arithmetic
tasks on their own, prior to the second session. The second
session took place two weeks later. In the first part of the
second session students were again required to answer test
items without any assistance, while in the second part of this
session they were environmentally supported to the same extent

as in the first session. Fischer's prediction was that a dramatic spurt in performance would be observed for the practice and support condition (although he does not make it clear whether this is applicable to the first, second or both sessions) with little evidence of an emerging spurt for the spontaneous conditions. While the data show the predicted patterns this paper differs in its interpretation of them.
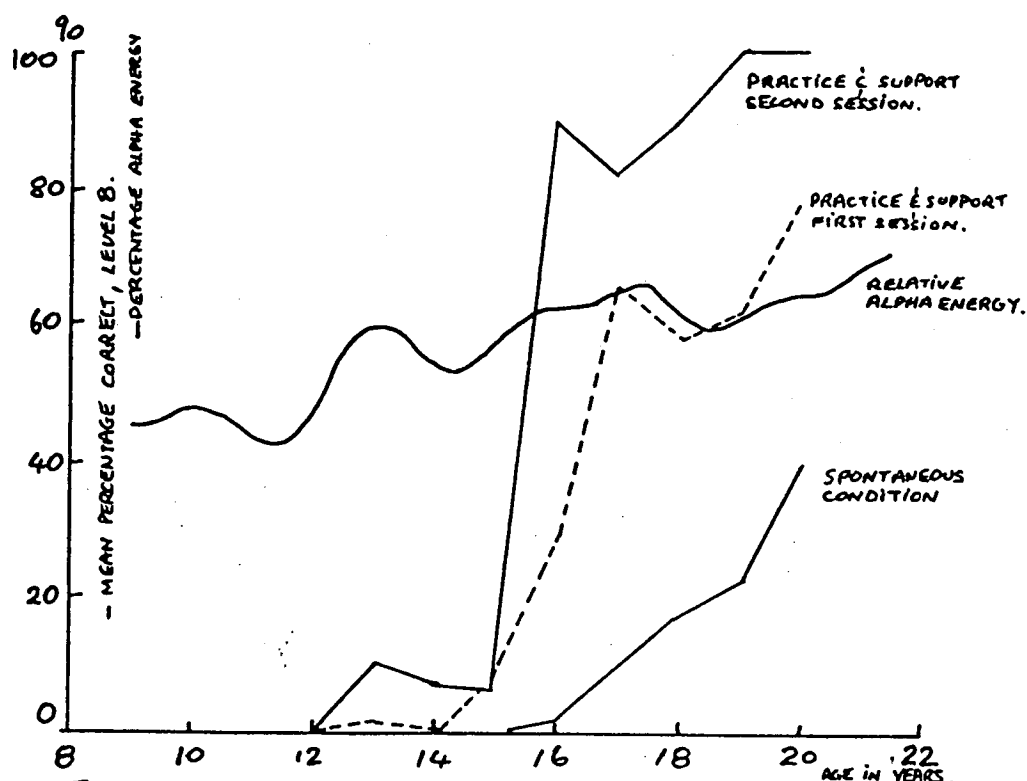
FIGURE 15. CHANGES WITH AGE IN THE PERCENTAGE OF LEVEL 8 ARITHMETIC PROBLEMS SOLVED UNDER DIFFERENT ENVIRONMENTAL CONDITIONS. RELATIVE ALPHA ENERGY SUPERIMPOSED.
DATA: FISCHER, PIPP & BULLOCK 1984.

Figure 15. displays the pattern for level eight performance on the arithmetic tasks, drawn point to point. The dashed line for the first session's practice and support condition has not previously been reported by Fischer et al.. It should be noted that the second session's spontaneous

condition has not been graphed, as it is similar to that session's practice and support condition. For the first session, the difference between the two conditions is quite dramatic. The spontaneous condition shows almost nil performance at fifteen years and then performance steadily increases to some forty percent success on items, at age twenty years. The practice and support line (dashed) displays the predicted spurt in performance at fifteen years and its relationship to the superimposed relative alpha energy curve in terms of peaks and troughs is apparent. It is suggested, that the additional two weeks practice, prior to the second session tests, exceeds reasonable environmental support. Under these conditions it seems that performances may reflect other components of the brain, apart from information processing, for instance, memorization. If this is so, then performance presumably reflects elements of "rote" memorization, without necessarily an enhancement of learning. This appears to be a reasonable explanation for the difference between the two support and practice conditions at level eight (FIG.15).

It should be noted that performance for the support and practice condition reflects the same regressions as displayed in the EEG alpha energy. Fischer et al (ibid.107) invoke a "second-spurt" hypothesis to account for this. They suggest that when the initial emergence does not result in "near-perfect" performance then a second spurt will occur upon the emergence of the next developmental level. Their reasoning, however, is compatible with the arguments put earlier in this paper in support of regression. They suggest (ibid.108) a second discontinuity occurs, "because the skills

for the earlier level undergo consolidation and differentiation when they are reorganized at the new level" (see also Fischer 1980; Flavell 1971).

While this view is seen as being reasonable, it is suggested that it is not so much a matter of "when it occurs", but rather "it occurs" as a natural function of cognitive development. This paper suggests that a skill (Fischer 1980), at a particular level, is ultimately controllable only from the end of that period of reorganization and differentiation. This point in time is predicted to occur for the various levels, (level six onwards), from the companion EEG alpha peak associated with each of the levels (see FIG.8). For each level, performance will plateau at this time at nearly one hundred percent, providing the environment is supportive of the performance. This can be seen to occur at approximately nineteen to nineteen and a half years for level eight, in Figure 15.

Finally, the minor peak at thirteen years (FIG.15) is of interest and without data can at best be speculated upon. In the discussion of performance at the next levels, it will be suggested that an enhanced peak, at a level prior to the one being tested, probably reflects inappropriate test items. If the performance data for that year group is enhanced by the performance of a few students, then it implies that these students are located in a class, two year groups below their capacity. On the other hand, as the phenomenon is extensive throughout the performance literature, it is suggested that it may be a manifestation of the interaction of the alpha-1 and alpha-2 generators referred to previously in this paper.

In Figure 16, the patterns for level seven performances
are shown and again considerable difference is seen between the
spontaneous and support conditions.

CHANGES WITH AGE IN THE PERCENTAGE OF LEVEL 7 ARITHMETIC
PROBLEMS SOLVED UNDER DIFFERENT ENVIRONMENTAL CONDITIONS.
DATA: FISCHER. PIPP & BULLOCK 1984.

Fischer, Pipp and Bullock (1984,107) report that for the
spontaneous condition only the spurt between fifteen and
seventeen years is statistically significant, i.e. to one level
(8) beyond the level of the test item (7).   However, this paper
cautions that the qualitative nature of the changes implicit in
both competence and performance tends to underscore what might
be of statistical significance.   If it is assumed that the unit
of measure of a quality effectively changes, as the quality
itself changes.

A point of significant departure in interpretation exists
for the level seven practice and support data (FIG.16).
Fischer and his colleagues imply that the continuation of the
spurt, through ten to eleven years, to some sixty-six percent
correct performance, constitutes the level seven spurt. This
paper suggests that this is part of the level six spurt
magnified out of proportion due to inappropriate test items and
artifacts incurred during testing. It is suggested that the
test items (Russell & Fischer, in press) for this level do not
sufficiently differentiate from those at level six,
particularly for addition and subtraction. Further to this,
the same students had already performed the level six test
items (communication, Fischer 1985). This would have both a
compounding and a confounding effect at level seven and again
Fischer et al. invoke their second-spurt hypothesis. It is
suggested that the so called second-spurt in this instance is
really the level seven spurt, while the true second-spurt is
observed to occur at fifteen years of age.

It is again important to note the concurrence of the
pattern for level seven performance, with respect to the peaks
and troughs of the superimposed alpha energy curve. Moreover,
the one hundred percent performance plateau for level seven
skills occurs at about fifteen and a half to sixteen years of
age. This coincides with the companion EEG alpha energy peak
(FIG.8) for level seven and the point from which single
abstractions can be controlled in supportive environments.

The level six performance data is shown in FIGURE 17.
The most significant thing to note about this data, apart from
the fact that it is treated in two parts as previously

mentioned, is that performance is near ceiling level from the start for the support and practice condition. The only interpretation that can be given to this is that the test items were inappropriate and too easy. This in itself suggests that at least in part, the interpretation given to the level seven data is correct.
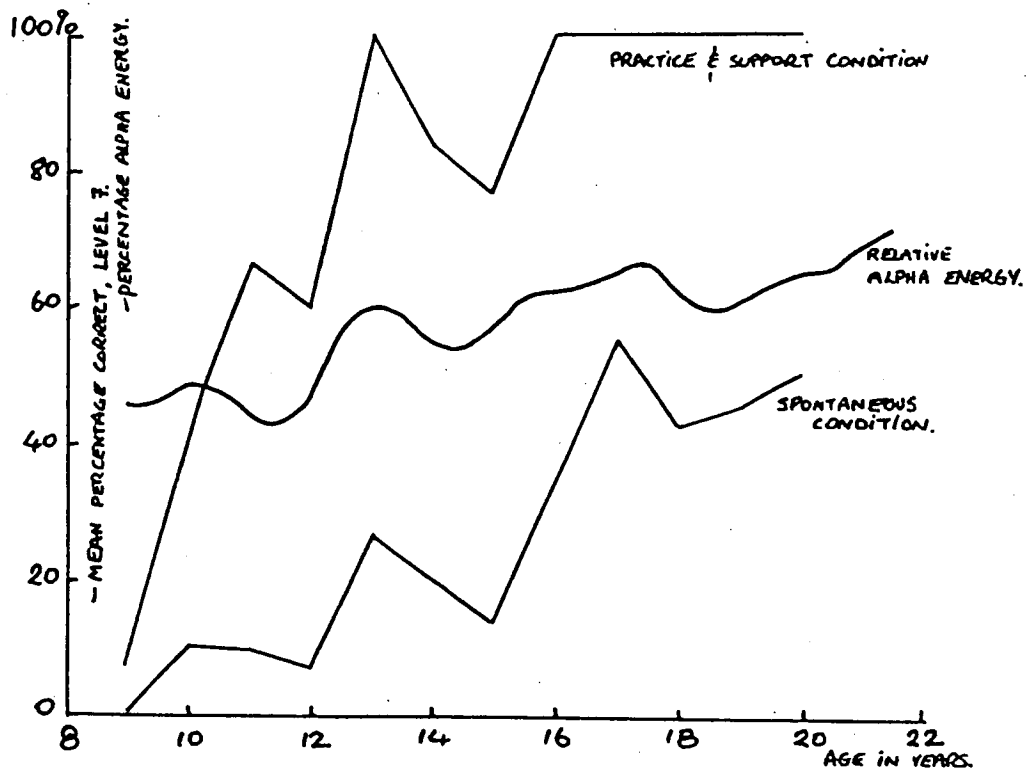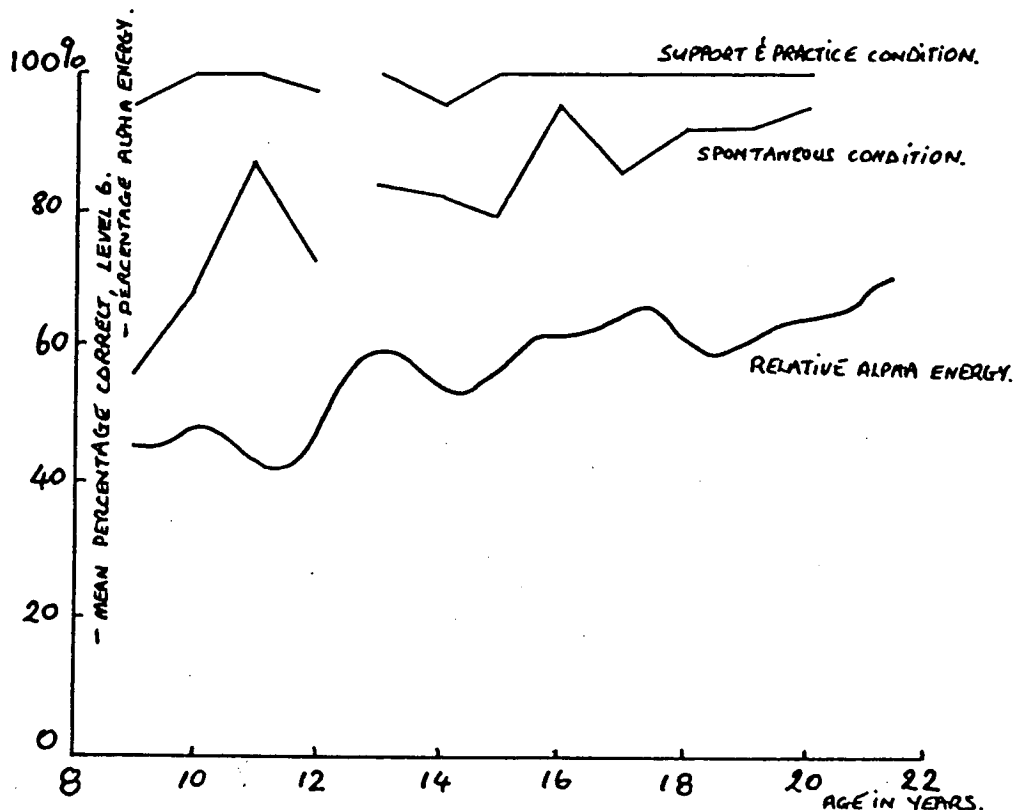

FIGURE 17. CHANGES WITH AGE IN THE PERCENTAGE OF LEVEL 6 ARITHMETIC PROBLEMS SOLVED UNDER DIFFERENT ENVIRONMENTAL CONDITIONS; WITH A CHANGE IN TEST ITEMS.
DATA: PRIVATE COMMUNICATION FISCHER 1985.

With a little imagination, a rise to, and a regression from, a level six peak in performance can be seen to approximately coincide in time with the level six EEG alpha energy peak. Considering that elementary division problems are included as test items for students in grade seven upwards, which was not the case for level seven items, the slight regression in performance from the level seven peak at thirteen

years is both predictable and observable.

When it is considered that Fischer's performance data are for school grades (average age is approximated by adding six to grade), and that data are plotted point to point, there is considerable agreement between the peaks and troughs for both performance profiles and competence profile, based on EEG alpha data. Remarkably, from age nine through twenty, the average displacement for the three peaks; levels six, seven and eight, is approximately seven months. The age from which a level is controllable is also displaced, but by a lesser amount. This needs to be viewed from the perspective that for performance data, spurts occur at approximately the same age for all eight subjects tested, at any level (Fischer & Pipp 1984b). While some comparisons can be made between the Swedish EEG sample and the Denver performance sample, regarding socio-economic status, it is suggested, that the timing of the peaks does not appear to be dependent upon this to any great degree.

In effect the agreement between the optimal performance profiles exhibited above and the competence profile based on EEG data (FIGURE 12), suggests that it is a reasonable hypothesis that performance profiles reflect the cognitive component of a collaboration between individuals and their environments, when the learning environment is manipulated to induce their best performances

EVIDENCE CONSISTENT WITH A PROFILE OF DISCONTINUOUS COGNITIVE PERFORMANCE:

The pattern of data or cognitive performance profile obtained from Fischer's investigation into the levels of performance demonstrated under different environmental conditions needs to be considered relative to other performance data. In particular performance data need to be viewed in terms of the assumed periods of regression in cognitive performance. It also needs to be seen if other performance data might permit an extension of the profile derived from Fischer's work so as to map the extent of the cognitive competence profile derived from EEG data (FIG.12).

Probably the first indication of discontinuous performance, which appears to imply a regression in behaviour, is the disappearance after some months of the archaic reflexes in the neonate (Mounoud 1982,125). Kagan (1982,6; 1983) also cited fundamental behavioural changes in neonates. He reported that neurophysiologists have detected three major changes in EEG wave form at three, eight (theta energy) and twelve to twenty-four months. These wave changes, he suggested, imply morphological or functional changes to the central nervous system which correlated with the onset of behavioural changes. This is supportive of Fischer's (1980) first three levels of operation, and suggests the possibility of a link between performance and EEG.

Piaget (1972) describes behaviours associated with the structures of thought. Following the acquisition of language and the semiotic function, actions are interiorized and become representations. Even so, Piaget claims internal actions

during this period are "preoperatory" and lack operational

logic until the age of seven or eight. Viewing this with

reference to an extrapolated performance profile this age (7/8

yrs.) correlates, not with the $^{\square}L$ peak but rather with the time

from which $^{\square}L$ skills can be controlled, providing they are

environmentally induced and supported.

Behaviours associated with "operations", however, involve:

> "a logic of reversible actions...characterized by the
> formation of a certain number of stable and coherent
> structures, such as a classification system, an
> ordering system, the construction of natural numbers,
> the concept of measurement of lines and surfaces,
> projective relations (perspectives), certain types of
> causality ...,etc." (Piaget 1972,3)

Piaget proposes that these behaviours conform to a period

between 7/8 and 11/12 years. In this case, when compared to

the performance profile, the behaviours associated with this

period fall precisely between the point of $^{\square}L$ control and the

point of $^{\diamond}L$ control, and are defined by the $^{\diamond}L$,

[$^{\diamond}R_{JK}$ ⟷ $^{\diamond}A_{JM}$] skill structure (Fischer 1980).

The next major behavioural change, according to Piaget,

is a decisive turning point. A new logic emerges which is

accompanied with:

> "the capacity to reason in terms of verbally stated
> hypotheses and no longer merely in terms of concrete
> objects and their manipulation" (Piaget 1972,3).

Piaget observes that these behaviours conform with the period

11/12 to 14/15 years. Again, with reference to the performance

profile, this corresponds precisely with the period between the

control of $^{\diamond}L$ skills and the control of ^{7}L skills. The

behaviours, during this period are defined by the ^{7}L structure

(Fischer 1980):

$$\begin{bmatrix} {}^{7}R \longleftrightarrow {}^{7}A \\ {}^{7}B \longleftrightarrow {}^{7}C \end{bmatrix} \equiv [\ {}^{7}M\ ]$$

Piaget (1972,7) acknowledges the influence of environmental stimulation in terms of quality and quantity on the retardation of cognitive performance, whereas, he makes no provision for regressions in cognitive competence.

Bearison (1974,26) suggests that this is a weakness in Piagetian theory. He hypothesizes that the use of a construct like "successive stages of operativity" would imply a regression in both an individual's competence and not merely in his performance.

Neuro-physiological justification for regressions in competence have already been discussed in this paper, however, regressions in performance appear throughout the literature in many domains, including the affective (Monge 1973; Montemayor & Eisen 1977; Harter 1982; Greenspan 1979; Crain 1980). Unfortunately, there are some difficulties with interpretation of the cognitive performance data because seldom are the degrees of environmental support or practice applicable at the time of data collection, reported. Even so, there is extensive agreement among performance data in general with the performance profile derived from Skill theory considerations, irrespective of whether it is viewed from the perspective of peak performance or from the perspective of regressions.

Flavell and Wohlwill (1969, cited Bearison 1974,25) seek recognition for transitional periods between the points in time at which logic structures are "first-in-competence" and which they are "always-in-performance". The logic of the argument in this paper would change the emphasis from

"always-in-performance", to "always-in-competence", and hence "always-in-performance", providing the structures are environmentally induced and supported.

This transitional period is recognized in the literature. Strauss (1982) cites five categories of explanations for regressions in behavioural growth. Logically, these centre on the relation between the phases of the behaviours: Phase 1, when the behaviour appears; Phase 2, when it disappears; and Phase 3, when it reappears. Several of the explanations can be dismissed as being transitory or artifactual in nature and thus fundamentally non-cognitively developmental, while others are extremely nativist in approach. This paper suggests that the collaborative interaction of individuals with their environment and the mechanistic explanation of synaptic reorganization that results from the collaboration, alluded to previously, is an adequate explanation of the phenomenon. In this regard, cognitive performances at Phase 1 and Phase 3 are suggested to be developmentally related through cognitive competence structures. Performances appear to be similar at Phases 1 and 3 and it is suggested that they can be represented by the same mathematical structure (Fischer 1980) for practical purposes. It should be kept in mind, however, that the structures of competence are embedded in different neurological structures and are thus likely to have a different meaning, even though performances appear to be similar. This perspective of regressions in cognitive performance is consistent with the views of Bever (1982), Strauss (1982a), Bowerman, Emmerich, Gardner, and Winner (cited, Strauss 1982b), and Mehler (1982), Stavy, Strauss, Orpaz, and Carmi (1982) who place it in the

traditions of Piaget, Werner, and Vygotsky.

In general, the performance data presented by Renner and Stafford (1976), reflect the peaks and regressions that appear to map an extrapolated performance profile (based on Fischer et al 1984) from the ^mL through ^mL peaks. Also on Piagetian tasks, Shayer, Kuchemann and Whylam's (1976) performance data manifests regressions from the ^4L, ^7L, and ^mL peaks.

In particular, the ^4L peak can be observed in Mehler's (1982,283) work, while regressions from this peak are also noted by him, as well as by Bever, Mehler and Epstein (1967, cited Bever 1982,177). In addition, Mehler records a performance peak corresponding to ^mL, as does Garcia and Trujillo (1979) who, together with Mounoud (1982,124) also demonstrate a regression from it. Moreover, the ^4L peak and regression are extensively mirrored in the literature and several specific examples are cited: Carey (1982), Dasen (1982), Johansson (1977), Mann, Diamond and Carey (1979), Shultz and Coddington (1981) and Thompson (1982). Meanwhile, the ^7L peak is demonstrated in data reported by Dasen (1982), Shultz and Coddington (1981), as well as by Radel (1982), whose data also reflects regressions from this peak. Vygotsky (see Zender & Zender 1974,37), on the other hand, refers to this period as "the crisis at age 13", when a decrease in children's mental capacity can be explained in terms of a shift from object discernment to understanding and deduction [see also Cattell's comments on reduced g_f (fluid intelligence at this age), (cited Epstein 1974a,213)].

Extensive references are cited in Fischer and Silvern (1985,633-636), outlining cognitive behaviours consistent with

levels of development from the first sensory motor level
through level seven and beyond into adolescence.

As mentioned in a cross-cultural study, Dasen (1982)
investigated several of Piaget's concrete operations. Some
aspects of which he discussed, relative to discontinuities and
regressions in cognitive performances.
However, it is not clear from his report, but assumed, that his
results refer to the spontaneous test condition. This does not
prevent the data from being assessed in terms of culturally
supported, or not supported environments. For his study, Dasen
selected three eco-cultural populations: "(1) Eskimos (Cape
Dorset) at one extreme (nomadic, hunting, low
food-accumulating, low population density); (2) African
agriculturalists (Adiopodoume) at the other extreme (sedentary,
high food-accumulating, high population density); and (3)
Australian Aboriginies (Hermannsburg) in an intermediate
position but definitely on the nomadic side. Three Piagetian
tasks were used to assess the development of topological,
projective and Euclidean spatial concepts." (ibid, 222).

Where it can be argued that a cultural relevance to a
specific task exists, then the data reflects a performance peak
in the vicinity of ^{6}L, followed by a regression, then an
advance towards either the ^{7}L peak or towards an asymptotic
plateau. This is assumed to be indicative of a level six
performance task. On the other hand, where the cultural
irrelevance of the task can be argued the cultural order of the
data is reversed and reflects as a rising curve similar to
Fischer's spontaneous condition. In several cases the pattern
reaches an early asymptotic plateau which Dasen suggests

represents a "performance" rather than a "competence" measure. This accords with the arguments previously advanced in this paper and probably represents a lack of practice on the test items and, hence, a less than optimal performance.

The cross-cultural data is viewed as supportive of the performance profile developed in this paper from Fischer's data. More importantly, however, it suggests that the profiles are not simply artifacts of either northern European and middle-class American environments, or of peoples from basically European stock. Earlier in this paper it was suggested that if the peaks and troughs could be shown to be common to all peoples, then it might be a reasonable hypothesis, to suggest that competence structures are genetically embedded. This hypothesis is a little less ominous, if competence structures place only age limitations on peoples' ability to process information.

Almost without exception where tasks used in performance assessment can be structually analysed and assigned a level according to Fischer's set theory (1980), and this includes most of the Piagetian tasks, the data reflect the pattern of peaks and troughs displayed in the Fischer et al (1984) performance profiles.

PRACTICAL IMPLICATIONS
OF THE PROFILES
FOR SCHOOL LEARNING:

A visual comparison between the competence profile derived from EEG data (FIGURE 12.) and performance profiles (FIGURES 15, 16 & 17) derived from Fischer's data can now be made. With respect to the form and synchrony of the profiles it can be seen that an acceptable mapping of the two profiles ensues. In other words, within reasonable limits, the peaks and troughs of one profile synchronize with the other. Because of this synchronization either profile, competence or performance, may be presumed to fulfil a function, as a profile, which reflects a pattern of change for cognitive development.

In view of the linear relationship between Skill level (as defined by Fischer 1980) and age (FIGURE 7), it is not at all surprising that much of the effort used in attempting to determine the rules and conditions of learning have focussed on quantitative, linear, hierarchical and continuous systems. However, it is only the peaks that constitute the linear function and as such, the function must therefore be regarded as being discontinuous. Furthermore, although the levels are qualitatively defined as being one unit apart, in this paper they are also quantitatively related to the exponential function, "e" raised to the power of relative alpha energy. In other words, this paper suggests that the real "measure" between levels is not constant. This supports the commonly held view that levels of cognitive competence represent a qualitative aspect of cognitive developmental change. The implication of this suggests that where qualitative changes are

involved this presents mathematical difficulties for both the statistical analysis and assessment of students' performances.

It has also been suggested that competence might be viewed as an index of the qualitative logic processing component of the brain. When considered in this way, competence takes on a role something like Piaget's (1970,722) "structure operatoire d'ensemble". However, there exist significant differences from this Piagetian construct. First, in that the structures should be considered as undergoing periods of regression in the cause of efficient development. Secondly, in that the structures might only be reflected in performances that are both environmentally induced and supported. While a state of competence may exist at a particular point in time, providing students with the capacity to construct skills (Fischer & Pipp 1984,14) performances must be constructed anew for each environment. For practical classroom purposes though, competence structures assist predictions to be made concerning the potential of synchronous behaviours in various content domains. When learning tasks are selected in this way it may result in learning being more readily transferred to new domains.

As Fischer suggests throughout his work, the order of competence structures, in this case from the profile, enables predictions to be made concerning the sequence of skill development that an individual will follow. The mathematical structures associated with cognitive levels (Fischer 1980) and underlying performance tasks can assist in curriculum design. In designing a curriculum for groups of students the profile may provide structural parameters for predicting what might be

reasonable performance expectations and a guide to arranging the sequence of content. The profile is likely to be of more use in this way, if the parameters can be shown to be associated with logic structures underpinning the ability to simultaneously process information. In addition, the profile might also aid in assisting teachers to determine the level at which to pitch their teaching in order to create stimulating learning environments.

The discontinuous nature of the cognitive competence profile appears to enable predictions to be made concerning periods of performance decrements.

In designing a curriculum for groups of students this point seems to negate the traditional linear or hierarchical curricula structuring. Consequently the profile emphasizes the need to incorporate periods of content revision into the curriculum design, perhaps along the lines suggested in Bruner's (cited Bigge 1976,266) "spiral curriculum". Revision of course, is often built into courses of study. The cognitive competence profile at best offers a theoretical justification for revision. Given the dynamics of competence changes for individuals and the environmental dynamics of classroom situations, teachers at least need to be sensitive to the possibility of periods of performance decrements which their students may encounter from time to time throughout learning experiences.

Assuming that under suitable environmental conditions the performance profile mirrors the EEG competence profile, then from a practical consideration, only two criteria need to be met in order to index a student's competence; i) appropriate

test items and ii) appropriate environmental conditions.
Simple as this sounds, it belies the ease of either adequately
structuring appropriate items, or establishing environmental
conditions that approach an optimal level.

It would seem desirable to monitor students' cognitive
development on a frequent basis using tasks designed to assess
Fischer's skill levels. However, it needs to be kept in mind
that the set-theory structures associated with skill levels
(Fischer 1980) can at best be thought of as mathematical
approximations for physiological cognitive structures. Also,
it needs to be recalled that a period of some six years appears
to exists between the emergence of a new level (e.g. levels six
& seven) and the eventual control of skills at that level.
Consequently, in view of the above and of the suggested
dynamics of both the competence and environmental components of
behaviour, it appears that regular and reliable Skill
measurement may be difficult and time consuming to obtain, in
the day to day asessment of performance. Under these
circumstances Skill assessment may become impractical for
classroom situations. To overcome these difficulties, simple
indices more appropriate to observation, rather than testing,
might be considered. In this respect the SOLO taxonomy (Biggs
and Collis 1982), although appearing to confound skill levels
via overlapping significant features of the developmental
profile, as indicated in FIGURE 12., appears to provide
appropriate and relatively simple techniques. SOLO levels
present as a practical means of day to day monitoring of the
quality of a student's collaboration with his environment. In
this respect SOLO appears to integrate a person's competence

with his environment in the overall assessment of the quality

of his performance. There is also a suggestion of a

relationship between SOLO and the simultaneous processing of

information (ibid.193). This appears to make the use of SOLO

more appropriate, in view of the connection suggested earlier,

between cognitive competence levels and the simultaneous

processing of information.

It must be stressed that both the cognitive competence

and performance profiles are based on normalized

cross-sectional data. Consequently they at best represent

development for groups of students and can not be viewed as

prescriptive of any individual.

When adequately tested an individual of known age can be

located relative to the cognitive competence profile.

Furthermore, there appear to be two major variables in this

matter. First, the timing of the acceleration to a new

qualitative level of competence and secondly, the rate of

achieving the new level. With respect to the first variable,

there is surprising agreement among the performance data, cited

in the previous chapter, concerning the age of emergence of new

levels. Prima facie, this factor does not seem to play a

significant role in determining individual differences. The

second factor, however, appears to be a logical candidate, for

affecting individual differences, particularly, when viewed in

terms of synaptic plasticity and the structuring of neural

pathways dependent upon environmental experiences.

If an individual is located, relative to the normalized

profile, then any environmental decline will effectively cause

that individual to be relocated, vertically down from where he

was previously. Consequently, an individual's performance under reduced environmental conditions, is logically assumed to be reflected in poorer levels.

The emphasis this paper suggests is on changing environmental conditions to accommodate individual differences, as opposed to a changing students to accommodate to rigid environments. In this respect, Fischer, Hand, Wilson, Van Parys and Tucker (1984,55), suggest that early preschool children require little environmental support to perform at the level of their competence. Whereas, from the age of four, increasing environmental support and encouragement is required, in order for children to display their best performances. Bullock (1983,106) and Fischer and Bullock (1984,115) present a convincing argument in the Vygotskyan tradition that suggests that higher cognitive skills develop through social interaction. From this point of view, the role teachers need to play in the learning environments they create for their students is one of the "master craftsman", where learning might be achieved through "guided reinvention" (ibid 115; Lock,1980). In other words, through students and teacher interacting throughout goal-directed activities.

The objective of education is to effect learning and consequently to change behaviour. Thus, the arguments advanced in this paper support the view that learning environments need to be manipulated so as students' performances reflect their competence.

While this paper has some misgivings in general to the concept of mental growth and in particular to Epstein's (1974b) treatment of some eleven independent studies (ibid 220) to

suggest a normalized incremental relationship with age, a remarkably good (inverse) correlation results, in terms of peaks and troughs, between Epstein's mental growth profile and the cognitive competence profile FIGURE 12.

This paper suggests, however, that Epstein (1974a, 1974b, 1978), Epstein and Toepfer (1978) and Toepfer (1979) are mistaken in their interpretation of the data and in their suggestions for reorganizing middle grades educational policy. At the risk of over simplifying their argument they suggest that during periods of slow brain/mental growth, learning should be deferred until more suitable periods of fast brain/mental growth. They also suggested that these periods can be determined, for individuals, simply from different rates of skull growth. It could be that the misinterpretation occurs as a result of a confusion between the quantitative and qualitative aspects of the profiles.

The interpretation offered in this paper suggests that the periods of so called slow development should not be assumed as periods of "no development" per se, but rather the regressions in competence might be viewed as placing limitations on the ability of students to qualitatively process information. There is no suggestion from the available performance data that these periods place any restrictions on the ability of students to quantitatively extend learning in any domain or domains. The restrictions that appear important to what is learnt, or might be learnt, appear to be the structural limits placed on competence and environmental constraints applicable at the time of learning.

SUMMARY AND CONCLUSION:

The opening premise to this paper adopted the common view that cognitive development might best be considered as a collaboration between the cognitive structures of the human mind and its working environment. Reinterpretation of both physiological data related to the human mind and performance data extracted from the literature seemed to support this premise. Performance was noticeably improved when environmental conditions were improved. In itself, this is obvious, but the reinterpretation of data suggested that the patterns of change in performance, mirrored changes that occurred in the brain; when brain changes were indexed by EEG energies, and people were encouraged to give their best performance. Furthermore, physiological indices suggested that cognitive competence structures regressed prior to the emergence of more sophisticated structures. These regressions were observed to be in phase with regressions in students' performances.

In seeking a suitable index of the cognitive competence component of behaviour this paper selected the EEG, primarily because EEG was seen as an index of the energy changes associated with a brain in tone. Consequently, under these conditions, the brain was viewed as being primed and ready to commence processing information. Matousek and Petersen's (1973) EEG alpha data were reinterpreted from the perspective of it being a discontinuous function of age. While peak alpha energies were found to be a function of the natural logarithm of age, the overall function was resolved into a logarithmic component and two oscillating components. These latter two

components were fundamental to the arguments presented in this paper. They were suggestive of powerful alpha generators being located in the occipital-parietal region of the brain. While this possibility is raised in the literature, little significance or interpretation has been attributed to them. From energy considerations these generators appeared to have periods of predominance which corresponded in time with the concrete and abstract stages of development, as elaborated by Piaget. Energy changes to the generators appeared to correspond in time to levels of change in cognitive performance, as elaborated by Fischer (1980). Following the attainment of a level, the generators declined in their energy production prior to accelerating to a new higher level of production. These periods of decreased energy production seemed to correlate with periods of poorer cognitive performance. Because indications were, that the generators might be located in the O-P region of the brain, they were interpreted as perhaps engaging in the simultaneous processing of information, as articulated by Luria (1976).

A model of possible alpha wave generation was proposed, and the synchronous nature of the generators was advanced as reason for their resistance to more rapid structural reorganization. This suggested a stability in the processing region of the brain which seemed essential for providing a degree of constancy in the interpretation of information.

The discontinuous view of alpha energy production suggested the interpretation that neural structures are quantitatively added to until they become unstable and reorganize. The result of this seemed to be a new qualitative

level of operation. Moreover, these periods of structural reorganization enabled predictions to be made concerning decrements in students' performances along the lines elaborated by Bever (1982) and Strauss (1982b) and as displayed in Fischer's performance data.

When peak alpha energies are attributed skill structures, defined by Fischer (1980) as being one, qualitative unit apart, the function with age became linear (FIG.7). Under these conditions it is not surprising that cognitive development has been assumed to be both continuous and linear. However, it was only the peaks that constituted the linear function and as such, the function must be regarded as being discontinuous. Furthermore, although the levels were qualitatively defined as being one unit apart, in this paper they were also quantitatively related through EEG alpha energy. Qualitative changes in students' competence have been assumed to present mathematical difficulties for both the statistical analysis and assessment of students' performances.

The educational implications of performance decrements suggested that revision is needed to be specifically built into courses of study, rather than to be something that was traditionally done because it was believed to work. Additionally, the cognitive profile can act as a guide, along the lines suggested by Fischer (1980), for the sequencing and synchronizing of content material and as a basis for the rationale of mapping a curriculum to individual needs. It also provides an explanatory power for understanding an intervention into the learning process. Considerations implicit in the cognitive performance profile supported the common view of

environmental constraints restricting efficient and effective learning. It therefore concurred with the common practice of establishing supportive learning environments and placed emphasis on the need for practice.

It was proposed that qualitative outcomes from learning experiences can be observed, as opposed to constantly being tested. Furthermore, it was suggested that SOLO levels (Biggs & Collis 1982) can be interpreted with respect to the profile. The SOLO taxonomy provides an appropriate and relatively simple technique that evaluates the integration of cognitive competence with prevailing environmental conditions and enables a qualitative assessment of changes in performances.

An emphasis is suggested on changing environmental conditions to accommodate individual differences, as opposed to changing students to accommodate to rigid environments. The normative, and cross-sectional nature of the data and correlations preclude suggestions concerning individuals. For this reason, aspects of the correlations cause concern and require specific follow-up research. In particular, the profiles need to be investigated for a longitudinal sample. Furthermore, the competence and performance profiles are derived from independent samples, whereas, to be really convincing both profiles need to relate to the same sample. As well, the connection between the structures inherent in cognitive levels, mathematically defined by Fischer (1980) and the simultaneous processing of information requires empirical investigation.

REFERENCES:

ADELSON,J.(1972).The Political Imagination Of The
Adolescent. In J.Kagan & R.Coles (Eds.) Twelve To Sixteen:
Early Adolescence. N.Y.,Norton.

ANDERSEN,P. and ANDERSSON,S.A.(1968).Physiological Basis Of
The Alpha Rhythm,N.Y.,Appleton-Centaury-Crofts.

APPELBAUM,M.J.,McCALL,R,B.(1983). Design And Analysis In
Developmental Psychology. In W.Kessen(Ed.) Handbook Of Child
Psychology Vol.1.History,Theory And Method,N.Y.,John Wiley.

BEARISON,D.J.(1974). The Construct Of Regression: A
Piagetian Approach, Merrill-Palmer Quarterly,20,21-30.

BEVER,T.G.(1982).Regression In The Service Of Development.
In T.G.Bever (Ed.) Regressions In Mental Development: Basic
Phenomena And Theories, Hillsdale,N.J.,Erlbaum.

BICKHARD,M.H.(1978).The Nature Of Developmental Stages,
Human Development, 21,217-233

BIGGE,M.L.(1976).Learning Theories For Teachers (Third
Edition), N.Y.,Harper & Row.

BIGGS,J.B. and COLLIS,K.F.(1982).Evaluating The Quality Of
Learning: The SOLO Taxonomy,New York,Academic Press.

BLAUENSTEIN,U.W.,HALSEY,J.H.,WILSON,E.M.,WILLS,E.L.,
RISBERG,J.(1977).133-Xenon Inhalation Method Stroke,
Vol.8.,No.1.,92-102.

BOWERMAN,M.(1982). Starting To Talk Worse: Clues To Language
Acquisition From Children's Late Speech Errors. In
S.Strauss(Ed.) U-Shaped Behavioral Growth,N.Y.,Academic
Press.

BOYD,E.(1962).In P.Altman and D.Dittmar (Eds.)
Growth,Washington,D.C.,Federation Of American Societies Of
Experimental Biology.

BRIERLEY,J.K.(1976).The Growing Brain: Childhood's Critical
Years,Alantic Highlands,N.J.,Humanities Press.

BROWN,M.C.,JANSEN,J.K.S.,and VAN ESSEN,D.(1976).Polyneuronal
Innervation Of Skeletal Muscle In New-Born Rats And Its
Elimination During Maturation.J. Physiology.261,387-427.

Bullock,D.(1983).Seeking Relations Between Cognitive And
Social Interactive Transitions. In K.W.Fischer(Ed.), Levels
And Transitions In Children's Development: New Directions
For Child Development,No.21,San Fransisco,Jossey-Bass.

CAREY,S.(1982).Face Perception: Anomalities Of Development.
In S.Strauss (Ed.),U-Shaped Behavioral Growth.N.Y.,Academic
Press.

CHATRIAN,G.E.,LAIRY,G.C.(1975).Spatial And Temporal
Relationships Of EEG Signals.In G.C.Lairy (Ed.) The Normal
EEG Through-Out Life. In Handbook Of EEG And Clinical
Neurophysiology.Vol.6A,Amsterdam,Netherlands,Elsvier Pub.Co.

COPPOLETTA,J.M.,WOLBACH,S.B.(1933).Body Length And Organ
Weight Of Infants And Children. American Journal
Pathology,9,55-70.

COTMAN,C.W.,NEITO-SAMPEDRO,M.(1982).Brain Function, Synapse
Renewal, And Plasticity. Annual Review Psychology,
33,371-401.

CRAIN,W.C.(1980).Theories Of Development: Concepts And
Applications. Edgewood Cliffs.N.J.,Prentice-Hall.

CRUETZFELDT,O.(Ed.) (1974).Neuronal Basis Of EEG-Waves. In
A.Remond.(Ed.in Chief).Handbook Of EEG And Clinical
Neurophysiology, Vol.2.,Part C.Amsterdam, Netherlands,
Elsvier Pub.Co.

CREUTZFELDT,O.(Ed.) (1974).Electrical Activity From The
Neuron To The EEG Or EMG. In A.Remond.(Ed.in Chief).Handbook
Of EEG And Clinical Neurophysiology, Vol.2, Part D.
Amsterdam,Netherlands,Elsvier Pub.Co.

DAS,J.P.,KIRBY,J.R.,JARMAN,R.F.(1975). Simultaneous And
Successive Synthesis: An Alternative Model For Cognitive
Abilities.Psychological Bulletin,82,(1),87-103.

DASEN,P.R,(1982).Cross-Cultural Data On Operational
Development: Asymptotic Developmental Curves. In T.G.Bever
(Ed.).Regressions In Mental Development: Basic Phenomena And
Theories. Hillsdale,N.J.,Erlbaum.

DOBBING,J.,SANDS,J.(1973).Quantitative Growth And
Development Of Human Brain.Arch.Dis.Child.,48,757-767.

DONALDSON,H.H.(1895).The Growth Of The Brain. London,Walter
Scott Ltd.

EMDE,R.,GAENSBAUER,T.,HARMON,R.(1976).Emotional expression
in infancy: A biological study. Psychological Issues,
10,No.37.

EPSTEIN,H.T.(1974).Phrenoblysis: Special Brain And Mind
Growth Periods.1.Human Brain And Skull
Development.Developmental Psychobiology,7,207-216.

EPSTEIN,H.T.(1974).Phrenoblysis:Special Brain And Mind
Growth Periods.11.Human Mental Development.Developmental
Psychobiology,7,217-224.

EPSTEIN,H.T.(1978).Growth Spurts During Brain Development:
Implications For Educational Policy And Practice. In
J.S.Chall and A.F.Mursky (Eds.).Education And The Brain.
Chicago,University of Chicago Press.

EPSTEIN,H.T.(1979).Correlated Brain And Intelligence
Development In Humans. In M.E.Hahn (Ed.),Development And
Evolution Of Brain Size: Behavioral Implications.
N.Y.,Academic Press.

EPSTEIN,H.T.(1980).EEG. Developmental Stages. Developmental
Psychobiology,13,629-631.

EPSTEIN,H.T.,TOEPFER,C.F.(1978).A Neuroscience Basis For
Reorganizing Middle Grades Education. Educ. Leader.
35:656-660.

FISCHER,K.W.(1980).A Theory Of Cognitive Development: The
Control And Construction Of Hierarchies Of Skills.
Psychological Review,87,477-531.

FISCHER,K.W.(1982).Human Cognitive Development In The First
Four Years.The Behavioral And Brain Sciences,5,282-283.

FISCHER,K.W.(1983).Developmental Levels As Periods Of
Discontinuity. In K.W.Fischer (Ed.),Levels And Transitions.
In Children's Development. Child Development,No.21. San
Fransisco,Jossey-Bass.

FISCHER,K.W.(Manuscript in Preparation)
Understanding,Understanding.

FISCHER,K.W.,BULLOCK,D.(1981).Patterns Of Data: Sequences,
Synchrony, and Constraint In Cognitive Development. In
K.W.Fischer (Ed.), Cognitive Development. New Directions,
Child Development,No.12.,San Fransisco,Jossey-Bass.

FISCHER,K.W.,BULLOCK,D.(1984).Cognitive Development In
School-Aged Children: Conclusions And New Directions. In
W.A.Collins (Ed.),Development During Middle Child-hood.
Washington,D.C.,National Academic Press.

FISCHER,K.W.,Hand,H.H.,RUSSELL,S.L.(1984).The Development Of
Abstractions In Adolescence And Adult-hood. In M.Commons,
F.Richards and C.Armon (Eds.), Beyond Formal Operations.
N.Y.,Praeger.

FISCHER,K.W.,HAND,H.H.,WATSON,M.W.,VAN PARYS, M.M.,
TUCKER,J.L.(1984).Putting The Child Into Socialization: The
Development Of Social Categories In Pre-school Children. In
L.G.Katz, P.J.Wagemaker and K.Steiner (Eds.),Current Topics
In Early Child-HoodEducation,Vol.5., Norwood,N.J.,Ablex.

FISCHER,K.W.,KENNY,S.L. (In press). Environmental
Considerations For Discontinuities In The Development Of
Abstractions. In R.Mines and K.Kitchener
(Eds.).Social-Cognitive Development In Early Adult-Hood,
Praeger.

FISCHER,K.W.,PIPP,S.(1984).Processes Of Cognitive
Development: Optimal Level And Skill Acquisition. In
R.J.Sternberg (Ed.),Mechanisms Of Cognitive Development,
San Fransisco,Freeman.

FISCHER,K.W.,PIPP,S.,BULLOCK,D.(1984).Detecting
Discontinuities In Development: Method And Measurement. In
R.Harmon and R.N.Emde (Eds.),Continuities And
Discontinuities In Development, N.Y.,Plenum.

FISCHER,K.W.,SILVERN,L.(1985).Stages And Individual
Differences In Cognitive Development,Ann. Rev. Pschol.,
36,613-648.

FLANAGAN,D.J.(1984).The Science Of Mind. Cambridge,
M.I.T.Press.

FLAVELL,J.H.(1971).Stage-Related Properties Of Cognitive
Development, Cognitive Psychology, 2,421-453.

FLAVELL,J.H.(1983).Structures, Stages,And Sequences In
Cognitive Development. In W.A.Collins (Ed.),Minnesota
Symposium On Child Psychology, Hillsdale,N.J.,Erlbaum.

FLAVELL,J.,WOHLWILL,J.(1969). Formal And Functional Aspects
Of Cognitive Development. In D.Elkind & J.Flavell (Eds.)
Studies In Cognitive Development: Essay In Honor Of Jean
Piaget. ,N.Y.,Oxford Uni. Press.

FOUTS,K.W.(1983).Chimpanzee Language And Elephant Tails: A
Theoretical Synthesis. In J.de Luce and H.T.Wilder (Eds.).
Language In Primates, N.Y.,Springer-Verlag.

FURUKAWA,T.,FURSNPAN,G.(1963).Two Inhibitory Mechanisms In
The Mauthner Neurons Of Gold-Fish. J. Neurophysiol.,
36,613-648.

GARCIA,E.E.,TRUJILLO,A.(1979).A Developmental Study Of
Spanish English Production In Bilingual Children.Journal Of
Educational Psychology,Vol.71,No.2 ,161-168.

GAREY,L.J. (Ed.),(1976).Synaptic Organization Of Afferent
Fibres And Intrinsic Circuits In The Neo Cortex. In A.Remond
(Ed.in Chief) Handbook Of EEG And Neurophysiology,
Vol.2,Part A.Amsterdam,Netherlands,Elsvier Pub.Co.

GELMAN,R.(1978).Cognitive Development.Annual Review Of
Psychology, 29,297-332.

GLASER,G.H.(Ed.) (1963).EEG And Behavior, N.Y.,Basic Books.

GREENSPAN,S.J.(1979).Psychological Issues: Intelligence And
Adaption, N.Y.,International Uni. Press.

GRUBER,H.E.,VONECHE,J.J.(1977).The Essential Piaget: An
Interpretive Reference And Guide, N.Y.,Basic Books.

GUR,R.C.,PACKER,I.K.,HUNGERBUHLER,J.P.,REIVICH,M.,
OBRIST,W.D.,AMARNEK,W.S.,SACKEIM,H.A.(1980).Differences In
The Distribution Of Grey And White Matter In The Human
Cerebral Hemispheres,_Science_,Vol.207.,1226-1228.

HAGNE,I.(1968).Development Of The Waking EEG In Nornal
Infants During The First Four Years Of Life- A Longitudinal
Study Including Automatic Frequency Analysis. In P.Kelloway
and I.Petersen (Eds.)._Clinical Electroencephalography Of
Children_, Stockholm,Sweden,Almqvist & Wiksell.

HAGNE,I.,PERSON,J.,MAGNUSSON,R.,PETERSEN,I.(197)Spectral
Analysis Via Fast Fourier Transform Of Waking EEG In Normal
Infants. In P.Kellaway and I.Petersen (Eds.),_Automation In
Clinical EEG._, N.Y.,Raven Press.

HARTER,S.(1982).Cognitive-Developmental Considerations In
The Conduct Of Play Therapy. In Schaefer and O'Conner (Eds.)
Handbook Of Play Therapy, Wiley & Sons.

HEBB,D.O.(1948)._Organization Of Behavior_, N.Y.,John Wiley.

HILL,D.,PARR,G.(1963)._Electroencephalography_,
N.Y.,MacMillan.

HOLMES,O.,HOUCHIN,J.(1967).A Model Of The Potential Evoked
From The Cerebral Cortex By Afferent
Stimulation._J.Physiol.(Lond.)_,191,3-4.

HORI,H.,HAYASAKA,K.,SATO,K.,HARADA,D.,IWATA,H.A.(1969).A
Study Of Phase Relationships In Human Alpha Activity:
Correlation Of Different Regions._Electroencephalography And
Clinical Neurophysiology_,26,19-24.

INHELDER,B.,PIAGET,J.(1958/1955). _The Growth Of Logical
Thinking From Childhood To Adolescence_. N.Y.,Basic Books

ISAAC,D.J.,O'CONNOR,B.M.(1975).A Discontinuity Theory Of
Psychological Development. _Human Relations_,29,41-61.

JOHANSSON,B.S.(1977).Levels Of Mastery Of The Co-Ordinators
" And " And " Or " And Logical Test Performance.
Br.Journal Psy.,68,311-320.

JOHN,E.R.(1977)._Functional Neuroscience: Neurometrics_,
Hillsdale,N.J.,Erlbaum.

KAGAN,J.(1979). Structures And Processes In The Human
Infant: The Ontogeny Of Mental Representation. In
M.H.Bornstein & W.Kessen (Eds.) _Psychological Development
From Infancy: Image And Intention_, Hillsdale,N.J.,Erlbaum.

KAGAN,J.(1982)._Psychological Research On The Human Infant:
An Evaluative Summary_, N.Y.,Holt,Rinehart & Winston.

KAGAN,J.(1985). Guiding Themes In Human Development. In
The Nature Of The Child, U.K.,Basic Books.

KANDEL,E.R.(1970). Nerve Cells And Behaviour, Scientific American Inc., N.Y.,Vol.223,1,57-70.

KIRBY,J.B.(1980).Individual Differences And Cognitive Processes. In J.R.Kirby and J.B.Biggs (Eds.),Cognition, Development And Instruction, N.Y.,Academic Press.

LAIRY,G.C.(1975). EEG And Psychology Of The Child. Handbook Of EEG And Clinical Neurophysiology, Vol.6B,Amsterdam,Netherlands, Elsvier Pub.Co.

LAIRY,G.C.(1976). The Normal EEG Throughout Life. Handbook Of EEG And Clinical Neurophysiology, Vol.6A,Amsterdam,Netherlands, Elsvier Pub.Co.

LICHTMAN,J.W.(1977),The Reorganization Of Synaptic Connections In Rat Submandibular Ganglion During Post-Natal Development. J.Physiol.,273,155-177.

LOCK,A.(1980).The Guided Reinvention Of Language, N.Y.,Academic Press.

LORENZ,K.(1977).Behind The Mirror: A Search For A Natural History Of Human Knowledge. N.Y.,Harcourt, Brace and Jovanovich.

LORENZ,K.(1982). The Foundations Of Ethology, N.Y.,Touchstone: Simon and Schuster.

LUNZER,E.A.(1965).Problems For Formal Reasoning In Test Situations. In P.h.Mussen (Ed.), European Research In Cognitive Development. Monographs Of The Society For Research In Child Development, 30,2, serial No.100.

LURIA,A.R.(1966). Human Brain And Psychological Processes, N.Y.,Harper & Row.

LURIA,A.R.(1976). The Working Brain. England,Harmonsworth,Penguin.

MANN,V.A.,DIAMOND,R.,CAREY,S.(1979).Development Of Voice Recognition: Parallels With Face Recognition. J.Experimental Child Psy., 27,153-165.

MATOUSEK,M.,PETERSEN,I.(1973).Frequency Analysis Of The EEG In Normal Children And Adolescents. In P.Kellaway and I.Petersen (Eds.),Automation Of Clinical Electroencephalography, N.Y.,Raven Press.

McCALL,R.B.,EICHORN,D.H.,HOGARTY,P.S.(1977). Transitions In Early Mental Development Monographs Of The Society For Research In Child Development, 42,3,serial No.171.

McCALL,R.B.,MEYERS,E.D.Jr.,HARTMAN,J.,ROCHE,A.F.(1983). Developmental Changes In Head-Circumference And Mental-Performance Growth Rates: A Test Of Epstein's Phrenoblysis Hypothesis. Developmental Psychology 16,457-68.

McQUEEN,R.(1982).Brain Growth Periodization: Analysis Of The
Epstein Spurt-Plateau Findings. Multnomah County Education
Service District Education Association. Portland,Oregon.

MEHLER,J.(1982a).Studies In The Development Of Cognitive
Processes. In S.Strauss (Ed.), U-Shaped Behavioral Growth,
N.Y.,Academic Press.

MEHLER,J.(1982b).Unlearning: Dips And Drops- A Theory Of
Cognitive Development. In T.G.Bever (Ed.) Regressions In
Mental Development: Basic Phenomena And Theories,
Hillsdale,N.J.,Erlbaum.

MEYER,J.S.,ISHIHARA,N.,DESHMUKH,V.D.,NARITOMI,H.,SAKAI,F.,
HSU,M-C.,POLLACK,P.(1978). Improved Method For Noninvasive
Measurement Of Regional Cerebral Blood Flow By Xenon-133
Inhalation. Stroke, Vol.9.,No.3.,195-205.

MONGE,R.H.(1973).Developmental Trends In Fators Of
Adolescent Self-Concept. Developmental Psychology,
8,No.3,382-393.

MONTEMAYOR,R.,EISEN,M.(1977). The Development Of Self
Concepts From Childhood To Adolescence,
Developmental Psychology, Vol.13,No.4,314-319.

MOUNOUD,P.(1982).Revolutionary Periods In Early Development.
In T.G.Bever, Regressions In Mental Development: Basic
Phenomena And Theories. Hillsdale,N.J.,Erlbaum.

NELLHAUS,G.N.(1968).Head Circumference From Birth To
Eighteen Years, Pediatrics, Vol.41,No.1,Part 1,106-211.

PATTERSON,P.H.,PURVES,D.(Eds.) (1982). Readings In
Developmental Neurobiology. N.Y., Cold Spring Laboratory.

PERSSON,J.(1972). A Computorized Spectrual Analysis Of EEG
From Normal Children During The First Year Of Life,
Technical Report 20, School Of Electrical Engineering,
Goteborg, Sweden, Chalmers Uni. Of Technology.

PIAGET,J.(1971).The Theory Of Stages In Cognitive
Development. In D.Green,M.Ford and G.Flamer
(Eds.),Measurement And Piaget, N.Y.,McGraw-Hill.

PIAGET,J.(1972). Intellectual Evolution From Adolescence To
Adulthood. Human Development, 15:1-12.

PIAGET,J.(1970).Piaget's Theory. In P.Mussen (Ed.),
Manual Of Child Psychology, Vol.1,Third Edition,N.Y.,Wiley &
Son.

PLOMIN,R.(1983).Developmental Behavior Genetics,
Child Development, 54,253-259.

PRECHTL,H.F.R.(1982).Regressions And Transformations During
Neurological Development. In T.G.Bever (Ed.), <u>Regressions In
Mental Development: Basic Phenomena And Theories</u>,
Hillsdale,N.J.,Erlbaum.

PURVES,D.,LICHTMAN,J.W.(1980).Elimination Of Synapses In The
Developing Nervous System, <u>Science</u>, Vol.210,153-157.

RADEL,P.J.(1982). <u>The Acquisition Of A Scientific Language</u>,
Dissertation For M.Ed.Stud., Uni.Of Tasmania.

REINIS,S.,GOLDMAN,J.M.(1980). <u>The Development Of The Brain:
Biological And Functional Perspectives</u>,
Springfield,Il.,C.Thomas Pub.

RENNER,J.W.,STAFFORD,D.G.(1976). <u>Research, Teaching And
Learning With The Piagetian Model</u>, Uni.Oklahoma Press.

RUSSELL,S.,FISCHER,K.W.,(In Press) <u>Scoring Manual For The
Development Of Concepts Of Addition, Subtraction,
Multiplication And Division From Grade School To College</u>,
Cognitive Development Laboratory Manual No.6, University Of
Denver,Co.

SHAYER,M.,KUCHEMANN,D.E.,WHYLAM,H.(1976).The Distribution Of
Piagetian Stages In British Middle And Secondary School
Children, <u>Br.J.Ed.Psy.</u>, 46,164-73.

SHEPHARD,R.N.(1984).Ecological Constraints On Internal
Representations: Resonant Kinematics Of Perceiving, Imaging,
Thinking And Dreaming, <u>Psychological Review</u>,
Vol.91.,No.4.,417-447.

SHULTZ,T.,CODDINGTON,M.(1981).Development Of The Concepts Of
Energy, Conservation And Entropy. <u>J. Experimental Child.Psy.</u>
31,131-153.

STAVY,R.,STRAUSS,S.,ORPAZ,N.,CARMI,G.(1982). U-Shaped
Behavioral Growth In Ratio Comparisons. In S.Strauss (Ed.),
<u>U-Shaped Behavioral Growth</u>. N.Y.,Academic Press.

STEWART,L.F(1961). <u>Introduction To The Principles Of
Electroencephalography</u>, Illinois,C.C.Thomas Pub.

STORM VAN LEEAWEN,W.,KEMP,A.(1980).Event Related Changes Of
Rhythmical Cortical Potentials. In G.Pfurtscheller, P.Buser,
F.H.Lopes De Silva and H.Petsche (Eds.), <u>Rhythmic EEG
Activities And Cortical Functioning</u>, North Holland,Elsvier.

STRAUSS,S.(1982a).Ancestral And Decendant Behaviors: The
Case Of U-Shaped Behavioral Growth. In T.G.Bever (Ed.),
<u>Regressions In Mental Development: Basic Phenomena And
Theories</u>, Hillsdalr,N.J.,Erlbaum.

STRAUSS,S.(Ed.) (1982b). <u>U-Shaped Behavioral Growth</u>,
N.Y.,Academic Press.

THATCHER,R.W.,JOHN,E.R.(1979). <u>Foundations Of Cognitive Processes: Functional Neuroscience Vol.1.,</u> Hillsdale,N.J.,Erlbaum.

THOMPSON,M.E.(1982).The Assessment Of Children With Specific Reading Difficulties (Dyslexia) Using The British Ability Scale. <u>Br. Journal Psy.</u>, 73,416-478.

TOEPFER,C.F.Jr.(1979).Brain Growth Periodization: A New Dogma For Education. <u>Middle School Journal</u>, 10,20.

TURKO,M.E.,GIURINTANO,L.P.,GUIRINTANO, S.L.,ANDY,O.J.(1974).Spontaneous Awake EEG Patterns In Three Lines Of Primitive Evolution. <u>Behavioral Biology</u>, 10,337-384.

UZGIRIS,J.C.(1976). Organization Of Sensory Motor Intelligence. In m.Lewis (Ed.) <u>Origins Of Intelligence: Infancy And Early Childhood</u>, N.Y.,Plenum Press.

WALTER,D.O.,RHODES,J.M.,BROWN,D.,ADEY,W.R.(1966).Comprehensive Spectral Analysis Of Human EEG Generators In Posterior Cerebral Regions. <u>Electroenceph. Clin. Neurophysiology</u>, 20,224-237.

WALTER,W.G.(1963),Techniques And Interpretation. In D.Hill and G.Parr (Eds.), <u>Electroencephalography</u>, N.Y.,MacMillan Co.

WALTER,W.G.,PARR,G.(1963).Recording Equipment And Techniques. In D.Hill and G.Parr (Eds.), <u>Electroencephalography</u>, N.Y.,MacMillan Co.

WERNER,H.(1957).The Concept Of Development From A Comparative And Organismic Point Of View. In D.B.Harris (Ed.), <u>The Concept Of Development</u>. Minneapolis,Uni. Of Minnosota Press.

ZENDER,M.A.,ZENDER,B.F.(1974). Vygotsky's Views About Age Periodization Of Child Development, <u>Human Development</u>, 17:24-40.