# MENTAL CAPACITY AND EXECUTIVE STRATEGIES AMONG ZULU-SPEAKING CHILDREN

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## Abstract

The poor school performance among black children in South Africa is best understood by focussing on the generative mechanisms which underlie performance. This research was undertaken within Pascual-Leone's neo-Piagetian Theory of Constructive Operators, which models cognitive functioning as a bilevel system of content-specific schemes and situation-free silent operators. Of the seven silent operators posited, Pascual-Leone is able to distinguish cognitive competence, or mental capacity (structural $M$, or $M_s$), from learning ($L$ structuring) which is dependent upon environment. The $M$-construct is a reserve of mental attentional energy which can be applied to task-relevant schemes to boost their activation weights. The Compound Stimulus Visual Information (CSVI) task was used to distinguish the amount of $M$-power subjects employed in a given task (functional $M$, or $M_f$), as well as the efficiency with which they used this $M_f$. Children from the black township of Indaleni, outside Richmond, Natal, South Africa, were selected. Thirty subjects in each of four age groups, seven-, nine-, eleven-, and thirteen-year-olds, were tested. The Children's Embedded Figures Test (CEFT) and the Raven's Standard Progressive Matrices (RSPM) test were administered in groups. Two versions of the CSVI were given: the Free Response (CSVI-FR) and the Tachistoscopic version. The latter was analysed in terms of first look (CSVI-1STL), which gives an estimate of $M_f$, and repeated looks (CSVI-TACH), which estimates the number of attending acts made over the task. The CEFT was found not to distinguish cognitive style in this sample. As the sample was of low socioeconomic status and rural, it was argued that the subjects were predominantly field

dependent. Results were analysed for the total sample as one FD group. Results showed eleven- and thirteen-year-old children's arousal executives were increasingly poor (i.e., the eleven-year-olds brought one unit less than their available $M$ to the task). Performance on the RSPM showed a dramatic decline in percentile rank with age, which confirmed these increasingly poor arousal executives. This concurs with a regular cross-cultural Piagetian finding which shows no formal operational thinking in certain cultures. All subjects evidenced poor temporal executives (i.e., made fewer attending acts than predicted in task analyses). In the CSVI-FR analysis it was shown that children employed more efficient temporal executives as the stimulus became more complex, but their maximum performance still did not reach the predicted level. The results confirm patterns found among children from other disadvantaged environments. Proposals are made for further research to isolate the factors involved in the poor arousal executive strength of the present sample, which conflicts with a previous finding that Zulu-speaking children employ their full $M_s$. The findings are related to the poor educational environment of the children and suggestions are made for improving school performance by encouraging active problem solving. This would focus first on maximising $M$ arousal, afterwhich temporal executives may be improved. Further, a warning is made to those who see training as a useful method to improve performance, for this does not maximise arousal and temporal executives within the child, but rather reduces the demand of the task.

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## 1. Contextualising the Research

The shocking and unacceptable state of black education in South Africa is a symptom of the inequality inherent in the State's policy of institutionalised racial segregation, apartheid. This inequality cannot fail to impact itself on those exposed to the system. For example, the Commonwealth report begins "None of us was prepared for the full reality of apartheid. ... It is awesome in its cruelty ... creating human misery and deprivation and blighting the lives of millions" (1986, p.23).

The educational inequality itself is awesome. It has been central in the development of apartheid "that blacks should not be over-educated" (Ibid., p.34). Consequently, the government spends one tenth the amount on each black schoolchild as they spend on white children (Omond, 1985, p.77). It is not an overstatement to refer to the crisis in black education.

"A serious concern on the part of responsible researchers that their work should not feed into social systems that may pervert the meaning of the research and use its findings to justify repressive policies" (R. Miller, 1984, p.4) has resulted in a lack of knowledge about the social, cultural and environmental influences on cognitive development and education. Differences, easily found with psychometric measures, are available as 'scientific' support for unjust social systems. Such data however, are misleading, for although the poor school performance in township schools is well-known, data which do not explain the nature and interrelation of the forces responsible for this performance merely describe a phenomenon without giving any 'scientific' understanding to the issue. Psychometric tests "measure illness simply by taking the temperature of the patient. If a cure is to be effected, it is important also to diagnose the nature of the

disease" (Wilson, 1986, p.5).

An appropriate strategy is to focus on underlying competence, which seen in interaction with culture can explain the poor school performance while at the same time preventing the exploitation by racists of superficial differences. If all children have the same mental capacity, black children have the potential to learn as well as their advantaged white counterparts. This is the strategy adopted in the present study. The poor school performance is seen as a result of an executive-learning deficiency, or poorly developed "general reasoning and conceptualisation skills acquired through experience" (M. S. Miller, 1980. p.3). The link between the development of executive skills (strategies) and the quality of the educational environment (in its broad sense) should be evident. In other words, the environment must provide opportunities (stimulation and encouragement) for children to use this (universal) capacity for maximum benefit.

To separate capacity from executive ability, the present study was developed within a neo-Piagetian theory, formulated by Pascual-Leone (eg., 1970, 1974, Pascual-Leone and Goodman, 1979). As the developmental mental competence previously was found among Zulu-speaking children (R. Miller, Pascual-Leone, Campbell, and Juckes, in preparation), the present study was undertaken to confirm again this capacity, and second, to understand the nature of the executive strategies used by the children, for it is these structures which should account for the poor school performance.

It is important that research of this nature be undertaken in South Africa, for scientific understanding (under-standing) of cognitive development will be most relevant to compensate for the present

inequality when "the doors of learning shall be opened !" (Commonwealth EPG Report on Southern Africa, 1986, p.159). "An awareness that we are engaged in a long, complex, and perilous course of social change should be a great stimulus to social scientific investigation" (Sutton, 1983, p.111).

## 2. Methodological Issues

In the present research the aim was to further understanding of cognitive functioning by observing a different culture. While contributing to knowledge about the cognitive development of Zulu-speaking children, the study attempted to further validate the explanatory power of a general theory of cognitive development and functioning, namely Pascual-Leone's Theory of Constructive Operators (TCO).

Cross-cultural studies in cognition need guidance from integrative theories which can explain cognitive functioning. For psychology in general, although the issue becomes particularly clear in cross-cultural research, it is necessary to explain, or model, those processes underlying, and generating, manifest (behavioural) performances. The environment-heredity debate, more commonly referred to as the nature-nurture controversy, is a direct result of a preoccupation with performance rather than process (or competence).

Jensen (1969) and Eysenck (1971; vs. Kamin, 1981) are two key players defending the genetic or heredity side. Cognitive performance, particularly intelligence, is largely ("about 80 percent" (Loehlin, Lindzey and Spuhler, 1975, p.8)) genetically determined. Having considered the differences in IQ scores between Negroes and whites, Jensen concludes: "So all we are left with are various lines of evidence, no one of which is definitive alone, but which, viewed all together, make it not an unreasonable hypothesis that genetic factors are strongly implicated in the average Negro-white intelligence difference" (1969, p.82). Despite some strong protestations to the contrary (eg., Eysenck, 1971, p.iif), these views, by giving 'scientific' status to a claim of genetic inferiority among

black people, foster racist views (cf. Brazziel, 1969). Jensen attempts to fortify his stance by undercutting the position environmentalists take against him. "There is an increasing realisation ... that the discrepancy [between Negro and white] average performance cannot be completely or directly attributed to discrimination or inequalities in education" (1969, p.82).

Perhaps the most notable reaction among environmentalists, who have argued for a 'cultural deprivation' explanation of such data has been to adopt a cultural relativist position (eg., Tulkin, 1972), which claims intelligence is adaptive behaviour, appropriate for the environment of a particular group or culture: a notion of universal intelligence is believed to be misdirected, and comparisons between groups are considered inappropriate. Referring specifically to cross-cultural psychology, the Laboratory of Comparative Human Cognition (LCHC) state the issue thus: "*In this sense*, we must adopt the position of cultural relativists ... that no universal notion of a single, general ability, called intelligence, can be abstracted from the behavior of people whose experiences in the world have systematically been different from birth in response to different life predicaments handed down to them in their ecocultural niche. In this sense, all cultures have to be considered equally effective in producing ways of dealing with the problems of survival of our species under unique patterns of constraint" (1982, p.710).

These two positions, of the environmentalists and hereditarians, appear to be in conflict. The manifest performance differences are clearly evident. However, it will be shown that these two apparently opposing research groups can be understood (rather than merely described) by looking beneath the manifest differences to explicate the methodology

inherent in, and uniting, these two poles of the nature-nurture continuum. Although in a different context, Searle (1984) has spoken of "a froth on reality". Behaviour is merely the 'froth' riding the wave of forces moving toward the shore. The fruitlessness of describing froth atop waves when the goal is to understand what is occurring in waves and causing the froth is obvious. But the problem with both hereditarians and environmentalists, different as they appear, is precisely this limited focus on the product of the organism (manifest performances) rather than on the causal mechanisms generating behaviour. Both approaches fail to appreciate the essential distinction in cross-cultural research between *competence* and *performance*.

Concern with manifest performance is a direct result of the methodology implicit in both positions. The "experimental methodology"[1] conceptualises the relationship between the individual and his/her environment as unidirectional and causal. For hereditarians, performance on IQ tests is (largely) the result of genetics. Cultural relativists (or more broadly, environmentalists) see intelligence as a product of the environment (LCHC, 1982, p.650). Both conceptions therefore, can be formalised by the function: $y = f(x)$. Cognition, or mind, in both instances is the variable dependent upon genes or environment (culture). However, this conception is "fundamentally wrong" (R. Miller, 1984, p.3). The *change* occurring in the individual can be explained only when the focus is shifted from overt behaviour to "the generative 'mechanisms' that give rise to the behaviour" (Harré and Secord, 1976, p.9).

Critics of Jensen and Eysenck (cf., Kagan, 1969; Eysenck vs. Kamin, 1981) find distasteful the notion of the apparent genetic inferiority of certain groups. Unacceptable as this may be, Jensen's contention (1969) is

clearly that 'scientific' facts must be faced: even if we do not like a spade, it is still a spade. But "increasing our knowledge of reality" (Ibid., p.79) serves only negative purposes when research cannot increase our understanding of reality. The 'facts' become 'myth' (Kamin, 1981, p.182) when it is realised "that comparing cultures in terms of manifest performances may be a misguided venture, based on essentially erroneous concepts of mind [IQ, as a measure of intelligence] and culture [genes], and the relationship between them" (R. Miller, 1984, p.5).

Traditional cross-cultural psychology also has focussed on manifest performance differences between cultures. Explanations were not provided, although their unidirectional conception of the relation between mind and culture led researchers to conclude that performance differences were manifestations of different underlying psychological processes, which were produced by different cultural environments. "If, as was usually the case, a statistically significant difference emerged this was duly reported; it was often stated or implied that the two populations varied not only in response to particular testing or experimental situations, but in their underlying psychological processes" (Jahoda, 1980, p.70f) The ethnocentrism of this approach ("how well they do our tricks" (Wober, 1969, cited in Berry, 1974, p.227)) led to views of inferiority or "'deficiency'" (Cole and Scribner, 1974, p.200).

In reaction cultural relativists "avoid spurious comparisons that rank and judge cultures as superior or inferior based on ethnocentric criteria" (R. Miller, 1984, p.5). This approach rejects psychological universals (Berry, 1974, p.225), preferring rather to focus on single cultures to isolate the eco-cultural variables responsible for manifest performances. While aware of the repercussions inherent in reporting apparent

differences, cultural relativists, like hereditarians, provide justification for racist policy. "In a malignant form it [cultural relativity] becomes separate development in which the so-called cultural relativity of various groups provides a basis for a social system that, at best, encourages and, at worst, forces people to remain locked into their own cultural past" (R. Miller, 1984, p.5).

Jensen and Eysenck foster determinist (as distinct from racist) views: Intelligence tests are seen to "'constitute a last judgment on the child's capacity, that they reveal "scientifically" his predestined ability'" (Lippmann, 1922, cited in Eysenck vs. Kamin, 1981, p.90). Cultural relativity, too, stifles, for the status quo is justified. At issue is the LCHC claim that "all cultures have to be considered equally effective in producing ways of dealing with the problems of survival" (1982, p.710). Cultures and individuals change continually; adaptation, which for Piaget constituted intelligence (Vuyk, 1981, p.49), is an ongoing *process*. The adapting organism is not simply a reaction to internal (genetic) or external (cultural) stimuli, as unidirectional models would have one believe, but human activity is "both responsive to, *and generative of*, the world within which such activity occurs" (R. Miller, 1984, p.6, emphasis added). The research focus on states of 'being' needs to be replaced with a concern to understand the process of 'becoming' (Ibid.). At any time, behaviour is only the manifestation of an underlying dynamism of generative mechanisms.

The concerns of hereditarians and cultural relativists have been illustrated. Because their conception of the relationship between mind and culture is erroneous, to see behaviour as isomorphic with, or at least a function of, the underlying cause (genes or culture) makes no contribution

to understanding. Manifest performances are meaningful only when embedded in a conception of the human organism which is able to explain change (R. Miller, 1984, p.5).

In reviewing both sides of the environment-heredity debate, the inadequacy inherent in any approach using the experimental methodology to distinguish competence from performance should be evident. Rather than focussing on differences between cultures, it is important that these differences be understood by explicating the psychological organismic mechanisms that generate (make possible) culture, or manifest forms. For cross-cultural psychology to make competence its focus, it is necessary that research be guided by constructive theories which are able to explain change and in this way make manifest behavioural differences comprehensible.

To overcome the limited scope of unidirectional models, a methodology must be adopted which can explain both the essentials of human action (change) as well as the manifestations (moments) of the productive processes. It is not unreasonable to accept Bhaskar's (1979) position that only such a model, which gives understanding to performance, can legitimately call itself scientific. "Bhaskar's position on science contains the important principle that the essence of science involves a movement from manifest phenomena to the generative mechanisms of such phenomena" (Craig, 1985, p.41). A clear exposition of the characteristics of such a developmental methodology is provided by Vygotsky (1978). Essential to the "developmental study of a problem [is] ... the disclosure of its genesis, its causal dynamic basis" (p.62). And to achieve this, the phenomenon must be seen *in the process* of change (Ibid., p.64f), for it is in the overcoming of constraints that one is able to

witness the genesis of behaviour.

The manifest behaviours studied by psychometricians, as well as traditional cross-cultural psychologists and cultural relativists, are developed performance schemes, or "fossilised forms". "These fossilised forms of behavior are most easily found in the so-called automated or mechanised psychological processes. ... They have lost their original appearance, and their outer appearance tells us nothing whatsoever about their internal nature" (Vygotsky, 1978, p.63f).

Vygotsky uses a distinction first made by Lewin in referring to the manifest performance as the phenotype and the causal dynamic as the genotype (Vygotsky, 1978, p.62). Jensen too noted the distinction (1969, p.17), but because of the "unidirectionally reactive"[2] (Vygotsky, 1978, p.71) nature of his proposal, focussed only on fossilised forms. Likewise, cross-cultural psychology considers only the phenotype. However, if one "believe[s] that human behavior comes to have [a] 'transforming reaction on nature'" (Ibid., p.61), the manifest behaviour must be subordinated to the discovery of the generative processes, or "actual origin" of the performance (Ibid., p.63). Hereditarians and cultural relativists describe the phenomenon, but without an explanation for the development of, or processes underlying, such a phenotype, their claims cannot justly be labelled scientific. Or, from an alternative perspective, "Piaget suggests ... a model of intelligence that starts with a ready-made organism and a ready-made environment is hard put to explain why any environmental stimulation should ever be welcomed" (Furth, 1969, p.228).

Key figures working in the developmental methodology have been Vygotsky and Piaget. Because he lived during a period of rapid social change, Vygotsky's contribution has been predominantly to explicate the

role of culture, or the extrinsic generative mechanisms (Craig, 1985, p.59). His student, Luria, has reported on these researches: "All of [this book's] observational material was collected in 1931-32, during the Soviet Union's most radical restructuring ... This period offered a unique opportunity to observe how decisively all these reforms affected not only a broadening of outlook but also radical changes in the structure of cognitive processes" (1976, p.v).

Piaget's concern was the intrinsic generative mechanisms, the individual's contribution to action. "The Piagetian psychologist is not concerned with the score on a test, but attempts to describe the basic structures and functioning of higher mental processes" (Dasen, 1974, p.409). He focussed on the overcoming of constraints to understand the development of logico-mathematical structures. This process of overcoming constraints, proceeding from "the unfamiliar to the familiar", he labelled equilibration (R. Miller, 1984, p.19).

The essence of the developmental methodology, explaining change, demands researchers follow Piaget's insight and observe individuals overcoming constraints, or performing tasks for the first time. Pascual-Leone has referred to such qualitatively different (cf. Craig, 1985, p.76), or new, performances as truly novel (Pascual-Leone, 1976d, 1980; Pascual-Leone and Goodman, 1979; Pascual-Leone, Goodman, Ammon, and Subelman, 1978) and shows that a complete analysis of a truly novel resolution has five dialectical moments. 'Objective' analysis describes the manifest behavioural phenomena, 'phenomenological' analysis accounts for the experiences of the individual, 'subjective' analysis emphasises the organisation and operation of schemes which contain the content of thought, 'ultrasubjective' analysis is concerned with higher order

executive schemes, and finally, 'metasubjective' analysis allows the explanation of truly novel behaviour by postulating a necessary bi-level psychological organisation of schemes and situation-free organismic metaconstructs (Craig, 1985, p.71f). It should be evident that, while all five moments are necessary levels of analysis, *explanation* , which necessarily entails a process-structural model of generative mechanisms, must be given at the metasubjective level. "A *meta-level* may be suggested as an appropriate basis for the consideration of the generative mechanisms underlying overt patterns" (Ibid., p.73). In contrast, the shortcomings of the experimental methodology are illustrated, for it only deals on the 'objective' level of analysis.

Piaget's epistemic subject is an attempt to explicate the intrinsic generative forces, for the child comes to know (understand) the world through his/her action. Vygotsky too sees understanding developing from action, but he was able to note how cultural influences are "internalised as intrapsychological functions" (R. Miller, 1984, p.20). Piaget and Vygotsky complement each other, for a model of psychological functioning must combine mind and culture as the two forces which realise "individuals acting in social groups" (Ibid., p.14). Whereas Piaget's epistemic subject is a conceptualisation of universal human capability, Vygotsky's social actor expresses particular developmental directions occurring when the epistemic subject is faced by particular socio-historical constraints. Thus Piaget's and Vygotsky's theories were formulated at different epistemological levels (Craig, 1985, p.73).

After his theory was taken into other cultures, Piaget became increasingly aware of culture as an important and necessary factor (mechanism) in cognition. "In the field of cognition, the main advantage of

cross-cultural studies is to allow a dissociation of socio-cultural and individual factors in development" (Piaget, 1974, p.300). Individual factors are universal capacities which interact with particular learning environments to generate behaviour. However, Piaget's theory remains primarily concerned with ideal structures, or universal capacities.

As a cross-cultural study, the present research aimed to dissociate cognitive competence or capacity from executive strategies developed to use and direct this capacity. In this way, an attempt was made to show that Zulu-speaking children have a universal, theoretically-predicted mental capacity. While the size of this organismic construct should be unaffected by environment, culture, as a learning environment, affects the strategies developed to employ this mental competence in relevant situations. Thus, it was expected that the poor school performance among Zulu-speaking children would be shown to be the result of poorly developed (or inappropriate) executives and independent of cognitive competence. In other words, the research, because of the theoretical foundation on which it was based, was able to distinguish development (universal competence) from learning (environment). The intrinsic (organismic) generative mechanisms in interaction with extrinsic (cultural) generative mechanisms produce manifest performances.

Such an approach need not deny or ignore differences between groups, as cultural relativists do, but nor can it encourage racist views, for the performance differences are possible only because culture is a universal human condition, which demands for its existence universal psychological organismic mechanisms, or competencies. The universality of human behaviour preceeds particular differences, or as Piaget (1976) notes, learning is secondary to development.

The model guiding the research was Pascual-Leone's neo-Piagetian Theory of Constructive Operators (TCO, see Chapter 3). The theory is useful insofar as it models both situation-free metaconstructs and content-specific schemes. As has been emphasised, cross-cultural research has not been successful in separating situation-free, or universal, competencies from content-specific, or cultural, differences. As a result, performance measures have confounded situation-free development with content-specific learning. Because Pascual-Leone notes the significance of the development-learning distinction (1976b, 1976c), his model is (and resulting tests are) valuable in cross-cultural studies: when learning is controlled, performance exhibits developmental competence alone.

A further advantage of the TCO is its ability to model performance (on the test used in the present study) with a mathematical (theoretical) distribution, and thus avoid comparing performance by one sample to that of another sample in the same design. The model against which performance is assessed is independent of any particular (usually "Western") cultural reference point. In this way, cross-cultural research need not test samples from different cultures to make comparisons which invariably rank cultures against one another. Nor need researchers shy away from cross-cultural studies, as suggested by cultural relativists. Cross-cultural studies within the model proposed allow each sample to be assessed independently. Incorporating the development-learning distinction, any cross-cultural comparison, by necessity, must account for both (universal) similarities and (culturally specific) differences.

Within the model, Piaget's descriptive term equilibration is explained as the increase in $M$-power, a universal cognitive capacity. Thus, it can be

"suggested that the primary role of children's culture might be to shape their executive repertoire, while the primary role of maturation might be to determine the rate at which their $M$-space [increases]" (Case, 1985, p.45).

Notes: Chapter 2

1. A term used by Vygotsky (1978) to emphasise the preoccupation with the manifest, S-R behaviour, rather than the generative mechanisms or competencies which underlie and explain the overt performance of subjects. To refer to the latter methodology, Vygotsky uses the term "developmental", for such an approach explicates the genesis of behaviour, instead of merely describing manipulated (S) behaviours (R). Note also that empirical studies are appropriate under both methodologies: the difference rather is one between empiricism and rationalism.

2. "A psychology built only on what people can do must, by its very nature, encompass a reactive view of man, and a concern with manifest phenotypic products rather than with the processes that generate performance" (R. Miller, 1984, p.18).

### 3. Pascual-Leone's neo-Piagetian Approach

Pascual-Leone presents his Theory of Constructive Operators, or TCO, (Pascual-Leone, 1970, 1974, 1976a, 1980; Pascual-Leone and Goodman, 1979; Pascual-Leone, Goodman, Ammon, and Subelman, 1978) as a constructive theory, originating in Piaget's genetic epistemology. From Piaget's theory, Pascual-Leone retains three features: development is a *constructive process* regulated by the organism, i.e., an intrinsic generative mechanism, and is consequently not explainable solely by learning, and that development proceeds through steps or stages, implying, at least, qualitative differences in cognitive structures and content (Goodman, 1979, p.1).

While accepting Piaget's constructivism (Vuyk, 1981, p.319), it is through this concept that Pascual-Leone's formulation transcends that of the Geneva School. Piaget's label for the process underlying (movement between) stages, equilibration, was no more than a descriptive term necessitated by the stage manifestations. "The progressive equilibration is an indispensible process in development and a process whose manifestations show modifications from stage to stage" (Piaget, 1977, p.17). Equilibration is the *necessary* process to account for the joint activity of assimilation and accomodation. However, the crucial, and difficult, component is to explain "what the causes are of the disturbance of the equilibrium, in other words, of disequilibrium" (Vuyk, 1981, p.68).

It is here that Pascual-Leone provides an important advance on Piaget's theory, as the TCO proposes a causal *explanation* of equilibration and stages (Ibid., p.320). In order to explain behaviour, the "generative mechanisms" underlying that behaviour (Harré and Secord, 1976, p.9) must

be modelled. The TCO is a general theory of cognitive functioning, and as such can explain the genesis of manifest behaviour (cf., Vygotsky, 1978). The theory is able to model the forces underlying human action and therefore can explain development (change) as well as the manifest performances, or "fossilized forms" (Ibid.), produced by these interacting mechanisms. This methodology is constructivist, for "to be constructive the theory should function as a conceptual gadget capable of simulating the genesis in the subject of his performances, i.e., capable of deriving these data, by means of a 'rational reconstruction' (Carnap, 1929) carried out on the theory's symbolic medium. A rational reconstruction explains the data by way of exhibiting the genesis of their construction" (Pascual-Leone, 1976d, p.90).

In formulating such a theory of the intrinsic generative mechanism, Pascual-Leone introduces a central term – "metasubject" (MS), named "after Freud's pioneering constructive notion of *metapsychology* " (Pascual-Leone, 1976a, p.111). A clear definition of the MS is "the subject's psychological organism, i.e., the silent (unconscious) organisation of functional structures or 'psychological machinery' underlying the subject's activity" (Pascual-Leone and Goodman, 1979, p.303). A constructive theory is necessarily metasubjective: it must describe the MS as well as metasubjectively represent or describe all relevant tasks (Pascual-Leone, 1976d, p.91). "By *constructive-rationalist method* I mean some form of metasubjective task-analytic procedure capable of yielding metasubjective simulation models of the organismic processes (strategies) which underlie any *type* of performance in a *type* of task by a *type* of subject" (Pascual-Leone, 1980, p.290). To state the problem differently, "the puzzle of the psychological organism consists in

finding a constructive model of the MS which permits, given adequate information, to infer the metasubjective description of any environment or task, and the metasubjective process underlying the behaviour which the subject produces in that task or environment" (Pascual-Leone, 1976a, p.111).

Two of the ten requirements which Pascual-Leone proposes (1976d) for a constructive theory deserve comment. Requirement 6 demands that the theory employ an MS language which can represent the temporality of behaviour and mental processes. Piaget's theory does not meet this requirement (p.98): his theory is a descriptive-structural model (Pascual-Leone et al., 1978, p.244). Violating this requirement prevented Piaget from explaining, or finding the causal mechanism underlying, equilibration.

Rather, Piaget proposed that stages (descriptive-structural model) are caused by equilibration (another descriptive-structural model). But equilibration is a *process* which is manifested in performance as stages. In fact, equilibration and stages "both exist as structural aspects of the data base" (Pascual-Leone, 1980, p.275). Equally, stages do not cause performance: stages describe, structurally, behavioural invariances (Ibid.). The question which Piaget was unable to answer is what is involved in the process of equilibration, or, in Pascual-Leone's terms, Piaget was unable to give a process-structural account of equilibration. For this reason, Pascual-Leone's theory can be said "to be a model of the psychological organism (*the metasubject*) which is at work inside Piaget's 'epistemic subject' for each age group" (Pascual-Leone et al., 1980, p.271).

It is not sufficient, although it is necessary, "to study something ... in the process of change" (Vygotsky, 1978, p.64f), as the overcoming of

constraints, *seen* in change, needs a metasubjective analysis, i.e., a model of the functioning of the underlying "psychological machinery". Against Piaget, Pascual-Leone can "claim that psychological theories ... must be *process-structural*; a causal account of the processes of equilibration and the manifestation of general stages must include an explicit representation of the step-by-step temporal *functioning* of the developing system" (Pascual-Leone et al., 1978, p.244). This difference will be illustrated below when considering Pascual-Leone's metasubjective task analyses of Piaget's (and his own) tasks.

By posing the learning paradox (Pascual-Leone, 1976d, 1980; Pascual-Leone and Goodman, 1979; Pascual-Leone et al., 1978), Pascual-Leone requires constructive theories go beyond mere learning to include organismic-structural factors (Requirement 8). Constructive theories must be able to explain truly novel performances. Whereas "a novel performance is not explicitly represented in the subject's repertoire (LTM) by any given structure but is *implicitly represented* in the constructive possibilities that the repertoire of structures as a generative system can produce ... [truly novel performances] ... result from the interaction (integration) of several productions or production systems (schemes or structures) which together co-determine the performance, but such that *no pre-existent*, learned or innate, integration mechanism of the situation-specific production type (eg., a suitable goal organisation in the productions or a special high-level goal production system) that might monitor the performance in question is likely to exist" (Pascual-Leone, 1980, p.283f).

A learning paradox is involved when a subject produces a truly novel behaviour, a behaviour qualitatively different from those previously

executed (Craig, 1985, p.76), and this behaviour has never been produced (by that person) before, and is "complex and improbable enough not to have been produced by 'chance'" (Pascual-Leone, 1976d, p.94). This behaviour cannot be the result of learning, as a subject cannot learn before he/she has had a chance to produce a simple instance of the behaviour. "To say otherwise (this is the learning paradox) is to imply that learning can take place without experience. This paradox can be resolved by concluding that truly novel behaviour does exist and that it is produced by organismic factors different from learning" (Ibid.).

At this point it is worth noting that Piaget's reliance on descriptive-structural models, rather than process-structural models, prevented him from clearly differentiating learning (habitual structures) and development (ephemeral structures resulting from creative acts or equilibration processes) (Ibid.).

Truly novel behaviour is the result of a "choice" between various possibilities (schemes) orchestrated by organismic factors (Pascual-Leone and Goodman, 1979, p.304). This intrinsic "choice" mechanism also emphasises the intentionality, or goal-directedness, of human action (cf. Searle, 1983, 1984) and reflects again the active (constructivity of the) organism, or MS. In the TCO this is formalised in the Principle of Assimilatory Praxis (see below).

Pascual-Leone thus overcomes the learning paradox by postulating in the TCO a Bilevel Psychological Organisation Principle of schemes (learned contents or subjective operators) and metaconstructs (basic organismic factors or silent operators responsible for the "choice" among schemes, and basic principles) (Pascual-Leone et al., 1978, p.253 and 265).

Schemes: The Subjective System of the Metasubject

Through interaction with the environment, the organism gains information. For Piaget, this meant the assimilation and accomodation of objects into schemes, or knowledge units. "A scheme is 'an organised set of reactions that can be transferred from one situation to another by the assimilation of the second to the first' (Piaget and Morf, 1958, p.86)" (Pascual-Leone, 1978, p.253). While accepting the important notion of scheme, Pascual-Leone emphasises that schemes are units representing the *processes* which exist in Reality (with a big "R"), the outer world. The subject's reality (with a small "r") is the repertoire of schemes, or "the universe of semantic-pragmatic constraints", which the subject has found in interaction with Reality (Pascual-Leone and Goodman, 1979, p.311). "Knowledge and praxis are two sides of *the same* coin. ... To know an object one must interfere with it or act upon it; only in this praxis can the constraints of reality be generated in the MS and create knowledge" (Pascual-Leone, 1976a, p.112). For this reason, Pascual-Leone refers to schemes as semantic-pragmatic units (Ibid., p.116).

Schemes apply under minimal conditions of satisfaction, meaning a scheme (or cluster of compatible schemes) will assimilate information unless prevented by a more dominant scheme (or group of schemes). This tendency of schemes to apply under minimal conditions is formalised as the Principle of Assimilatory Praxis, discussed below (Pascual-Leone et al., 1978, p.269). Internal and external (input) processes can activate schemes. Once activated, and dominant, the set of effects determined in the scheme modifies the ongoing behaviour of the MS (Ibid., p.,253).

All schemes are constituted by two components[1]: a releasing

component (*rc*) and an effecting component (*ec*). To institute a scheme the conditions existing in the *rc* must be matched with constraints (features) of Reality. These matched conditions are cues which bring the *ec* of the scheme to bear. "The *effecting component (ec)* of a scheme is the set of *effects* (pragmatic or semantic consequences, meaning, action blueprints, expectancies – the structural descriptions, plans or procedures) which the scheme in question reflects (stands for, carries)" (Pascual-Leone, 1976a, p.116).

Before considering the types of schemes Pascual-Leone distinguishes, note that schemes are the only situation-bound units in the MS, and *because* schemes are semantic-pragmatic units, they must carry in them the epistemological notions underlying semantics and pragmatics, respectively *truth* and *causation* (Pascual-Leone, 1976a, p.117). Although the functional organisation of the MS does incorporate schemes and metaconstructs in a dynamic model, only schemes have a referent, and therefore will be true, if and only if, they represent correctly (have the attributes) of this referent. Equally, metaconstructs alter activation weights of schemes, but it is only the (set of) dominant *scheme(s)* which results in (cause) behaviour.

There are three types of schemes:

(a) Predicates:

A predicative scheme ($\emptyset'_i$) is any set of constraints which adds properties or relations to, or abstracts properties or relations from, another scheme ($\emptyset_j$), and so creates a new scheme ($\emptyset_k$), but does not subtract (destroy, cancel) any property or relation of $\emptyset_j$ (Pascual-Leone, 1976a, p.117). Adding "small" to "red rose", and

the alternative of abstracting "small" from "small red rose" are examples. Only predicates have referents; epistemological truth must be based on schemes of the predicative form (Ibid.).

(b) <u>Transformations</u>:

In contrast to predicates, transformational schemes ($\Psi_i$) change, by subtracting (destroying) properties of a second scheme, a mental object ($\emptyset_j$), to produce a new mental object ($\emptyset_k$). Thus, a rose attached to a plant ($\emptyset_j$) is transformed ($\Psi_i$) by cutting the flower, resulting in a bloom separated from the plant ($\emptyset_k$). Of course, transformations carry with them the notion of *causation*. Pascual-Leone speaks of "*direct causation effectiveness*", and notes that "causation is the necessary and sufficient characteristic of a transformation as truth was of a predicate" (Ibid., p.118).

(c) <u>Fluents</u>:

Fluents, or transformation-representing predicates ($L_{ijk}$), are a special type of predicate structure which, in effect, adds motion to (or project) a static mental object. None of the properties or relations of the mental object ($\emptyset_j$) are destroyed in generating the mental object $\emptyset_{ijk}$, but $\emptyset_{ijk}$ is now of a conditional form: if transformation i ($\Psi_i$) applies on mental object j ($\emptyset_j$) a new mental object k ($\emptyset_k$) will be produced. The fluent adds transformational relations to a mental object to generate a Tolmanian expectancy (a new mental object) (Ibid.,

p.119). Elsewhere Pascual-Leone has referred to "operative expectancies ... [which] ... reflect the consequences of a transformation, without actually effecting a transformation" (Pascual-Leone, 1978, p. 254).

Because fluents represent transformations, and function in a conditional form, they "have access to *indirect MS causation*" (Pascual-Leone, 1976a, p.120). This would be the case, for example, if a driver saw a child standing at the side of a street with a foot raised ($\emptyset_j$) and generated, through the action of a fluent, the mental object $\emptyset_{ijk}$ "the child is beginning to cross the street". This expectation would effect the transformation ($¥_l$) "stopping" to apply to the mental object ($\emptyset_m$) "moving car". The fluent has not directly caused the driver to stop the vehicle. In the sense that $\emptyset_{ijk}$ is an *expectation*, the fluent resulting in this mental object also has an *indirect truth value*. Although referring to simple predicates, Pascual-Leone's comments can apply to fluents: "Any applied predicate ... will acquire the truth value *true* if, and only if, the set of figural or semantic effects which it attributes to the referent can in fact be found in the referent" (Ibid., p.118). The new (terminal) mental object ($\emptyset_{ijk}$) is not immediately true or false. This emphasises the important characteristic of fluents that "their set of effects contain a temporal organisation ... To emphasise that the flow of time-ordered events and possibly time itself are metasubjectively created by transformation-representing

predicates I have proposed to call this type of predicates, *fluents*" (Ibid., p.119).

Piaget's three types of schemes are descriptive-functional (Ibid., p.124). Action necessarily involves change (i.e., temporality) and a model of the MS must understand schemes process-structurally. Thus, Piaget's figurative, or "presentative schemes ... [which] ... concern permanent and contemporaneous characteristics of objects" (Vuyk, 1981, p.175) (i.e., "schemes which describe and function as mental objects" (Pascual-Leone, 1976a, p.115)), can be either "ordinary predicates or fluents *activated on their arguments*" (Ibid., p.124). The latter refers to non-instantiated fluents, or fluents which remain in the conditional form. A fluent activated on its argument, if it represents the most appropriate (or most activated) expectancy, will process (i.e., release) only when the transformation in the fluent also is activated.

Operative or "procedural schemes consist of sequences of actions serving as means to attain a goal, while the goal determines the actions" (Vuyk, 1981, p.175). For Pascual-Leone, operatives are transformations as well as fluents, "fluents *activated on their transformations*" (1976a, p.124). Such fluents are 'in motion' as their representation is activated *with* (or *by*) the transformation represented.

The executive[2] or "operational schemes" in Piaget's writing "are a synthesis of procedural [operative] and presentative schemes [figurative]" (Vuyk, 1981, p.175). These schemes can be thought of as management schemes in the MS organisation, meaning they "monitor (i.e., the control, planning functions) the combination and temporal order of activation of schemes so as to produce a given complex goal-directed performance" (Pascual-Leone, 1976a, p.115). Executives correspond to Pascual-Leone's

fluents because "they stipulate *ways to proceed* which are appropriate for accomplishing the task" (Goodman, 1979, p.24). As 'plans', executives must be transformation-*representing*.

Finally, note that schemes are "a sort of recursive function" (Pascual-Leone, 1978, p.254). The *rc* and/or *ec* of any scheme may be constituted by other schemes. Such a functional structure allows for superordinate schemes or superschemes to be constituted (Pascual-Leone, 1970, p.306). Functionally, however, all schemes are indivisible units: any represented (situation-specific) constraints which allow different actions must be functionally separate in the MS (Pascual-Leone et al., 1978, p.254). An activated and dominant scheme must produce its effect (conclusion), but this process may demand the processing of other subordinate schemes.

Metaconstructs: I. Basic Organismic Resources: Silent Operators

The learning paradox demands for its resolution that a set of situation-free organismic resources be postulated (cf. Pascual-Leone, 1976d, p.94). These constructive (silent) operators are able to account for truly novel performances, and Pascual-Leone, borrowing a term from Chomsky, refers to this ability of the MS to produce habitual *and* truly novel performances as "generative constructivity". But silent operators are also needed to explain the developmental process, i.e., "changing the internal organisation of structures by way of *enduring* novel constructions in order to increase the organism's adaptation" (Goodman, 1979, p.27). Using a Piagetian term, Pascual-Leone speaks of "psychogenetic constructivity" (1980, p.263).

Seven silent operators are incorporated in the TCO:

(a) <u>Two types of Learning</u>:

Pascual-Leone's model clarifies Piaget's fuzzy notion of equilibration; consequently he is able to distinguish Learning (one organismic factor) from Development (the factor responsible for movement between stages) (Pascual-Leone, 1976c, p.292). Piaget linked learning and development, arguing that the fundamental relation underlying both is assimilation (Piaget, 1976, p.77). And learning is subordinated to development: "learning of structures seems to obey the same laws as the natural development of these structures" (Ibid., p.76). There are two types of learning in Pascual-Leone's theory, Content ($C$) learning and Logical ($L$) learning.

i. "$C$ learning corresponds to a differentiation of schemes and to empirical abstraction of Piaget" (Vuyk, 1981, p.381). Empirical abstraction (or physical experience) is brought about through both assimilation and accommodation. When the invariants of a scheme cannot assimilate experience, the scheme has to "modify itself (change its invariant) and bring the invariant to a closer agreement with reality" (Pascual-Leone and Goodman, 1979, p.340). As noted, the $rc$ or $ec$ of a scheme can be constituted by subordinate schemes. $C$ learning involves the scheme representing the $rc$ or $ec$ of the main scheme ($H_i$)

becoming a subordinate scheme $(H_j)$, activated henceforth whenever $H_i$ is activated. However, activation of $H_j$ alone cannot lead to the activation of $H_i$ (Ibid., p.340f). "Because of this unidirectional activation pattern, $C$ learning could be regarded as a metasubjective explication of the behaviourist notion of simple conditioning" (Ibid., p.341). This non-mutual "relation of functional service" (Ibid.) prevents the creation of epistemologically higher-level schemes (Vuyk, 1981, p.381).

It also is possible that the objects of change (*rc* or *ec*) are not (yet) schemes but rather "physiological, receptor or effector, central processes *which were not previously* represented in the metasubject" (Ibid., p.340). Clearly, the $C$ learning involved in representing purely physiological processes in $H_i$ results in truly novel conditions and/or effects in the MS (Ibid.). $C$ learning of this sort explains "differentiation (eg., practice without feedback...) as well as the processes which cause much of the so-called trial-and-error learning, skill learning through practice, 'know how' and purely experiential learning ('know it')" (Ibid.).

ii. *L* learning, or Logical learning, has been referred to as enduring "coordinations" of schemes by Piaget. In contrast with $C$ learning, "$L$ structures are superschemes, i.e., schemes defined at a higher epistemological level than the level on which the schemes which $L$ structures reflect have been defined" (Ibid., p.341). $L$ structures represent "the relations of coactivation existing among or between schemes" (Pascual-Leone, 1974, p.29). This suggests $L$

learning results in complex "networks" or "structural" models within the MS. Pascual-Leone notes the equivalence of $L$ learning with terms used by both Piaget's theory and the information-processing approach (Pascual-Leone and Goodman, 1979, p.342).

a) <u>$L$ structuring via overlearning ($LC$ learning)</u>

If the conditions which allowed $C$ learning to occur were encountered repeatedly, the schemes involved would all be co-activated on each occasion. When activated, these schemes will all have high assimilatory strength allowing that, over time, these schemes may come to assimilate one another (Goodman, 1979, p.51). This will result in "a structural chunk or $LC$ structure" (Pascual-Leone, 1974, p.29). Piaget used a descriptive term for such learning: "'reciprocal assimilation among schemes'" (Pascual-Leone and Goodman, 1979, p.341). The resulting structure of densely interlocked associations remains appropriate only for those tasks which would require the joint activation of the schemes now united in the $LC$ structure. $LC$ structures are thus "functionally rigid", but succeed in simplifying a task by reducing the task demand (or number of schemes which need to be activated to complete the task) (Pascual-Leone, 1974, p.29). Whenever a scheme within the $LC$ structure is independently required for a task *"strong interference effects* occur. [But] when the conglomerate as a whole is relevant to a task its activation is fast (*largely parallel processing*) and its phenomenal character is holistic

and gestalt-like" (Pascual-Leone and Goodman, 1979, p.344).

$LC$ structures form a repertoire of experiential knowledge, simply due to repeated encounters with reality. Overlearning is not the result of conscious awareness, and is continuous and cumulative throughout development. Perceptual $LC$ structures (patterns) are especially frequent: in any visual field many features have been united - it may even be difficult for a subject to realise that previously he/she had attended to constituent features (schemes) (Goodman, 1979, p.51f).

b) $L$ structuring via $M$ weighting ($LM$ learning)

When mentally aroused the subject adds mental attentional energy ($M$-power, see below) to relevant schemes to increase their activation weight. This results in all schemes having similar and maximum activation weights, the condition for $L$ learning to begin (Pascual-Leone and Goodman, 1979, p.344). $L$ structuring through $M$ boosting creates superschemes which are general (mobile) rather than contextually anchored and "present the reversibility, associativity, combinatorial properties etc. of Piaget's operational structures. $LM$ structures are like multi-purpose programmes" (Pascual-Leone, 1974, p.31). Piaget's term "reflective abstraction" (Pascual-Leone and Goodman, 1979, p.341) captures the notion that a higher level structure is produced from mentally attending to the schemes.

Temporal task executives, or time-characterised fluents, are plans or general "ways to proceed" (Goodman, 1979, p.24),

and clearly must be created through $LM$ structuring. Because $M$ limits the number of schemes which simultaneously can be activated and $M$ increases developmentally, $LM$ learning is limited by $M$-capacity. "When $M$-power is equal or greater than $M$-demand, rapid learning will occur; learning will not be possible if $M$-power is smaller than $M$-demand" (Ibid., p.54).

Because of its dependence on $M_p$, $LM$ learning should improve within each developmental stage, and overall exhibit "a more or less linear growth developmental trace function" (Ibid., p.63). This growth in $LM$ structures within stages is similar to Piaget's notions of "preparation" and "consolidation" within stages (Ibid., p.55).

Interestingly, Pascual-Leone has reviewed neuropsychological literature, saying it "suggests that $LM$ structures tend to be localised in the dominant (usually left) hemisphere, $LC$ structures tend to be localised in the minor (right) hemisphere" (Pascual-Leone, 1974, p.31). More recently (9 June 1986), Pascual-Leone confirmed these findings in a personal communication to the author.

(b) The $M$-operator:

This is the primary developmental construct of the TCO, which allows Pascual-Leone to *explain* the process of equilibration as an increase in $M$-power. "The $M$-operator can be conceptualised as a reserve of mental energy which is allocated to raise the activation weight of task-relevant schemes" (Pascual-Leone and

Goodman, 1979, p.323). From the outset, it should be emphasised that $M$, as a *constructive* operator, is a *scheme booster*: $M$ is more than a developmentally qualified version of a short term memory space or capacity. Pascual-Leone's earlier writings (eg.,1970) may have encouraged this simplified view as he refers to $M$ as "the central processor or computing space" (1970, p.307). But de Ribaupierre and Pascual-Leone present data distinguishing the $M$-construct from "the empiricist concept of short term memory" (p.36). In the very active MS, $M$ is more than a space !

Although $M$ is the operator which makes development possible, all activity generated by the MS is the result of the constructive operation of all silent operators on schemes, following the principles set out in the TCO. "Mental capacity (the $M$-construct) will be recognised as a *necessary* condition for development, but not a *sufficient* condition to explain how this development comes about" (Kuhn, 1983, p.93). Nevertheless, $M$ is "the *transition rule* or key organismic *change* for passing from one Piagetian stage to the next" (Pascual-Leone and Goodman, 1979, p.328; see also Pascual-Leone, 1970).

While studying with Piaget in the early 1960's, Pascual-Leone proposed $M$, having undertaken semantic-pragmatic analyses of many Piagetian tasks. All tasks relevant to a particular Piagetian substage required the simultaneous activation of a *minimum* number of schemes in order to solve the task (Pascual-Leone and Goodman, 1979, p.325). Solutions to Piagetian tasks are possible only when the reserve of $M$ ($M_r$ , or $M$-power, $M_p$ ) of the organism equals or exceeds the $M$-demand of the task. Thus, the

$M_p$ of an organism is the *maximum* possible number of schemes which a subject can hold in $M$ simultaneously (centrate, $M$-operate) to work out the solution to the problem. The quantitative value of $M$ represents a number of schemes and has nothing to do with the content (amount of information) held in the schemes (Ibid.). An $LC$ chunk and a simple $C$ structured scheme would both require one unit of $M_p$ for activation.

Pascual-Leone proposed that $M_p$ remains constant during each Piagetian developmental substage, but increases by one unit every two years from age three to 15. Table 1 shows this growth in $M_p$.

Two points need to be made concerning the table. First, $M_p$ is represented as a function of $e + k$. Part of the dominant executive, the arousal executives, brings $M$ to bear when task relevant schemes, appropriate to satisfy the dominant affective goal (i.e., allow the implementation of the dominant executive) need a boost in their assimilatory strength (M. S. Miller, 1980, p.7f). Of this $M_p$, temporal task executives (plans) are activated by $e$, and remain $M$-boosted for the duration of the task. "The *executive function* ... includes 'keeping in mind' a goal to be achieved and selecting means of reaching the goal" (Chapman, 1981, p.147). Thus $e$ keeps a plan dominant and at the same time inhibits (interrupt control, see below) other activated schemes, which are irrelevant to the present task (M. S. Miller, 1980, p.8). The $M$-capacity needed by $e$ is developed during the sensorimotor period and remains constant hereafter. The $k$ variable reflects the

Table 1

Predicted <u>*M*-Capacity Corresponding to the Average</u>

<u>Chronological Age of Normal, Field-independent</u>

<u>Subjects: Piaget's Developmental Substages</u>

| Predicted maximum power of $M$: $M_p = e + k$ | Piaget's substage | Average Chronological Age ( in year pairs) |
|---|---|---|
| e + 1 | low substage of preoperational period | 3 – 4 |
| e + 2 | high substage of preoperational period | 5 – 6 |
| e + 3 | low concrete operations | 7 – 8 |
| e + 4 | high concrete operations | 9 – 10 |
| e + 5 | substage introductory to formal operations | 11 – 12 |
| e + 6 | low formal operations | 13 – 14 |
| e + 7 | high formal operations | 15 – adults |

(Pascual-Leone and Goodman, 1979, p.324)

developmental growth of $M$, for $k$ is the number of schemes which simultaneously can be activated by the subject; these are the integer values Pascual-Leone found in his analyses of Piagetian tasks. Note the maximum value of $M$ corresponds to G. A. Miller's (1956) "magical number seven".

The title of table 1 qualifies that the predicted $M_p$ applies only to "Normal, Field-independent Subjects". This does not mean that field-dependent subjects have a different $M_p$, but only that, under normal conditions, they perform with less $M_p$. Pascual-Leone explains this as follows: "The $M$ controls (arousal executives) can be adjusted through learning so that they mobilise an amount of $M$-energy proportional to the evaluated difficulty of the task. These $M$ arousal controls may be connected with general affective arousal which possibly regulates their driving power" (Pascual-Leone et al., 1978, p.267). A distinction between reserve $M$ ($M_r$) and functional $M$ ($M_f$) is necessary. "Pascual-Leone distinguishes *structural M* capacity, the maximum potential capacity available to the subject, and *functional M* capacity, the capacity that the subject uses at any given moment" (Chapman, 1981, p.147). Functional $M$ "can be influenced by a multiplicity of factors, from the degree of motivational arousal and the degree of fatigue to some individual difference variables such as Witkin's field-dependence-independence" (Pascual-Leone, 1970, p.304f). Goodman further notes that "subjects with few opportunities to develop a rich repertoire of executive schemes" (1979, p.43) may

show a discrepancy between $M_s$ and $M_f$.

These differences notwithstanding, $M$ growth is posited to increase regularly in all[3] children. However, performance differences in the executives ($LM$ structures) allow variation across subjects of the same age (Ibid., p.41). Pascual-Leone claims "indirect" research evidence that $M$ "has a heavy biogenetic determination if it is not purely so" (Pascual-Leone and Goodman, 1979, p.352). The physiological or neurological growth underlying $M$ probably is continuous, although psychologically $M$ is an integer value, implying an all-or-none manifestation. "There will be no psychological expression of the underlying physiological process until an additional scheme can be fully activated" (Goodman, 1979, p.46). Pascual-Leone and Goodman (1979) have suggested neurological correlates for $M$: "$M$ may correspond to the functional link connecting the prefrontal lobe with the descendent track of the reticular system. As Luria (1975) and others suggest, this functional link may serve to affect, via the reticular system, the electrical activity in other parts of the cortex" (Note 7, p.359f).

A central feature of the $M$ -construct in predicting performance is that the $M$-demand of a task be metasubjectively analysed. In the following chapter a metasubjective task analysis for Pascual-Leone's Compound Stimulus Visual Information (CSVI) task, used in the present study, will be presented. At this point it is sufficient to consider the dimensionality of a Piagetian conservation task. Conservation of substance problems are generally solved at about age 7 years. In the TCO, this means

three schemes (additional to $e$) are simultaneously involved. The task is graphically illustrated in figure 1. In the task a child is shown two equal-sized balls of plasticine, a and b, and acknowledges that both balls contain equal amounts of plasticine. Ball b then is rolled into a sausage-shape, b´, in front of the child. The question posed to the child is whether the two objects, a and b´, have the same amount of plasticine in them.

The three schemes and executive are:

1. A semantic representation of the relation between the two original plasticine balls, a and b.

2. A semantic dimension representing the transformation, b to b´.

3. A semantic dimension that must classify the transformation. In this case, the classification could be either a quantity-preserving transformation or a quantity-changing transformation.

$e$. To estimate whether plasticine ball a contains the same amount of substance as plasticine sausage b´.

These three schemes (with $e$ ) need to be simultaneously $M$-boosted in order to realise a and b´ contain equal amounts of substance. This is an example of the type of semantic-pragmatic (task) analyses Pascual-Leone undertook in Geneva (Pascual-Leone, 1980, p.268f)[4].

Note that repeated exposure to a task can reduce the $M$-demand through chunking ($LC$ learning) (Pascual-Leone, 1976b, p.277). This explains how it is possible to have children successfully solve tasks which Piagetian theory and the TCO would not predict. The $M$-capacity of the individual is not altered.

Training can also allow children to perform beyond their stage level, "by giving tasks of the same type but which require less $M_p$. Then, when the $M$-demand of the task is gradually increased, via learning, the child succeeds where he at first failed" (Vuyk, 1981, p.393). In other words, the amount of $M$ needed for $e$ is reduced as $e$ becomes automated (Pascual-Leone and Goodman, 1979, p.324).
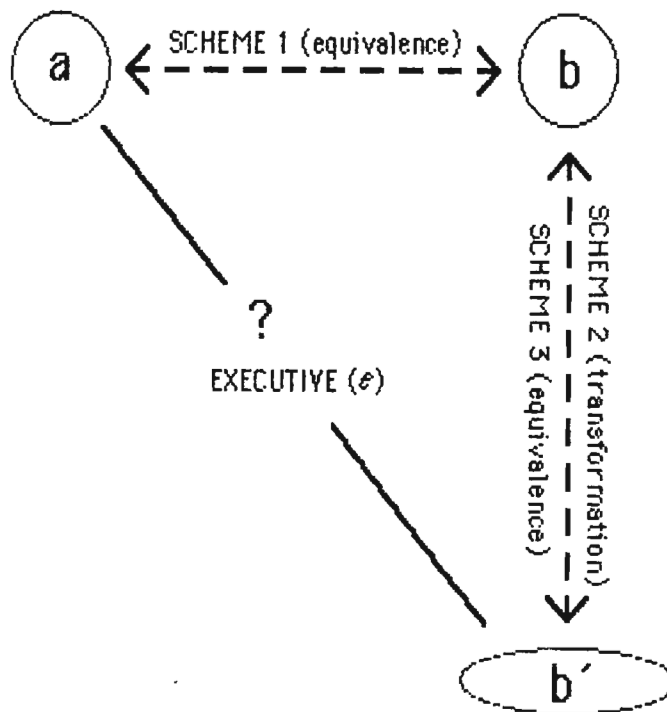


Figure 1: Piaget's conservation of substance task, indicating Pascual-Leone's structural task analysis

Any reference to the TCO emphasises the *M*-operator. Of four anomalies Pascual-Leone found in Piaget's programme (all of which are overcome in the TCO), the *M*-operator accounts for two[5]:

(b) the unexplained role of information-processing load in children's performance, and

(d) the age-bound transition process from one Piagetian state to the next (Pascual-Leone and Sparkman, 1980, p.95).

Geneva's difficulty in explaining the process underlying (Piaget's descriptive label) equilibration has been overcome by postulating the *M* silent operator. "The strength to overcome B [misleading strategy] that A [correct strategy] exhibits the first time the task is spontaneously solved must come from some situation-free organismic factor. This factor, is, I claim, *M*" (Pascual-Leone, 1980, p.287).

## (c) The *F* Operator:

*F* reduces complexity (both informational and structural) in the MS by organising perceptions on their most salient psychophysical features (Goodman, 1979, p.31). This sensorial *F* ($F_s$) applies early in processing. "$F_s$ ... corresponds to the content saliency of cues, which is due to the nature of the stimulus (magnitude, intensity) and/or the innate characteristics of the receptors. $F_s$ therefore reflects the psychophysical properties of the stimulus ... the innate content saliency of cues" (Pascual-Leone and Goodman, 1979, p.314).

A processing $F$ effect ($F_p$) applies after all other silent operators have added their individual weights to the schemes. $F_p$ aims to bring to bear (weight) those schemes which will produce economic, consistent and structurally cohesive performances. If this activated set of schemes is relevant in the task, the situation is called *F-facilitating*, while an $F$-boosted set of irrelevant schemes results from an *F-misleading* situation (Goodman, 1979, p.35). Pascual-Leone and Goodman (1979) make explicit the equivalence of $F_s$ to the autochthonous field forces of Gestaltists, the field effects and figural factors of Piaget, the Minimum Principle of neoGestaltists, and the S-R compatibility factor used by Learning researchers (p.314).

The CSVI task has been able to show the influence of $F$. The Bose-Einstein (BE) probability model Pascual-Leone employs to predict performance does not anticipate perfect performance, even though subjects make most responses while viewing a stimulus. Pascual-Leone argues that cues attended to become more salient and are thus more likely to be sampled with each successive attending act (sampling with replacement). "This translates in the CSVI to the redundant attention to cues already responded to" (Goodman, 1979, p.33). This saliency factor ($F$-effect) makes the BE predictions appropriate for performance on the task, rather than an alternative model which expects (nearer) perfect performance (sampling without replacement).

As $F$ aims for compactness, consistency and information minimisation, and $LC$ structures embody such reduced

complexity, $F$ becomes increasingly influential (strengthens) as the $LC$ repertoire develops. Like $LC$ structures, $F$ increases regularly throughout development.

Pascual-Leone summarises well the $F$-operator, noting both the $F_s$ (external) and $F_p$ (internal) component roles of $F$: "It could be fruitfully regarded as the metaconstruct bringing about a response resolution or performance closure to *any metasubjective state of affairs* externally or internally induced" (1974, p.31).

(d) The / Operator:

In a cognitive conflict situation a 'choice' must be made between two competing sets of activated, but incompatible, schemes. Pascual-Leone therefore postulates the Interrupt operator which "anti-boosts" (Pascual-Leone et al., 1978, p.268) one set of schemes. Insofar as / applies to "schemes external (irrelevant) to the dominant executive process" it could be termed an *external interrupt* (Ibid., p.270f). / applies equally in non-misleading contexts, for it is necessary to continually "cut down" or interrupt (Ibid., p.268) the assimilatory strengths of irrelevant schemes. The / operator is monitored by $E_I$[6], and will function either to "filter" attention (i.e., narrow the attentional beam), by strongly interrupting competing (irrelevant) schemes, or, to the contrary, open the input channel (widen the beam) by weakening its effect, i.e., de-interrupting (Ibid.). Pascual-Leone notates these functions $I$ and $\bar{I}$, respectively. "Clearly the $I/\bar{I}$ functions are, together with $M$-power and $E_I$, the mechanisms of

Piaget's centration/decentration" (Ibid.).

Related to the / operator is a decay or habituation mechanism which accounts for deactivation of dominant schemes. Pascual-Leone refers to this as an *internal interrupt* "because it interrupts the very schemes that are internal to the dominant executive process" (Ibid., p.270). "Over time then, an active scheme that is no longer boosted by any silent operator or by the input should be subject to a decay of its assimilatory strength" (Goodman, 1979, p.43).

Because the interrupt is controlled (directed, monitored) by $E_I$, its developmental course parallels that of $E_I$. "The more articulated the subject's executives and the more precise their criteria of relevance and irrelevance, the more will interruption effects be manifest in the course of mental processing" (Ibid., p.59). However, Goodman notes that this characterisation needs qualification, and shows how it may be necessary to both interrupt (I) and de-interrupt ($\bar{I}$) at different moments in a problem-solving process. De-interruption-controlling executives will develop after interruption-controlling executives, for the former can only develop after negative effects have resulted from I. In the latter part of each stage (second year) the efficiency with which subjects employ both I and $\bar{I}$ should be improved, as executive controls (*LM* structures) improve within each *M* stage (Ibid., p.61).

The two final silent operators will only be mentioned to complete the overview:

(e) The *A* Operator:

Affective factors (*A* ) are either motivational or arousal scheme boosters ("*general affective arousal*" (Pascual-Leone et al., 1978, p.267)), or they can be situation-bound "specific instinctual needs" (Pascual-Leone and Goodman, 1979, p.316). Pascual-Leone subsumes both forms under the *A* silent operator, for the latter, too, "*merely change the activation weight of some of the perceptual-motor or cognitive schemes*... [and] ... *do not bring about a change in the MS's figurative* (i.e., mental object) *state*" (Pascual-Leone, 1974, p.26) as is generally characteristic of schemes.

(f) The *B* Operator:

Personality biases and beliefs (*B* ) are "essentially superordinate structures that reflect interactions, in particular types of situations among all the silent operators. It follows that *all* control executives are to some extent *B* controls" (Pascual-Leone et al., 1978, p.268). Like *A*, *B* is considered a silent operator as it boosts (biases) cognitive schemes (Pascual-Leone and Goodman, 1979, p.318).

Metaconstructs: II. Basic Principles governing the MS

The most extensive coverage of the "theoretical and epistemological presuppositions of the theory" lists six principles (Pascual-Leone et al., 1978, p.269ff)[7]. As Pascual-Leone notes, the principles serve to express the "basic rules governing functional relations among constructs of the theory" (Ibid., p.269). It is in this latter sense, as a summary of the *functioning* MS, that the principles are reviewed. The preceeding discussion of schemes and silent operators has indirectly expressed these principles; herewith a more formal statement:

1. Principle of Assimilatory Praxis

   The *active* , *goal-directed* nature of the MS is emphasised, and especially the tendency of schemes, under *minimal* conditions of satisfaction, to apply in performance (Ibid.).

2. Principle of Equilibration

   As equilibration is the process connecting successive states of equilibrium-disequilibrium-equilibrium (Vuyk, 1981, p.67), it is important for the MS, after each structural change, to "(a) *maximise the internal consistency* among its functional parts, (b) *maximise adaptation* (functional payoff) in its dealings with the environment, i.e., maximise the number of different *types* of situations with which the organism can successfully interact without having to learn (i.e., to change its internal structures), and (c) *minimise internal complexity* (organismic structural cost) in its organisation, i.e., organise its psychogenetic and generative constructive processes in such a manner that (a) and (b) are satisfied with a minimum of learned and innate resources"

(Pascual-Leone and Goodman, 1979, p.304).

3. Principle of Bilevel Psychological Organisation

The learning paradox made it necessary to postulate a set of content-free organismic factors, thus producing a bilevel psychological organisation of schemes and silent operators. The metaconstructs "apply on the first-level constructs (not on the output) to modify their activation strength (i.e., assimilatory strength) or to modify the constructs themselves (learning) in accordance with organismic requirements" (Pascual-Leone and Goodman, 1979, in Vuyk, 1981, p.322, quotation modified by Pascual-Leone in a personal communication to Vuyk).

4. Principle of Psychological Logical Modular Organisation

Pascual-Leone views the MS as a kind of "organismic logical machine" (Pascual-Leone et al., 1978, p.269) composed of "relatively autonomous components [modules]" (Ibid.), i.e., the schemes and the silent operators.

5. Principle of Schematic Overdetermination of Performance (SOP Principle)

Groups of compatible schemes "sum their activation weights [assimilation strengths] in order to increase their degree of dominance" (Ibid., p.270). The cluster of schemes which, at any moment in the generative process, has the highest terminal (summed) activation weight (i.e., is dominant) will apply. This is the SOP principle.

6. Principle of Scheme Inhibition and Decay (SID principle)

This principle formally states the need to posit a mechanism to deactivate irrelevant modules. As noted, the TCO allows both the

decay and habituation (internal interrupt) and interruption (external interrupt) to control scheme activation.

The coverage of Pascual-Leone's TCO has been detailed; although the study focussed ostensively on the $M$-operator and the development (complexity) of executives among Zulu-speaking children, to explain the task analyses and interpret the results it is necessary to understand the schemes and metaconstructs interacting in the MS.

Notes: Chapter 3

1. Some schemes, however, do have an added terminal component (tc).

2. Pascual-Leone replaces Piaget's term 'operational', translated from 'operatoire', with 'executive', arguing that the former term "is grossly misleading in its usual English translation because of its homonymity with the quite different concept of operational, found in the empiricist 'operational definitions' or 'operationalism'" (Pascual-Leone, 1976a, p.115, footnote).

3. The third requirement for a constructive theory Pascual-Leone states thus: "As the constructive theory has to be a theory of human psychology it must be general enough to apply in principle to any human being" (1976d, p.92).

4. Notice that a complete metasubjective task analysis involves the explanation of the step-by-step processing (above, only a structural analysis is given) involved in performing the task. The Attend-Operate-Evaluate (A-O-E) processing cycles involved in the CSVI task is a temporal executive, bringing to the fore the role of repeating $M$ applications. This will be considered in the following chapter.

5. The other anomalies are:

   "(a)  the unexplained role of misleading (or facilitating) perceptual field factors and learning factors which affect children's performance; [and]

   (c)  the existence of horizontal decalages" (Pascual-Leone and Sparkman, 1980, p.95).


6. "The subscript I is intended to stress this interrupt function of the set $E_I$, in addition to its role in carrying the metasubject's 'instructions' (its cognitive goal) and the corresponding plans which statisfy these instructions" (Goodman, 1979, p.44).

## 4. Review of Empirical Studies

### 1. Cross-cultural Piagetian Research

While no cross-cultural research has denied the sequence of Piaget's stages, there is evidence indicating that subjects in some cultures do not reach concrete operations (Dasen, 1974). Even more regular is the finding that some samples do not exhibit formal operational thinking (eg., Laurendeau-Bendavid, 1977). Further, the rate of acquisition of the stages varies across cultures. Dasen (1974) reviews findings which show that in a cross-cultural context it is not unlikely to find 'early' or 'late' acquisition of stages. These findings can be summarised in terms of an invariant sequence of stages and a variable rate of acquisition across cultures (Dasen and Heron, 1981).

Although Piaget emphasises that cross-cultural psychology is advantageous in dissociating "sociocultural and individual factors in development" (1974, p.300), his descriptive term 'equilibration' does not distinguish clearly development and learning. Consequently, researchers tried to replicate the developmental stages in different cultures without addressing in sufficient detail the effect of the culture or learning environment. In other words, cross-cultural Piagetian tasks, while reflecting the qualitative stages, are not able to isolate competence from factors involving the learning environment. Because Piaget's theory underemphasises learning in favour of development, it cannot explain cross-cultural differences. As has been shown (see chapter 2), a cross-cultural approach needs to be able to explain both similarities (universals) and differences (particulars) between cultures.

For this, a theory such as the TCO is necessary, for it accounts for both development and learning, and, in providing a quantitative value to the former, is able to make a (universal) competence measure by controlling learning. Further, it is able to assess the quality and strength of learned structures (schemes) which produce the cultural differences.

## 2. Empirical Support for $M$-Growth

Since proposing the developmental construct $M$, Pascual-Leone has created a number of tasks to verify his $k$ estimates. The empirical evidence supporting these quantitative predictions has been impressive (Case, 1974; DeAvila, Havassy, and Pascual-Leone, 1976; Globerson, 1981; Goodman, 1979; M. S. Miller, 1980; R. Miller, Pascual-Leone, Campbell and Juckes, in preparation; Parkinson, 1985; Pascual-Leone, 1970; Pascual-Leone and Smith, 1969; Pascual-Leone and Goodman, 1979).

One of the standard, and most frequently used, $M$-capacity measures is the Compound Stimulus Visual Information (CSVI) task. The CSVI involves learning a number of simple S-R associations. Visual stimuli are linked to behavioural responses. During the test, which follows once subjects have learned these associations, the number of visual cues presented on each trial is compounded. Because of the $M$ increase, older children are able to activate more task relevant schemes than younger children. A mathematical model is used to make specific performance predictions based on the hypothesised $k$ estimates. As this task was used in the present research, studies which have employed this test will be reviewed.

In 1970, Pascual-Leone reported what has since become the modal study on $M$, showing it to be the transition rule for the progression

through Piaget's developmental stages. Since that keynote paper, the tone and direction of many studies have been limited to expanding the data base provided.

In Pascual-Leone's study, the visual stimuli were presented on cards, and gestural responses were taught. For example, a 'large' shape would be associated with the response 'open mouth', while 'square' would be linked to 'raise hands'. Pascual-Leone theoretically limited the number of pairings to be learned by each of four age groups (five, seven, nine, and eleven) to $3 + k$. Thus, a seven-year-old ($k = 3$) learned six associations (1970, p.310). The number of cards in each compound class of the test series also varied for each age group, with the majority of test stimuli clustering around those compounds predicted to demand $k$ and $k + 1$ units of $M$ (i.e., expected ability level and too difficult for that age group). In later studies these theoretical loadings were removed.

Another facet of this study is that Pascual-Leone used a free-response procedure. Subjects viewed the compounds for five seconds and were able to begin responding as soon as they saw the test card. There was no limit on the time taken to respond to each compound, although subjects could no longer refer back to the compound after the five second viewing period.

Clearly, $M$ measures attempt to isolate $M_s$, meaning that steps must be taken to equate $M_f$ with $M_s$. For the CSVI tests, field-independent (FI) subjects must be selected (Pascual-Leone, 1970, p.309). However, this control has not always been necessary. Globerson (1985) has shown that both field-dependent and field-independent subjects have the same mental capacity, while the CSVI study reported by R. Miller et al. (in preparation)

did not control for cognitive style and yet supported Pascual-Leone's $M$ model.

Pascual-Leone showed a dramatic correspondence between the theoretically predicted distributions, based on predicted $k$ values, and the empirical data (1970, p.325f). While the results strongly support the $M$-operator, a quantitative difference between Piaget's substages of cognitive development, the study was attacked severely by Trabasso and Foellinger (1978). However, Pascual-Leone's first response (1978) showed his critics' misrepresented facts and misunderstood the methodology involved. This latter point became central: "Trabasso and Foellinger's criticism of my paper illustrates the problem of comparing research programmes based on a general-modelling (eg., rationalist) epistemology ... with those based on a local-modelling (eg., empiricist) one" (Ibid., p37). The debate continued (Trabasso, 1978; Pascual-Leone and Sparkman, 1980), but the focus became this rationalist-empiricist methodological divide, rather than the CSVI data. Nevertheless, Pascual-Leone showed (1978) how effectively the $M$-operator model predicts and explains the data.

Goodman (1979) also has verified the predicted $k$ values. The administration of her test differed from Pascual-Leone (1970) insofar as all subjects (seven- to twelve-year-olds) learned nine associations and were all tested on the same number (42) of compounds. She argued that this procedural modification was necessary, as there is a "lack of justification for theory-based adjustments" (1979, p.190). Six sets of seven compounds (stimulus class 2 through 8) were presented in the test series, with randomisation within each block. In the present study the test series were constructed in a similar manner. Goodman followed

Pascual-Leone in using gestural responses, but replaced the free-response procedure with a delayed-response format. This prevented children responding during the five second viewing period, although here too, no terminal limit was set on response time.

The data supported the predicted $k$ estimates for each age pair, but interestingly Goodman was able to distinguish a practice (learning) effect in the latter year of each age pair. Goodman showed $LC$ structuring to be continuous, but dependent upon the $M$ stage of the child. Such a finding provided empirical support for Pascual-Leone's theoretical reasoning which demanded a developmental construct be postulated (distinct from learning) to avoid a learning paradox.

Until recently, the CSVI has not been used outside "Western" culture, although DeAvila et al. (1976) did use other $M$ measures to support the model in Mexican-American children. Two studies have focussed on socio-economic status (SES).

In her study, M. S. Miller (1980) used two versions of the CSVI which allowed three forms of analysis. The tachistoscopic procedure was analysed in terms of 'first look' and 'repeated looks' responses. The free-response procedure, following Pascual-Leone (1970), was also administered. The first look analysis, being the best estimate of $k$ used ($M_f$) can be employed to predict performance in the repeated looks procedure, for the latter gives a measure of the number of attending acts (looks) made using $M_f$.

Miller only tested two age groups on the CSVI (9-10 and 11-12 years), but found low SES children of both groups used a $k$ of 4, while high SES subjects showed the predicted increase, from 4 to 5 units, in $k$ (p.101f).

In the repeated looks analysis, low SES children of both groups used the same $k$ (4.5), while high SES subjects showed an improvement (5 to 6 units). Although performance for both groups on the free-response procedure remained constant across ages, the high SES subjects performed at a $k = 5$ level, and low SES children performed with $k = 4$ (Ibid.).

The present study followed Miller by giving both forms of the test and making the same three analyses. However, one difference introduced altered the order of tests: the free-response preceded the tachistoscopic version. A second difference concerned analysis. As the first look gives an estimate of $M_f$ and the repeated looks procedure an estimate of the number of attending acts, a theoretical prediction was made for repeated looks which used these two values.

Miller's study, undertaken in response to Jensen's 'genetic deficiency' arguments, showed performance in low SES children is poorer than for high SES children due to an "executive-structural deficiency (general concepts and abstract reasoning that require human mediational learning) relative to high SES children" (M. S. Miller and Pascual-Leone, 1981, Abstract, p.i). Miller concludes her thesis by claiming that "only when the child is equipped with the necessary executive power to maintain a consistently high $M^k$ [$M_f$] processing level can the CSVI be regarded as an estimate of $M^k$ capacity [$M_s$]. Since the executive conditions can typically be met only by high SES children, CSVI measures can be regarded as a capacity measure only for high SES children, not for low SES children" (1980, p.136). However, her study was able to show a capacity-strategy distinction, and thus refuted Jensen's claims.

Globerson (1981), working with Israeli children, also showed $M$ is

independent of environment (SES). She argued that "it is possible that tests on which marked social class (SES) differences are found confound factors of development with learning" (p.2). Because $M$ is an organismic situation-free construct, $M$ must be universal. Therefore, "the transition rule of this mechanism is a self-regulatory developmental system ... not easily affected by experiential differences" (Ibid., p.3f).

R. Miller et al. (in preparation) report the first CSVI study outside "Western" culture, having tested Zulu-speaking children in South Africa. Further, the study was the first to use the CSVI in group sessions. The delayed-response procedure was given to children in each age-year group from seven to twelve years. Results supported the $M$ stage model, except that 8-year-olds overperformed at the 9 year level. Relating these findings to Goodman's data, the even-year performance improvement due to learning was not found. The Zulu-speaking children, coming from a disadvantaged environment, were unable to learn more efficient task executives in the second year of each $M$ stage. Goodman's subjects, by contrast, were from an advantaged situation, and consequently were faced with situations demanding full and efficient use of $M$.

The present study developed from the earlier study (R. Miller et al., in preparation) in an attempt to understand more clearly the executive-structural deficiency in terms of arousal-parallel-processing executives (bringing $M$ to the task) and temporal task executives (repeatedly using $M$ to improve performance and to deinterrupt competing but irrelevant schemes) (cf., M. S. Miller, 1980). For disadvantaged children in South Africa, this research is important on two levels: first, it aims to show developmental factors can be distinguished from learning, implying the poor school performance of these children can be traced to political,

economic and cultural factors facing township dwellers in South Africa. Politically, South Africa's blacks are victims of apartheid. Economically, apartheid has used the capitalist social structure to force blacks to the working class. Culturally, the rapid movement towards, and absorption by, an urban and "Western" social form, prevents cultural mediators (eg., parents, traditional caretakers) from preparing children adequately for their new and rapidly changing environment. Secondly, following from the above, the research should provide direction for those intervening, presently and in the future, to improve school performance.

## 5. Method

The only previous study undertaken among Zulu-speaking children to confirm Pascual-Leone's $M$-construct and its developmental change (R. Miller, Pascual-Leone, Campbell and Juckes, in preparation) showed the expected $M$-power. However, the Zulu-speaking children were less efficient when using their $M$ than advantaged children studied in Canada (Goodman, 1979). Although their arousal executives were as efficient (they brought their full $M_s$ to the task), their temporal executives were weaker. This was shown in the fewer attending acts made by the Zulu-speaking children relative to the Canadian children. To investigate the capacity-strategy issue, two alternative versions of Pascual-Leone's Compound Stimulus Visual Information (CSVI) task were used in the present study. Further, Pascual-Leone has argued (1970, p.309) that Witkin's cognitive style difference affects $M_f$, the amount of $M$ used in a task. To assess field-independence-dependence, the group administered Children's Embedded Figures Test (CEFT), "developed by Karp and Konstadt (1963) for children in the 5 - 8 year age range" (Witkin, 1967, p.246), was given to all subjects.

Following M. S. Miller (1980), who showed an executive-learning deficiency among children of low socioeconomic status, the Zulu-speaking children, because of their disadvantaged situation, were also expected to exhibit an executive weakness. To independently assess the executive level of the subjects, the Ravens Standard Progressive Matrices Test (RSPM) was administered to all children. The RSPM test, as a general intelligence measure, has been shown to reflect $M$, insofar as a task

analysis of the RSPM reflects the $M$-demand of the items in the test (Bereiter and Scardamalia, 1979). Thus performance on RSPM will reflect amount of $M$-demand which subjects can satisfy, i.e., a measure of $M_f$. But equally, as $LM$ structuring (temporal executive learning) depends on amount of $M$ activated, the RSPM test also gives an indication of the level of $LM$ structuring in the subjects.

1. The CEFT and RSPM

In the CEFT children are introduced to a geometric shape (tent or house) and told to look at the pictures in their booklet and indicate where the geometric shape is hidden (embedded). The geometric shape found must be the same size and in the same orientation as the original shape. Children may refer back to the original shape, but cannot view both the shape and picture (shape in embedding context) simultaneously.

The RSPM has 60 items, each of which "consists of a matrix of figures with a missing element. The subject's task is to identify which of several options is the missing element" (Bereiter and Scardamalia, 1979, p.45).

2. The Compound Stimulus Visual Information (CSVI) Task

The CSVI task, developed by Pascual-Leone (1970), has become a central $M$ measure. The advantage of the test, especially in the context of cross-cultural studies, is that it attempts to control learning, and in this way it tries to isolate a purely developmental factor. However, the CSVI cannot measure $M$-capacity ($M_s$) for low SES children (M. S. Miller, 1980), nor is it an $M_s$ measure for FD subjects (Pascual-Leone, 1970). For both groups, arousal executive deficiencies prevent subjects using their full $M$

-power. Although $M$ is theoretically (and necessarily) independent of other metaconstructs, it is not independent in performance or measurement. Prior to $M$-application, the other constructive operators contribute weights to the relevant schemes and this may produce a set of schemes which require little $M$-weighting, for the weight contributed by the other operators alone makes this set of schemes dominant and avoids the conflict ("choice") which would require strong $M$-arousal executives. FD subjects, for example, have strong $LC$ and $F$ operators and poor arousal executives (see task analysis below).

M. S. Miller (1980), however, did show low SES children have the predicted $M_s$, while Globerson (1985) showed $M_s$ is not affected by cognitive style differences and R. Miller et al. (in preparation) validated $M$ cross-culturally. Thus, any healthy and sufficiently nourished child can be expected to have a normal $M$ capacity, irrespective of his/her $M_f$. Of course, malnourished and otherwise handicapped children show maturational effects. As $M$ is physically based in the organism's maturation, it too will be affected (eg., growth slowed or prematurely halted). But empirical support for $M$, based on any physically normal, healthy subjects gives $M$ universal validation for all such subjects.

The strength of the CSVI is its ability to distinguish $M_f$ and executive strategies. By measuring $M_f$, the difference between $M_s$ and $M_f$ can be used as an indication of the arousal executive deficiency. Further, the number of attending acts made can be compared with the number predicted by the task analysis. Again, the magnitude of this difference estimates the strength of temporal (task) executives. As arousal executives apply prior to temporal executives (for the latter depend upon

amount of $M$ brought to the task), both need to be assessed to avoid attributing weakness to temporal executives where this weakness actually results from poor arousal or $M$ controls.

In the CSVI subjects are taught a repertoire of nine simple S-R associations, illustrated in table 2. Each stimulus (eg., "square") can be linked either to a motoric gesture (raise arms) (Pascual-Leone, 1970; Goodman, 1979) or to a specific design on a button in a response display box (M. S. Miller, 1980).

Once subjects have learned the associations they are pretested on a strict criterion, to ensure their repertoire equals that of other samples. In the test phase the stimulus displays are "stimulus compounds presenting a variable number of nested cues ... the very same cues they have learned before" (Pascual-Leone and Goodman, 1979, p.38). Subjects have to respond to all the cues (messages) they see in the compound. The test displays compounds from two to eight cues.

As the TCO predicts an $M$-power for each two year age group from three to 15 years, the recall for each of these ages should reflect the $k$ estimates. Younger subjects should reach a maximum recall level (ceiling) reflective of their $M$-power as the task demand ($M$-demand, or number of cues presented) increases. With increasing $M$-power more of the task's $M$-demand can be satisfied. An overall mean expected empirical score can be calculated for each subject as well as for each age group. The expected scores for each stimulus class and for the total task, for each age, are compared with values calculated, using the theoretically predicted $k$ values, in the Bose-Einstein Occupancy Model of Combinatorial Analysis (Pascual-Leone, 1970; Feller, 1957).

Table 2

Repertoire of S-R Associations, indicating also the recording symbols used in Free Response (CSVI-FR) Procedure.

| Simple $S_n - R_n$ | Positive Instance | Negative Instance | Response to Positive Instance | Recording Symbol |
|---|---|---|---|---|
| $S_1 - R_1$ | Square | Circle, cross, triangle | Raise arms | / |
| $S_2 - R_2$ | Red | Various colours | Clap hands twice | // |
| $S_3 - R_3$ | Big | Small | Open mouth and say "Ah" | O |
| $S_4 - R_4$ | Broken border | Solid border | Arms to side | — |
| $S_5 - R_5$ | Circle in centre | Absent | Stamp floor | ⊥ |
| $S_6 - R_6$ | Frame | Absent | Stand up | ∿∿ |
| $S_7 - R_7$ | Cross in centre | Absent | Cross arms over chest | X |
| $S_8 - R_8$ | Purple background | White background | Hit bench | V |
| $S_9 - R_9$ | Underline | Absent | Touch nose | Λ |

Two procedures of the CSVI were used in the present study. In both, the structure of the task followed Goodman (1979): all subjects were taught the nine associations and were tested on 42 compounds. The test series comprised six blocks of seven slides. Each block contained one instance of each compound, from two to eight cues. Slides were randomised within each block. Appendix A describes each of the test slides and gives the presentation order for each procedure.

The first procedure used, the CSVI-Free Response (CSVI-FR), allowed the children to view each test slide for five seconds, during and after which they were able to make gestural responses. In the tachistoscopic version, CSVI-TACH, subjects viewed the stimulus for 120ms each time they pressed a control button on the response box before them. After each viewing of the slide, a mask was displayed and children responded to as many cues as they could recall. In this procedure, children could view each compound as many times as they felt necessary to respond to all the stimuli. To perform well on both these procedures, it is important for subjects to employ a temporal task executive, exhibited as a persistent searching strategy (M. S. Miller, 1980, p.37).

## 3. Task Analyses

### (a) Cognitive Style: Field-dependence-independence

All subjects face a cognitive conflict situation in tests of cognitive style. But it is the outcome of this conflict which characterises the subject as FD or FI. To discover (disembed) the geometric shape hidden in the complex drawing, subjects need a strong *overcoming process* if they are to avoid the power of the *embedding context*. Field independent subjects therefore have high

*M*-arousal and efficient task relevant schemes. In contrast, field dependency is due to a low *M*-arousal and poor executives ($e_I$), which allow the misleading (embedding) context to have relatively high weight and come to bear in the situation. Strong *LC* and *F* structures enhance the probability of producing FD performance. Both FI and FD subjects have a large repertoire of *LM* structures, which with improved saliency and cohesiveness, strengthen *F*, but FI subjects have a relatively strong overcoming process. In logical form, this cognitive conflict situation can be stated as

$$(M . e_I) x_f \vee (LC \vee F) y_f$$

where $x_f$ represents the overcoming process undertaken in the figurative domain, and $y_f$, the embedding process, which also is figurative. The logical connective ('and') is represented by '.' and the disjunction ('or') is expressed by 'v' (Pascual-Leone, 1974).

Because children from disadvantaged learning environments are known to show low *M*-arousal ($M_f$ not equivalent to $M_s$), and poor executives (cf., M. S. Miller, 1980), the children in the present study were expected to be predominantly FD.

(b) <u>CSVI Tasks</u>

The learned S-R associations are represented in the metasubject by nine superordinate schemes ($\emptyset_{z1}$, $\emptyset_{z2}$, $\emptyset_{z3}$ ...) in the subject's total repertoire of schemes, H. Within each superscheme there is a perceptual scheme ($z_i$) representing the stimulus cue ($S_i$), an

operative scheme ($z_i'$) corresponding to the motor response ($R_i$), and a fluent (transformation-representing scheme) of the form: $z_i \rightarrow z_i'$ (Pascual-Leone, 1970, p.313).

Sensorial input that matches the perceptual scheme, $z_i$, brings into activation, $H^*$, the superordinate scheme $\emptyset_{zi}$. The CSVI test compounds thus result in a "perfect representation of the stimulus compound $S^n$" (Pascual-Leone, 1970, p.313) in $H^*$. Unless the superscheme has been overlearned, $M$ is needed to move (proceed with) the transformation. Therefore, although all children may have the same repertoire, the $M_p$ of each subject limits the number of schemes which simultaneously can be activated and can bring about a response. Recall that part of $M$ (i.e., $e$) keeps active the task instructions ($\yen_I$) and the representation of the task situation ($\yen_S$). The balance of $M$ (i.e., $k$) activates the superordinate schemes in $H^*$.

Pascual-Leone further analyses the metasubjective processing, arguing $M$ is applied to the schemes brought into $H^*$ by the stimulus compound. From one to $k$ schemes can receive $M$ energy, depending on how this energy is distributed across the schemes. "Note that each of the $k$ energy units is *randomly* applied ... simultaneously with and *independently from* all other $k-1$ energy units available in the $M$ system" (Pascual-Leone, 1970, p.315). Each application of $M$ energy is considered an 'attending act' or 'psychological moment'.

(i) CSVI-FR

Having made one attending act, a subject is likely to attend again. Metasubjectively, after attending (A) and responding (or operating, O), a subject must evaluate (E) his/her performance. This involves attending to the $e$-activated schemes ($\Psi_I$ and $\Psi_S$) and the scheme representing (resulting from) the just-completed A-O activity. In applying $M$ to these schemes, $k-1$ units of energy are redundant. For Pascual-Leone, the "$M$-operator is left 'unsaturated'" (1970, p.316), and this effects another attending act. A-O-E cycles continue until $M$ is saturated: $k$ attending acts, each using $k$ units of $M$, are made. Thus, $k^2$ energy units are used, afterwhich the subject halts attending.

Performance on the free-response procedure of the CSVI has been shown to correspond to this analysis (Pascual-Leone, 1970; M. S. Miller, 1980). However, to continue making attending acts, the subject must employ executive controls which "prevent a premature stop rule" (M. S. Miller, 1980, p.136). Furthermore, Miller notes, "to maintain a consistently high $M^k$ processing level" (Ibid.) also demands executive power. But "the executive conditions can typically only be met by high SES [socioeconomic status] children" (Ibid.).

Thus, in the present study, performance on the CSVI-FR is expected to use an $M_f$ lower than $M_s$ (available $k$). If the discrepancy between $M_s$ and $M_f$ increases across age, even an across age constant temporal task executive (eg., $k(k-1)$) will result in relatively poor performance, for such subjects will begin

the task with less $M$ to apply, due to poor arousal executives. The executive level indicated by the RSPM test compares $LM$ structuring to the norm: If $M_f$ is increasingly distinct from $M_s$ (poor arousal), RSPM scores should show a relative decline across ages, even though temporal executives may remain constant.

(ii) CSVI-TACH

The tachistoscopic, or repeated looks, version of the task is obviously more sophisticated than the free response procedure. While the task analysis for the CSVI-FR is essentially equivalent in this procedure, the advantage here is that this version allows the dissociation of the temporal executive (number of looks made) from the $M$ used (arousal executives).

The analysis performed on the results of this task was divided into first look and repeated looks components (cf. M. S. Miller, 1980). From the task analysis it should be clear that the first look performance is the best estimate of the $k$ used. As noted above, FD subjects are characterised by poor arousal executives, suggesting $M_f$ would be lower than predicted. It is to be argued that the disadvantaged environment of the present sample results in an inequality between $M_s$ and $M_f$.

The CSVI-TACH task followed the CSVI-FR procedure to minimise the transfer of any executive learning which may have accrued in the first task. While the subjects in the present study were not expected to have well developed executives, the tachistoscopic version is more likely to encourage the development of a persistent temporal strategy. It was therefore a necessary

precaution to give children the CSVI-FR procedure first.

### 4. The Bose-Einstein Occupancy Model

The TCO's $M$-operator analysis of the CSVI "can in turn be interpreted in terms of an occupancy model of combinatorial statistics, namely the Bose-Einstein model (Feller, 1957)" (Pascual-Leone and Goodman, 1979, p.38). For each age group an expected theoretical score can be calculated for each stimulus class ($S^n$) and for the overall task.

Metaphorically, the Bose-Einstein (BE) statistic is concerned with "the outcomes generated by the process of throwing randomly a number k of balls into a number n of cells ... How many cells will be filled (with at least one ball) after having thrown k balls into n cells ?" (Pascual-Leone, 1970, p.318). The expected theoretical score can be thought of as the number of cells from the number (n) available, filled with at least one ball. In the CSVI model, the expected scores (theoretical and empirical) indicate the mean number of responses predicted or made, or the number of schemes $M$-boosted, out of the number of cues presented ($S^n$).

In the BE, only *distinguishable* arrangements of balls are considered (Feller, 1957, p.39f). And unlike the more common Maxwell-Boltzman probability model[1], the BE assigns probabilities to cells based on the number of balls already in each cell. "In the Bose-Einstein model the more balls already in a cell, the more likely is another ball to fall in the cell" (Goodman, 1979, p.220). This represents accurately the CSVI model, for once sampled, a scheme has an increased saliency, or $F$-weight, making its resampling more likely. In other words, sampling ($M$-boosting) of schemes in $H*$ is *probabilistic*, based upon the saliency of the S-R associations, due to a "compatibility $F$ effect" (Ibid.).

To calculate the BE probabilities the number of cells and number of balls must be specified. Each distinguishable arrangement has an equal probability of

$$\left( \begin{array}{c} n + r - 1 \\ r \end{array} \right)^{-1}$$

(I)

where n = number of cells available and r = number of balls (Feller, 1957, p.39f). In the CSVI-BE model, the number of cues presented (stimulus class, $S^n$) represents the cells, and the number of units of $M$ energising schemes (Pascual-Leone, 1970, p.319) corresponds to the balls thrown. Expected scores ($E(x)$) for each stimulus class can be found by calculating the product of the BE probability and the corresponding stimulus class.

Further, it is possible to predict the number x of cells which will contain at least one ball after k balls have been thrown. The probability that k balls will be distributed through x cells is

$$Pr\,(x) = \frac{\left( \begin{array}{c} n \\ n - x \end{array} \right) \left( \begin{array}{c} k - 1 \\ x - 1 \end{array} \right)}{\left( \begin{array}{c} n + k - 1 \\ k \end{array} \right)}$$

(II)

If in the CSVI-FR procedure subjects use a $k^2$-k model, probabilities can be calculated using

$$Pr(x) = \frac{\binom{n}{n-x}\binom{k^2-k-1}{x-1}}{\binom{n+k^2-k-1}{k^2-k}}$$

(III)

For the CSVI-1STL (first look) procedure, subjects will only be able to make one attending act. Therefore, for the first look analysis, formula (II) is appropriate (The expansion of this formula along with a worked example are given in Appendix B).

Reinterpreting this more complex function in the TCO-CSVI terminology, x reflects the number of different relevant responses, from 1 to n (the total number possible), produced by subjects with a limited, age-predicted $k$ energy level.

5. Subjects

The sample was drawn from two schools, both of which are situated in the black township of Indaleni, outside Richmond, Natal. Thirty children were selected in each of four age categories, seven, nine, eleven and thirteen years, where those chosen were closest in age to the given age category. All children performed the Children's Embedded Figures Test (CEFT), the Ravens Progressive Matrices Test (RPMT) and the Free Response Compound Stimulus Visual Information Task (CSVI). However, in the Tachistoscopic procedure of the CSVI some children were excluded. Some could not reach criterion on the pretest, while others evidently

were overcome by the task demand. These latter subjects had to be continually reminded by the teachers to "Ask for another slide, if you have finished", "Do you want to look again ?", "Have you seen all the messages ?". Still other subjects had left school. Table 3 shows the distribution of the sample in each test. Table 4 shows the age and sex distribution for the sample.

6. Procedure

Both the CEFT and RPMT were performed in groups of ten children. The Zulu instructions given the children for both these tests, along with the English originals, are given in Appendix C.

The CEFT was given to the subjects twice. Approximately six weeks separated the two tests. It was necessary to give the test twice as some children clearly did not understand the task instructions. However, in analysing the data, those children who did understand the task demand on both occasions had their scores averaged. The correlation between the two CEFT scores was r = 0.592 ($r^2$ = 0.350).

For the two versions of the CSVI task used, instructions followed those used by M. S. Miller (1980), although as noted earlier, the structure of the task followed Goodman (1979).

Children were trained on the nine associations for the Free Response procedure in groups of approximately 10 children. The introductory cards were each divided into quadrants. For each S-R association to be learned there were two introductory cards. The first card had, in the upper left corner, a positive instance of the association, with three negative instances in the other quadrants. The second card reversed this structure, indicating a negative instance of the cue in the top left quadrant, followed

Table 3

Sample of Subjects involved in each Test

| Test | Age group (years) | | | | |
| | 7 | 9 | 11 | 13 | Total |
|---|---|---|---|---|---|
| CEFT | 29 | 24 | 30 | 28 | 111 |
| RSPM | 29 | 24 | 30 | 28 | 111 |
| CSVI | | | | | |
|   i.  1STL | 26 | 22 | 29 | 21 | 98 |
|   ii.  TACH | 26 | 22 | 30 | 22 | 100 |
|   iii.  FR | 29 | 20 | 29 | 24 | 102 |

Table 4

Age and Sex Distribution of Largest Sample in each Age Group

| | Age group (years) | | | | |
| | 7 | 9 | 11 | 13 | Total |
|---|---|---|---|---|---|
| n | 29 | 24 | 30 | 28 | 111 |
| Age (years.months) | | | | | |
| $\bar{x}$ | 7.0 | 9.0 | 11.0 | 13.0 | |
| Range | 6.11-7.2 | 8.11-9.1 | 10.9-11.5 | 12.10-13.1 | |
| Sex | | | | | |
|   Male | 13 | 10 | 17 | 9 | 49 |
|   Female | 16 | 14 | 13 | 19 | 62 |

by three positive instances. Once the teacher had given the subjects some practice, and she believed they knew the associations well, they were pretested individually. The few who had not learned the associations adequately were given more practice and again pretested. Forty cards, each with a single cue presented, were used in the pretest. Children were shown one card at a time: if they responded correctly a number was recorded on the response sheet. With each successive correct response the score increased by one until a score of forty was achieved. A mistake entailed beginning again at a score of one. Although this is a strict criterion, even children who made three or four errors usually reached criterion in 10 to 15 minutes. Children who did not know the gestures associated with each cue made many errors in a short run of cards. In other words, teachers easily distinguished those children who needed more practice.

As testing on the CSVI-FR task may have been up to one day after the pretest, all subjects were given 14 revision stimuli. These were selected from the forty pretest cards. This revision period also introduced the children to the slide presentation procedure used in the testing. Slides were projected onto a white wall approximately 7m from the child. The display measured approximately 1.5m x 1.2m. A few children went through the 14 revision items twice to ensure they were familiar with the procedure and knew the associations. This, however, was rare.

Testing began immediately upon completion of these revision slides. (Figure 22 in Appendix D gives layout of apparatus and location of subject). All 43 slides (including one practice slide) were shown. One assistant operated the slide projector, and timed 5 seconds with a stopwatch, while the other assistant recorded responses using the symbols depicted in table 2. These were later transcribed onto record sheets. Each child was told

that he/she could begin 'sending messages' as soon as he/she saw the picture and could continue after the picture had been removed. Nevertheless, most children stopped responding as soon as the image disappeared, if they had not already halted responding.

The first slide in the test series was a practice slide to ensure that the subjects understood what was required. After this slide, teachers could remind the children of any instructions they appeared to have forgotten. On a few occasions this was also necessary after the first test slide (i.e., second slide in series of 43).

To prepare subjects for the tachistoscopic version of the CSVI task, the nine simple associations had to be relearned, replacing gesture responses with specific button pushes. Children were given photocopies representing the top of the response box and were retrained, usually in groups of approximately 15 subjects. (Appendix E illustrates such a page, but includes also the stimulus associated with each button).

Once subjects knew the associations, they were introduced to the response box, tachistoscope, "computer" (recording box), and mask slide (see figure 22 in Appendix D). Children were given practice with the pretest stimuli, allowing them to familiarise themselves with the short presentation time (120ms), the mask and the red button on the response panel which controlled the tachistoscopic shutter. At this time, it was important for the subjects to realise they needed to look at the screen when pressing the red button, as the flash was very fast. Because of the structure of the equipment, it was also necessary for the children to count, usually to five, from the time they heard the slide move into place and the time at which they could activate the shutter.

As soon as the children understood the procedure, the pretest was

begun. Again, criterion was forty consecutive correct responses. This was a very strict criterion and, as noted, some children were excluded from testing as they could not reach this criterion.

Where the practice and pretesting session was long, children were not tested immediately. Testing then took place later the same day, or on the day following. Always, if a break occurred, subjects were given approximately 10 reminder (practice) slides immediately prior to testing. Those children who met the pretest criterion without any errors were tested immediately as in this case the practice and pretesting only took 15 to 20 minutes.

Before testing, children were told to respond to all the messages they saw in the picture. But because the messages came so fast, they were able to look as often as they needed to see all the messages. On the first practice slide, all children were forced to take a second look at the picture. After the second look the assistant asked the subject whether he/she had seen all the messages. Further, after the first test slide, and sometimes after the second, subjects were asked if they had seen all the messages, or if they wanted another look, or if they were finished. After this the assistants did not interfere with the children's performance. The test took from 15 to 25 minutes. Children remained interested and alert throughout.

Responses for the tachistoscopic procedure were shown by an array of lights on the recording box. There were nine rows of lights, with each row holding one light for each response button, and one further light to the right of each row, indicating the number of rows activated (i.e., looks taken) by the subject for each compound. A teacher laid a thin sheet of paper, coded for each compound stimulus for each subject, over the light

array and recorded those lights which lit up for responses made. Every page had printed on it a block matrix in which each block overlaid a specific light.

## 7. Scoring of Tasks

### (a) CEFT

There are three sections to the test; an introductory (five items) and a test (six items) phase dealing with the tent shape and a test set of 14 items with the house shape embedded. A total score out of the possible 25 correct is calculated. Data for subjects who scored less than three out of five for the introductory phase (on either testing occasion) were excluded. Such low scores were assumed to reflect a misunderstanding of the task instructions. Subjects with two CEFT scores had their totals averaged, while those who only performed the test once, or had only one test score, received the score achieved on the single test.

In this study, the criterion set to distinguish cognitive style followed Burtis (1982), and labelled subjects between the 40th and 85th percentiles as FI, and FD subjects below the 40th percentile.

### (b) RSPM

Although there are five progressively more difficult sections, each containing 12 items, only the total score out of 60 was used. For each age group, the mean RSPM score was compared with the norms provided in the test manual (Raven, 1958). From this an estimate of the percentile rank for each age group was made.

### (c) CSVI Tasks

For each compound stimulus ($S^n$) presented, subjects could

produce from 1 to n correct responses. Only correct responses (task relevant responses) were scored. If, for example, six cues were presented ($S^6$), and a subject produced four correct responses with an error response, his/her response score for that compound would be four (cf. Goodman, 1979, p.194).

In most instances, at least one correct response was produced. It did happen on some occasions that no correct response was made. These responses were excluded from the analysis, as one cannot consider no cells filled with at least one ball when at least one ball is thrown into n cells, as predicted by the CSVI-BE model. These zero scores reflect no use of $M$ on the task (Pascual-Leone, 1970, p.320, footnote).

For each stimulus class, and the total task, for each age group the frequency of responses in each response class ($R^1$ to $R^n$) is calculated. From these values the expected scores (E(X)) and variances (Var. Emp.) were calculated for each stimulus class and the total task[2]. Appendix F gives the formulae for calculating E(X) and Var. Emp. as well as illustrating these with worked examples. To estimate the number of balls thrown (i.e., the $k$ value) for each age group "the empirical expected values or average number of correct responses per stimulus class [and for the total task] are compared with the theoretical expected values predicted by the Bose-Einstein model for a given number of balls thrown" (M. S. Miller, 1980, p.100).

Notes: Chapter 5

1. The Maxwell-Boltzman model calculates probabilities based on the assumption that all arrangements of balls have equal probabilities, i.e., random placement of balls (Feller, 1957, p.39f). Consider the following example: If three balls are thrown into three cells there are 27 possible arrangements of balls ($3^3$) each with an equal probability. The BE however, considers only the 10 distinguishable arrangements giving each a probability of 1/10. The Maxwell-Boltzman calculates probabilities based on all 27 possible arrangements. Thus, if the 10 *distinguishable* arrangements are:
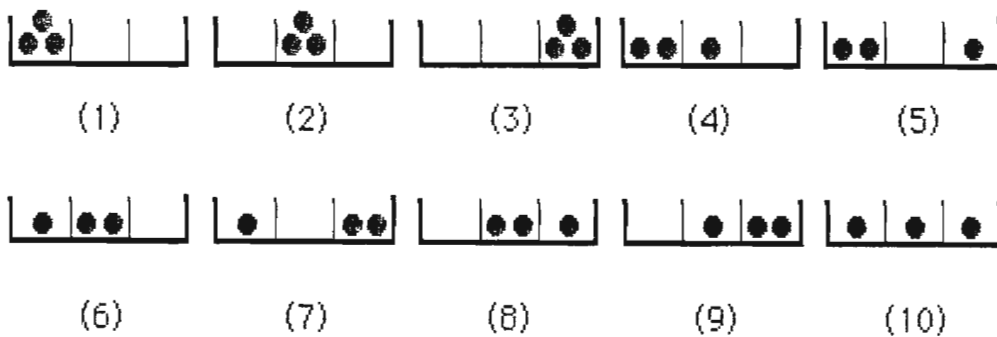


(cf. Feller, 1957, p.12).

The calculated probabilites are:

| | Arrangement | | | | | | | | | |
| Model | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Maxwell-Boltzmann | $\frac{1}{27}$ | $\frac{1}{27}$ | $\frac{1}{27}$ | $\frac{1}{9}$ | $\frac{1}{9}$ | $\frac{1}{9}$ | $\frac{1}{9}$ | $\frac{1}{9}$ | $\frac{1}{9}$ | $\frac{2}{9}$ |
| Bose-Einstein | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ |

(cf. Ibid., p.20f).

2. An error was made in scoring the fifth instance of $S^3$ on the CSVI-1STL and CSVI-TACH procedure. Thus, this score was excluded from the analyses.

## 6. Results

The results are presented in terms of each test given the subjects. For the CSVI procedures the 'first look' analysis preceeds the 'repeated looks' analysis. Finally, the free-response results are presented.

### 1. CEFT

Following Burtis (1982), the criterion used to distinguish cognitive style groups labelled as FI all subjects above the 40th percentile and below the 85th percentile. Subjects in the lowest 40% were considered FD. Subjects in the top 15% were excluded to prevent outlying subjects with only one CEFT score being included in the analysis. Table 5 shows the number of subjects in each cognitive style group, for each analysis at each age. The $t$-test comparisons of CSVI scores for FI and FD subjects showed no significant differences. These calculations comparing FI and FD mean scores for each CSVI analysis at each age are given in table 20, Appendix G.

Even without a limited time control, subjects underperformed, as is shown by the CEFT means in table 6. Recall that the CEFT was designed for use only with subjects up to eight years of age (Witkin, 1967). This suggests strongly that the subjects were predominantly FD. The non-significant difference between the two cognitive style groups (cf., Table 20, Appendix G) should be seen as further evidence supporting the argument that both groups come from a FD population. As performance on the CSVI showed low $M$, the CSVI analysis that follows treats all subjects as one (predominantly FD) sample. The mean CEFT scores and standard deviations for the total sample are given in table 6.

Table 5

Number of Subjects in each Cognitive Style Group for $t$-test

Analyses, indicating also Number of Subjects above the 85th

Percentile that were Excluded

|  | Age Group | | | |
|---|---|---|---|---|
|  | 7 | 9 | 11 | 13 |
| CSVI-1STL |  |  |  |  |
| FD | 10 | 9 | 12 | 8 |
| FI | 12 | 10 | 13 | 10 |
| EXCLUDED | 4 | 3 | 4 | 3 |
| TOTAL | 22 | 19 | 25 | 18 |
| CSVI-TACH |  |  |  |  |
| FD | 10 | 9 | 12 | 9 |
| FI | 12 | 10 | 14 | 10 |
| EXCLUDED | 4 | 3 | 4 | 3 |
| TOTAL | 22 | 19 | 26 | 19 |
| CSVI-FR |  |  |  |  |
| FD | 12 | 8 | 12 | 10 |
| FI | 13 | 9 | 13 | 10 |
| EXCLUDED | 4 | 3 | 4 | 4 |
| TOTAL | 25 | 17 | 25 | 20 |

Table 6

Means and Standard Deviations for CEFT and RSPM Tasks for each

Age Group

| | Age Group | | | |
|---|---|---|---|---|
| | 7 | 9 | 11 | 13 |
| CEFT | | | | |
| n | 29 | 24 | 30 | 28 |
| Mean | 14.966 | 15.375 | 19.367 | 18.250 |
| Standard Deviation | 3.365 | 3.924 | 2.463 | 3.985 |
| RSPM | | | | |
| n | 29 | 24 | 30 | 28 |
| Mean | 14.552 | 16.333 | 22.833 | 30.786 |
| Standard Deviation | 3.582 | 6.204 | 8.184 | 7.651 |
| Approx. Percentile Rank | 38 | 26 | 20 | 16 |

## 2. RSPM

The means and standard deviations for the RSPM test are presented in Table 6. Performance on the RSPM test showed an increase in the total task score, but a severe decline in the approximate percentile rank with increasing age (see figure 2). The $t$-test comparisons for adjacent age groups for the scores are given in table 21, Appendix H.
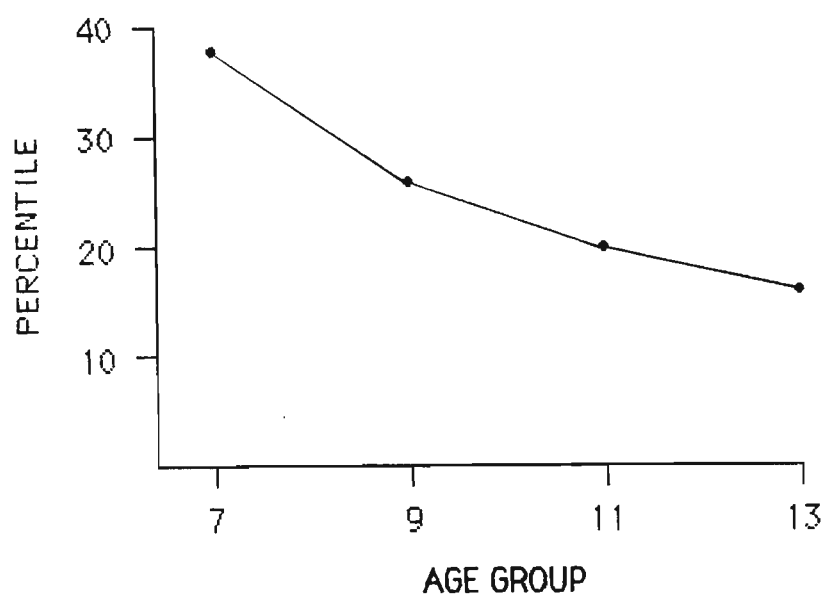
Figure 2: Decline in percentile rank by age for RSPM

## 3. CSVI

The mean expected empirical score and variance for each stimulus class and for the total task for each analysis are given in tables 7 to 9. At this point, note the total task expected score for the first look (CSVI-1STL) analysis fluctuates across ages, while the repeated looks (CSVI-TACH) performance removes these differences, exhibiting relatively constant and equivalent performance for the age groups. A gradual increase in mean total task score in the free response (CSVI-FR) procedure is halted at the 13-year-old age group where an unexpected drop is shown. A possible explanation for this phenomenon is provided below. These mean expected scores are illustrated in figure 3.

Table 7

Mean Expected Score (E(X)) and Variance (E. Var.) by Stimulus Class ($S^n$) and for the Total Task for each Age Group in CSVI-1STL Analysis

| $S^n$ | AGE GROUP | | | |
|---|---|---|---|---|
| | 7 (n=26) E(X)  E. Var. | 9 (n=22) E(X)  E. Var. | 11 (n=29) E(X)  E. Var. | 13 (n=21) E(X)  E. Var. |
| 2 | 1.445  0.247 | 1.558  0.247 | 1.551  0.247 | 1.598  0.240 |
| 3 | 1.886  0.426 | 2.028  0.443 | 2.001  0.440 | 1.973  0.517 |
| 4 | 2.155  0.766 | 2.137  0.653 | 2.088  0.712 | 2.215  0.632 |
| 5 | 2.167  0.926 | 2.333  0.796 | 2.094  0.658 | 2.352  0.654 |
| 6 | 2.351  1.098 | 2.702  1.003 | 2.634  1.127 | 2.816  1.126 |
| 7 | 2.540  1.262 | 2.947  1.575 | 2.750  1.083 | 2.857  1.345 |
| 8 | 2.750  1.431 | 3.265  1.331 | 2.942  1.014 | 3.079  1.359 |
| TOTAL TASK | 2.200  1.070 | 2.439  1.291 | 2.314  0.994 | 2.431  1.127 |
| MDN | 2.240 | 2.405 | 2.240 | 2.400 |
| RANGE | 1.150-3.560 | 1.510-3.490 | 1.730-3.000 | 1.760-3.290 |

Table 8

Mean Expected Score (E(X)) and Variance (E. Var.) by Stimulus

Class ($S^n$) and for the Total Task for each Age Group in

CSVI-TACH Analysis

| $S^n$ | AGE GROUP | | | |
| | 7 (n=26) E(X)  E. Var. | 9 (n=22) E(X)  E. Var. | 11 (n=30) E(X)  E. Var. | 13 (n=22) E(X)  E. Var. |
|---|---|---|---|---|
| 2 | 1.575  0.244 | 1.585  0.243 | 1.645  0.229 | 1.638  0.231 |
| 3 | 2.280  0.346 | 2.302  0.399 | 2.294  0.361 | 2.308  0.540 |
| 4 | 2.711  0.729 | 2.659  0.800 | 2.739  0.826 | 1.704  0.736 |
| 5 | 2.837  0.921 | 2.817  0.974 | 2.905  1.013 | 3.046  1.136 |
| 6 | 3.413  1.133 | 3.496  1.090 | 3.483  1.272 | 3.545  1.248 |
| 7 | 3.714  1.347 | 3.917  1.546 | 3.867  1.527 | 3.916  2.138 |
| 8 | 3.891  1.533 | 4.258  1.449 | 4.183  1.539 | 4.242  2.138 |
| TOTAL TASK | 2.949  1.549 | 3.028  1.710 | 3.044  1.670 | 3.086  1.925 |
| MDN | 2.880 | 3.000 | 3.020 | 3.115 |
| RANGE | 2.140-3.760 | 2.170-3.830 | 2.050-4.050 | 2.000-4.200 |

Table 9

Mean Expected Score (E(X)) and Variance (E. Var.) by Stimulus Class ($S^n$) and for the Total Task for each Age Group in CSVI-FR Procedure

| $S^n$ | AGE GROUP | | | |
|---|---|---|---|---|
| | 7 (n=29) E(X)  E. Var. | 9 (n=20) E(X)  E. Var. | 11 (n=29) E(X)  E. Var. | 13 (n=24) E(X)  E. Var. |
| 2 | 1.451  0.248 | 1.670  0.221 | 1.810  0.154 | 1.752  0.187 |
| 3 | 2.078  0.503 | 2.330  0.447 | 2.569  0.353 | 2.306  0.448 |
| 4 | 2.415  0.769 | 2.786  0.835 | 3.071  0.630 | 2.924  0.696 |
| 5 | 2.965  0.881 | 3.286  1.028 | 3.637  1.085 | 3.366  0.993 |
| 6 | 3.249  1.065 | 3.765  1.390 | 4.169  1.338 | 3.931  1.315 |
| 7 | 3.799  1.506 | 4.437  1.473 | 4.667  1.441 | 4.368  1.399 |
| 8 | 4.017  1.821 | 4.767  1.579 | 5.075  1.184 | 4.771  1.927 |
| TOTAL TASK | 2.869  1.713 | 3.319  2.068 | 3.586  2.057 | 3.350  2.026 |
| MDN | 2.790 | 3.225 | 3.810 | 3.435 |
| RANGE | 1.650-4.330 | 2.370-4.330 | 2.570-4.120 | 2.070-4.100 |
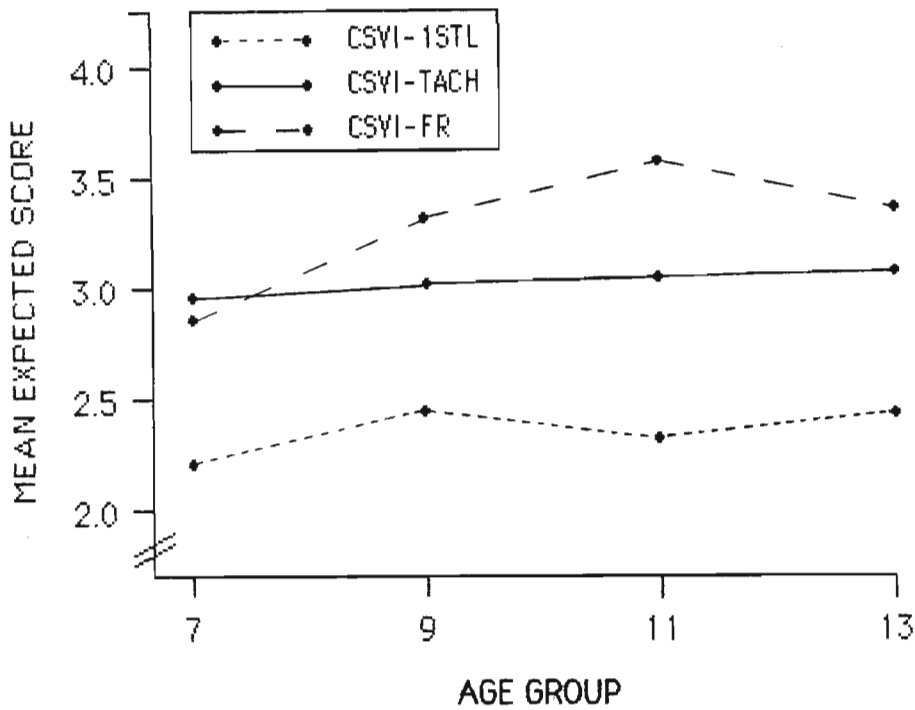
Figure 3. Mean expected score (E(X)) by age group for three CSVI analyses.

To map the empirical data onto the theoretically predicted values, the expected empirical score for each stimulus class is divided by the stimulus class to express the proportion of stimuli correctly recalled per stimulus class. These values are compared with the Bose-Einstein (BE) theoretical proportions, for given numbers of balls ($k$ x attending acts). The CSVI data is considered first in terms of 'first look' (CSVI-1STL) performance to make an estimate of $M_f$, then 'repeated looks' (CSVI-TACH), and finally the free response (CSVI-FR) procedure is analysed. As a summary of the analyses which follow, table 10 shows for each age the expected empirical score for the total task and compares these with theoretical expectancies based on the $k$ estimates derived. These theoretical values give an estimate of $k$ as they are the values

Table 10

Theoretical and Empirical Expected Scores (E(X)) for the Total Task

| ANALYSIS | AGE | EMP. E(X) | TH. E(X) | k | TH. E(X) (Combination Model) |
|---|---|---|---|---|---|
| CSVI-1STL | 7 | 2.200 | 2.073 | 3 | |
| | 9 | 2.439 | 2.408 | 4 | |
| | 11 | 2.314 | 2.418 | 4 | |
| | 13 | 2.431 | 2.410 | 4 | |
| CSVI-TACH | 7 | 2.949 | 2.901 | 6 | |
| | 9 | 3.028 | 3.072 | 7 | |
| | 11 | 3.044 | 3.079 | 7 | |
| | 13 | 3.086 | 3.076 | 7 | |
| CSVI-FR | 7 | 2.869 | 2.884 | 6 | 2.855 |
| | 9 | 3.319 | 3.221 | 8 | 3.409 |
| | 11 | 3.586 | 3.633 | 12 | 3.623 |
| | 13 | 3.350 | 3.332 | 9 | 3.409 |

closest to the empirical scores.

### (a) CSVI-1STL Analysis

For the CSVI-1STL, performance reflects $M_f$, as only one attending act is made. The Bose-Einstein theoretical expected proportion recall and the empirical proportion recall for each stimulus class and each age group are provided in Table 11. Figures 4 to 7 depict the empirical data and theoretical values for each age group on the CSVI-1STL. Fitting BE values to the empirical curves shows the seven- and nine-year-olds use their age appropriate $M$-power of 3 and 4, respectively. However, the 11- and 13-year-olds also use $k = 4$, which reflects an increasing discrepancy between $M_s$ and $M_f$, for the age appropriate values are 5 and 6 respectively.

As an estimate of the best-fitting curve, for each age group the absolute difference between the empirical and theoretical proportions was summed across stimulus classes for various Bose-Einstein models to produce total task absolute difference scores. The model producing the lowest absolute difference score represented the curve best-fitting the empirical data. Table 12a shows these values, and indicates the appropriateness of the $k$ estimates made.

Table 11

Theoretical and Empirical Proportion Recall for each Stimulus
Class ($S^n$): CSVI-1STL

Theoretical:

| | STIMULUS CLASS | | | | | | |
|---|---|---|---|---|---|---|---|
| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 3 | .750 | .600 | .500 | .429 | .375 | .333 | .300 |
| 4 | .800 | .667 | .572 | .504 | .454 | .420 | .393 |
| 5 | .834 | .714 | .625 | .556 | .501 | .457 | .422 |

Empirical:

| | | STIMULUS CLASS | | | | | | |
|---|---|---|---|---|---|---|---|---|
| AGE | k | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 7 | 3 | .723 | .629 | .539 | .433 | .392 | .363 | .344 |
| 9 | 4 | .779 | .676 | .534 | .467 | .450 | .421 | .408 |
| 11 | 4 | .776 | .667 | .522 | .419 | .439 | .393 | .368 |
| 13 | 4 | .799 | .658 | .554 | .470 | .469 | .408 | .385 |
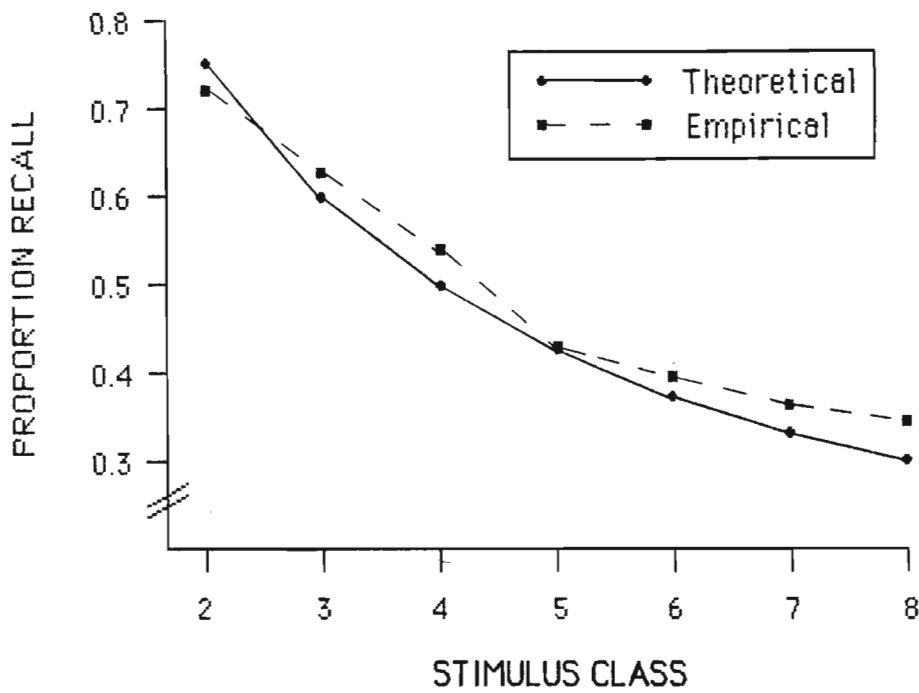
Figure 4. Empirical and theoretical proportion recall by stimulus class: Seven-year-olds, CSVI-1STL, (k = 3).
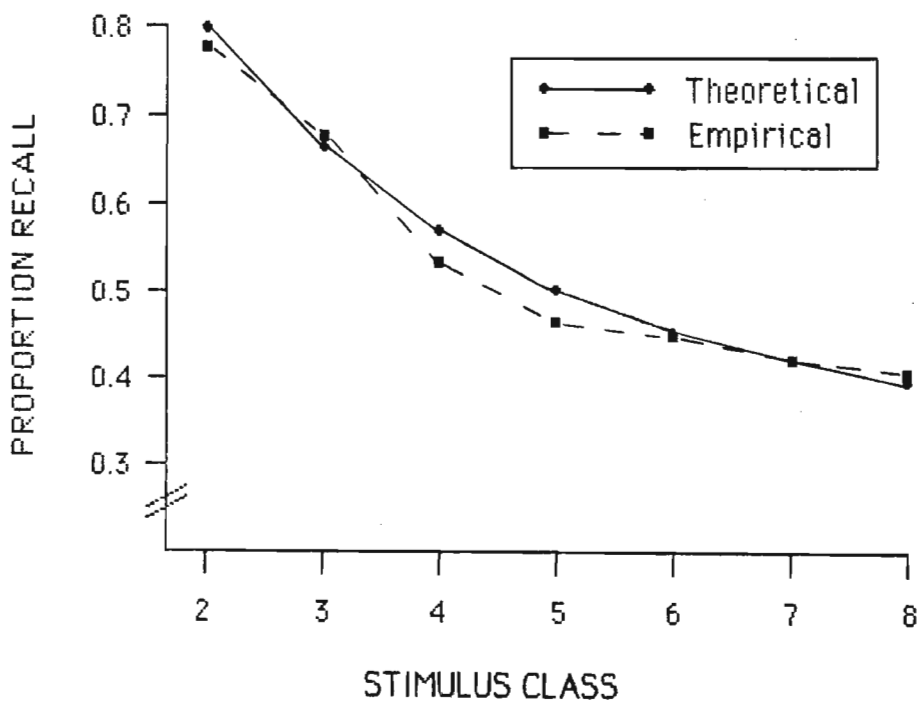


Figure 5. Empirical and theoretical proportion recall by stimulus class: Nine-year-olds, CSVI-1STL, (k = 4).
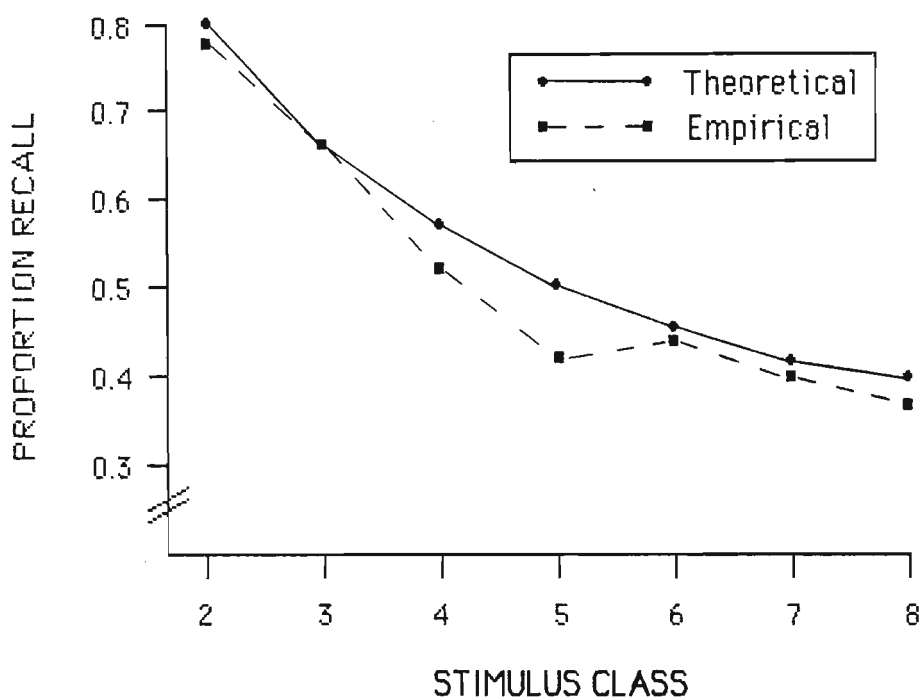
Figure 6. Empirical and theoretical proportion recall by stimulus class: Eleven-year-olds, CSVI-1STL, (k = 4).
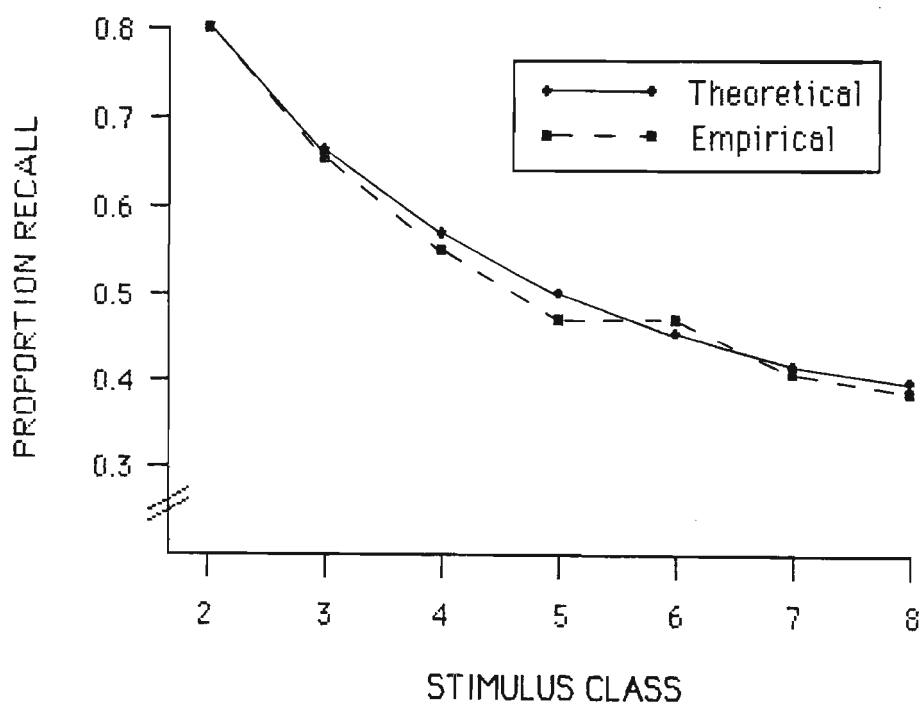


Figure 7. Empirical and theoretical proportion recall by stimulus class: Thirteen-year-olds, CSVI-1STL, (k = 4).

Table 12

Absolute Difference between Theoretical and Empirical Probabilities summed across Stimulus Classes and Absolute Difference for Combination Model (COMB. MODEL)

a) CSVI-1STL:

|  | ABSOLUTE DIFFERENCE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| AGE | 2 | 3 | 4 | 5 | 6 | 7 | 8 | : balls |
| 7 | .768 | .190* | .387 | | | | | |
| 9 | | .448 | .117* | .374 | | | | |
| 11 | | .317 | .226* | .525 | | | | |
| 13 | | .456 | .097* | .366 | | | | |

b) CSVI-TACH:

|  |  | ABSOLUTE DIFFERENCE | | | | | | |
|---|---|---|---|---|---|---|---|---|
| AGE | MEAN LOOKS | 3 | 4 | 5 | 6 | 7 | 8 | : balls |
| 7 | 1.703 | | .593 | .362 | .201* | .234 | .425 | |
| 9 | 1.506 | | | | .287 | .256* | .341 | |
| 11 | 1.627 | | | | .234 | .175* | .294 | |
| 13 | 1.567 | | | | .247 | .172* | .251 | |

* best-fitting curve

Table 12 (cont.)

<u>Absolute Difference between Theoretical and Empirical Probabilities summed across Stimulus Classes and Absolute Difference for Combination Model (COMB. MODEL)</u>

c) <u>CSVI-FR</u>:

| AGE | ABSOLUTE DIFFERENCE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13: balls | |
| | 2(2) | | 2(3) | | 2(4) | 3(3) | 2(5) | | 2(6) | : model | COMB. |
| | 1(4) | | | | | | | | 3(4) | | MODEL |
| 7 | .541 | .394 | .345* | .422 | | | | | | | .238 |
| 9 | | | .486 | .299 | .256* | .276 | | | | | .180 |
| 11 | | | | | | | .156 | .098 | .089* | .177 | .087 |
| 13 | | | | | .210 | .178* | .196 | | | | .173 |

\* best-fitting curve

(b) <u>CSVI-TACH Analysis</u>

Considering next the results for repeated looks (CSVI-TACH), given in Table 13, the best fitting curve for the 7-year-olds is a 6 ball model. For the remaining three age groups, a 7 ball function is most appropriate. The goodness-of-fit for each function is estimated, as before, in table 12b. The empirical and theoretical curves for each age group are compared in figures 8 to 11. A summary of the total task scores and theoretical predictions is given in table 10.

Table 13 shows the mean number of looks (attending acts) made by

each age group over the total task. Thus, dividing the number of balls estimate by mean looks gives an indication of $k$ used. Interestingly, these values, approximately 0.5 above the $M_f$ measured on the CSVI-1STL analysis, confirm a pattern M. S. Miller (1980) found among low SES children. However, Miller provides no explanation for this slight increase, choosing rather to focus on the across task similarity in $M_f$ among low SES subjects. This higher-than-expected $M_f$ pattern across ages is also evident in the present study, and will be discussed in the following chapter.

Table 13

Theoretical and Empirical Proportion Recall for each Stimulus

Class $(S^n)$: CSVI-TACH

Theoretical:

|   | STIMULUS CLASS | | | | | | |
|---|---|---|---|---|---|---|---|
| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 6 | .857 | .750 | .667 | .600 | .546 | .500 | .462 |
| 7 | .875 | .778 | .700 | .636 | .585 | .539 | .500 |

Empirical:

| Age | Mean Looks | | | STIMULUS CLASS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
|   | a | k | a(k) | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 7 | 1.703 | 3.5 | 6 | .788 | .760 | .678 | .567 | .569 | .531 | .486 |
| 9 | 1.506 | 4.6 | 7 | .793 | .767 | .665 | .563 | .583 | .560 | .532 |
| 11 | 1.627 | 4.3 | 7 | .823 | .765 | .685 | .581 | .581 | .552 | .523 |
| 13 | 1.567 | 4.5 | 7 | .819 | .769 | .676 | .609 | .591 | .559 | .530 |

Figure 8. Empirical and theoretical proportion recall by stimulus class: Seven-year-olds, CSVI-TACH, (1.703k; k = 3.5; a(k) = 6).



Figure 9. Empirical and theoretical proportion recall by stimulus class: Nine-year-olds, CSVI-TACH, (1.506k; k = 4.6; a(k) = 7).

Figure 10. Empirical and theoretical proportion recall by stimulus class: Eleven-year-olds, CSVI-TACH, (1.627k; k = 4.3; a(k) =7).



Figure 11. Empirical and theoretical proportion recall by stimulus class: Thirteen-year-olds, CSVI-TACH, (1.567k; k = 4.5; a(k) = 7).

(c) CSVI-FR Procedure

Recall that performance for normal, field-independent subjects on the CSVI-FR procedure is task analysed to involve $k^2$ balls ($k$ energy units x k attending acts). For subjects with poor executives, $k$ should be less than expected, and fewer than $k$ ($M_f$) attending acts should be made, as temporal executives also may be weak. The CSVI-FR data from the present study do not to fit this expectation. However, below a modified version of this model, a combination model, will be presented which can account for these data. Table 14 gives the empirical data, and indicates the best fits are provided by a 6 ball model for the seven-year-olds, an 8 ball model for the nine-year-olds, a 12 ball model for the 11-year-olds and 9 balls for the 13-year-olds. While it may be possible to argue the seven- and nine-year-olds use their $M_f$ twice, and 11-year-olds develop an added executive, allowing a further attending act, the 13-year-olds cannot easily be incorporated into such an analysis. These data are graphically represented against the theoretical curves in figures 12 to 15.

To understand these data, a combination model can be considered in which multiples (a) of the $M_f$ (k) attributed to the age group are compared to the expected empirical scores for each stimulus class (i.e., a(k), where a is an integer value greater than or equal to the value of a at the preceeding stimulus class level, and k is the value found in the CSVI-1STL analysis). The a(k) multiple closest to the empirical score is selected. This shows at which stimulus class subjects begin employing a more efficient strategy. The results of this analysis are indicated in table 15. Note that the number of attending acts (a) increases across stimuli classes, but at different rates for each age group. Further, note all age

groups use a ($k$ - 1) strategy at the $S^8$ level. The values are depicted in figures 16 to 19, and table 12c indicates that the new theoretical values are as good or better fitting than the earlier values. This interpretation has the added advantage of making the 13-year-old performance comprehensible in a model which applies consistently across age groups. While the poorer performance of the 13-year-olds relative to the trend shown by the other age groups in the CSVI-FR procedure (cf., figure 3) cannot be overlooked, this may be related to the slower rate at which the 13-year-olds employ a more efficient temporal executive strategy.

Table 14

Theoretical and Empirical Proportion Recall for each Stimulus Class ($S^n$): CSVI-FR(a)

Theoretical:

|  | STIMULUS CLASS | | | | | | |
|---|---|---|---|---|---|---|---|
| k | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 6 | .857 | .750 | .667 | .600 | .546 | .500 | .462 |
| 8 | .889 | .801 | .727 | .667 | .615 | .571 | .534 |
| 9 | .900 | .818 | .750 | .693 | .644 | .601 | .564 |
| 12 | .923 | .857 | .801 | .749 | .707 | .666 | .632 |

Empirical:

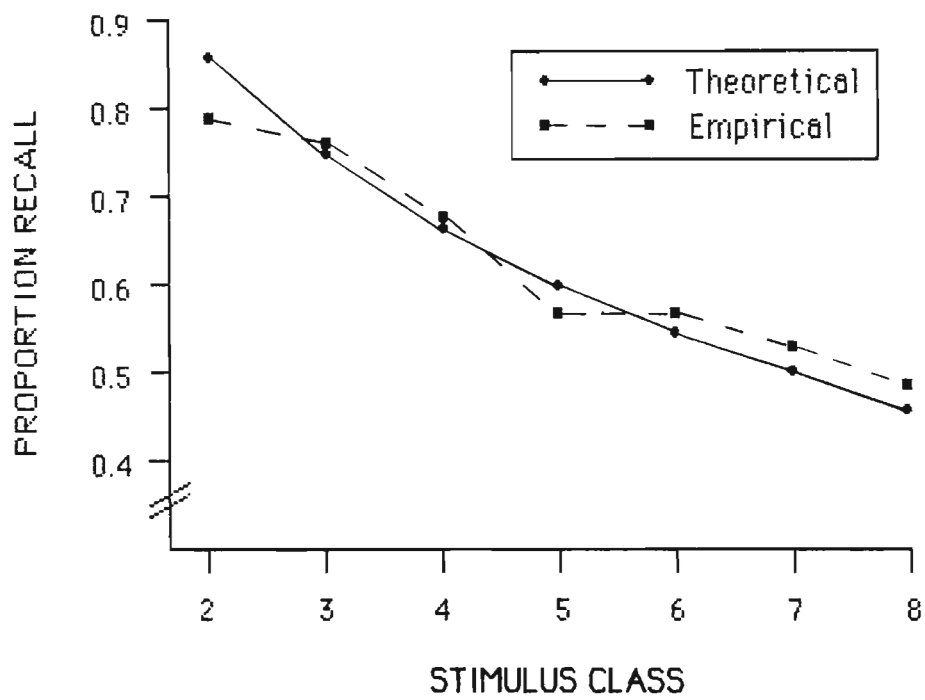|  |  | STIMULUS CLASS | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age | k | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 7 | 6 | .726 | .693 | .604 | .593 | .542 | .543 | .502 |
| 9 | 7 | .835 | .777 | .697 | .657 | .628 | .634 | .596 |
| 11 | 7 | .905 | .856 | .768 | .727 | .695 | .667 | .634 |
| 13 | 7 | .876 | .769 | .731 | .673 | .655 | .624 | .596 |
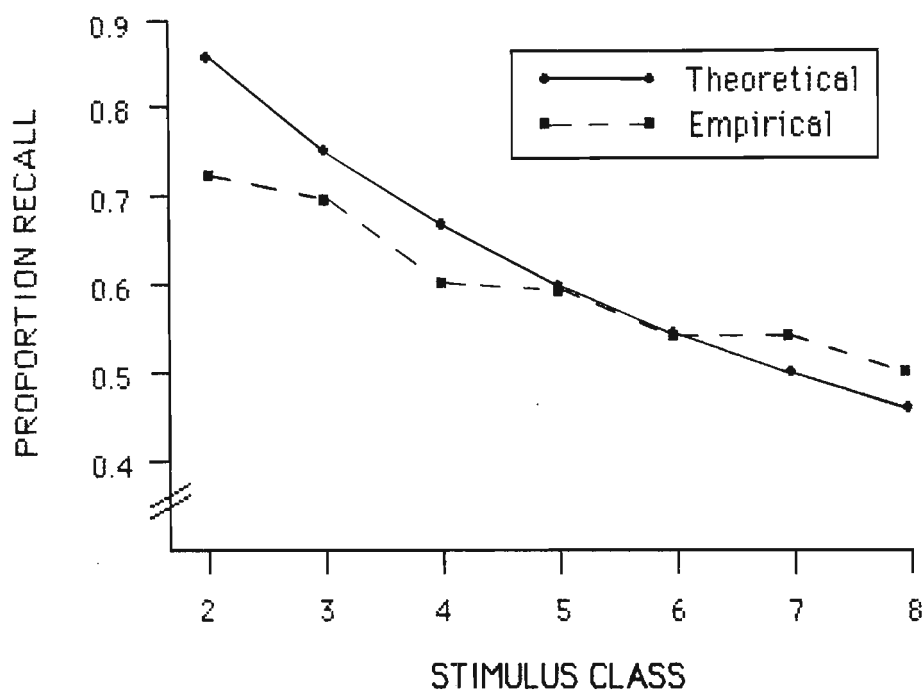
Figure 12. Empirical and theoretical proportion recall by stimulus class: Seven-year-olds, CSVI-FR (a), (k = 6).
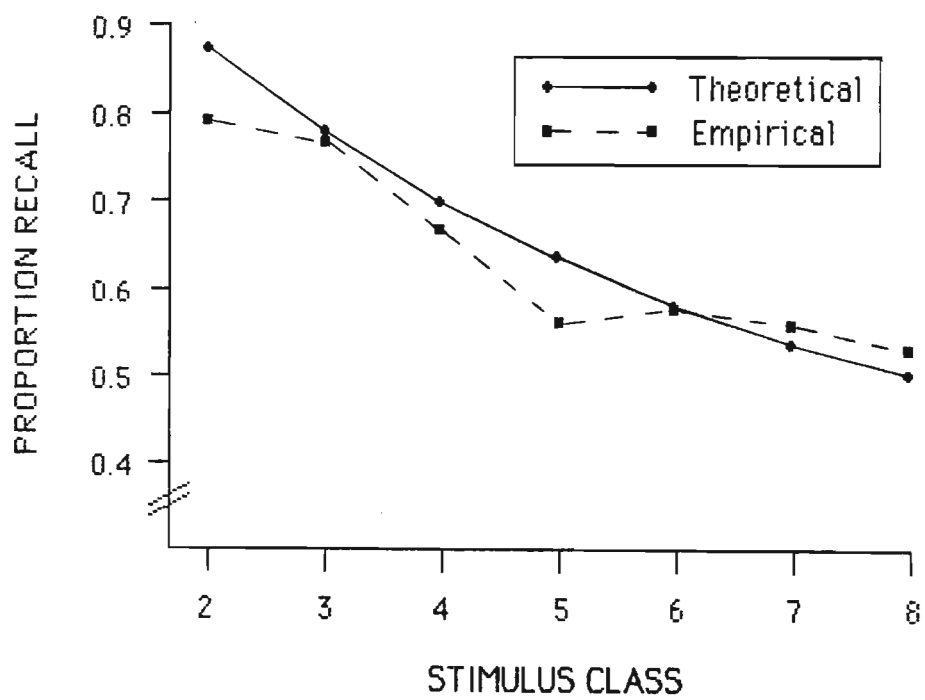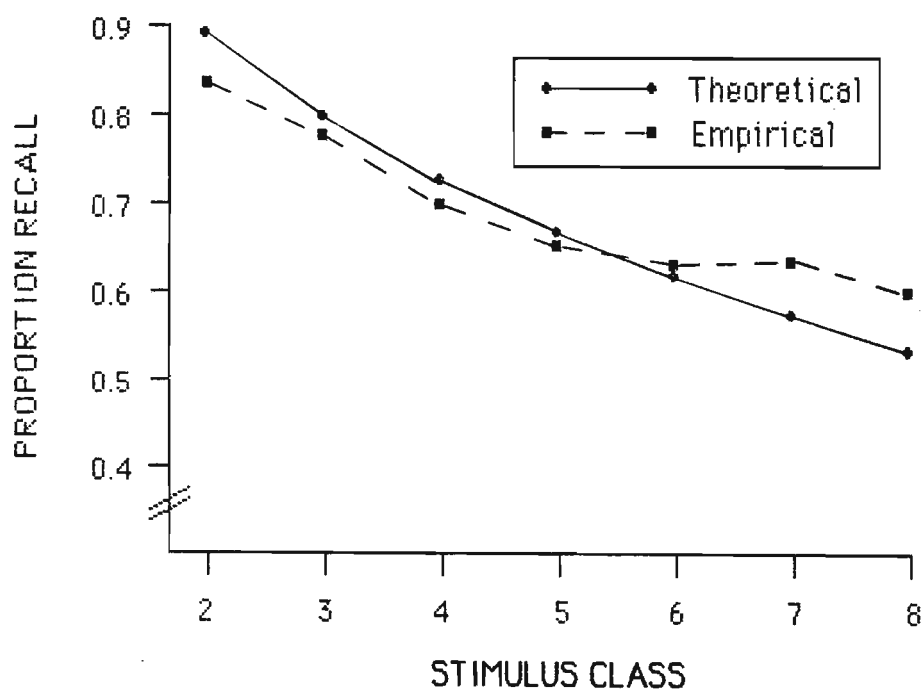


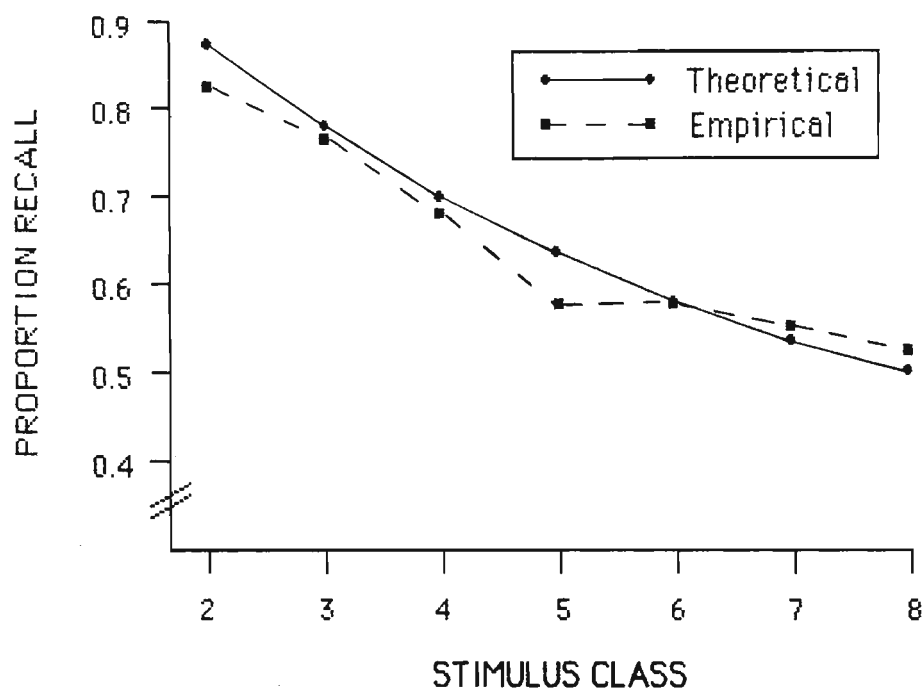Figure 13. Empirical and theoretical proportion recall by stimulus class: Nine-year-olds, CSVI-FR (a), (k = 7).
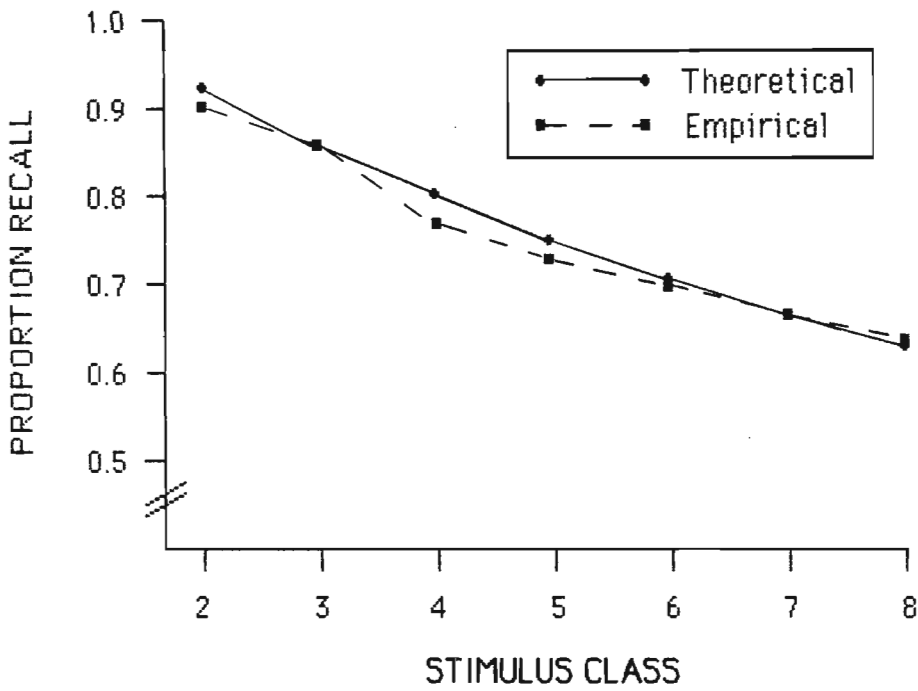
Figure 14. Empirical and theoretical proportion recall by stimulus class: Eleven-year-olds, CSVI-FR (a), (k = 7).



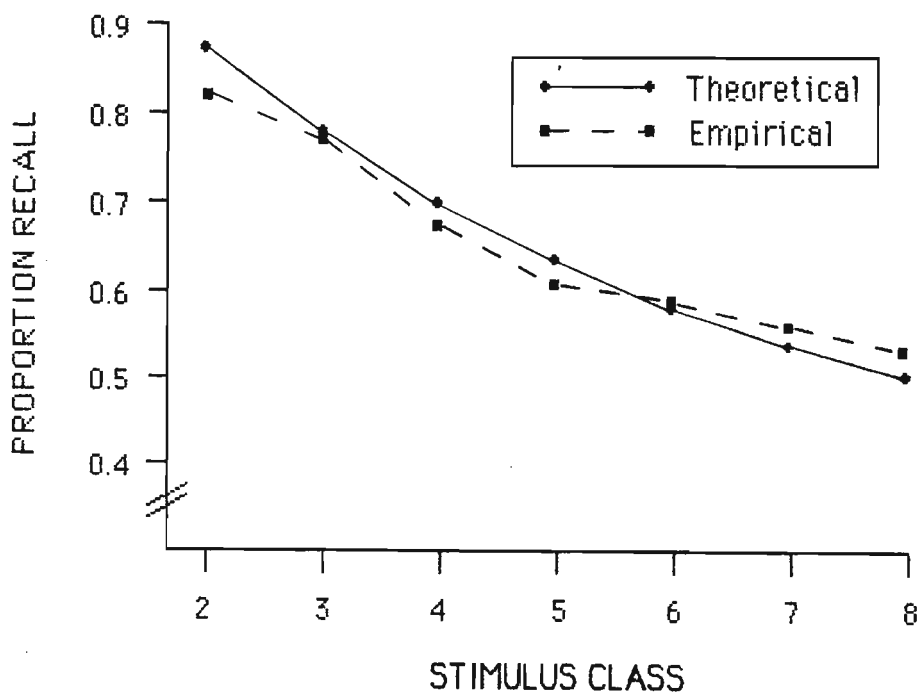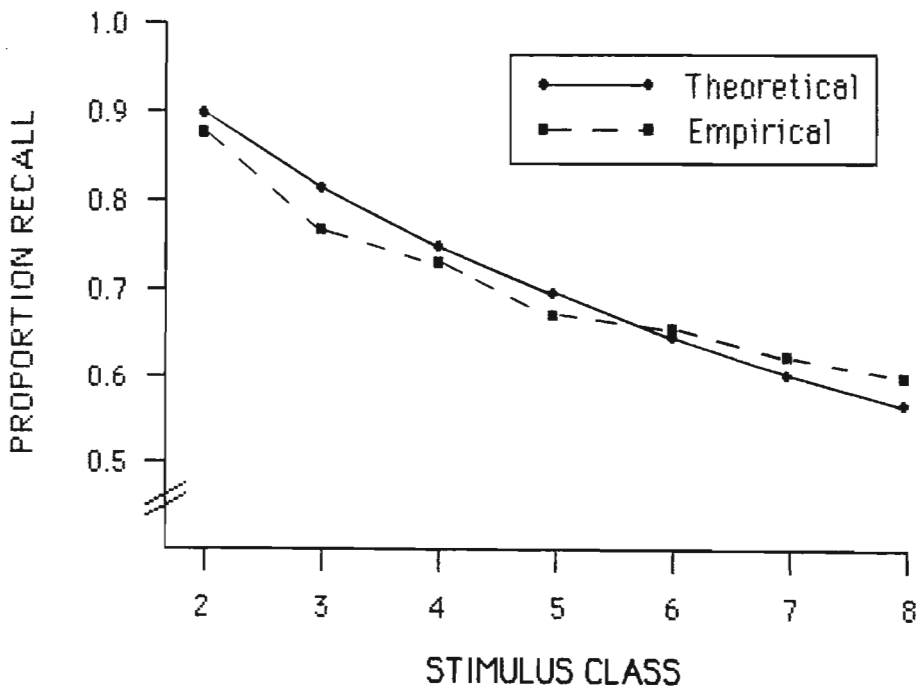Figure 15. Empirical and theoretical proportion recall by stimulus class: Thirteen-year-olds, CSVI-FR (a), (k = 7).

Table 15

Theoretical and Empirical Proportion Recall for each Stimulus

Class $(S^n)$: Combination Model, CSVI-FR(b)

| Age | | STIMULUS CLASS | | | | | | |
|-----|--|------|------|------|------|------|------|------|
| | | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 7 | Empirical | .726 | .693 | .604 | .593 | .542 | .543 | .502 |
| | Theor. Prop. | .750 | .750 | .667 | .600 | .546 | .500 | .462 |
| | a(k) estimate | 1(3) | 2(3) | 2(3) | 2(3) | 2(3) | 2(3) | 2(3) |
| 9 | Empirical | .835 | .777 | .697 | .657 | .628 | .634 | .596 |
| | Theor. Prop. | .800 | .801 | .727 | .667 | .615 | .666 | .632 |
| | a(k) estimate | 1(4) | 2(4) | 2(4) | 2(4) | 2(4) | 3(4) | 3(4) |
| 11 | Empirical | .905 | .856 | .768 | .727 | .695 | .667 | .634 |
| | Theor. Prop. | .889 | .857 | .801 | .749 | .707 | .666 | .632 |
| | a(k) estimate | 2(4) | 3(4) | 3(4) | 3(4) | 3(4) | 3(4) | 3(4) |
| 13 | Empirical | .876 | .769 | .731 | .673 | .655 | .624 | .596 |
| | Theor. Prop. | .889 | .801 | .727 | .667 | .615 | .666 | .632 |
| | a(k) estimate | 2(4) | 2(4) | 2(4) | 2(4) | 2(4) | 3(4) | 3(4) |

Figure 16. Empirical and theoretical proportion recall by stimulus class: Seven-year-olds, Combination Model, CSVI-FR (b).
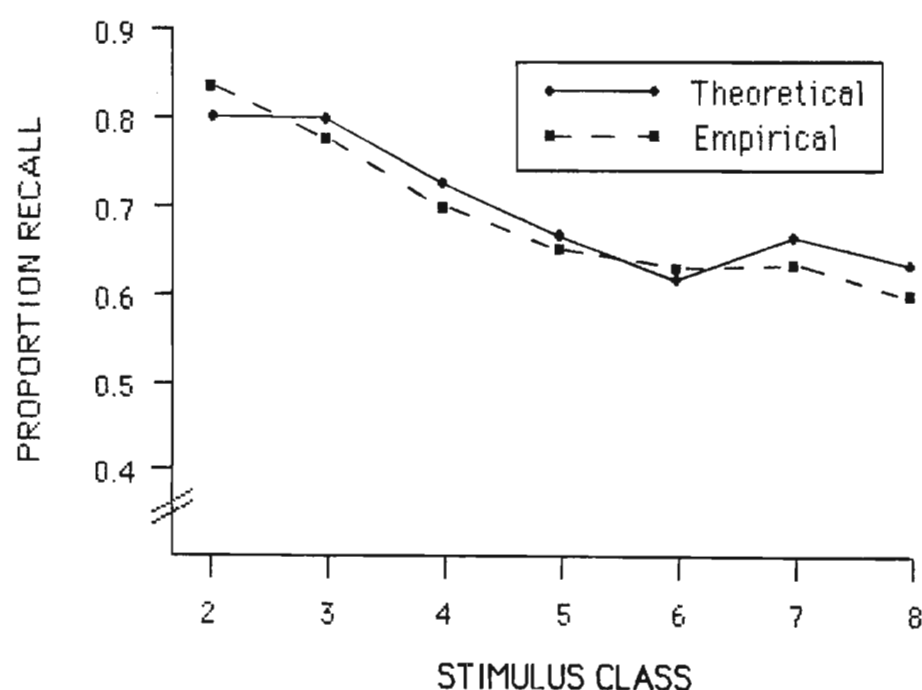


Figure 17. Empirical and theoretical proportion recall by stimulus class: Nine-year-olds, Combination Model, CSVI-FR (b).
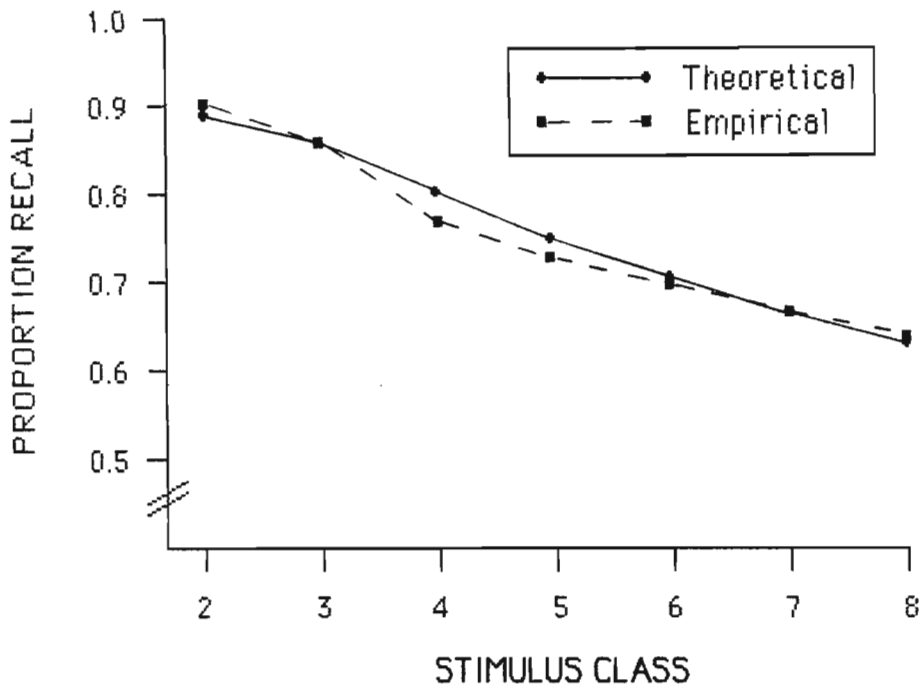
Figure 18. Empirical and theoretical proportion recall by stimulus class: Eleven-year-olds, Combination Model, CSVI-FR (b).
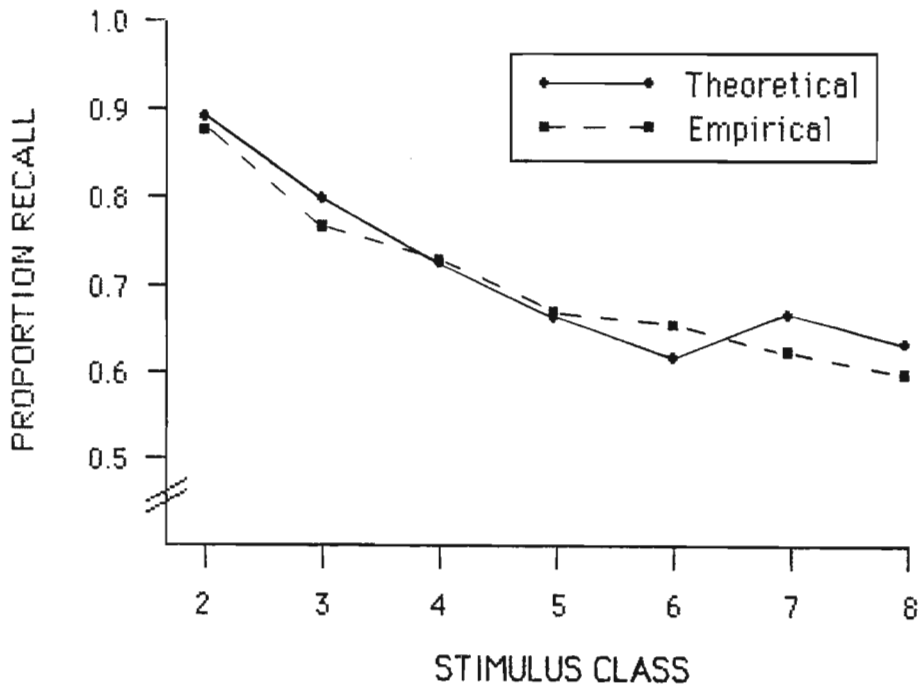


Figure 19. Empirical and theoretical proportion recall by stimulus class: Thirteen-year-olds, Combination Model, CSVI-FR (b).

Previously it has been found that a $k(k-1)$ model sometimes is appropriate for interpreting CSVI data (Pascual-Leone and Goodman, 1979). This would explain 7- and 11-year-old performance, but the modification suggested above is necessary to explicate 9- and 13-year-old performance

### (d) Temporal Task Executive Learning

Following Goodman (1979), the first 21 test responses were analysed separately from the second half in order to assess whether subjects improved their temporal task executives with practice on the task. Mean expected scores and perfect recall values were calculated, and are shown in tables 16 and 17. (The perfect recall scores have been corrected in the repeated looks (CSVI-TACH), second half, for the excluded compound response). Figures 20 and 21 depict the differences in scores between first half and second half performance on both tests. From figure 20 it can be seen that seven- and nine-year-olds gained relatively little from practice while the 11-year-olds showed the greatest improvement on both task procedures. The 13-year-old learning effect also is relatively high, but not as strong as for 11-year-olds. Looking to figure 21, only the 11-year-olds show a slight improvement in the CSVI-TACH procedure, but both 11- and 13-year-olds improve in the CSVI-FR procedure. This means that 13-year-olds developed a relatively more efficient temporal executive with practice, but this is only evident in tasks where the subjects are passive (CSVI-FR) rather than actively having to request re-viewings (CSVI-TACH). Nevertheless, both these intra-task learning effects are small for all ages: the slight differences should rather be seen as reflecting an inefficient use of a learning opportunity by all subjects.

Table 16

Temporal Task Executive Learning: Mean Expected Score (E(X))

for First Half and Second Half of CSVI-TACH and CSVI-FR

Performance

|  | AGE GROUP | | | |
|---|---|---|---|---|
|  | 7 | 9 | 11 | 13 |
| I. CSVI-TACH |  |  |  |  |
| 1st Half | 2.902 | 3.000 | 2.897 | 2.987 |
| 2nd Half | 3.032 | 3.076 | 3.197 | 3.191 |
| II. CSVI-FR |  |  |  |  |
| 1st Half | 2.853 | 3.245 | 3.434 | 3.216 |
| 2nd Half | 2.885 | 3.394 | 3.741 | 3.486 |

Table 17

Temporal Task Executive Learning: Mean Number of Items

Perfectly Recalled for First Half and Second Half of

CSVI-TACH and CSVI-FR Performance

|  | AGE GROUP | | | |
|---|---|---|---|---|
|  | 7 | 9 | 11 | 13 |
| I. CSVI-TACH |  |  |  |  |
| 1st Half | 3.462 | 3.909 | 3.500 | 4.500 |
| 2nd Half | 2.600 | 2.887 | 3.824 | 3.678 |
| II. CSVI-FR |  |  |  |  |
| 1st Half | 2.966 | 4.550 | 5.690 | 4.375 |
| 2nd Half | 2.207 | 4.100 | 6.345 | 5.542 |
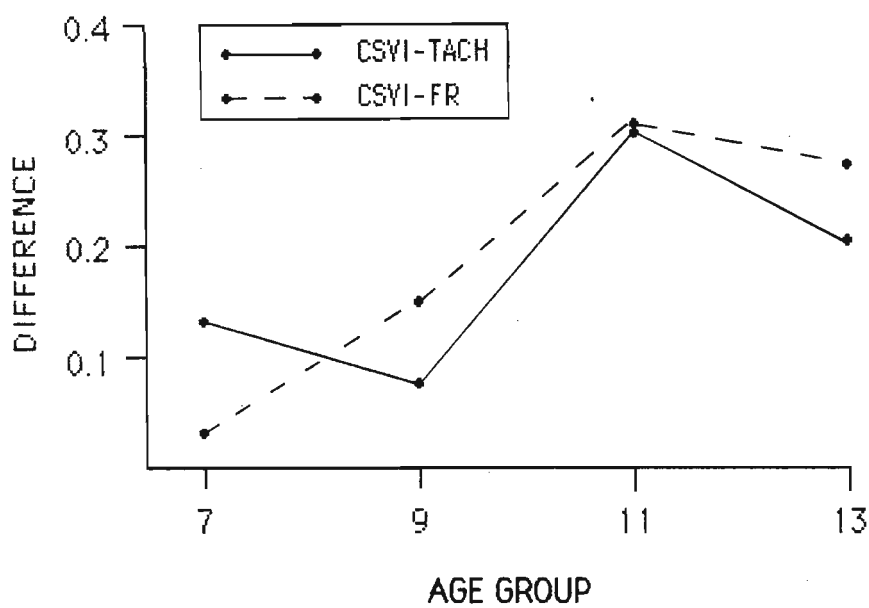
Figure 20. Difference in mean expected score (E(X)) by age group between first half and second half performance.
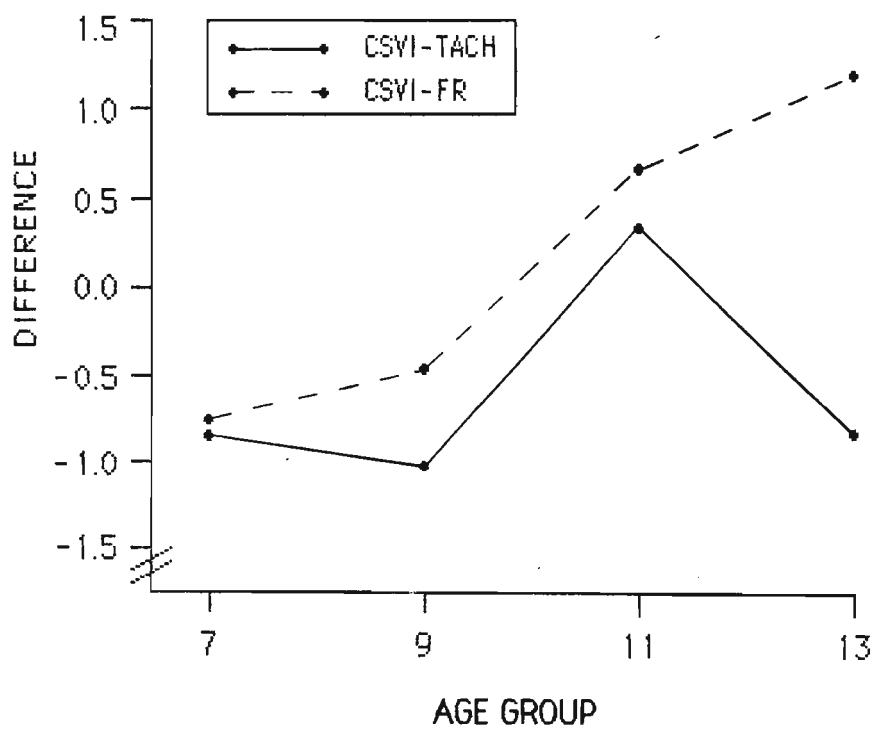


Figure 21. Difference in number of items perfectly recalled by age group between first half and second half performance.

## 4. Multiple Linear Regression Analysis

Finally, a multiple linear regression analysis was performed. These data are presented in table 18. The variables were entered in a stepwise manner, with no predetermined order, resulting in the best single predictor (of those available) being entered at each step. For the CSVI-1STL, none of the variables was a significant predictor. This is not unexpected as $k$ ($M_f$) was shown not to increase as predicted ($M_s$): only in the CSVI-FR is age the best predictor of performance. In all three analyses, the CEFT and RSPM account for very little in CSVI performance. A statistical analysis of this nature simply confirms that the small differences in CSVI scores across age groups are not due to variables which change across groups (age, CEFT, RSPM).

Table 18

Multiple Linear Regression Summary on CSVI Total Task

Expected Scores

| | MULTIPLE R | $R^2$ | F |
|---|---|---|---|
| CSVI-1STL (n=98) | | | |
| 1. CEFT | .151 | .023 | 2.223 |
| 2. Age | .160 | .026 | 1.249 |
| 3. RSPM | .163 | .027 | 0.859 |
| CSVI-TACH (n=99) | | | |
| 1. Looks | .539 | .290** | 39.621** |
| 2. Age | .568 | .323* | 22.848** |
| 3. CEFT | .575 | .330 | 15.632** |
| 4. RSPM | .579 | .335 | 11.824** |
| CSVI-FR (n=102) | | | |
| 1. Age | .358 | .128** | 14.663** |
| 2. CEFT | .376 | .141 | 8.125** |
| 3. RSPM | .378 | .143 | 5.460** |

$* p < .05$

$** p < .01$

## 7. Discussion

Results of the present study were expected to reconfirm Pascual-Leone's predicted $M$ values among Zulu-speaking children, thus acknowledging these children possess appropriate arousal executives. The study aimed also to measure the strength, among these children, of temporal executives, which were expected to be weak due to poor $LM$ structuring, suggested by poor school performance.

The maximum $M_f$ value found in the present sample was $e + 4$, which does not reconfirm the predicted $M$ values, found in Zulu-speaking children by R. Miller et al. (in preparation). While $M$, as a theoretical construct, is necessary to avoid a learning paradox and is given universal validity by any findings confirming this construct, $M$ has been shown to be independent of economic status (M. S. Miller, 1980), cognitive style (Globerson, 1985), and culture (R. Miller et al., in preparation).

By not reconfirming the developmental increase in $M$, the results of the present study show that the older children (11- and 13-year-olds) have an increasingly serious arousal executive deficiency. In other words, the 11-year-olds only employed an executive capable of bringing 4, instead of the predicted 5, units of $M$ energy to the task, and 13-year-olds only used 4 from an expected (potential) 6 units.

Importantly, the RSPM scores give indirect support to this expectation that subjects perform with an $M_f$ increasingly discrepant from their $M_s$, as RSPM scores showed a dramatic decline in approximate percentile rank with increasing age (see table 6 and figure 2). Bereiter and Scardamalia (1979) showed in a task analysis of the RSPM test that $M$

scores and RSPM scores can be derived from each other as both $M$-measures and the RSPM reflect $M$-demand. "A general intelligence test can be rationally analysed so as to yield estimates of $M$-capacity" (Bereiter and Scardamalia, 1979, p.57). Clearly, this is an $M_f$ capacity measure, even when $M_f$ equals $M_s$. But when $M_s$ equals $M_f$, the RSPM percentile rank of subjects remains (relatively) constant with increasing age. If the percentile rank drops with increasing age, as is the case in these data, the $M_f$ is becoming increasingly different from the normal ($M_s$).

The maximum $M_f$ value of $e$ + 4 found in the present sample corresponds to the end of Piaget's concrete operational period. In his well-known summary of cross-cultural Piagetian studies, Dasen (1974) cites studies which found no evidence of formal operational thinking in certain cultures. Further, Laurendeau-Bendavid (1977) showed rural children in Rwanda evidenced little or no formal operational reasoning, depending on school attendance. She concludes that "school attendance is a necessary but not a sufficient condition for the attainment of formal operations" (p.165).

Pascual-Leone's insight that a quantitative organismic construct underlies stage manifestations allows the problematic Piagetian findings concerning formal operations to be explained, without denying the universality of development (or the developmental construct). In interaction with the environment, this intrinsic generative mechanism produces manifest performances. Where the child is not faced with demanding situations which only can be solved using formal operational

reasoning, or in Pascual-Leone's terms, high $M$ arousal, performance will exhibit the predicted ability. Without practice (learning) in such reasoning skills (executives), children will continually function below their maximum potential.

The second finding in these data is that all children exhibited, as expected, poor temporal executives, when using the $M_f$ brought to the task. In the CSVI-TACH analysis, mean looks made by each age group were low, ranging from 1.506 to 1.703 looks per stimulus compound. Because the CSVI-TACH analysis is a more controlled version of the CSVI-FR procedure, the task analytic expectation of a $k^2$ performance model ($k$ attending acts x $k$ units of energy) is also applicable to the CSVI-TACH. However, all ages clearly show performance much below this expectation (see table 13).

While considering the CSVI-TACH analysis, recall that subjects performed with a $k$ value approximately 0.5 units above their $M_f$ predicted from the CSVI-1STL performance. This was congruent with a finding by M. S. Miller (1980). A possible explanation for this slight improvement may be that a second (or further) look strengthens (recovers) the image from the first look, i.e., subjects recognise or realise they have seen *that* picture previously. Because of the very structured nature of the CSVI-TACH procedure, facilitating (encouraging) temporal executives which in part inhibit competing but irrelevant schemes, the subjects periodically may be able to hold an image allowing an extra ball to be thrown. This explanation would also be able to explain Miller's (1980) finding that high SES children show a whole $k$ unit difference between 'first look' and 'repeated looks' analyses, for such children are more likely

to have and/or develop efficient temporal executives than low SES children.

Consider next the CSVI-FR results (table 14 and figures 12 to 15). A clear trend in these graphs, especially in the lower two age groups is that the empirical curve at the lowest stimulus class is lower than predicted, while at the higher stimulus classes subjects performed better than the theoretical curve would suggest. Therefore a modification within the model, the Combination Model, was produced whereby subjects consistently used their $M_f$ derived from the CSVI-1STL, but exhibited an improving (more efficient) temporal executive with increasing complexity in the compound stimuli. M. S. Miller (1980) makes a similar suggestion (applicable also to the CSVI-TACH results, where too few attending acts were made) when she claims "the low SES child may use an improper self-instruction control executive, e.g., 'This one is easy, don't have to search as hard'" (p.109f).

This Combination Model (table 15 and figures 16 to 19) shows well how many looks are made at each stimulus class level. Pascual-Leone and Goodman (1979) cite data which can be mapped onto a $k(k-1)$ model, but performance among the present sample is even poorer than this, as they only use this $k(k-1)$ strategy (or premature stop rule) at the higher stimulus class levels. The 7- and 11-year-old subjects however, begin using the $k(k-1)$ strategy at the $S^3$ level, while, in contrast, both the 9- and 13-year-olds only use the strategy at the $S^7$ and $S^8$ levels.

All these data show clearly that not only do all subjects show a premature stop rule in their most efficient performance (i.e., $k(k-1)$), but subjects' stop rule appears to be dependent upon the complexity of the stimulus compound. Metasubjectively, in the absence of strong temporal

task executives, the $e$-activated scheme, representing the task situation (i.e., "This one is easy") dominates at the evaluation point (in the A-O-E cycle). Only when strong temporal executives exist, inhibiting this premature stop rule (i.e., the dominant executive now says "There is unsaturated $M$, so take another look to check you have not missed any messages"), will subjects' performance show a dependence on $k$ rather than the complexity of the stimulus. In his original study, Pascual-Leone (1970) showed subjects with strong task executives consistently performed at a $k^2$ level, even when only two stimuli were compounded.

That temporal executives are poorer than expected and that the temporal executive strength is dependent upon the complexity of the stimulus, rather than the strength of $M_f$, as Pascual-Leone's task analyses suggest, may be significantly related to the cognitive style of subjects, for Pascual-Leone's task analysis predicts, and he finds (1970), a $k^2$ performance model for FI subjects, subjects whose 'overcoming process' is stronger than factors associated with the field or 'embedding context' (see FDI task analysis). (Recall that subjects in the present sample were considered FD due to the non-significant differences between the two cognitive style groups and also the fact that these children were rural and of low SES (cf., Pascual-Leone, 1974)). FD subjects, on the other hand, are constrained by $F$, meaning that their ($M$. $e_I$) component is relatively weak. In this way, poor arousal executives (low $M_f$) and poor temporal executives ($M_f$ processing) may be due to the reliance by subjects on the context (field) rather than their ability to overcome. Certainly such a relation should be further investigated.

The suggestion, in other words, is that where the intrinsic generative

mechanism (Harré and Secord, 1976) (capacity) is forced to dominate, FI results, but until this mechanism's strength is exploited by subjects, the extrinsic generative mechanism (context) dominates. In development it is necessary for subjects to realise their independence from the concrete world. Unless this occurs, subjects' development will not exceed concrete operations.

Because $M$-growth is maturational, the $M$-power Pascual-Leone predicts *is* available. Thus, the TCO, unlike theories developed within the experimental methodology, is able to both explain the manifest performance in terms of development (universal) and learning (particular) and also to allow optimism that the poor school performance of disadvantaged children can be overcome. Of course, acknowledging the possibility of change gives researchers a social responsibility to aim at overcoming injustice and inequality by providing suggestions for practical intervention strategies.

In presenting the results of the research, emphasis has been given to the executive deficiency of these subjects. As temporal executives are developed through $LM$ learning, these can be improved, but in the longer term, it would be more expedient first to maximise the arousal executives, and thus improve the potential for temporal executive learning.

Tasks requiring $LM$ structuring skills (as opposed to $LC$ structuring) are likely to motivate children to apply greater amounts of their available $M_S$ to the task. In other words, problem situation tasks, where children are the 'discovering scientist' (cf. Piaget's tasks), will increase arousal and, in addition, demand ordered and efficient use (represented by temporal executives) of the $M$ brought to the task. Education must be

directed to this active (constructive) role of the subject: the following chapter considers further the implications of these findings for education in South Africa. The subjects in the present study, like other disadvantaged children, have grown up in environments encouraging passivity. Further, this is related to cognitive style, for field dependence, found in rural and low SES populations, is characterised by social conformity and parental authority (Pascual-Leone, 1974, p.42) rather than self-reliance. "Witkin and associates ... proposed that 'the encouragement of autonomous functioning' and the freedom of initiative in the child stimulate field-independence and psychological differentiation" (Ibid., p.41). Pascual-Leone continues by noting that experience in conflict situations gained by autonomous functioning results in relative growth of the $LM$ structures, $M$-mobilisation, and $A$ factors (Ibid.), allowing the 'overcoming process' component dominance in the FDI conflict situation.

Before concluding, some practical suggestion for future research can be made, which may help understand why the older children in the present sample did not perform with the predicted $M_S$, while those children tested in the urban township of KwaMashu, outside Durban (R. Miller et al., in preparation) performed with the predicted $M_S$ for the same age groups.

The most obvious difference between the two studies involves the CSVI testing procedures used. The KwaMashu study used the delayed response CSVI procedure while the present study used the tachistoscopic and free response procedures. Further, the children in the present study were tested individually, while those in Miller et al.'s (in preparation) study were tested in groups. This may have increased affective arousal,

for subjects may have tried harder because they were aware friends were pressing buttons. However, such a claim conflicts with researchers' usual preference for individual testing, which is believed to maximise arousal and motivation through individual attention. Nevertheless, this procedure may not be preferable in cross-cultural studies, for less individualistic (community oriented) societies may perform best in groups. This idea will be pursued in the following chapter where suggestions are made for intervention strategies to improve education in South Africa.

To ascertain the factor(s) involved in this difference it will be necessary to undertake further research in both an urban and a rural community. Firstly, an appropriate and accurate cognitive style measure should be used, possibly the portable Rod and Frame Test (RFT), as it will determine the relative field dependence of each sample. Should both groups be equally FD, their CSVI performance ($M_f$) should not exhibit full $M_s$ functioning, i.e., their arousal executives should be poor. However, because the urban sample has been found to have, and function with, the predicted $M_s$, either they are FI or the delayed response procedure facilitates performance for FD subjects so that it is equal to that of FI subjects. To resolve this problem, both the urban and rural children should be tested on the CSVI delayed response procedure and the tachistoscopic version.

In this proposed study subjects should be aged 9, 11, 13, and possibly 15 years. This distribution will capture both the end of the concrete operational stage as well as the onset (if any) of formal operations, even if this stage may begin later than predicted: thus the possibility of also testing 15-year-olds.

A further important control needs to be included: subjects must be

balanced into two groups with half tested individually and the remaining tested in groups. This control will determine the importance, among Zulu-speaking children, of the (social) group testing procedure versus the (insular) individualistic procedure.

While this proposal may be unmanageable for a single project, it is necessary that these factors all be investigated in order to understand the important difference between the present results and those reported by R. Miller et al. (in preparation).

## 8. Conclusions

The executive deficiencies found among the present sample are due to poor learning opportunities in the environment. Social class inequality, which applies to South Africa's apartheid structure, for the engineering of the system forced racial boundaries to correspond with class, results in marked disadvantage at lower levels. As Liebow (1967) emphasises, the social form is the fundamental level (extrinsic generative mechanism) responsible for poorly developed learned executive structures. "...The son goes out and independently experiences the same failures, in the same areas, and for much the same reasons as his father. What appears as a dynamic, self-sustaining cultural process is, in part at least, a relatively simple piece of social machinery which turn out, in rather mechanical fashion, independently produced look-alikes" (cited in Tulkin, 1972, p.333f). Removing the apartheid machine is essential.

At the individual level, Pascual-Leone et al. (1978) suggests that "suitable mediated affective goals [be] 'planted' in the child by the educator" (p.264). Such goals will bring strong arousal executives to bear. This suggestion is similar to Vygotsky's (1978) notion of mediation in the Zone of Proximal Development. However, Vygotsky incorporates extrinsic generative mechanisms, emphasising the child is an actor in a social environment. Nevertheless, Pascual-Leone's (1974) suggestion that dealing with cognitive conflict situations effects executive structuring is compatible with Vygotsky's mediation. Mediators (adults, more capable peers) guide children to solve problems beyond their present level of independent problem solving. Effective mediators encourage efficient use of the developmental competence endowed to the child (i.e., executive

learning).

Transcending both points is the need for the child to envisage some long-term social opportunities or rewards for improved effort. Affective goals cannot take root where education is seen as a training for an unskilled and exploited role in society. The suggestions made below assume a fundamental social change if any success is to be expected.

Firstly, following Pascual-Leone's suggestion encouraging autonomous functioning (1974, p.41), children must not be viewed as passive, empty vessels to be filled with knowledge ($LC$ learning), as is presently the case, but rather should be seen as active, independent problem-solving discoverers of the world. Conflict situations, inherent in such activity, will result in executive learning ($LM$ structuring, $M$-mobilisation, and growth in affective factors) (Ibid.). Complementing this is a second suggestion, resulting from Vygotsky's mediator role. The educational qualifications of black teachers, now significantly lower than their white counterparts, have to be raised. Teachers should be trained as mediators for the developing children, rather than information transmitters[1].

A cautionary note for those re-designing school curricula must be made. The aim should not be to reduce the demand of a task in order that it be successfully performed, but rather to have the child use his/her full mental capacity ($M$) and, through structured (directed) problem solving activity, have the child *discover* solutions to previously (and otherwise) difficult tasks. Problem solving items should have an organised sequence and all come from the same "process-structural family (i.e., all presenting at least in part the same or a related problem-solving process structure), and varying in difficulty" (Pascual-Leone, 1976b, p.272). These items unite

into a learning loop, and together with other loops, "may assist the subject to spontaneously develop (i.e., without being directly *taught* ) the executive (operational) schemes which are needed to solve the latter segments" (Ibid., emphasis added).

Unfortunately, the simpler training procedure has been seductive, because of its rapid and dramatic effect. It appears that a concern to help those with learning difficulties (including those "who come from cultural backgrounds that are different from that of the majority") has led Case (1978) to champion training as a method to improve performance. Case makes explicit his strategy of reducing the $M$-demand of the task. One of his techniques for planning instruction is to "reduce the working memory requirements of the learning situation to a bare minimum" (Case, 1978, p.442).

But as the present study illustrates, it would be best for subjects to begin by employing their maximum $M$-power. With this capacity, the very active subject can be *guided* or *directed* (as Vygotsky explicates the role of the mediator in the Zone of Proximal Development) to discover more efficient executive strategies. Such "spontaneous" learning as opposed to "externally induced" learning will not accelerate learning (Pascual-Leone, 1976b, p.275f), but rather will encourage the long-term advantage of mobile (versatile) executive learning. Training easily can be construed as disadvantaging, for below the surface success lies the fact that these subjects will use less of their capacity and therefore have less $M$ to use in potential $LM$ structuring. Intervention of this sort makes subjects dependent on simplified problem situations rather than developing the independent problem solving abilities of subjects who then are able to deal with their own problem situations (and possibly reduce task demand

themselves !).

However, the training procedure may be useful in helping adults, disadvantaged in their education, whose cognitive development is largely concretised (cf., Case, 1978). Developing new executives is unlikely, and it may be most effective to teach subjects useful strategies. In South Africa this may be important for those people who already have been victims of apartheid education. But the relevance of the more beneficial mediational (guided, directed) procedure for designing appropriate new curricula for post-apartheid education cannot be underestimated. The significance of development and education is not to speed the process but to use each stage to greatest long-term benefit. It is for this reason that "Piagetian theory is unsuited to serve as a basis for *instructional* practice" (R. Miller, 1984, p.19, emphasis added).

The results of the present research make explicit the educational inequality existent in South Africa. But more important, because the research was grounded in a framework which can model generative mechanisms, the problem can be understood and theory-based proposals forwarded which promise significant and enduring performance improvements. Regrettably, these concrete suggestions depend upon the replacement of an inequality-perpetuating system with a society which allows fair and equal educational opportunities for all its children. Optimistically, however, the antecedent conditions preventing positive improvements being initiated soon may be removed.

## Notes: Chapter 8

1. Here the attractive notion of television teaching (and possibly also computer-based systems) cannot compare with the adaptable mediator, who can mould him-/herself to the needs of the child.

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Appendix A

Table 19

Description of Compound (Test) Stimuli Indicating Presentation

Order for each Procedure

| Stimulus Class | Block | FR Order | TACH Order | Square | Red | Big | Broken border | Circle in centre | Frame | Cross in centre | Purple background | Underlined |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | A | 7 | 2 | X | | | | | | X | | |
| | B | 8 | 12 | | | | | | | | X | X |
| | C | 21 | 17 | X | X | | | | | | | |
| | D | 28 | 28 | | | X | | | X | | | |
| | E | 31 | 34 | | | X | X | | | | | |
| | F | 39 | 41 | | | | | | | X | X | |
| 3 | A | 1 | 6 | | X | X | | | | X | | |
| | B | 14 | 10 | | | | X | X | X | | | |
| | C | 17 | 16 | | | | | | | X | X | X |
| | D | 26 | 26 | | | | X | | | | X | X |
| | E | 29 | 29 | | X | | | | X | | X | |
| | F | 38 | 38 | X | | | X | X | | | | |
| 4 | A | 4 | 3 | | | | X | | X | | X | X |
| | B | 13 | 8 | X | | X | | X | X | | | |
| | C | 15 | 19 | | | X | X | X | | | | X |
| | D | 25 | 25 | | X | X | | X | X | | | |
| | E | 34 | 31 | X | X | | X | | | X | | |
| | F | 41 | 39 | | | X | | X | X | X | | |

Table 19 (cont.)

| Stimulus Class | Block | FR Order | TACH Order | Square | Red | Big | Broken border | Circle in centre | Frame | Cross in centre | Purple background | Underlined |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | A | 6 | 7 | | X | X | X | X | | | X | |
| | B | 11 | 9 | X | | X | X | | | X | | X |
| | C | 20 | 20 | | X | | | X | X | X | X | |
| | D | 27 | 24 | X | X | | | X | | X | X | |
| | E | 35 | 32 | | | | X | X | X | | X | X |
| | F | 36 | 37 | X | X | | | | X | X | X | |
| 6 | A | 2 | 1 | X | | X | | X | X | | X | X |
| | B | 12 | 11 | | X | | X | X | X | X | X | |
| | C | 18 | 18 | X | X | X | X | | X | | X | |
| | D | 22 | 22 | X | X | X | X | | | X | | X |
| | E | 30 | 35 | X | X | X | | X | | X | | X |
| | F | 37 | 40 | | X | X | X | | | X | X | X |
| 7 | A | 3 | 4 | X | X | | X | X | X | X | | X |
| | B | 9 | 14 | X | X | X | | | X | X | X | X |
| | C | 19 | 15 | X | | X | X | X | X | X | | X |
| | D | 24 | 27 | X | | | X | X | X | X | X | X |
| | E | 33 | 30 | X | | X | | X | X | X | X | X |
| | F | 42 | 42 | X | X | X | X | X | | X | | X |
| 8 | A | 5 | 5 | | X | X | X | X | X | X | X | X |
| | B | 10 | 13 | X | X | X | X | X | | X | X | X |
| | C | 16 | 21 | X | X | | X | X | X | X | X | X |
| | D | 23 | 23 | X | X | X | | X | X | X | X | X |
| | E | 32 | 33 | X | X | X | X | | X | X | X | X |
| | F | 40 | 36 | X | X | X | X | X | X | | X | X |

Appendix B

Expanded Formula and Worked Example for Bose-Einstein Distribution

Using formula II:

$$Pr\,(x) = \frac{\binom{n}{n-x}\binom{k-1}{x-1}}{\binom{n+k-1}{k}}$$

(II)

Expanding formula II:

$$Pr\,(x) = \frac{\left[\dfrac{n!}{(n-x)!\,x!}\right]\left[\dfrac{(k-1)!}{(x-1)!\,(k-x)!}\right]}{\dfrac{(n+k-1)!}{k!\,(n-1)!}}$$

If k = 5, n = 3, and x = 3:

$$Pr\,(x) = \frac{\left[\dfrac{3!}{1!\;3!}\right]\left[\dfrac{4!}{2!\,2!}\right]}{\dfrac{7!}{5!\;2!}} = \underline{0.286}$$

Appendix C

Test Instructions: English Originals and Zulu Translations

Children's Embedded Figures Test (CEFT): Group Version

Guidelines for monitoring CEFT:

1. Make sure book is not tilted. (Should remain perpendicular to desk).

2. Children are not allowed to look at original shape and embedded figure *at the same time* ! However, they can look back at the original shape as many times as they wish.

3. If a child is spending a long time on one page, suggest to him/her to try the next page and go back to that one later (time permitting).

4. Do not let children glance at another child's booklet.

5. Make sure that children who correct an incorrect answer show clearly which answer is their choice. (A large cross over shape or a coloured in shape could be used to show which answer is *incorrect*).

6. Check booklets when each child is finished to see that all pages are complete.

CEFT: Instructions

Each child received a test booklet and coloured crayon. Instructions to each class were as follows:

"Now we are going to work in this green booklet. Keep your booklet straight in front of you and do not turn any pages until I tell you to.

"In this booklet you will be looking for a hidden shape on each page. Let's learn the rules first. On the page that you are looking at [booklet cover] there is a black shape [triangle] that looks like a tent [booklet held up and black tent pointed to]. I want you to look at it carefully and then see if you can find the same shape below it. It doesn't matter if it is coloured differently but it has to be the same shape, the same size and right-side-up.

"Has anyone found it ? ... Good ! That one [point to it] is the same shape as the one at the top. What about this one [point to another of the triangles] ? Why isn't it the same ? ... That is right, it is upside down. What about this one ? ... [All the remaining triangles were discussed and judged as too large, crooked etc.].

"Okay, turn the page. Again at the top there is the same tent shape. Where is it down below ? Is it this one [point to one] ? ... No, it isn't; that one is too _____ (flat, pointed, sideways etc. All triangles are discussed until the correct one is arrived at]. This one ? Right, this one is the same shape, same size, and it is right-side-up. It doesn't matter if it is coloured differently.

"Now I want you to look carefully at that tent shape at the top so that you can remember it. Okay, does everyone have it in their mind ? Turn the page. Now, somewhere in the picture of the truck that same tent shape is

hidden. Remember, it has to be the same shape, same size and right-side-up. Anyone found it ? Good. Here it is [point to it and trace it with finger]. Now draw a line around it with your crayon, like this ...

"Turn the page again. Somewhere in the picture of the umbrella is that same tent shape. This one is a little harder. I am going to draw it on the board. Okay, I've drawn the same umbrella that is in your booklet. Could this be the hidden tent shape [point to an incorrect area] ? No ? Why not ? ... Could it be here ? ... Where could it be hiding ? Look carefully, remembering the shape and the rules. Has anyone found it ? Okay, the shape we are looking for is here [point to and trace]. Let's all trace it."

The next example was treated in the same fashion. The class was then advised about the general test procedure. They were told that they would be looking for the same shape on each of the subsequent pages, until they came to the page that had the word "Stop !" in bold letters. This page was shown to the so that it would be recognised, i.e.:

"That is what you will be doing in the rest of the booklet – looking for the shape and tracing it with a heavy line when you find it. I want you to work very quickly; there won't be much time. Don't worry about tracing the shape exactly – I just want to be able to see if you have found the right one. If you get stuck and can't find the tent shape, just go on to the next page. There may be time for you to go back to it before your time is up. Remember I am interested in what you can do, not what your neighbour can do. Any more questions ? ... Okay, ready ? Go ahead."

When the last item of the first section of 11 'tent' items was reached by all children, the time was called and all were asked to put down their crayons. The next section with the 'house' shape was approached in the same manner as before. The only practice item was drawn on the board and

solved. Children were advised that this section was a little harder, but were told to do the best they could and that they had done well on the previous section.

Before testing proceeded, the children were told to fold back the previous section so that they could easily refer to the house shape when needed.

RSPM Test: Instructions

"Look at the first page of your booklet. Do not turn over any pages. The first page looks like this one."

- Show the children a copy of the booklet.

"Look at the picture with A.1 written above it. Do you all see the picture ? Do you see that this big pattern has a piece missing ? Each of these little bits below [point to each of them in turn] is the right shape to fit the space in the big pattern, but only one will complete the pattern. Number 1 [point to the bit and then to the pattern] is quite the wrong pattern. Numbers 2 and 3 are wrong - they fit the space, but they are not the right pattern. What about number 6 ? It is the right pattern [show children that the pattern is the same as the pattern above] but it does not go all over. Put your finger on the one that is quite right."

- Check that this is done correctly. If necessary, give the children more explanation, then say:

"Yes, number 4 is the right one. So the answer to A.1 is 4. Draw a circle around bit 4 with your crayon."

- Wait for everyone to do this, then say:

"Your book is full of patterns like the one you have just seen. You have to decide each time which of the bits below is the right one to complete the big pattern above the bits. When you have found the right one, draw a circle around the bit with your crayon. They are simple at the beginning and get harder as you go on. There is no catch. But if you pay attention to the way the easy ones go you will find the next ones less difficult. *Try each one, from the beginning right to the end of the booklet* . You can take as long as you need. Do not miss any out. Do not turn back. See how many you can get

right. Remember you can have as much time as you like.

Now look at picture A.2 – it is also on the first page of your booklet. Do you all see it ? Try and do it on your own. When you have done A.2, do not turn over the page."

– When everyone has done A.2, say:

"The right one of course is number 5. Have you all drawn a circle around number 5 ? [Check that this has been done]. Now do you all know what to do ?"

– If all children know what to do, say:

"Now you can turn over and go on by yourself until you get to the end of the book. Remember, do not miss any out and do not turn back. Take as long as you need."

– Check that all children know what to do, and that they are drawing a circle for each problem. Do not help children work out the problem, but you may have to explain to them again what they have to do.

– As each child finished, he/she handed in his/her booklet and left.

CSVI-FR: Instructions

For 7- and 9-year-olds:

"Today we are going to learn how to play a spy game. Do you know what a spy is ? He/she is a secret agent, a person who tries to discover secrets about other people and then sends these secrets back to his/her friends in a special code.

The spy uses a code so that only he/she and his/her friends can know what the secret message says. Do you know any codes ? ...

In this game we will both be spies. I will be sending you secret messages on the screen here and you will let me know that you have seen the messages by making certain signals I will teach you. But before we can send any messages we must first learn the secret code.

For 11- and 13-year-olds:

Today we are going to learn to use a code to send messages. Do you know what a code is ? Do you know any codes ?

When you have a code, you can send special messages by making certain signals. People in ships at sea and pilots in airplanes send messages by code.

Have you ever sent a message to a friend that you don't want someone else to read, a secret message ? Well, then you would be (were) using a code.

I will be sending you messages on this screen here and you will let me know that you have received them by making the signals which I will teach you. Before we can send any messages, we must first learn the secret code.

All children: Introductory Phase:

Here is the first message in the code. It is the square shape. Every time you see a shape that is square you must raise your arms like this. All right, *you* raise your arms now.

- Pointing to the top right figure:

"What would you do here ?"

- Either: "Yes, that is right, there is no message here", or

"No, you don't know anything for that one. The only message you

know is the square shape. There is no message here."

- Pointing to bottom right figure:

"How about this one ?"

- Pointing to bottom left picture:

"Is there a message here ?"

Now we have a new message. This time it is the colour red. Whenever you see a shape that is red, you must clap your hands together."

Continue introducing messages in the following order:

| | |
|---|---|
| Big | Open mouth and say "Ah" |
| Broken border | Extend arms to side, shoulder height |
| Circle in centre | Stamp on floor |
| Frame around shape | Stand up |
| Cross in centre | Cross arms over chest |
| Purple background | Hit bench |
| Underline | Touch nose |

Note: Some pictures contain more than one message. If subjects produce more than one response, say to them:

"You are right, there are a few messages here. But all you really have to do now is make one signal."

If a child does not attempt a multiple response, i.e., responding to more than one message in a picture, *twice* during the introductory set, the experimenter points out that there is more than one message contained in the picture:

"That's right, you sent the signal for the message _____ You could also have sent the signal _____, because the picture is also _____ Don't worry though; all you really need do is make one signal."

Do not wait for children to give this extra response, but move on to the next card. The idea is to *give the information without giving practice*.

When a circle in centre and cross in centre occur together, child may ask if that's a new message. Say to child:

"There is a circle in the centre and the cross in the centre is there too."

If child asks what to do, say: "You decide."

Errors: If child makes an error, say:

"No, that is not correct. When you see the message _____ you must make the signal _____.

More than one message: If a child makes more than one signal when there are many messages, say:

"That's right, but you only have to give one signal now."


Learning Phase:

Learning begins immediately after the intoductory cards are finished.

"That was very good. Those pictures were just to show you what the messages are. But to play the game, you have to learn the messages very well. So I will give you some practice now. Okay ? I will show you one

picture at a time. If you see a message, make the signal for that message. If you don't see a message, you tell me that there is no message. Here is the first message."

Let all the children practice until they are getting all (most) of the messages correct. After this the children must be pretested and tested *individually*.

Individual Session: (Slide presentation began in this phase)

"Do you remember the secret code you learned the other day ? Let's go through the messages again to make sure you know them very well. Then we will play the game."

Begin recording responses immediately. As soon as the child gets 40 responses correct *in a row*, stop learning and begin testing.

Testing:

"Now we are ready to send the real messages. You have learned the code very well. From now on there will be more than one message on each slide. Your job is to make signals for all the messages that you see. As soon as you see the picture you can begin sending messages. I will show you each picture for a little while. But after I take the picture away, you can still send messages. Keep sending messages until you have sent all the messages you saw. Are you ready to start ? Okay, here is the first picture."

Show each slide for 5 seconds. Record responses on recording sheet.

CSVI-TACH: Instructions

"You did very well on the spy game the other day. But sometimes enemy spies are watching and we must still send messages. When this happens we must send the messages very fast so that nobody else has time to see them. We often use computers to send fast messages. Instead of making gestures like you did last time, you are going to press these buttons on this sheet of paper. When we play the game properly, you will be using a box with buttons. For you to be able to tell me that you have seen all the messages, you must learn which buttons go with which messages."

Remind the children of all the messages and teach them which buttons to press for each message. Follow this order:

Square

Red

Big

Broken border

Circle in centre

Frame

Cross in centre

Purple background

Underline

To help the children learn the new associations, give them practice with the pretest cards. When they know the associations well, they may proceed to testing.

Training Phase:

"You have learned the new code very well. Now that you know which buttons to press for each message, you must learn to see the message very fast. Sometimes we use computers to send messages, and these messages come very fast. Now we are going to play the spy game with this machine which sends messages very fast. We will practice that now.

"Before we start, I want to show you this funny looking picture. When you see this, do not pay any attention to it. It will come after every message, but it is just to confuse the enemy/ anyone wanting to break the code, so don't pay any attention to it.

"Now these pictures will come on very fast and then the funny looking message will come on afterwards. Your job is the same as before. If you see a message in the picture, press the button for that message. If you don't see a message, tell me. After you have seen the picture I will move

the slides on. When you are ready to see the next picture, push this big red button. Be sure to look at the wall when you do so, because the message comes very fast."

Mark each response. Children must get 40 correct *in a row*, before going on to the test.

Test Phase:

"From now on there will be more than one message on each slide. Before, there was only one message each time, but from now on there will be several messages on each slide. Your job is to push the buttons for *all* the messages that you see.

"Because there may be a lot of messages and each picture comes *very fast* like before, you can look at each slide as many times as you need. You can push this big button as often as you need to see all the messages. Each time you press the big red button you will be able to see the picture again. But the trick is to get all the messages in *as few looks as possible*. Do you understand ? Remember, you can look at the same slide as many times as you want, but try to get all the messages in as few looks as possible.

"Once you hear the slide change [count to five and], you can begin. Remember to look at the wall when you press the big button, otherwise you will not see the message."

Child looks once. Ask child: "Did you see any messages ?"

If child says "Yes", say:

"Push the buttons for all the messages you can remember."

If child says "No", say:

"Look again and be careful to watch the wall."

In both cases, say: "Now look again to see more messages." Force two looks

or more on the first slide. After the first slide ask the child if he/she has seen all the messages. If they are sure they have seen all the messages, say: "Do you want the next slide now ?" If child is not sure whether he/she has seen all the messages, say: "If you think there are still other messages, have another look." After the first slide *do not force* many looks, but make sure that the child knows he/she should make more than one look.

If: 1. Child pushes same buttons for each look, say: "You need only push each button once for each picture. Just try to get the messages you missed before.

2. Child does not realise he/she is looking at the same slide with each look, say: "This is still the same slide - are you ready for the next picture ?"

3. Child takes many looks with one or no new response for each look, say: "Remember, try to get all the messages in as few looks as possible. Take as few looks as you can, but be sure to get all the messages."

4. Child presses wrong button and wants to correct mistake. Record the response, and warn child to think carefully before pressing buttons.

5. Child starts saying the cues or buttons out loud, remind child that he/she must play the game without talking, or the enemy spies will hear the secret messages."

6. Child presses shutter button before next slide has been moved on, say: "Wait until I move the next slide on. You will hear a click... [count to five]...

7. Child asks: "Did I press the _____ already ?", reply: "You decide."

Instructions for CEFT: Zulu Translation

Manje sizosebenza kulelebhuku ehluhlaza. Beha ibhuku liqonde phambi kwaliho ungavuli elunje ikhasi ugize ugikutshele mina.

Kulelibhuku uzofuna isakhiwo esicashile ekhasini ngalinye. Ake sifunde imithetho kuqala. Kulelikhasi ohbukayo [ingaphandle lebhuku] kukhona isakhiwo esimuyama [unxantathu] esifana netende [ibhuku liphakanyiswe kukhonjiswe itende elunuyama]. Ngifuna mbuke kahle mbone ukuthi ningasithola yini isakhiwo esifanayo ugezansi. Akusko hitho noma umbala ungafani kodwa isakhiwo sifane, kulingane futhi kubeyicala eliyilo phezulu.

Ukhona osekutholile ? Kuhle ! Yiloko [khomba kukona] okufana naloku okuphezulu. Uthini ngaloku [khomba okunye konxantathu] ? Yini kungafani ? Kuhle loko; kubheke phansi. Uthini ngaloku ? [Bonke ouxantathu abasele babeehazwa babonakale bebakhulu kakhulu begewegwile].

Kuhungile, phenya ikhasi. Futhi phezulu kukhona isakhiwo selende esifanayo. Kulaphi phansi ? Yileli ? [Khomba eklodwa] ? Cha akulona, lelo li _____ [yisicaba, licijile, emaceleni etc. Bonke ouxantathu bachazwa kwaze kwafikwa kwabawufunayo]. Yilona ? Kulungile, bona isakhiwo siyefana, nyalingana futhi necala eliyilo phezulu. Akusho lutho noma umbala ungafani.

Manje ngifuna ubukisise kahle isakhiwo setende phezulu. Yikhona uzolikhumbula. Kulungile, Nonke ngabe umalo engqondweni ? Phenyani ikhasi. Manje endaweni ethile emfanekisweni weloli lesosakhiwo setende esifanayo sicashile. Khumbula, kube isakhiwo esifanayo, kulingane futhi necala eliyilo phezulu. Ukhona osekutholile ? Kulengile. Naku [kukhombe ukulandele ngomunwe]. Manje dweba umugqa ngeCrayon ukuzungeze, kanje...

Phenya ikhasi futhi. Endaweni ethile emfanekisweni wesambulela kukhona isakhiwo esifanayo setende. Lesi sibukhunyana kancane. Ugizosidweba oqwenibeni kulungile, ngidwebe isambulela esifana naleso esisebhukwini lakho. Kungenzeka loku kube isakhiwo setende elicashile [khomba indawo okungeyona] ? Cha ? Ngoba yini ? Kungenzeka kube lana ? Kungabe licashephi ? Buka kahle, ukhumbule isakhiwo nemithetho. Ukhona osekutholile ? Kulungile, isakhiwo esisifunayo silapha [sikhombe usilandele]. Asisilandele sonke.

Isibonakaliso esilanelayo senziwe ngendlela efanyo. Izingane zabesezilulekwa ngendlela yokuhlolwa. Zatshelwa ukuthi zizofuna isakhiwo esifanayo ekhasini ngalinye zize zifike ekhasini elinegama elithi "Yima !" ngamagama amakhulu . Lelikhasi balikhonjiswa ukuze bakwazi ukulibona.

Yilonkho enizokwenza ebhukwini lonkenifune isakhiwo futhi nisilandele ngomugqa obonakalayo uma senisitholile. Ngifuna nisebenze ngokushesha okukhulu; asizubakhona isikhathi esikhulu. Ningazikhathazi ngokulandela isakhiwo njengoba sinjalo - ngifuna ukubona ukuthi nithole okuyikho ngempela. Uma nibambeka ningakwazi ukuthola isakhiwo setende qhubekelani ekhasini elelandelayo. Singabakhona isikhathi sokuba niphinde emiwa ngaphambi kokuba isikhathi siphele. Khumbula ngiyothokoziswa ongase ukwenze hayi okungenziwa umakhelwane wakho. Ikhona eminye imibuzo ? Kulungile, lundela ? Qala.

Instructions for RSPM: Zulu translation

"Bheka ekhasini lokuqala encwadini yakho. Ungephenyi kwelinye ikhasi. Ikhasi lokuqala lifana naleli."

- Khombisa abantwana incwajana efanayo.

"Buka isithombe esibhalwe uA.1 phezulu. Niyasibona nonke isithombe ? Niyabona ukuthi kulomboniso kukhona isicucwana esingekho ? Esisodwa kulezi ezingezansi [khomba esisodwa esifanayo] siyafana nomfanekiso ukugcwalisa isikhala embonisweni omkhulu, munye kuphela ulungile. Umbuzo 2 no 3 awalungile ayigcwalise isikhela kodwa nayo ayilungana. Unjani umbuzo 6 ? Iwona mboniso olungile [khombisa abantwana ukuthi umfanekiso uyafana nongenhla] kodwa awungeni yonke indawo. Beka umunwe emdwebeni ekuyiwonawona."

- Hlola ukuthi lokhukwenziwe kahle. Uma kufanele nika ababtwana incazelo ebanzi. Bese uthi:

"Kulungile umbuzo 4 ulungile. Kusho ukuthi uA.1 impendulo ku-4. Dweba indilinga ezungeze u4 ngekhilayoni."

- Linda bonke baze bakwenze. Bese uthi:

"Incwajana yakho inenifanekiso eminingi efana nesesiyibonile. Uzokheta wena ukuthi imuphi umdwebo ofanele ukugadele umfanekiso omkhulu. Uma usuwutholile olungile dweba indilinga kulowo owukhethile ngekhilayoni. Yonke ilula ekuqaleni bese kuya ngokuqina uma uqhubeka. Akukho ukuqagela. Uma ubhekisisa kuleyo eluea uyothola ukuthi kuleyo elukhuni kungconywana. Zamayonke kuza kufike ekugcineni kwencwajana. Ungathatha isikhathi eside ngokwanele. Ungashiya lutho. Ungaphenyi ngemuva. Bheka ukuthi mangaki yenza ubone ukuthi ongakuthola. Ukhumbula unesikhati esiningi ngokuthanda. Bheka isithombe A.2 – isekhasini lokuqala lebhuku lakho. Niyabona nonke zama uzenzele wena. Uma usumenzile uA.2

ubgalivuli ngale ikhasi."

- Uma wonke umuntu esenzile uA.2 yithi:

"Oku lungile umbuzo 5. Nidwebile nonke indilinga nezungeza uNo 5. [Bheka ukuthi lokhu uwenziwe]. Manje nonke niyazi ukuthi kufanele nenzani?"

- Uma bonke sebazi ithi:

"Seningavula kwi ikhasi elisha nenze umsebenzi nize nifike ekugcineni. Ningeqi lutho futhi ungavuli ubhale lapho ubuse udlule khona. Bhala okuningi ngangokuthanda."

Bheka ukuthi zonke izingane ziyzai ukuthi zenzani indilinga kubuzo ngamunye. Ungabasizi ukuthola umphumela, kodwa ungabachazele ukuthi benzani futhi. Uma umntwana eseqedile angaletha incwadi yakhe aphume.

Instructions for CSVI-FR: Zulu Translation

<u>For 7- and 9-year-olds</u>:

Namhlanje sizofunda ukudlala ngomdlalo wenhloli. Uyazi ukuthi yini inhloli ? Umuntu othola izimfihlo, ozama ukuthola izimfihlo ngabanye abantu bese ethumela lezimfihlo kubangane bakhe ngendlela ezahlukile. Inholi isebenzisa izindlela ezithize ezinokwaziwa abangane bayo abazo kwazi ukuthi lomayalezo oyimfihlo uthini. Uyazazi ezinye izindlela ?

Kulomdlalo sonke sizoba izinhloli. Ngizokuthumelela umyalezo oyimfihlo kuloluqwembe bese uyangazisa ukuthi oboneni kulomyalezo ngokwenza izimpawu ezithize engizokufundisa zona. Kodwa ngaphambi kokuba sithumele imiyalezo kufanele kugala ufunde indlela yemfihlo. Nangu umyalezo wokuqala kulendlela. Isikwele. Ngaso sonke isikhathi ubona isikwele kufanele uphakamise isandla sakho kanje. Kulungileke, phakamisani izandla zenu manje.

- Ukhombba inombolo ephezulu ngakwesokudla:
Ungenzani lapha ?

- Okunye: Yebo kulungile. Awukho umyalezo lapha,

- Noma: Cha, awazi lutho ngalokhu. Umyalezo owaziyo kuphela isikwele. Akukho myalezo lapha.

- Ukhomba inombolo ephansi:
Injanike lena ?

- Ukhomba isithombe esiphansi kwesobunxele:
Ukhona umyalezo lapha ?

Manje sinomyalezo omusha. Ngalesi khati umbala obombu. Noma yinini uma ubona isakhiwo esibombu, uboshaya izandla uzihla-nganise.

Qhubeka uthaze imiyalezo ngalendlela elandelayo:

| | |
|---|---|
| Kukhulu | : Vula umlomo uthi "A" |
| Umngcele owephukile | : Yeluka izi ngalo emaceleni ngobude |
| Indilinga esiyingini | : Shaya phansi ngamandla |
| Yingilizela isakhiwo | : Phambanisa izingalo esifuben |
| Purple namachashaza | : Shaya itafula |
| Umdwebo ngezansi kwesakhiwo | : Thinta ikhala |

Qaphela: Ezinye izithombe ziphethe ngaphezu komyalezo owodwa. Uma izifundo zikhipha ngaphezu kokukodwa:

"Ulungile, kunemiyalezo emincane lapha. Kodwa konke okufanele ukwenze manje ukwenza uphawu."

Uma ingane ingazami ukwenza okiphindiwe, kusho ukuthu ngaphezu komyalezo owodwa esithombeni, kabili thali sencazelo.

"Kulungile, thumela uphawu lalomyalezo _____ Unathimela futhi uphawu _____, ngoba isithombe naso _____. Ungahlupheki nokho, okuphingayo nge mpela ukwenza uphawu olulokudwa. Musulinda ingane ize yande nenpendulo kodwa qhubekela kokula ondelayo. Inhloso eyokunikeza ingqi-kithi ngaphandle kokuyenza.

Uma isiyingi phakathi nesiphambano esiyingini, kuhlangawe ingawe ingabuza umakungumyalezo omusha. Yisho kumutwana:

"Kunesiyingi, phaakathi nendawo nesiphambano nalapho futhi."

Uma ingane ibuza,yithi:

"Zicabangele wena."

Amaphutha: Uma ingane yenza iphutha yithi:

"Cha, akulungile. Uma ubona umyalezo _____ ubokwenza uphawu _____."

Ngaphezu komuyalezo owudwa: Uma ingane yenza ngaphezu kophawu olulodwa uma kunemi yalezo emi ningi:

"Yithi kulungile kodwa kufanele wenze uphawu kumyalezo owodwa.

Ukufunda: Ukufunda ugede ngokushesha ngemuva kokuba umyalezo usuqediwe.

"Kuhle kakhulu. Lezi zithombe kade zikhombisa ukuthi yini umlayezo kodwa ukudlala umdlalo, kufenle ufunde kahle umlayezo. Manje ngizo kunikeza isikwathi sokuyeza mbisa isithembe."

Instructions for CSVI-TACH: Zulu Translation

Trainer:

"Nenze kahle emdlalweni wenloli izolo. Kodwa kwesinye isikhathi izitha zenhloli ziyabuka futhi kufanele esheshayo ukuze omunye angakwaziukubona. Sisebenzisa amakhomputha ukuthumela lemibiko. Esikhundleni sokwenza ngezandla njengakuqala, nizokwenza ngokugcinezela izinkinobho ephepheni. Uma sidlala lomdlalo ngokucophelela nizosebenzisa ibhokisi elinezinkinobho. Okwwakho ukuze ukwazi ukungitshela ngemiyalezo oyibonile, ufanele ukufunda ukuthi zinkinobo zihambisana namiphi imiyalezo."

Khumbuza abantwana ngayo yonke imiyalezo bese ubafundisa ukuthi iziphi izinkinobo abafanele ukuzigcinezela kulowo nalowo myalezo. Landela lendlela:

| | |
|---|---|
| Isikwele |  |
| Okubomvu |  |
| Okukhulu |  |
| Imigqa ephukile |  |
| Indilinga phakathi |  |

Oku biyelwe

Isiphambano phakathi

Isakhiwo esipurple

Okudwetshelwe

Ukusiza abantwana funda ukuhlanganisa, ubanike ithuba lokuzama ngamakhadi okuvivinya. Uma sebekwazi kahle, sebengaqhubeka ekuhlolweni.

Umvivinyi: "Senifunde kahle icode entsha. Manje usuyazi ukuthi iyiphi inkinobho ozoyigcindezela kulowo myalezo, funda ukubona imiyalezo ngokushesha. Ngesinye isikhathi ikhomputha ithumela imiyalezo bese lemiyalezo izangokushesha okukhulu. Manje sizodlala umdlalo wempimpi ngalomshini othumela imiyalezo ngokushesha sizozama manjena ukwwenza.

"Ngaphambi kukuba siqale, ngifuma ukubonisa lemiboniso ebukeka ihlekisa. Uma ukubona lokhu, ungagxilisi ukansaka kakhulu. Kuzovela ngemuva kwayo yonke imiyalezo, kodwa eyoku dida isitha/noma ubani ofuna ukuphula icode musa ukunaka lutho."

"Manje lezizithombe zizoza ngokushesha okukhulu bese ziba nomboniso ozovela kamuva. Umsebenzi wakho uyafana nakuqala. Uma ubona imiyalezo eminingi esithombeni, gcinezela inkinobho yalowo myalezo. Uma ungaboni myalezo, ngitshele. Emva kokubona isithombe ngizodlulisa isithombe. Uma usulungele ukubona esinye isithombe, gcinezela inkinobho enkulu. Kodwa

qiniseka ubuka odongeni uma wenza, ngoba umyalezo uqhamuka ngokushesha."

Lungisa okufanéle. Izingane azithole okungu-40 emgqeni ngaphambi kokudlulela ekuhlolweni.

Ukuvivinywa: Kusukela manje, siqhubeke kuzovela imiyalezo engaphezu kowodwa. Ekuqaleni bekuno myalezo owodwa kuphela, kodwa manje isizoba miningana esithombeni ngasinye. Umsebenzi wakho ukugcindezela izinkinobho kuyo yonke imiyalezo oyibonayo.

"Ngoba kungase kube nemiyalezo eminingi, futhi izithombe ziza ngokushesha, ungabheka esithombeni izikhati eziningi ngangokuthanda kwakho. Unayigcindezela inkinobho enkulu ukuze ubone yonke imiyalezo ngokuthanda. Sonke isikhathi uma ugcindezela inkinobho enkulu, uyakwazi ukubona isithombe futhi. Isihibe ukubona yonke imiyalezo ngokubuka kancane. Uyezwa ? Khumbula, ungabuka isithombe esifanayo izikhathi eziningi ngangokuthanda kwakho, kodwa zama ukuthola imiyalezo ngokubuka kancane,

"Uma uzzwa isithombe sishintsha, usungaqala. Khumbula ukubheka odongeni uma ugcindezela inkinobho, ngaphandle kwalokho ungeke wawubona umyalezo."

Ingane ibuka kanye. Buza ingane ukuthi:

"Kukhona imiyalezo eyibonile ?"

- Uma ithi "Yebo", yithi:

"Phusha inkinobho kuyo yonke imiyalezo ongayikhumbula."

- Uma umntwana ethi "Cha", yithi:

"Beka futhi, bese uqaphelisisa odongeni."

<u>Kuso sonke isikhathi yithi</u>: Maje bheka futhi ubone neminye imiyalezo Cinelela ubone imiyalezo noma engaphezulu.

Emva kwesokuqala isithombe buza umntwana ukuthi yonke imiyalezo. Una sebeyibone yonke imiyalezo, yithi:

"Niyasifuna esesibili isithombe manje ?"

Uma ingane ingakazi kahle noma isiyibone yonke imiyalezo, yithi:

"Uma ucabanga ukuthi isekhona eminye imiyalezo, bheka futhi."

Emva kwesithombe sokuqala ungacineleliukubona okuningi. Kodwa qiniseka ukuthi ingane ikwazi ukubona ngaphezu kokukodwa.

<u>Uma</u>:

1.  Umntwana ecinezela inkinobho efanayo, kulowonalowo mboniso, yithi:
    "Cindezela inkinobho eyodwa kanye ngesithombe ngasinye. Zama ukuthola imibiko ekade ungayitholanga."

2.  Umntwana akaboni ukuthi umfanekiso usafana esithombeni uma ebkheka kanye, yithi:
    "Kusewumboniso owodwa – usulungele esinye isithombe ?"

3.  Umntwana ubuka kaningi embonweni owodwa engakuboni okunye, yithi:
    "khumbula, zama ukuthola yonke imiyalezo ngokubuka kambalwa uma kwenzeka. Buka kancane, kodwa uqiniseke ukuthi uyithole imiyalezo."

4.  Umntwana uphusha inkinobo okungesiyo afune ukulungisa iphutha. Kubhale bese umbonisa ukuthi acabangisise ngaphambi kokugcindezela inkinobho.

5.  Umntwana uqala ngokusho ngezenzo, noma ngezinkinobho mkhumbuze ukuthi angawudlala ngaphandle kokukhuluma noma izinhloli zimuzwa esho izimfihlo zemiyalezo."

6.  Ingane icindezela inkinobho ngaphambi kwesithombe sesicishile: "Linda

ukuze ngidlulise isithombe. Uzuzwa umsinjwana."

7. Ingane ibuza: "Sengiyicindezele _____ ?", yithi: "Uzobona wena."

Appendix D

PROJECTED IMAGE

(STAGE SIZE REDUCED FOR PRESENTATION PURPOSES)

EDGE OF STAGE

POWER
CONTROL

SUBJECT'S
POSITION

TEACHER'S
POSITION
(HOLDING
REMOTE
CONTROL)

CAROUSAL
PROJECTOR
(test slides)

a) CSVI-FR Procedure

PROJECTED IMAGE

RECORDING
BOX

TEACHER'S
POSITION

RESPONSE
BOX

MASK
SLIDE

REMOTE
CONTROL

SUBJECT'S
POSITION

POWER AND
TIME CONTROLS

EDGE OF STAGE

CAROUSAL
PROJECTOR
(test slides)

b) CSVI-TACH Procedure

Figure 22 Layout of apparatus and position of subject for CSVI testing.

Appendix E

Underline

Circle in
centre

Frame

Square

Red

Broken
border

Big

Purple
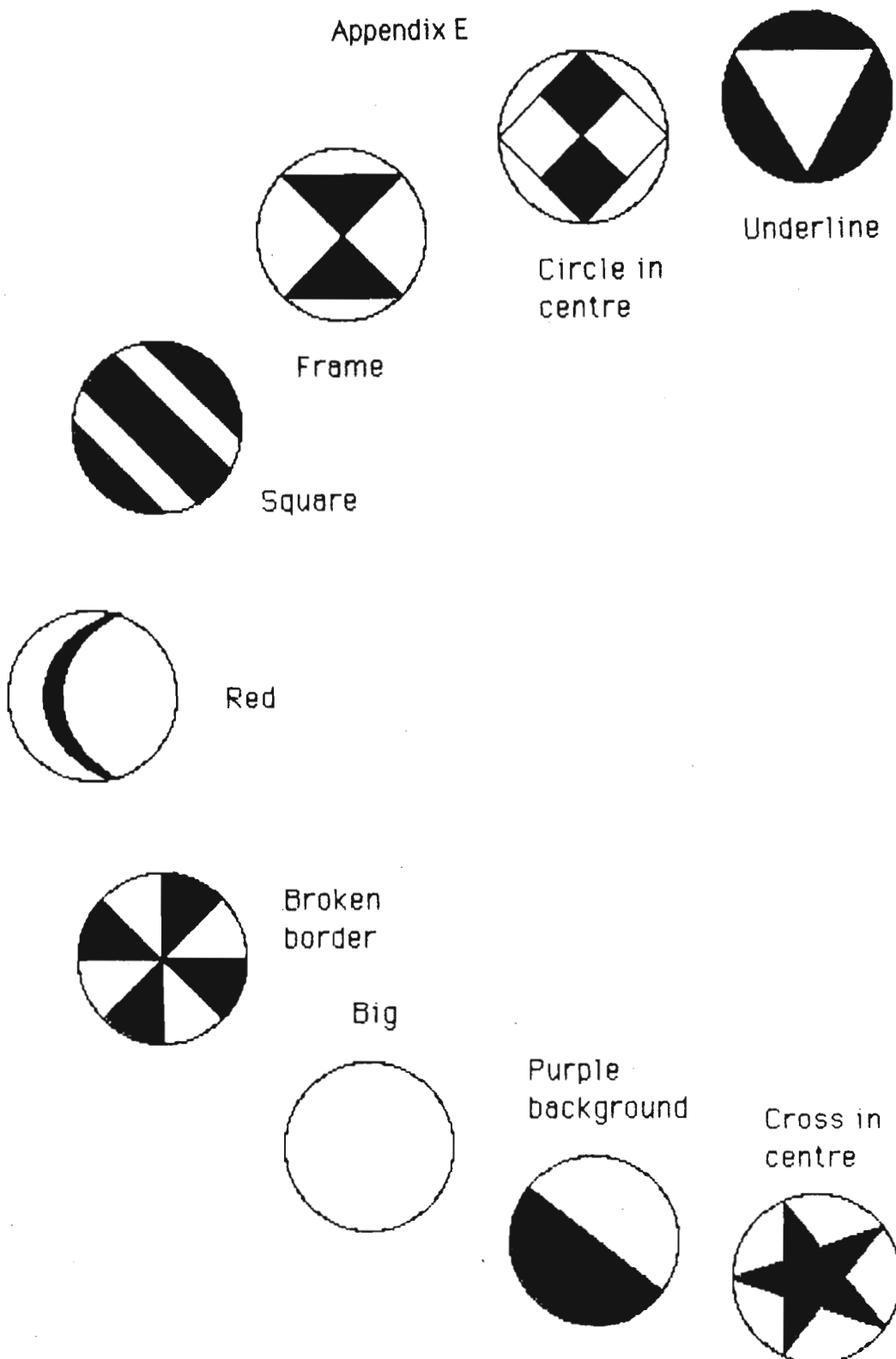background

Cross in
centre

Figure 23. Page representing the top of a response box, indicating cues associated with each button.

Appendix F

<u>Calculation of E(X) and Emp. Var.: A Worked Example</u>

<u>For each $S^n$ and Total Task:</u>

i.  $E(X) = \dfrac{1(R^1) + 2(R^2) + \ldots + n(R^n)}{R^1 + R^2 + \ldots + R^n}$

ii. Var. Emp. $= \dfrac{R^1(E(X)-1)^2 + R^2(E(X)-2)^2 + \ldots + R^n(E(X)-n)^2}{R^1 + R^2 + \ldots + R^n}$

where $R^1$ = frequency of single responses

$R^2$ = frequency of double responses

$R^n$ = frequency of n responses

Eg. If for $S^4$ frequencies are:

| | Total | $R^1$ | $R^2$ | $R^3$ | $R^4$ |
|---|---|---|---|---|---|
| $S^4$ | 70 | 10 | 20 | 30 | 10 |

i.  $E(X) = [1(10) + 2(20) + 3(30) + 4(10)] / 70$

$= \underline{2.571}$

ii. Var. Emp. $= [10(2.571-1)^2 + 20(2.571-2)^2 + 30(2.571-3)^2 + 10(2.571-4)^2]/70$

$= \underline{0.816}$

Appendix G

Table 20

<u>*t*-Test Comparisons for FI and FD Subjects for Three CSVI Analyses</u>

| AGE | ANALYSIS | FI | | FD | | df | *t* | p |
|-----|----------|------|-------|------|-------|----|--------|--------|
| | | Mean | $s^2$ | Mean | $s^2$ | | | |
| 7 | 1STL | 2.171 | 0.834 | 2.082 | 1.100 | 20 | 0.213 | > .1 ns |
| | TACH | 3.023 | 1.679 | 2.877 | 1.269 | 20 | 0.279 | > .1 ns |
| | FR | 2.941 | 1.900 | 2.775 | 1.414 | 23 | 0.321 | > .1 ns |
| 9 | 1STL | 2.146 | 0.894 | 2.704 | 1.343 | 17 | -1.155 | > .1 ns |
| | TACH | 3.064 | 1.951 | 3.038 | 1.590 | 17 | 0.042 | > .1 ns |
| | FR | 3.291 | 2.042 | 3.372 | 2.331 | 15 | -0.113 | > .1 ns |
| 11 | 1STL | 2.371 | 1.022 | 2.256 | 0.872 | 23 | 0.295 | > .1 ns |
| | TACH | 3.081 | 1.438 | 3.335 | 1.729 | 24 | -0.515 | > .1 ns |
| | FR | 3.610 | 2.155 | 3.584 | 1.906 | 23 | 0.046 | > .1 ns |
| 13 | 1STL | 2.569 | 1.347 | 2.340 | 0.984 | 16 | 0.443 | > .1 ns |
| | TACH | 3.251 | 2.732 | 2.039 | 1.470 | 17 | 0.849 | > .1 ns |
| | FR | 3.275 | 1.994 | 3.266 | 1.980 | 18 | 0.014 | > .1 ns |

Appendix H

Table 21

<u>*t*-Test Comparisons for RSPM Scores</u>

| AGES | n | Means | $s^2$ | df | $t$ | p |
|------|-----|--------|--------|-----|---------|---------|
| 7 | 29 | 14.552 | 12.831 | 51 | - 1.307 | > .1 ns |
| 9 | 24 | 16.333 | 38.490 | | | |
| 9 | 24 | 16.333 | 38.490 | 52 | - 3.219 | < .01** |
| 11 | 30 | 22.833 | 69.978 | | | |
| 11 | 30 | 22.833 | 69.978 | 56 | - 3.816 | < .01** |
| 13 | 28 | 30.786 | 58.538 | | | |