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COGNITIVE DEVELOPMENT IN ABORIGINES OF CENTRAL AUSTRALIA :

CONCRETE OPERATIONS AND PERCEPTUAL ACTIVITIES

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degree of Doctor of Philosophy
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This thesis incorporates original research carried out by the author during the tenure of an Australian National University Research Scholarship in the Department of Psychology of the Australian National University from November 1967 to December 1970.

This thesis has been submitted for the degree of Doctor of Philosophy, but has not yet been examined. It is circulated on the understanding that it will not be quoted or otherwise used without the written consent of the author.

Canberra, December 21, 1970.

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ABSTRACT

This study investigates aspects of the cognitive development in Australian Aborigines which are related to the theory of Jean Piaget.

The following tests were used:

(a) Logico-mathematical tests: Conservation of Quantity, Weight, Volume and Length, and the Seriation of lengths;

(b) Spatial tests: Linear, reverse and circular Orders, Rotation of landscape models and Horizontality;

(c) Illusions: Müller-Lyer, Horizontal-Vertical, Delboeuf and Oppel-Kundt figures, and the Size-Weight illusion.

These tests were administered to children aged 5 to 16 years (and to some adults) in the following three samples:

(1) 65 "low-contact" Aborigines, living on a remote reserve in Central Australia ('Areyonga').
(2) 100 "high-contact" Aborigines, living on a mission station in Central Australia with a long history of European contact ('Hermannsburg').
(3) 80 European children, living in Canberra.

Three hypotheses were derived from previous cross-cultural studies in genetic psychology and from an analysis of the ecological and cultural background of the Australian Aborigines:

Hypothesis 1: The qualitative aspects of operational development (i.e. the stages) are identical in Australian Aborigines and in Europeans, but the rate of development is slower in Aborigines.

Hypothesis 2: The rate of operational development is faster in the high-contact group than in the low-contact group.

Hypothesis 3: Aborigines, because of their cultural background will develop spatial concepts more readily than logico-mathematical concepts.

Hypotheses 4 and 5 were respectively based on Piaget's theory of perception (Piaget, 1966, 1969a), and on Segall et al.'s (1966) ecological cue validity theory:

Hypothesis 4: The following phenomena are inversely related to operational level: (a) the susceptibility to primary illusions; (b) the extent of the decrease with practice in susceptibility to primary illusions; (c) the age at which the maximum susceptibility to secondary illusions is reached.

Hypothesis 5: (a) The order of susceptibility to the Müller-Lyer illusion is the following (from highest to lowest): Canberra, Hermannsburg, Areyonga; (b) the order of susceptibility to the Horizontal-Vertical illusion is the following (from highest to lowest): Areyonga, Hermannsburg, Canberra.

The following hypotheses were set up on the basis of the results of a previous study dealing with the development of conservation concepts in Australian Aborigines (de Lemos, 1966, 1969b):

Hypothesis 6: The order of difficulty usually found with the tests of conservation of Quantity and Weight is reversed in Australian Aborignes: Weight is found to be easier than Quantity.

Hypothesis 7: At Hermannsburg, the performance of part-blood Aborigines is better than that of full-blood Aborigines.

Hypotheses 1, 2 and 3 were confirmed. Hypotheses 4 and 5 received only qualified support, and hypotheses 6 and 7 were rejected.

The results confirm Piaget's general theory of intellectual development, but indicate that specific environmental, cultural and ecological factors may influence the rate at which cognitive development occurs.

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LIST OF ABBREVIATIONS AND DEFINITIONS

The following abbreviations will be used throughout this report:

Conservation tests:

Q	=	Quantity			
S	=	Substance (e.g. plasticine)			
Liq.	=	Liquids	N	=	Number
W	=	Weight	F	=	Failure to communicate
V	=	Volume	NC	=	Non-conservation
L	=	Length	T	=	Transitional
A	=	Area	C	=	Conservation

Illusions:

M-L	=	Müller-Lyer illusion
H-V	=	Horizontal-Vertical illusion
Delb.	=	Delboeuf illusion
O-K	=	Oppel-Kundt illusion
S-W	=	Size-Weight illusion
PSE	=	Point of subjective equality

Definitions:

Genetic psychology :	The developmental psychology of Jean Piaget.
Operations:	Internalized, schematic and reversible representational actions which are an integral part of an organized network (or 'structure') of related acts. (Flavell, 1963, p.165-6)
Concrete operations :	The set of operations dealing with concrete situations or events, and obeying the laws of the 'grouping' (reversibility, associativity, composition, identity, and tautology) or of the group (reversibility, associativity, composition and identity).
Operational :	Related to the development of operations, in particular of concrete operations.
Pre-operational:	Related to the period preceding the development of concrete operations.

Logico-mathematical operations : Subset of concrete operations related to classification, seriation, conservation of physical properties and number.

Spatial operations: Subset of concrete operations related to the topological, projective and euclidean properties of space.

Primary illusions : "The primary illusions have two fundamental characteristics. The first is that their qualitative characteristics (...) do not change with age, while their absolute quantitative values, the extent of illusion, usually diminish, occasionally remain constant, but do not increase with age. The second characteristic ... is that they occur even in tachistoscopic presentations which are so short as to exclude ocular movements and consequently secondary activities of exploration, transportation, etc. These primary illusions can therefore be considered to result from simple field effects, that is to say from the quasi-simultaneous interaction of elements perceived together in one single field of centration without the involvement of a displacement of fixation". (Piaget, 1969a, p.3)

Secondary illusions: Illusions which are not always qualitatively constant at different ages, and which increase with age under the influence of multiple perceptual activities.

Perceptual activities: "... those perceptual processes which occur when centrations or their effects have to be related across spatial or temporal intervals. These include activities of exploration, of transportation, of spatio-temporal or purely temporal transposition, of referral (to perceptual co-ordinates), of schematisation, etc." (Piaget, 1969a, p.133).

INTRODUCTION

Cross-cultural research tends to follow in the footsteps of the major movements in psychology. Thus, during the first half of the century, interest has centered on intelligence testing. But cross-cultural research along these lines proved unrewarding, the tests being, often subtly, culturally loaded; attempts at devising culture-free, or culture-fair tests have generally been unsuccessful and, although some instruments have been devised which prove useful in applied psychology, their contribution to theory has been minimal. Indeed, it has been suggested (e.g. Berry, 1969) that the term 'intelligence', as defined by these performance tests, be abandoned completely in comparative work.

Recently, interest has turned to work which is concerned with basic mental functioning, and one of the seminal influences has been that of Jean Piaget. His approach to intelligence represents a radical departure from quantitative measures in favour of an attempt to uncover the nature of the structures of thought as they unfold in the development of the individual. Intelligence is defined as adaptation to the environment, and its ontogenetic development is shown to occur in a hierarchical series of stages, according to general laws of equilibration.

The nature of the structures and the stages through which they develop seem to be identical in all western cultures, whereas the rate of progression is affected by environmental influences, sensory dissabilities or mental retardation.

However the western cultures are usually considered to be too homogeneous to allow an adequate test to be made of the theory in respect of the universality of the nature of the structures and of the order of their unfolding. As a consequence of this, attention has turned to cross-cultural studies in non-Western societies.

There are three ways in which Piaget's genetic psychology can be applied to cross-cultural research:

(1) One may wish to know whether the concepts and thought structures Piaget has described apply equally well to non-western cultures and, if so, at what rate they develop.

This is a completely ethnocentric, or 'etic' (Berry, 1969) approach, but is potentially useful in its application if the population under study is in the process of adopting Western technology and Western values.

Piaget's tests may be used either in their original form, or adapted to the culture being studied. In this respect, this approach is subject to the same methodological inadequacies as 'culture-fair' tests, but the emphasis is changed: the interest no longer lies in the score on a test, but in the underlying concept.[1]

(2) A second way is to search for Piagetian concepts in the actions, communications, customs and mythology of the cultural group under study, either by direct observation or by referring to anthropological material, but without using tests.

Since the concepts under investigation would still be the products of Western psychological theory, this second method would also be ethnocentric, but it would not be subject to the difficulties of test administration. On the other hand, this approach would raise the problem of the relationship between individual thought structures and collective, cultural structures.

In regard to this, however, Piaget (1968b, p.98) has the following to say about Lévi-Strauss' structuralism:

> Without doubt the kinship systems described by Lévi-Strauss bear witness to a far more advanced logic. But, for the ethnologist especially, it is obvious that these are not the products of individual inventions (of Tylor's "savage philosopher"), and that only a long collective elaboration has made them possible. It is then a matter of "institution" and the problem is thus identical to that of linguistic structures, the power of which goes beyond that of the average speaker. If the concepts of collective autoregulation or equilibration have any meaning, it is clear that in order to judge of the logic or the prelogic of members of a given society, it is not enough to refer to its cristallized cultural products: the real problem is the use made of these collective instruments in day to day reasoning. These instruments could well be of an appreciably higher level than everyday logic.

---

[1] Although this has never been done, one could easily imagine that, given a particular Piagetian concept, an experimenter could invent a completely new test to study it, a test which would be devised in the terms of the target culture.

> Lévi-Strauss does remind us, however, that some individuals work out with accuracy the relations involved in a kinship system.[1] But this is not sufficient, for this system is already completed, regulated and limited in scope, while we would like to witness individual inventions.
>
> Thus we believe that the question will remain open until detailed investigations on the operational level of adults and children in various societies have been carried out in a systematic way.[2]

(3) Thirdly, the cognitive development of a particular cultural group can be studied from within that culture, adopting Piaget's framework and methodology, but without any prior reference to the concepts and structures described by Piaget. This can best be done by a psychologist belonging to that particular cultural group.

The present study, along with all previous cross-cultural Piagetian investigations, is an example of the first

---

[1] The Aranda, for example, have developed a very complex kinship system which seems to display the combinatory and reversibility properties of formal thought (in Piaget's definition), but, as the present study shows, most of the Arandas (even adults) do not display even concrete operational thought when tests are used. (Our footnote. See also Romney and d'Andrade, 1964).

[2] "Sans doute les systèmes de parenté décrits par Lévi-Strauss témoignent-ils d'une logique bien plus poussée. Mais il va de soi, surtout pour l'ethnographe, que ce ne sont pas là des produits d'inventions individuelles (du "philosophe sauvage" de Tylor) et que seule une longue élaboration collective les a rendus possibles. Il s'agit donc d'"institutions" et la question est ainsi la même que pour les structures linguistiques, dont la puissance dépasse celle de la moyenne des locuteurs. Si les notions d'autorégulation ou d'équilibration collectives présentent le moindre sens, il est alors clair que pour juger de la logique ou de la prélogique des membres d'une société donnée il ne suffit pas de se référer à ses produits culturels cristallisés: le vrai problème est celui de l'utilisation de l'ensemble de ces instruments collectifs dans les raisonnements courants de la vie de chacun. Or, il se pourrait que ces instruments soient d'un niveau sensiblement supérieur à celui de cette logique quotidienne. Lévi-Strauss nous rappelle, il est vrai, des cas d'indigènes qui "calculent" avec précision les relations impliquées dans un système de parenté. Mais cela ne suffit pas, car ce système est achevé, déjà réglé et de portée spécialisée, tandis que nous aimerions assister à des inventions individuelles.

Nous croyons donc, pour notre part, que la question reste ouverte tant que des recherches précises sur le niveau opératoire des adultes et enfants de sociétés variées n'auront pas été faites de facon systématique."

of these approaches. It is clearly ethnocentric, and does not claim to use culture-free tests.

It's aim is to investigate whether certain concepts, which are basic to Western scientific thinking, develop through the same stages, and at the same rate, in Australian Aborigines as in Europeans.

In this respect, it is a direct follow-up of earlier research which was also carried out under the supervision of Ass. Prof. G.N. Seagrim (de Lemos, 1966, 1969b; de Lacey, 1970a, in press). With the former study, it has in common some of the tasks (conservations) and one Aboriginal population (Arandas at Hermannsburg). With the second study, it introduces the study of two sub-samples of the same ethnic group, differing in the amount of European contact.

The present study attempts to assess the relative development of different areas of cognitive development (namely logico-mathematical operations, spatial operations, and visual perception), and attempts to make specific predictions from the cultural and ecological characteristics of the populations under study to performance in those areas.

It is assumed that the reader if familiar with the theoretical background of the study, namely Piaget's work, including his theory of visual perception (1961, 1969a), and with the general area of cross-cultural psychology. With this assumption in mind, it was thought preferable to devote more space to a detailed review of cross-cultural studies of genetic psychology and of perception.

As the design of this research is very complex, it will also be necessary to depart from standard practice and to discuss each set of results as they are reported. This should avoid confusion. An attempt will, however, be made, in the last chapter, to draw the different aspects of the study together in the interests of a general discussion of the findings and of their implications.

Cross-cultural research may have at least three functions (Strodtbeck, 1964; Frijda and Jahoda, 1966).

(a) It may serve as a process of decentration or of 'decentering' (Werner and Campbell, 1970): theories established in one society may be tested for generality by attempting to establish whether they apply to different cultures; the ultimate goal of such investigations is the elaboration of general ('universal') laws. (e.g. Campbell, 1961; Doob, 1965).

(b) When cultural or sub-cultural groups can be selected so as to differ in specific ways, their characteristics may be used as independent variables; the aim is usually to uncover casual relationships. The cross-cultural setting acts as a 'natural laboratory' (Brown, 1964).

These first two functions, or goals remain ethnocentric, in so far as the results are useful to the scientist, rather than to the cultural group(s) under study. Cross-cultural research, however, can have a third goal, albeit often an implicit or long-term one:

(c) the findings can be applied in some way, either to foster cross-cultural understanding, or to explain and assist social and cultural change. Education is the most obvious application of genetic psychology, whether cross-cultural or not.

It is hoped that the present study may be able to make a small contribution towards attaining all three of these goals.

CHAPTER I : REVIEW OF THE LITERATURE

The aim of this first chapter is to provide a detailed review of cross-cultural studies in two specific areas of cognition: (a) operational development, as defined in Piagetian theory, and (b) visual perception, especially susceptibility to optico-geometrical illusions.

A. CROSS-CULTURAL PIAGETIAN RESEARCH

In the last five years, interest in cross-cultural Piagetian research seems to have steadily increased. When Piaget gave his benediction to the field (Piaget, 1966), he could only refer to four cross-cultural studies in genetic psychology, and, in the same year, de Lemos' (1966) bibliography included only five references in this area. Since that time the number of publications has increased to such an extent, that an attempt at summarizing the findings of this new area of research seems to become urgent.

The present review will deal with the studies related to operational development. It will not deal with Piaget's early work on animism, causality, and moral judgment (Piaget, 1926, 1927), which has been extensively applied to various cultures (Mead, 1932; Dennis and Russell, 1940; Dennis, 1943; Huang, 1943; Huang and Lee, 1945; Jones and Arrington, 1945; Havinghurst and Neugarten, 1955; Jahoda, 1958 b/c, 1969; Dubreuil and Boisclair, 1960, 1966; Peluffo, 1962, 1967; Boehm, 1966; Nurcombe, 1969; Prince, 1969b). A good summary of the studies published prior to 1958 has been provided by Jahoda (1958a).

Furthermore, we shall restrict ourselves mainly to research dealing with non-Western cultural groups. A third limitation of a different kind should also be mentioned: although we are dealing with a relatively restricted area, there is no guarantee that the results are strictly comparable. The techniques, scoring methods, age ranges, the extent to which verbalisation is taken into account and indeed the whole conceptualization of Piaget's framework, vary a great deal from one investigation to the next. This question of comparability of results, has been expertly discussed by Goodnow (1969a), who points out

some major differences between the Genevan and Anglo-Saxon approaches.

Piaget (1966, p.8), is very cautious in his interpretation of the first cross-cultural results. Elsewhere (Piaget, 1968b, p.99) he himself warns:

> Cross-cultural studies are difficult to carry out because they presuppose a good psychological training in the techniques of operational testing, namely with free conversation and not standardization in the manner of tests, and all psychologists do not have this training; a sufficient ethnological sophistication and a complete knowledge of the language are also prerequisites. We know only a few attempts of this quality.[1]

On the other hand, this lack of comparability is not restricted to comparative genetic psychology. In fact, as Goodnow (1969b, pp.247-8) points out:[2]

> The biggest difficulty with cross-cultural studies has been the lack of overlap between pieces: each study a new culture, and, very often, a new task.

A noteworthy exception

> is a group of people who have come to overlap through no deliberate intent on their part, but through a shared interest in tasks developed by Piaget and his colleagues. It offers some nice overlaps in several respects: in the sample of tasks, the sample of Ss, the environmental variable, and happiest of all, in some of the results.

For the purpose of this summary, we shall omit a further discussion of the methods and techniques used in the various studies, and assume that the results of these are comparable.

The review will be successively concerned with the studies related to

(a) the cross-cultural verification of Piaget's stages, and

(b) the imbroglio of factors affecting operational development.

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[1] "Or ces recherches sont difficiles à mener car elles supposent une bonne formation psychologique sur les techniques de l'examen opératoire (avec conversation libre et non pas standardisation à la manière des tests, et tous les psychologues n'ont pas cette formation), ainsi que des connaissances ethnographiques suffisantes et une complète maîtrise de la langue des sujets. Nous ne connaissons que peu d'essais de ce genre."

[2] This is the first general discussion of the field (omitting Piaget's own 'benediction', 1966).

THE CROSS-CULTURAL VERIFICATION OF PIAGET'S STAGES

Implicity or explicitly, most cross-cultural studies in genetic psychology ask whether cognitive development in the culture under study follows the same sequential succession of stages as described by Piaget in Swiss children. And, if so, do these stages appear at approximately the same age levels?

This issue has been obscured by an unfortunate failure to distinguish three different interpretations of Piaget's "stages":

(1) The succession of the three global stages: sensori-motor, (pre-operational), concrete operational and formal.

(2) The successive acquisition of operations that bear on different contents, but obey identical structural laws, such as the famous conservations of Q (S), W and V.[1]

(3) The sequence of stages or sub-stages on any particular test.

These three interpretations should be discussed separately.

1. The three global stages

A verification of the succession of the three global stages would require longitudinal studies, or at least the examination of all three stages in the same ethnic group. As far as we know, this has not been done in any non-Western culture (except for one, ongoing project: Jacopin, pers. commun., in Dasen and Seagrim, 1970). We shall therefore be restricted to discussing the presence and nature of each stage independently from the others.

(a) The sensori-motor (s.s.m.) stage

The development of s.s.m. intelligence has received little cross-cultural attention, although a few investigations are currently under way, for example, a study conducted in Athens, Teheran and Israel under the direction of J. McV. Hunt (personal communication) with a scale of

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[1] See list of abbreviations.

infant development developed by Uzgiris and Hunt (1966). The only completed study is that of Golden and Birns (1968), using a Piaget (Permanent) Object Scale and the Cattell Infant Intelligence Scale, in which no social class differences in intellectual performance were found during the first two years of life in American Negroes.

(b) The formal stage

A few studies have been conducted on formal thought. Goodnow (1962) and Peluffo (1966, 1967) used tasks of 'combinations' and 'permutations' based on those of Piaget and Inhelder (1951). Goodnow, in Hong-Kong, found that Chinese children with English schooling performed as well or better than Europeans, whereas the results of her two other groups (low income and semi- or full-Chinese schooling) were somewhat depressed. Peluffo found that sons of workers, born and educated in Genova, and sons of clerks and professionals, born and living in Sardinia, attained a 50-60 per cent success level at age 11, while those living in an under-developed agricultural milieu in Sardinia and illiterate Sardinian adults performed less well (25% at age 11, and 20% respectively).

Were (1968) administered verbal-logical and empirical formal tests to 14-16 year old subjects in New Guinea. He states that: "Many of the New Guinean subjects had not reached the level of Formal Thought by their first year of secondary education. ... It could be hypothesized that for New Guinean students, Formal Thought is reached at an older age level than that studied", or, he might have added, is never reached at all. His findings have been confirmed with different tests and samples in New Guinea (Kelly, pers. commun.).

Neimark (pers. commun., in Dasen 1969a) on the other hand, using a variety of formal tasks of both Piaget's and her own devising, seems to find no difference between village school children in Ceylon and suburban school children in New Jersey.

Clearly, there is not nearly enough evidence on which to draw firm conclusions. However, it seems that Piaget's "prediction" (1966, p.13; 1968, pp.97-9) that many

individuals in so-called 'primitive' societies would not go beyond the stage of concrete operations, may one day be verified.

(c) The concrete operational stage

By far the largest number of studies deal with the passage from the pre-operational to the concrete operational stage, and all report that some subjects at least attain this latter. The question is, to what extent, and at what age?

If we look at the proportion (or percentage) of children attaining the concrete operational stage as a function of age, on any given and appropriate test, we obtain some sort of ogive (Fig. 1). Let us assume that curve x has been obtained with European children: all eventually acquire the given concept, but the age at which this occurs varies with the difficulty of the concept, or with the test-materials used.

If the same test is applied to a different cultural group, several possibilities exist:

(a) The concept develops at the same time as in European children.

(b) The concept develops earlier, or more quickly.

(c) The concept develops later, or more slowly; there is a 'time-lag', or retarded development, all children, however, eventually reaching concrete operational thinking.

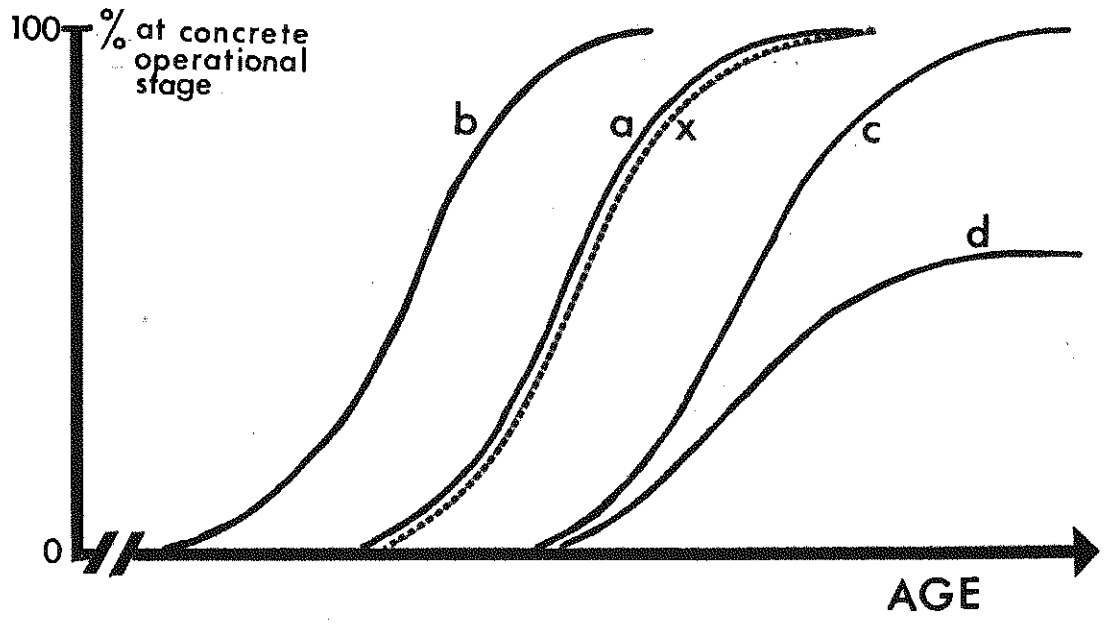
(d) The concept starts to develop at the same time or later, but the curve is asymptotic, it flattens out at the higher ages: some children, and even adults, do not reach the concrete operational stage.

Fig. 1 shows one possible example of each of these curves. We shall now discuss them individually.

(a) Curve a

Three authors have reported results corresponding to curve (a). Price-Williams (1961) finds no difference between Tiv (Central Nigeria) and European children: by age 7;6 to 8;0, all subjects of the sample had acquired the conservations of continuous Q (earth), discontinuous Q (nuts) and N.

FIG. 1 Percentage of subjects attaining the concrete operational stage as a function of age



In Goodnow's studies (1962; Goodnow and Bethon, 1966) three cultural sub-groups (Europeans in Hong-Kong, 'average' Americans and the Chinese with low (sic) socio-economic status and almost no schooling) were almost indistinguishable for conservation of A, W and V. However the performance of the Chinese who had full, English or Chinese schooling was much poorer, yielding a (c) or (d) type curve.

Thirdly, school children in Teheran (Mohseni, 1966, as reported by Piaget, 1966) developed conservation of Q, W and V at approximately the same time as Europeans, whereas they were one or two years retarded on I.Q. tests.

(b) Curve b

Tuddenham (1968, 1969), when applying a battery of 15 concrete operational tests to European, Negro and Oriental children in California, found that the Oriental children were superior to the whites on at least half of the items (possibly curve b).

(c) Curve c

An interesting example of an apparently intermediate case between (a) and (c) has recently been reported by Bovet (1968). When testing conservation of A (Liq. and S) in unschooled Algerian children, she found that the 7-8 year olds, in contrast to the younger children, seemed to have a solid concept of conservation; at 8-10 years, however, there was a 'regression' and only in the 9-11 year-old group was conservation established again. Bovet argues that the initial conservation found at 7-8 years of age was not completely operational; if so, this case can be assimilated into the next group of findings (curve c).

Kohlberg's (1968) results are also difficult to classify: Atayal children, a Malaysian aboriginal group in Formosa (Taiwan), acquired conservation of Q at the usual age (7-8 years) but partially 'lost' it between 11 and 15 years. However:

> the loss did not seem to be a genuine regression but an uncertainty about trusting their own judgement, that is, there was an increase in "don't know" responses. Apparently, adolescent confrontation with adult magical beliefs led them to be uncertain of their natural physical beliefs, whether or not they were in direct conflict with the adult ideology. (p.1029)

A typical curve (c), of 'retarded' development, has been reported many times. The extent of the time-lag, however, has not always been precisely established in these studies, either because a European standardization was not available, or because, in many cases, the age of the subjects could not be established with precision; it seems to vary from about one to six years.

The Tiv children tested by Price-Williams (1962) lagged slightly behind on classification. Schooled Wolof children (Senegal) all eventually achieved conservation of Q by age 11-13 years (Greenfield, 1966a/b; Greenfield and Bruner, 1966). A systematic time-lag of 2 to 3 years is reported in rural children in Iran (Mohseni, 1966, in Piaget, 1966), and a similar difference in the rhythm of development was obtained by Bovet (1968) on conservation of L in Algerian children.

A number of studies show that both non-Western and low socio-economic class Western children lag behind in their concept development when compared to middle-class Western children. Because of the restricted age-range used in these studies, however, it is not clear whether all subjects would have developed these concepts at some later age (curve c) or not (curve d). This ambiguity is evident in a study of Arab, Indian and Somali children, aged 6 to 8 years, tested in Aden with a battery of 13 tests (conservations, seriation, classification) by Hyde (1959; 1970), and similarly in a study of urban Shona (Rhodesia) aged 5 and 6, tested with a similar series of tests by Hendrikz (1965) and in a study of young Beganda children of Kampala, Uganda (Almy, 1967, 1969).

Vernon included a variety of Piaget items in a large battery of tests; his subjects were 11-12 year old boys of several ethnic groups. He confirmed (Vernon, 1967a/b, 1969) that Kampala boys scored lower than English ones. The worst deficiencies were found in all the conservation tasks - over 50% of the subjects being non-conservers on every item. Their performance was also very low on number concepts.

The median West Indian performance (Vernon, 1965a/b, 1969) was 86 on English norms, the greatest deficiencies

occurring in number concepts, in conservation of Q, L and A, and in a mental imagery task. The differences were negligible on conservation of S and on logical inclusion, and quite small on time concepts and on the concept of horizontality.

In Eskimo and Canadian Indians (Vernon, 1966, 1969), all sub-groups were weak relative to the English norms on conservation of Q, L and A as well as on time concepts, on knowledge of left and right and on number concepts, but only slightly inferior on logical inclusions. Eskimos were similar to whites on tasks involving spatial concepts. Indians were poorer on these tests, but were better on a test of mental imagery. The median score was 73 for Indians and Eskimos living in remote areas, and 85 for Eskimos living in hostels.

Exactly what these differential patterns mean, and how they are related to cultural characteristics, is not clear at a first glance; one partial interpretation has been made by Goodnow (1969b), who has tentatively identified the vulnerable tasks as those involving 'imaged transformations' or 'mental shuffling'.

A lower performance on Piagetian tasks for low socio-economic class European children is reported by Peluffo (1962, 1967), Wei (1966), Vernon (1969) and de Lacey (1969, 1970). In the last study, 10 to 20% of low socio-economic Australian Europeans had not reached concrete operational thinking (classification) at age 12.

(d) Curve d

In the fourth group of investigation, on the other hand, there is clear evidence that some subjects, even of the higher ages (12 to 18), do not reach the concrete operational stage.

However, the distinction between (c) and (d) is sometimes hard to make. Thus, Boonsong's (1968) results on conservation in Thai children seems to be an intermediate case: at age 13, about 80% of the subjects had attained conservation of Q and W and 50% conservation of V; most of those who were not conserving were at the transitional stage.

Similarly, Prince (1968c, 1969a) found that about 80%

of New Guinea pupils sampled by him acquired conservation of Q and W by Form III of high school (age 16-18), while the percentage was considerably less for conservation of V, L and A.

At age 12, many Zulu children (Pietermaritzburg, Natal) had not fully developed topological, projective, and euclidean concepts of space (Murray, 1961; Cowley and Murray, 1962). In the same area of spatial relations, Nepalese subjects apparently of even older ages, drew a sequence of actions rather than a set of relationships, when asked for a route-map from their home to school; the authors, Dart and Pradhan (1967), suggest that the reactions of adults would most likely have been the same.

In two sub-samples of Chinese children tested by Goodnow (1962), only some of those aged 13 had developed conservation of A, W and V.

Similarly, only a small percentage (25 to 67%) of 14-15 year old Australian Aborigines attained conservation of Q, W, V, L, A and N (de Lemos, 1966, 1969a/b).

Nor do all Australian Aborigines develop the concept of classification, except those who live in a European community, speak English at home, and generally live in the same way as Europeans of a low socio-economic status. In this latter group, classification is attained by all children at 10 to 14 years (depending on the particular sub-test), whereas only some subjects of a low-contact group have reached the concrete operational stage at age 15 (de Lacey, 1970a in press).

In New Guinea, some children of 12-15 years still lacked conservation of Q, L and A (Waddell, 1968), and these findings have been replicated by Prince (1968a/b/c, 1969a) and Kelly (pers. comm.).

Only about half of the unschooled rural Wolof children (Senegal) tested by Greenfield (1966b; Greenfield and Bruner, 1966) attained conservation of Q at 11-13 years, and the proportion of Zambian children of African extraction, tested with a non-verbal method of conservation of W (Heron and Simonsson, 1969), reached a near-asymptote of 55-60% after the age of about 11 years.

There is no proof in these studies that the subjects who had not attained the concrete operational level at the higher age levels would not do so sometime later. However, Ponzo, as reported by Peluffo (1967), found that conservation was uncertain in Kohorosciwetari and Tukano adults (Amazon). Waddell (1968) found relatively little (16 to 66%, depending on test and sub-sample) conservation of Q, L and A in illiterate adults in the Highlands of New Guinea, and Prince (1968a) reports that many trainees of two teachers' colleges in New Guinea did not have conservation of Q (S and Liq.), W, V, A and L.

Peluffo (1967) found only 20% conservation of V in adults of Sardinia (although it seems that practically all subjects had the conservation of Q).

Scant as it may be, this evidence points to the fact that it can no longer be assumed that adults of all societies reach the concrete operational stage.

The cross-cultural differences summarized above are <u>quantitative</u> ones only. It is the rate of development which is in question, not the structure of thinking. As such, the generality of Piaget's system is not threatened. The results simply point to the fact that, among the factors influencing cognitive development, cultural ones might be more important than had previously been hypothesized, a possibility which Piaget (1966) himself has stressed.

On the other hand, it may be considered surprising to find more and more evidence accumulating to show that concrete operational thought is not necessarily attained. Furthermore, considerable differences between individuals have been reported within ethnic groups, such as the Australian Aborigines, where the homogeneity of the physical and social environments, child rearing practices, health conditions, etc. is well established.

Evidence on this particular problem is scanty and negative. In a study of Zambian primary school children (Heron, 1969b), there was no statistically significant correlation between conservation of W and measures of non-verbal 'reasoning' ability ('induction' and 'matrices') or objective measures of school performance. This was so

even when matrices test items requiring 'multiplicative classifications' were treated separately.

Whether or not it is of any practical importance to be at the concrete operational stage can thus be questioned, and this topic urgently needs further research.

2.'Horizontal décalages'

A second conception of the succession of stages refers to the sequential application of the same structure of thought to different contents. The best known example of this is the succession of difficulty in the conservation of Q, W and V. Strictly speaking, the usage of the word 'stage' in this case is wrong, although Piaget has not always been consistent in his usage (e.g. 1966, p.8); 'horizontal décalage' is now generally understood and should be used to describe this event. The most sophisticated and up-to-date discussion of this issue is that of Pinard and Laurendeau (1969).

Piaget's hypothesis is that the equilibration processes which determine the progression by successive steps are very general and relatively independent of socio-cultural influences. A cross-cultural non-verification of these steps would be, on the contrary, an indication of the importance of more specific cultural and educational influences.

It is surprising that Piaget (1966, p.6) should include the phenomenon of 'horizontal décalages' in this hypothesis. It is a statistical rather than theoretical construct, and failure to verify its usual sequences would probably not be serious for Piagetian theory. Indeed, the writer has yet to find a really convincing explanation of why Q should always be acquired before W; that V should be acquired last is more obvious, since it no longer involves the coordination of two, but of three dimensions - although even this statement would need clarification.

Here again, comparative experimental evidence collected to date is not consistent. Mohseni (1966) is reported (Piaget, 1966) to have verified the sequence of difficulty of Q, W and V in Iran; Peluffo (1967) seems to find this

sequence as well, and Goodnow (1962) found W to be easier than V in all her sub-samples.

There is some indication in Boonsong's work (1968) that V is more difficult for Thai children than Q and W, which seem to be about equally difficult. Much the same conclusion can be drawn from Prince's work in New Guinea (1968c, 1969a, p.60), although Q seems to be slightly easier than W.

De Lemos (1966, 1969b), on the other hand, found conservation of W to be considerably easier than Q in Australian Aborigines, whereas the later development of V was confirmed.[1]

A point of confusion may be noted: the results for or against a constant order hypothesis are always reported in broad statistical terms, usually in terms of the frequency of conserving responses over age; it is in the total sample or sub-sample that one test appears to be or not to be more difficult than another. If the concept of hierarchical development has any qualitative value, however, a constant order of development should be found in each individual.

In Hyde's (1959) study, for example, there is some indication that Q(S and Liq.) is easier than W and V, "but the results of individual subjects suggest that the sequence is not invariable ... There was no support for the theory that the concepts of S, W and V are invariably acquired in that order."

The question cannot be decided until more data on 'horizontal décalages' in individuals is obtained, both in the usual middle-class European child and in children of other cultures. However, some further light might be shed on this problem by a re-analysis of existing data.

The concept of 'horizontal décalage' is limiting one of the criteria Piaget's notion of a stage must satisfy: "The stages of development are defined by structured wholes and not by any isolated pieces of behaviour." (Tanner and

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[1] See chapter 4, Section C for the present study's data and discussion concerning this topic.

Inhelder, 1960, p.84).

> According to this criterion, the typical actions or operations of a given level are not simply juxtaposed one with another in an additive fashion, but are organically interconnected by ties of implication and reciprocal dependence that unite and group them into total structures -- Piaget's structures d'ensemble. This criterion is no doubt one of the most fundamental in Piaget's concept of stage. (Pinard and Laurendeau, 1969, p.136).

Fundamental as it may be, it is a controversial topic, and this could explain the scarcity of cross-cultural data on this particular issue: most of the research has been concentrating on single aspects of Piaget's theory,[1] most of the time conservations. But when the child acquires concrete operational thinking, he is applying it (with the limitation, previously discussed, of 'horizontal décalages') to a large number of concepts; conservations, number (including seriation, classification, etc.), measurement, time, speed, projective and euclidean spatial relations, etc. all develop within this period.

The cultural and ecological characteristics of different ethnic groups may be used to predict a differential development of various concepts or conceptual areas. If this were found, it would, to some extent, limit culturally the generality of Piaget's 'structures d'ensemble'.

It is thus suggested that future research should include a variety of concepts for each cultural group, not using a blind conglomeration of tests, but trying to relate cultural variables experimentally to differential concept development.

3. Stages on individual tests

A third conception of Piaget's stages concerns the responses or reactions to individual tests; these are said to be hierarchically organized into a succession of stages for each particular concept. The number of stages varies with each problem.

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[1] Although Vernon (1965a/b, 1966, 1967a/b, 1969) and Poole (1968) have combined a large variety of Piagetian concepts, their analysis tends to be purely statistical and not structural.

'Stages', according to this interpretation, describe the increasing structuration of a concept within one of the three main stages (s.s.m., concrete operational and formal), until the structure implied by the last reaction is isomorphic with that of the particular main stage.

Only Hyde (1959), Murray (1961, Cowley and Murray (1962) and Waddell (1968) have reported any difficulty in classifying the children's reactions into readily identifiable stages.

Most authors of cross-cultural research have found the same stages as those described by Piaget (e.g. Noro, 1961; Price-Williams, 1961; Mohseni, 1966; de Lemos, 1966, 1969a/b; Almy, 1967; Boonsong, 1968; de Lacey, 1970a; Otaala, pers. commun.).

There could be several reasons for this consensus of opinion.

Firstly, the concepts described by Piaget, if and when they develop, could well do so qualitatively in exactly the same way in every culture; they would thus constitute universals, as it were, 'ab origine'.

Secondly, as our approach is etic, rather than emic, (Sturtevant, 1964; Pike, 1967), the consistency in the findings may be due to a failure to allow alternatives to be detected. According to Berry (1969), our existing descriptive categories and concepts (imposed etic) should be modified to the extent that they become a more adequate description from within the culture under study (emic); new categories valid for both systems (derived etic) could then be developed, and possibly expanded until they constitute a derived universal. Some thinking in this direction has started within the Piagetian area (Wald, Jacopin, pers. comm., in Dasen and Seagrim, 1970).

Thirdly, the absence of discrepancies could be due to the scale used in our investigations: we would be more likely to find differences if we identified a larger number of stages or sub-stages, as has recently been done by Pinard et al. (1969) for the conservation tests.

To this end, two authors (Greenfield, 1966a/b; Bovet, 1968) have added training techniques to the classical

test of conservation of Q. Both report, although in partially conflicting ways, that "different modes of thought can lead to the same results" (in Greenfield's words, 1966, p.255).

In conclusion, it is obvious that there is now much more experimental evidence available than when Piaget made his first review of cross-cultural studies in genetic psychology (Piaget, 1966), but we cannot yet be much more definite in our statements. It is thus very tentatively that we summarise the present state of affairs: in all cultures studied so far, some or all individuals reach the stage of concrete operations, although usually at a later age than middle-class Europeans. The fact, however, that some individuals, even of adult age, continue to show a pre-operational type of reasoning, and that some qualitative differences are being reported, indicates that environmental factors may be more important than Piaget seemed to hypothesize in his earlier writings. We shall now examine what these environmental factors could be.

THE IMBROGLIO OF FACTORS AFFECTING OPERATIONAL DEVELOPMENT

Cross-cultural research in genetic psychology has not been restricted to verifying Piaget's stages, qualitatively or quantitatively. In studying ethnic groups or sub-groups which differ in some specific ways, it is possible to assess the respective importance of factors influencing cognitive development, a task which is impossible or more difficult when research is restricted to relatively homogeneous Western cultures.

According to Piaget (1966, 1968, and in Tanner and Inhelder, 1960, etc.), four main factors are in constant interaction in enabling the child to acquire progressively more complex structures of thought:

(1) maturation (heredity)
(2) equilibration, or autoregulation
(3) general socialization
(4) educational and cultural transmission

Piaget himself, contrary to the opinion of some, does

not believe in a complete determination of cognitive development by maturation.[1] Piaget claims that "logic becomes a priori" (Piaget, 1950, p.256), but only through a continuous process of equilibration.

It is because of their constant interaction that it is difficult to examine these factors directly. In most studies concerned with the various influences on operational development, more than one of Piaget's four factors could be involved at any one time.

We shall now review these influences under the following headings : (1) European contact

(2) Genetic factor

(3) Pre- and post-natal brain damage; nutritional and health conditions

(4) Early physical and social stimulation and activity

(5) Schooling

(6) Language

(7) Other cultural factors

1. European contact

One influence is the degree of contact with Western civilization, or 'acculturation'.

In most cross-cultural studies of this factor, the urban/rural contrast is used, since it carries with it the Western/non-Western variable: Western influence tends to be stronger in cities, and is more readily accepted there, whereas rural areas are both more isolated and usually more conservative; not only are they less exposed to innovating influences, but they also tend to resist change (Poole, 1968). Usually the factor of European contact is also associated with literacy, knowledge of a European language, type of schooling, etc. and it is difficult to distinguish the general factor of European contact from the latter, more specific factors. Its

[1] This seems to be a common misconception, which has apparently penetrated as far as China: Cheng Tsu-hsin and Lee Mei-ke (1969) conclude that the conception of number depends on educational circumstances, "contrary to the results by the bourgeois scholar Piaget that children's conception of numbers is completely determined by age"!

explanatory value is therefore slim, and just as 'age', cannot be considered as a causal factor as such. It would be more useful if it could be broken down into its components.

Mohseni (1966, as reported by Piaget, 1966), found a systematic time-lag of 2-3 years between country and city children in Iran; however the former were also illiterate, whereas the Teheran children went to school. An opposite result is reported by Greenfield (1966): the performance of schooled urban children (Dakar, Senegal) was lower than that of schooled bush children, although they catch up by the age of 11-13 years.

Among a large battery of tests, the Piaget items were those differentiating most strongly between urban and rural boys in the Hebrides (Vernon, 1969, Chap. 10); the difference, here, could have been due mainly to the difference in the language (Gaelic or English) spoken in the home.

Language has been stressed in de Lacey's (1970b) concept of European contact. In an attempt to render this notion more precise, he has developed an 'index of contact' incorporating 17 items, of which those related to language receive a double weighting. This emphasis is also reflected in the design of the study: the two groups of Australian Aborigines differed, among others, on the language used at home. The 'low-contact' group almost exclusively spoke the vernacular outside school, whereas the 'high-contact' one used English at school and at home. Thus, the large difference de Lacey (1970a, in press), found between the two samples could be at least partly attributed to language.

Another study in Northern Nigeria where schooling, (and presumably language) were controlled, included three groups: rural, intermediate and urban; most of the results were in the expected direction (Poole, 1968).

Two more arguments for the influence of European contact other than schooling come from an informal study in New Guinea (Waddell, 1968). In one case, two groups of 13 children were matched on age and tested on conservation

of Q, L and A. One group attended the (western type) Mission School, whereas the other went to a school where they were taught only the vernacular and religion by a New Guinean teacher. The children in both groups, however, lived within walking distance of the mission, and shared various extra-curricular activities. The two groups differed only on conservation of A. It thus seems that, in this case, the mere presence of a western environment was just as influential as two years of a western-type schooling.

In another example in the same study, two groups of illiterate adults were compared on the same tests. The Wabag subjects were employed as house-servants, carpenters, mechanics etc.; the Mondopa adults (Enga) depended for their livelihood mostly on subsistence agriculture and a few cash crops. The Wabag adults performed better on Q and L. "The results here seem to show that the combined effect of living on a government station ... and of training in an occupation where quantification is relatively important, will in many instances suffice for the development of conservation of Q and L." (Waddell, 1968). The Mondopa, however, were superior on conservation of A, and this could be explained by a specific cultural influence: their agricultural system is one of the most developed in New Guinea, using a very special 'mounding' technique; "though the sweet potato gardens vary in shape, they remain proportional in size to the number of people they must cater for". (Waddell, 1968).

If children move from an underdeveloped, rural area to an urban, industrial environment, it seems that, in some cases, they could overcome their handicap within 3 years (Peluffo, 1967).

To summarize, it seems that European contact could be an extremely potent factor in operational development. Discrepancies in the results appear to stem from the fact that sub-samples usually differ also in other major respects.

2. Genetic factor

It could be assumed that genetic differences among

ethnic groups might contribute to some of the observed differences. Unfortunately, it is almost impossible to devise a well controlled experiment in which the genetic factor would be completely dissociated from any environmental one.

One such attempt, in the Piagetian field, has been made by de Lemos (1966, 1969a/b). She selected a group of Australian Aboriginal children, living, (as far as a detailed observation could tell), in exactly the same physical, social, cultural and educational environment. Some of these children were full-blooded Aborigines, others were known, according to well-kept mission records, to have some distant European ancestry. A significant difference in the number of children conserving Q, W, L and A was found in favour of the part-blood Aborigines; on conservation of V and N the difference approached significance. No other such studies appear to exist, and de Lemos' is discussed in more detail in Chapter 4, Section F.

3. Pre- and post-natal brain damage: nutritional and health conditions.

Increasing medical evidence is available that, in addition to physical or infectious brain damage, pre- or post-natal malnutrition affects the maturation of the brain, and that this can result in irreversible intellectual deficits (Cravioto, 1968; Scrimshaw and Gordon, 1968; Heron, 1968). No study has dealt specifically with the influence of such pathological conditions on operational development, but it seems likely that the effects would be similar to those found using psychometric tests of intelligence.

4. Early physical and social stimulation and activity.

The development of knowledge depends partly on the organism's interaction ("assimilation and accommodation") with the environment ("physical and logico-mathematical experience"). This interaction seems to follow the same rules, be it with the physical or the social environment (Piaget, 1950, 1965).

In many cultures (including under-privileged European social classes) there tends to be not only an absence of parental stimulation and a scarcity of objects to play with, but even a seemingly deliberate restriction of the child's activity and exploratory experience. This is the case, for example, with the Australian Aborigines, where young children are constantly carried and are discouraged from talking to adults and from asking questions. This is also true of many other ethnic groups.

The importance of such early stimulation and activity could be considerable, especially if the possibility of critical periods is considered, although Kohlberg (1968) warns against such a premature extrapolation from (mainly) animal experiments.

Whereas most authors (e.g. Cowley and Murray, 1962; de Lemos, 1966, 1969a/b; Hendrikz, 1966; Waddell, 1968; Bovet, 1969; Heron and Simonsson, 1969) mention this factor, on theoretical grounds, as a possible explanation of their results, no one has, so far, been able directly to demonstrate its causative effect.

5. Schooling

The effect of schooling has given rise to several research projects, of which we have already mentioned a few when discussing 'European contact'. Here, again, we are dealing with a complex and rather vague factor. For example, it is difficult to define the quality and type of schooling, and this probably explains why the results are somewhat inconsistent.

It is generally believed (e.g. Mermelstein and Schulman, 1967; de Lemos, 1969b) that there is no direct relationship between the development of concrete operations and western-type schooling.

Goodnow (1962) also concludes that, among Chinese children in Hong Kong, conservation tasks (but not a formal combinatorial problem) are relatively insensitive to lack of schooling: a low-income group of Chinese children with almost no schooling performed as well as a group of Europeans in Hong Kong and as average American children, whereas the performance of a low-income group with full

schooling was extremely low. "For the tasks we used it makes no difference, for example, whether a child has had only 1 year of school or the regular 6 or 7" (Goodnow, 1962, p.19). The poor performance of the low-income group with full schooling is partly attributed to the nature of the science course and to "poor textbooks along with the least trained teachers and the most traditional methods (namely rote learning)" (Goodnow, 1962, p.10).

Kelly (personal communication) confirmed that unschooled children in New Guinea often develop Piagetian (or 'Brunerian') concepts at the same time or earlier than schooled children.

Greenfield, on the other hand, found that "rural Wolof children exposed to a certain set of cultural influences, namely, the school, differ more from other rural Wolof children raised without school than they do from European children" (1966b, p.235). School was not only effective in raising performance, but influenced the kind of justifications given for conservation and non-conservation responses; in particular, it repressed 'action-magic', magical explanations of natural phenomena. Prince (1968a), too, claims that school grading is more relevant to conceptual development than is chronological age.

Waddell (1968) and, probably independently, de Lemos, (1969b), and de Lacey (1970), proposed a resolution of the apparent contradiction between these results; schooling would be influential in New Guinea or Senegal because it brings with it the cultural stimulation that children in Hong Kong obtain without schooling.

However, the situation is really more complex. In particular, specific teaching methods have to be studied; one of these, the Dienes method of teaching 'New Mathematics' has received particular attention. Since this method is partially based on Piagetian tests, if not theory, it is of particular interest for this discussion.

De Lemos (1969a/b) suggests that newer methods of teaching based on activity with concrete materials may be more effective than traditional ones, and adds that the teaching materials should be as varied as possible. On the

other hand, one of her non cross-cultural investigations (de Lemos, 1968b) "provided no evidence to support the view that the Dienes method is more effective than traditional methods in developing certain basic concepts of L, A, and V". (de Lemos, 1968b, p.34).

Similarly, Spears and Dodwell (1970), in an experiment which extended over three years, found no difference on tests of mathematics ability or on Piagetian type tests for three different methods of teaching mathematics (traditional, Cuisenaire, and Suppes' "sets and numbers"). These findings call for a cautious assessment of any new methods.

Prince found a surprisingly poor performance in a school using the Dienes method. He writes: "Their achievements in the various Dienes mathematics games was almost dazzling and yet it would seem that this programme, without practical experiences in measuring, had not assisted in developing conservation of the various physical quantities" (1968a, p.69). In Prince's case, the school which performed best on conservation of L, Q, W and V, but not A, was one which placed heavy emphasis on experiences of measuring lengths, weights, and volume, but not area. He therefore concludes: "It would seem that not merely Western education but particularly the quantitative aspects of this, and most specifically experiences in measurement, are responsible for developing conservation of physical quantities in the New Guinea situation" (1968a, p.71).

There is one study demonstrating the influence of pre-school on cognitive development. In an urban African group (Shona, Rhodesia) tested by Hendrikz (1966), the African nursery school children's performance overlapped that of the European non-nursery school children substantially, whereas the African children who had not attended pre-school performed significantly less well; European children with pre-school experience performed at a significantly higher level than the three other groups.

6. Language

The importance of language for concept development has been discussed, but not specifically studied, in a number of comparative Piagetian studies (Greenfield and Bruner,

1966; de Lemos, 1969b; Heron and Simonsson, 1969) and leads to the more general issue of whether language determines thought (Whorf, 1956, etc.) or vice-versa (Furth, 1966; Sinclair, 1967; Piaget, 1968b, etc.). We will not discuss this question, but would like to suggest that, for future research, a distinction should be made between: (a) the cognitive relevance of the vernacular, and (b) the impact of fluency in the Western language imposed through the school or through Western contact.

7. Other cultural factors

Several other, more specific, cultural factors have received some attention. In particular, interest has been shown in cultural 'ambiance' (Heron and Simonsson, 1969), or the presence in the child's social environment of certain implicit values with cognitive relevance. For example, with what degree of precision are questions of amount, quantity, weight, etc. dealt with? (Heron and Simonsson, 1969). How clear is the distinction between container and contained? (Waddell, 1968). Is conservation relevant to the daily activities of the people under study? (Waddell, 1968; Price-Williams and Gordon, in prep.).

The influence of child-rearing practices and parental attitudes on intellectual development and cognitive style has received close attention, but not yet in the area under review.

Conclusion

We are faced with the usual and quite obvious conclusion: operational development does not depend on any single factor alone, but on a complex interaction of a number of these factors. Cross-cultural research, however, has already helped, to some extent, to clarify their relative importance.

B. CROSS-CULTURAL RESEARCH ON PERCEPTION

There are probably no fields where the combination of psychological and anthropological knowledge is more urgent at the moment than those of perception and cognition" (Kluckhohn, 1954, p.937). "The actual evidence to date, unfortunately, is for the most part equivocal" (Segall et al, 1966, p.23). Most material is anecdotal, systematic research is rare and the methodology often faulty. This renders the reviewing of cross-cultural studies of perception rather difficult.

Another difficulty results from the fact that the topic has come to include a large variety of phenomena. Most reviewers take the definition of perception in a very broad sense to include audition, spatial and temporal relations, Rorschach, aesthetic expression, and general outlook on life. Kluckhohn (1954) includes remembering and forgetting, and Dennis (1951) the whole field of Piaget's conceptual development. Perhaps the best review is that provided by Segall et al. (1966).

The present review will be limited to studies of vision (excluding colour vision), visual perception, and pictorial representation, which are specifically related to the perceptual part of the present research.

1. Vision

Rivers (1901, p.42) states that:

> The visual acuity of savage and half-civilized people, though superior to that of the normal European, is not so in any marked degree. There is no doubt that errors of refraction producing defects of vision, and especially myopia, are much more common among civilized people, but when this source of difference is excluded, the races which have so far been examined do not exhibit that degree of superiority over the European in visual acuity proper which the accounts of travellers might have led one to expect.

Rivers attributes better discriminative power (for example in distinguishing birds among the thick foliage of trees, seeing boats at a great distance, etc) to specific training, the 'savage' being an extremely close observer of nature.

In Australian Aborigines, Fry and Pulleine (1931) found no great divergence from European norms on a series of sensory tests, but a much greater visual acuity.

More recently, a wide-ranging investigation into Aboriginal vision has been reported by Verney (1969). A total of 1085 Aborigines and part-Aborigines aged between 11 and 70 years were examined; these were drawn from five different populations experiencing different climates and environments. One of these groups was at Hermannsburg Mission.

Verney gives the following description of the Aboriginal eye and vision:

> The deep-set eyes of the Aboriginal are protected by thick eye-lashes up to half-an-inch long at the centre of the lid, which is pigmented although pink on its palpebral surface. Pigment is also present in the conjunctive, especially in the form of a full or broken ring around the corneal limbus...
>
> This conjunctival pigmentation is always more marked in the lower medial quadrant, and is in evidence at an earlier age in coastal regions than in the central region of Australia.
>
> The cornea of the Aboriginal eye is characteristic, corneal arcus being very prevalent in all the age groups examined of both Aborigines and part-Aborigines. Among the Central Australian people, where corneal arcus occurs without exception, it remains a diffuse area extending into the limbal region, never resolving into a discrete arcus with a clear corneal band surrounding it and separating it from the limbus...
>
> It does not appear that the Australian Aborigine possesses any peculiar physiological feature or mechanism that aids in the production of better vision. He has always made use of partial contraction of the orbicularis muscle with many describing him as having a fierce expression, the result of life-long contraction when searching intently for signs of movement of game or enemies in dense bush. There is the natural protection of deep-set eyes as a shield from the glare of the Australian sun, and the overhanging brow must assist in maintaining good visual acuity by partly removing or at least reducing the hindering fact of veiling glare. Also, the Aboriginal pupil is generally miotic, possibly due to increased amounts of accumulated iris pigment...
>
> Most Aborigines also enjoy the advantages of binocular vision. Manifest strabismus is rarely met, especially convergent strabismus...
>
> Colour vision deficiencies are markedly low in incidence in the Australian Aboriginal and part-Aboriginal...

> Hunting skills have been credited to excellent vision. No doubt the hunter enjoys a high degree of visual acuity, but power of observation, visual awareness and development of memory centre are important factors. Learning, along with anatomical and physiological features, does make the Aboriginal more likely to succeed in certain conditions. In Aboriginal childhood, training for survival, instruction in the recognition of tracks and food and water signs foster the development of skills which have been rightly or wrongly atributed to superior vision...
>
> The vision and visual acuity of the Australian Aborigine must be considered as varying greatly within wide limits. On the one hand we find such remarkable acuities as 6/2 in both right and left eyes of a Loritja 26-years-old male, employed as a stockman at Hermannsburg Mission...On the other hand, in the same age group and area unaided vision was found to be as low as 6/60 in the absence of ocular lesions.

2. Other senses

The possibility that weight discrimination might be more acute in some non-Western people, suggested by a recent study by Wober (1966), in which he showed that (Nigerian) Africans had a more proprioceptive or auditory sensotype[1] than Americans who in turn are more visually directed, was first studied by McDougall (1901). He conducted a weight-lifting task during the Cambridge Anthropological Expedition to Torres Straits, and concluded that:

> The power of discrimination of small differences in weight appear ... to be rather more delicate in the Murray Islanders than in Englishmen, and this may seem a somewhat surprising result in face of the fact that the Murray men were asked to make a judgement of a kind with which they lack any word to express the abstract idea of weight. (McDougall, 1901, p.198).

On the other hand, Heuse (1957) reports that the weight-discrimination of 86 black soldiers (from Soudan and French Guinea) was much poorer than that of a sample of 153 schoolchildren in Paris.

3. Gestalt principles

Michael (1953), in accord with Gestalt theory, found little or no difference, on a test of closure, between a

---

[1] Sensotype: "The pattern of relative importance of the different senses, by which a child learns to perceive the world and in which patterns he develops his abilities".

sample of Navaho Indians and American subjects. The task required the subjects to draw nine circles that were tachistoscopically projected one at a time; the circles varied in incompleteness from zero to eight degrees in one degree steps. According to the author, the results are especially significant because of the reluctance of the Navaho to close designs in their art and the general 'fear of closure' in their culture.

Results which contradict the above were found in another study (Berry, 1966a/b). A series of forms (triangles, squares and rectangles) were presented tachistoscopically; each figure presented a gap on the left or the right side, the gap increasing in size from 1 to 15 mm. Subjects were asked to draw these figures. Berry found that Eskimo subjects were less prone to close the figures than were Temne (Sierra Leone) and Europeans. Eskimos thus appear to be more aware of small details, the author argues, and suggests that this may be due to their dependence on hunting.

Verhaegen and Laroche (1958; reviewed in Dobb, 1965, p.383) showed that Katangan children performed poorly on the Seguin form-board test. They do not see errors immediately, but persevere for several seconds with wrong responses. "This indicates that these simple forms are entirely strange to them ..." (p.255). It is evident that such a conclusion has to be treated with caution, as the poor performance could be attributed to variables other than perceptual.

Clearly, further investigation is required in this field.

4. Optico-geometrical illusions

This review will be limited to optico-geometrical illusions.[1] Most cross-cultural research in this area has

[1] Two studies outside this area should, however, be mentioned. McDougall (1901) found that Murray Islanders were more subject to the S-W illusion than were Englishmen. Allport and Pettigrew (1957) reported that rural Africans were less susceptible (under certain, sub-optimal viewing conditions) to the rotating trapezoidal window illusion than were urban Africans or Europeans.

dealt with two illusions: the Muller-Lyer illusion (M-L)[1] and the Horizontal-Vertical illusion (H-V), on which our review will therefore concentrate.

A study of Segall et al. (1966) will be reviewed first, because it is the most complete, systematic and theoretically sophisticated cross-cultural investigation in perception. It has stimulated a series of replications and related research projects. The other studies will be reviewed in historical order.

(a) Segall, Campbell and Herskovits (1963,1966), Campbell (1964)

The responses of 1878 persons drawn from 14 non-European populations and from the United States, were collected, mostly by anthropologists working on other projects. A convenient booklet (Herskovits et a., 1956) was produced which contained the stimulus figures for the M-L illusion, the Sander parallelogram, two versions of the H-V illusion (inverted T and L figures), an illusion termed 'perspective drawing', and the Poggendorf illusion.

Special attention was paid by the authors to some methodological precautions:

(1) "Comprehension checks" were introduced to make sure that the subjects understood what was asked of them: these were lines of graduated complexity, for which the subjects had to show each time the 'short' and the 'long' one.

Check-item 4 for the M-L illusion, for example, was a M-L figure in which the illusion would be of 500%; such an illusion is thought to be impossible, and a non-veridical answer is interpreted as a 'failure to communicate' (Campbell, 1964).

(2) The communicability of the drawings was enhanced by spatially separating the different parts of the figure and by using colours.

(3) The results were reported with and without the inclusion of inconsistent responses.

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[1] See list of abbreviations.

The ecological cue validity theory

Following Brunswik, and in line with Gregory (1966), Segall et al. (1966, pp.77-97) based their theoretical system on the following premises:

(1) that the visual perceptual system uses numerous cues of low and probabilistic (but still positive) validity;

(2) that optical illusions demonstrate the function of normally useful cues but provide atypical visual performance settings;

(3) if human groups differ in their visual inference tendencies, it is because their visual environments differ.

The ecological cue validity theory can be applied in the investigation of two specific hypotheses as to how ecological differences might relate to visual-inference differences: (1) the carpentered world hypothesis, and (2) the foreshortening of receding horizontals, or open-vista hypothesis.

(1) The carpentered-world hypothesis

Segall et al. (1966) gave the following summary of the carpentered-world hypothesis, which is relevant to the M-L illusion and to the Sander parallelogram:

> For figures constructed of lines meeting in nonrectangular junctions, there will be a learned tendency among persons dwelling in carpentered environments to rectangularize those junctures, to perceive the figures in perspective, and to interpret them as two-dimensional representations of three-dimensional objects. Such a tendency produces, or at least enhances, the Müller-Lyer illusion and the Sander parallelogram illusion. Since the tendency is assumed to have more ecological validity for peoples in Western, or carpentered, environments, it is predicted that Western peoples will be more susceptible to these illusions than peoples dwelling in uncarpentered environments. (p.96-97).

Therefore, a direct relationship should exist between the extent of a person's M-L illusion and the number of right angles in his environment.

> We can in general assert that European and American city dwellers have a much higher percentage of rectangularity in their environments than any residents of non-Europeanized cultures. It also seems highly probable that ... rural residents live in less carpentered visual environments than urban ones (even

> if their houses and furnishings are equally carpentered) because they are out of doors more of the time. On similar grounds, it seems probable that residents of a cold climate have a more carpentered visual environment than residents of a hot climate if their climate leads the former group to spend more of their time indoors. And within the non-Europeanized cultures ... we would expect square-house cultures to be more rectangular in visual environment than round-house cultures. (p.88).

Results:

Segall et al.'s results on the M-L figure confirmed this hypothesis, at least in general terms. The difference in susceptibility to the illusion between Europeans and non-Europeans is striking; however, among the non-European samples, the rank-order of the extent of illusion does not correlate exactly with the ecological descriptions of their environments.

Furthermore, the ecological cue validity theory, if applied alone, would predict that adults should have a greater illusion than children; this is not the case, either in the European or in the non-European samples, and Segall et al. have to qualify the hypothesis by assuming that the inferential processes involved are learned at an early age, and "that maturation sometime after the age of 4 makes children more analytic, with greater access to the sensorial given and more ability to hold the inferential processes in abeyance so as to report on the specific stimulus components." (1966, p.198).

(2) The open-vista hypothesis

> The horizontal-vertical illusion results from a tendency to counteract the foreshortening of lines extending into space away from a viewer, so that the vertical in the drawing that is the stimulus for the illusion is interpreted as representing a longer line. Since the tendency has more ecological validity for peoples living mostly outdoors in open, spacious environments, it is predicted that such peoples will be more susceptible than Western peoples in urban environments. On the other hand, some non-Western groups should be less susceptible to the illusions, e.g., rain forest or canyon dwellers.

This hypothesis also received qualified support from the results. The Bété (living in a jungle environment) showed the lowest susceptibility to the illusion, Europeans

were in the middle of the range, and the Batoro and Banyankole (living in high open country) had the highest mean illusion. But the results of other cultural groups did not fit as well, and the authors conclude that there must be some factor other than ecology accouting for part of the results.

(b) Rivers (1901,1905)

Rivers, in the experiments he conducted with the 'Cambridge anthropological expedition to Torres Straits', included the H-V illusion (1901, p.108-117) and the M-L illusion (1901, p.117-128).

(1) The H-V illusion

Presenting his subjects with a horizontal line of 100 mm, Rivers asked them to draw an equal vertical line forming with the horizontal line an inverted T, the figure L, or a cross.

'Primitives' were found to be more subject to the H-V illusion than Europeans. Rivers concluded:

> The pronounced character of the illusion in children and in people in the stage of mental culture of the Murray Islanders shows that the illusion is primitive and deeply seated, and that its source is to be sought in some physiological condition. (Rivers, 1901, p.117)

His findings received confirmation from a study which he later conducted on the Todas in India (Rivers, 1905).

(2) The M-L illusion

Measurements of this illusion were obtained by the adjustment method, with a sliding apparatus. Murray islanders had an average illusion of 18.5%, Englishmen of 25.9%. Differences between adults and children were small in both groups.

> The fact that the illusion seemed to be distinctly less marked to the Papuan than to the European may possibly be due to the fact that the former concentrated his attention more completely on the special task he was given to perform, viz. to make the lines AB and BC equal to one another, and tended to disregard the other lines present in the figure. The European, on the other hand, ... tends to regard the figure as a whole. (Rivers, 1901, p.126-7).

While Rivers' findings have been criticized on methodological grounds (e.g. by Titchener, 1916), the overall results that

nonliterates are less subject to the M-L illusion, and more to the H-V illusion, has been confirmed by most of the more recent studies.

(c) Heuse (1957)

As part of an extensive anthropometric, medical and psychological study of Negro soldiers of the French army (from Soudan and French Guinea), Heuse presented a series of illusions to his subjects. These included the M-L and the H-V illusions, but unfortunately the extent of the illusions was not measured.

(1) The M-L illusion

Seventy-four of 82 subjects exhibited the illusion, 6 no illusion, and 2 an inverted illusion. All 78 of a comparison group of Europeans were subject to the illusion. This finding is not inconsistent with the generally reported tendency for Europeans to be more susceptible to this illusion.

(2) The H-V illusion

All Europeans but only 94% Negroes were subject to this illusion. These findings do not support the greater susceptibility of non-Europeans to this illusion.

However, the study is technically so deficient that not much weight can be given to its findings.

(d) Morgan (1959)

Morgan reports a study in which he administered the Herskovits et al. (1956) booklet of illusions to the following subjects: (1) illiterate South African black mine labourers; (2) illiterate Bushmen, and (3) literate whites of European origin. He obtained the following results for the illusions under discussion.

(1) The M-L illusion

The illiterate black labourers and Bushmen were significantly less subject to this illusion than were the white literates. However, there was also a very significant difference, which remains unexplained, between the two illiterate samples.

(2) The H-V illusion

In both forms of the illusion, the black labourers were more subject to the illusion than were the Europeans,

but this was not so for the Bushmen.

Segall et al.'s (1966) results are therefore only partly confirmed.

(e) Bonté (1960, 1962)

Bonté used two different techniques to measure the M-L illusion: (1) the method of adjustments using a sliding apparatus similar to Rivers' (criticized, in this case, because the grain of the wood was visible), and (2) the method of constant stimuli, using an earlier version of Hersovits et al.'s (1956) stimuli.

When method (1) was used, neither of the results obtained from the Bambuti (called Mbuti in Doob, 1965) nor those obtained from the Bashi (an agricultural tribe of the then Belgian Congo) differed significantly from those obtained from Europeans.

Bonté found it impossible to apply procedure (2) to the Bambuti pygmies, but by this method, the Bashi were less susceptible to the illusion than were the Europeans.

These results partly contradict Segall et al.'s (1966) data and interpretation. However, the latter authors seem to find this research methodologically too deficient to take it seriously into account.

(f) Mundy-Castle and Nelson (1962)

Using the Hersovits et al. (1956) booklet, Mundy-Castle and Nelson studied a group of white, poverty-stricken forest-workers, living in isolated huts in the forest. They report as follows :

> In the M-L series they were less affected than urban white adults, but more than illiterate black mine workers and Bushmen (Morgan, 1959). On the other hand, the H-V illusion was more prominent in our group than among urban white adults and (was) comparable to the black and Bushmen groups.

The authors conclude: "... visual perception of the forest workers (is) more similar to that of black and Bushmen groups than to that of westernized whites". (p.258).

(g) Gregor and McPherson (1965)

In the only previous study of illusions in Australian Aborigines, the Herskovits et al. (1956) booklet was administered to two groups of 50 full blood subjects at Hermannsburg Mission and at Yuendumu Settlement in Central

Australia. The perceptual environment of both groups is remarkably "open vistaed", but the two groups were felt to be sufficiently distinct in regard to the degree of "carpenterization" (with Hermannsburg being more carpentered) to permit a test of the carpentered-world hypothesis.

> The object of the present investigation was to test the Herskovits hypothesis using an experimental population in which the racial variable was held constant. In previous studies primitive subjects were of different ethnic origin from that of subjects drawn from carpentered environments. The possible effects of ethnic differences remained, consequently, a free variable. (p.2).

Results:

(1) M-L illusion: As expected, the Yuendumu sample was less susceptible to the M-L and Sander Parallelogram illusions than the Hermannsburg sample, but the differences obtained were not statistically significant. Furthermore, inter-group and intra-group comparisons of males and females produced inconsistent results.

(2) H-V illusion: The two Aboriginal groups were more susceptible to the two forms of the H-V illusion than any other ethnic group in the Segall et al. (1966) study. This provides strong support for the open-vista hypothesis. However, sub-group comparisons again failed to give consistent results.

The authors reach the following conclusion: "the Herskovits hypothesis cannot be construed as providing (an) exhaustive explanation of differential group and intra-group susceptibility to geometric illusion." (p.11).

(h) Jahoda (1966)

Three illiterate samples living in different environments in Ghana were examined. The samples were drawn from:

(i) the Lobi and the Dagomba, who live in open parkland in rolling country (Northern Ghana); the huts of both are round, and are usually devoid of rectangular furniture.

(ii) the Ashanti, who live in remote villages (central Ghana) enclosed in high tropical rain forest; their houses are rectangular, and usually contain a good deal of

'carpentered' furniture.

(iii) Europeans.

The relationship of this selection to the ecological cue validity hypothesis is obvious.

Results:

(1) M-L illusion: The mean percent illusion in the three illiterate samples were similar, so that the carpentered-world hypothesis failed to find support. "On the other hand, it appears from the comparison between the combined African versus the European group that the latter exhibits a significantly greater illusion effect, which is in accordance with the postulates of Segall et al. (1966.)" (Jahoda, 1966, p.196).

(2) H-V illusion: The following increasing order of susceptibility to the illusion would have been predicted by the open-vista hypothesis: Ashanti, Europeans, Lobi and Dagomba. The results obtained were:

Samples:	N	Mean illusion (%)
1. Lobi	34	1.65
2. Europeans	41	11.16
3. Ashanti	127	16.22
4. Dagomba	52	22.71

The Dagomba, as expected, were most susceptible to the illusion, but the Lobi, although living in the same environment, experienced the weakest illusion. The order in the susceptibility of the Europeans and the Ashanti was also reversed. These results thus provided no support for the open-vista hypothesis.

Johoda suggests that:

> Segall et al. (1966) failed to distinguish between a 'carpentered environment' and 'the interpretation of two dimensional drawings', both of which form part of their hypothesis. ... On the basis of the distinction, one might venture to propose that illusion effects of the M-L type may be a combined function of two distinct variables: (1) the degree of rectangularity in the environment, which is the primary one; (2) the extent of the ability to interpret two-dimensional representations. It may well be that in the absence

> of (2), or with a deficiency in it, relatively moderate variations in (1) produce such limited changes in habits of perceptual inference that the difference cannot be detected by the relatively crude methods employed in the present study. It is even possible that, as far as test responses are concerned, radical differences in (1) may not manifest themselves at all if there is a marked deficiency in (2). (pp.197-198)[1]

(i) Deregowski (1967)

Deregowski draws attention to the fact that, according to Künnapas (1955), the H-V illusion is due to two separate factors: (a) the overestimation of the dividing line, and (b) the overestimation of the vertical. The open-vista hypothesis applies only to (b). Therefore, to test the hypothesis, only L figures, or cruciform figures should be used, the bisection effect being eliminated or compensated; when using T figures, the results should be corrected for the bisection effect.

For adults at least, Segall et al.'s (1966) results fit the open-vista hypothesis better when only the L shaped illusion is considered. Deregowski also carried out a reanalysis of Rivers' (1901, 1905) data. All three forms of the illusion differed at beyond the .01 level, the illusory effect being largest for the T figure and least for the cruciform figure. If the two factors suggested by Künnapas were the only ones at play, the L and the cruciform figures would be expected to yield similar results; since this is not so, Deregowski suggests that a third factor, symmetry, should also be considered.

(j) Pollack and Silvar (1967)

Pollack (1963, 1966) found a negative correlation between sensitivity to contour ("contour detection") and the magnitude of the M-L illusion.

Silvar and Pollack (1967) also found that Negro children had generally a darker pigmentation of the Fundus oculi than white children. They hypothesized that increased

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[1] In view of the relation suggested by Jahoda between the susceptibility to illusions and the ability to interpret two-dimensional drawings, the literature related to the latter subject will be reviewed in a later section.

macular pigmentation would reduce contour detectability, and therefore also correlate with a decreased M-L illusion. The fact that macular pigmentation seems to increase and M-L decrease with age would support the same negative correlation.

To test this hypothesis, Pollack and Silver (1967) presented the illusion to two groups of subjects differing in macular pigmentation. The obtained difference was significant in the predicted direction.

Pollack suggested that cross-cultural differences in susceptibility to the M-L illusion could be explained, at least partially, by this physiological factor, non-European societies being likely to have a stronger pigmentation of the Fundus oculi or of the cornea (possibly under the influence of increased exposure to sunlight).

Segall et al. (1966, p.185) argued against this explanation in the following way:

> We do not find the explanation very plausible. Note that in one sense it is directly contrary to the 'greater acuity and attention' line of argument in Rivers' and Titchener's comments. It depends on an unchecked hypothesis relating sunlight and corneal density, and it does nothing to explain the direction of our results with the horizontal-vertical illusion.

Several other arguments could be advanced against Pollack's hypothesis:

(1) It cannot explain differences in susceptibility to illusions between subsamples of the same ethnic group (Mundy-Castle and Nelson, 1962; Segall et al., 1966; Berry 1968).

(2) It is not certain that Pollack and Silvar's (1967) two groups of subjects differed only as to macular pigmentation. (The two groups consisted of 13 Negroes and 2 whites for the dark-pigmented group, and 19 whites and 1 Negro for the light-pigmented group).

(3) Even if the hypothesis is correct, it appears to account only for a small part of the differences found. In Pollack and Silvar's (1967) experiment, the difference in susceptibility to the illusion between the two groups was only 4.8%, which is much less than the differences Segall et al. (1966) found.

(k) Berry (1968)

Berry suggests that the failure to find significant differences in susceptibility to the M-L illusion when subsamples from a single ethnic group are compared (Gregor and McPherson, 1965; Berry, 1966a; Jahoda, 1966) could be due to the confounding of the ecological and the developmental hypotheses. The latter stems from developmental work which shows that the susceptibility to the M-L illusion decreases with age, and from parallel research demonstrating that field-dependent individuals (Witkin et al., 1962) are more susceptible to the illusion than are field-independent persons (Gardner, 1957, 1961; McGurk, 1965). In other words, "the more perceptually developed a person is (as measured by Witkin's EFT or Kohs Blocks), the less susceptible he is to this illusion".

> The two hypotheses lead to opposite predictions:
>
> Where European samples are typically high in their degree of carpenteredness (predicting high susceptibility), they are also usually high (...) in perceptual development (predicting low susceptibility). But it is possible that the first hypothesized determinant might be strong enough to override the second and produce occasionally significant results. In comparisons within one ethnic group, the same confounding occurs; in the rural, traditional areas where there is little carpenteredness, there is also usually lower perceptual development (Berry, 1966a; Dawson, 1963) than in the urban transitional areas, where education and informal perceptual training (from the cinema, magazines and posters) are available. Once again opposite predictions would be made by the two hypotheses. (p.207).

In Berry's previous study (1966a) comparisons between subsamples (traditional and transitional) of two ethnic groups (Temne of Sierra Leone and Eskimo of Baffin Island) provided no support for the ecological cue validity theory. However, if the results are reanalysed, so that two subsamples having the same perceptual development[1] (as measured by Kohs Blocks scores) but living in differently carpentered environments are compared, a significant

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[1] The samples were also matched as to ethnic origin, degree of western influence, education, occupation, age, sex and visual acuity.

difference in susceptibility to the illusion appears, the sample living in the highly carpentered environment being more subject to the illusion.

Similarly, if two sub-samples, matched on the basis of the degree to which their environment is carpentered, but differing significantly in their performances on Kohs Blocks, are compared, the sub-sample with a higher perceptual development is shown to be less subject to the illusion.

However, the author does not claim to be able to explain all the differences which occur in the susceptibility to the M-L illusion with these two determinants, for two selected samples of different ethnical origin, having the same degree of carpenteredness, but differing on Kohs Blocks performance, fail to show a significant difference in the M-L illusion.

(1) Jahoda and Stacey (1970)

These authors administered a wide range of illusions to Scottish and Ghanaian students who were either trained or untrained in the fields of art and architecture.

Results:

(1) M-L illusion: No significant difference was found for the M-L illusion on any of the comparisons. With the Sander parallelogram illusion, one significant difference occurred, the untrained Scottish sample being more susceptible to the illusion than the untrained Ghanaian sample. These results are not necessarily inconsistent with Segall et al.'s (1966) hypothesis, since both samples had experienced a carpentered environment, but they do indicate that the moderate differences existing in the environments had no effect.

"Segall et al.'s prediction that artists and designers should be less susceptible to the SP (Sander parallelogram) and M-L illusions, because they are less subject to constancy effects, is confirmed only for the SP in the Scottish sample."

(2) H-V illusion: The untrained Ghanaian subjects were more susceptible to this illusion than the untrained Scots; this is in accordance with the foreshortening hypothesis, since there is more flat, open terrain in Ghana. With the

effect of training, however, this cross-cultural difference disappears. (This was also true for the Helmholtz Square, the Sander Parallelogram and the Boring Circles.)

"The results also for the H-V and DS (Dichosection, or T figure) illusions support Deregowski's contention that cross-cultural differences hold for the HV but not for the DS illusion."

This study also includes numerous other interesting findings,[1] which space does not allow to include here; these are discussed in relation to Over's (1968) review of the theories of illusions, in particular that of Piaget (1961, 1969a). The authors conclude the article by saying that "the problem of developmental influences on susceptibility to illusions ... is likely to be among the most fruitful next steps in advancing the understanding both of illusions in general and of cross-cultural differences in particular".

Since it has been suggested that susceptibility to optico-geometrical illusions could be related to (1) field-dependence (Berry, 1968) and to (2) the ability to interpret two-dimensional drawings in three dimensions (Jahoda, 1966) some studies relating to these two topics will be briefly reviewed.

5. Field independence, socialization practices and spatial/perceptual skills[2]

The Kohs Blocks test and the Embedded Figures test (EFT) have been administered to a number of non-Western populations. Shapiro (1960), McFie (1961) and Jahoda (1965) found that Africans had considerable difficulty in assembling the Kohs Blocks designs. On the other hand, Vernon (1966), found that Eskimos and Canadian Indians performed relatively well on these tasks, with the Eskimos proving superior to

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[1] For example, the assumption of a relationship between susceptibility to illusions and field-dependence (Berry, 1967, 1968) is not supported, all correlations between extent of illusion and EFT being nonsignificant (except for a negative correlation with the Poggendorf illusion).

[2] A summary of cross-cultural studies in this area has been provided by Witkin (1967).

the Canadian Indians.

Dawson (1963), extending Witkin et al.'s (1954, 1962) concept of field-dependence and psychological differentiation to cross-cultural studies, related the difficulties Africans usually experience with the Kohs Blocks and with the EFT to the severe disciplining and to the social conformity typical of African socialization practices. In Dawson's (1963) study, the scores for Kohs Blocks and EFT were well below Western norms, and inter-tribal differences were significantly related to socialization practices.

Dawson later extended his hypothesis concerning the relationship between field independence and socialization practices to include the difficulties in the three-dimensional (3-D) interpretation of pictures (Dawson,1967a) and to feminization due to Kwashiorkor (Dawson, 1967b).

Berry (1966a/b) found that the significant difference in field-dependence between Africans and Eskimos was related to the large difference in socialization practices which exists between these two cultural groups. Okonji (1969) related differences in rural and urban upbringing in Nigeria to differences in field-dependence.

6. Pictorial representation and primitive art

A common finding in anthropological studies and in cross-cultural studies of a psychological nature is that 'primitives' find it difficult to interpret pictures and photographs. These difficulties are particularly noticeable if the representative materials include:

(a) drawings of a symbolic nature (Nissen et al., 1935)
(b) part-whole relationships (id.)
(c) serial representations (Reader, 1963)
(d) cause and effect representations (id.)
(e) two-dimensional representations of three-dimensional scenes (Hudson, 1960, 1962, 1967; Mundy-Castle,1966; Deregowski, 1966, 1968; Wober, 1967b).

Segall et al. (1966, pp.32-34) give a good account of the notion that pictures and photographs are a cultural convention to which non-Europeans are not used. In particular, they argue that certain stimulus characteristics

which are irrelevant to Europeans (for example, the frame of a photograph) may interfere with content perception in non-European groups.

The following findings also support this interpretation:

(a) Cultures which use 'realistic' drawings and paintings in their decorative designs were found to understand pictures fairly easily (Nadel, 1937).

(b) In a series of tasks where the content was familiar and all three-dimensional cues were eliminated, there were no significant ethnic differences (Thornton, 1956).

(c) Acculturation, especially schooling, was shown to increase the efficiency with which interpretations can be made. However, schooling does not seem to be the only influential factor, for African University graduates were also shown to experience difficulties with two-dimensional representations (Hudson, 1960).

An alternative hypothesis has been proposed by Doob (1961): "It is possible that Africans perceive drawings and photographs no differently from anyone else, but that, from lack of experience or embarrassment in the interviewing situation, they are unable to express or report their percepts." But this does not seem to be a sufficient explanation for the difficulties which have been observed.

Dawson (1967a, 1969b) has suggested that another factor affecting the ability to interpret pictures may be field-dependence, as indicated by a high correlation between scores on Hudson's 3-D test and Kohs Blocks performance (Somerset, 1963).

According to Hudson (1960), pictorial depth perception is learned through exposure to pictures (specific experience) but "the process can be retarded or prevented by cultural environment and intellectual endowment" (p.205).

Deregowski (1966) found that a non-verbal 3-D construction test, as opposed to Hudson's verbal description-of-pictures test, failed to discriminate between two samples with (hypothetically) different exposure to Western civilization. His explanation was that subjects do not fail to recognize the depth cues as such, but tend to

disregard them in favour of other elements; if the cues are given sufficient prominence (as in his construction test), they are taken into account.[1]

Wober (1966, 1967a/b) also attributes the high correlation between some perceptual tasks (Kohs Blocks, EFT) and education to the influence of the high degree of contact with visual materials which is typical of Western education, but he adds that Africans in general are less visually directed than Europeans; in other words, their 'sensotype' is more proprioceptive or auditory.

A thorough review of the problem of pictorial perception among unacculturated groups, including practical applications of the findings, has been provided by Hudson (1967).

Art and perception

Evidence for "art as a convention" comes from a study of the history of art. "All graphic techniques operate with conventional notations" wrote Gombrich (1960, p.44). A new style is shocking at first because it adopts a new convention; on the other hand, once these have been adopted, one may find it difficult to adjust to an old painting.

Primitive art is sometimes described as 'conceptual': objects are drawn as the artists knows them to be, rather than as he sees them. Historically, art has evolved from this starting point along a continuum, until the impressionists (who, however, were also using certain conventions) best succeeded in painting 'what they really saw'. "There are few civilizations that ever made the change from making to matching". (Gombrich, 1960, p.314). This evolution was not brought about by mere passive observation, Gombrich argued, but by continuous trial and error: it is a 'decentration' (in Piaget's terminology) leading to the more objective.

The use of cues to indicate the third dimension

[1] Deregowski has also reported a number of other studies on related topics (Deregowski, 1968a/b, 1969a/b).

(overlap, shading, perspective) is one of these conventions which has appeared relatively late in the history of art, and has been a major problem to artists.

Few studies have dealt directly with the relationship between primitive art and perception (but see Thouless, 1933; Beveridge, 1935, 1939), and they have been far from being conclusive.

The present investigation is relevant to both areas of cognition which have been reviewed above: it is a study of the development, in Australian Aborigines, of concrete operational concepts, and it attempts to relate some aspects of visual perception (namely the development of the susceptibility to optico-geometrical illusions) to operational development.

In the next chapter, the specific hypotheses of the study will be described and general background information will be given.

CHAPTER II : HYPOTHESES, METHODOLOGY, BACKGROUND INFORMATION AND SAMPLING

A. RATIONALE AND HYPOTHESES

1. Stages and rate of development

In reviewing the literature, we attempted to show how cross-cultural research has started to make an important contribution to psychology, allowing the generality of theories established by Western psychologists and the respective influences of the factors determining cognitive development to be examined. Cross-cultural research, however, is still in the pioneering stage, and many questions remain unanswered.

Most previous studies in cross-cultural genetic psychology have attempted to establish whether operational development in non-Western cultures follows the same stages as those described by Piaget in Swiss children, and, if so, the rate at which those stages are attained.

On the basis of the findings of the two previous studies dealing with the development of concrete operations in Australian Aborigines (de Lemos, 1966, 1969a/b; de Lacey, 1970a, in press), we propose the following general hypothesis:

Hypothesis 1: The qualitative aspects of operational development (i.e. the stages) are identical in Australian Aborigines and in Europeans, but the rate of development is slower in Aborigines.

The present study will also attempt to examine the following specific aspects of that development:

(a) The influence on operational development of European contact.

(b) The comparison of the development of logico-mathematical and spatial concepts in relation to ecological and cultural factors.

(c) The relationship between operational level and the development of perceptual activities.

(d) The relevance of the ecological cue validity theory to perceptual development.

The study also provides a partial replication of the investigations of de Lemos (1966, 1969a/b) and enables tests to be made of certain implications of her findings.

2. The influence on operational development of European contact

De Lacey (1970a, in press) has shown that a group of Australian Aborigines, living in close contact with Europeans, developed concepts of classification at the same rate as low-socioeconomic Europeans, and faster (or earlier) than Aborigines living in remote areas.

The present study also makes a comparison of two sub-groups of Australian Aborigines differing in the "amount of European contact" they have experienced. In the present case the difference between the two sub-groups is smaller than that in de Lacey's investigation. In particular, both sub-groups live in the same, relatively remote area of Australia, and both have retained the vernacular as their main language.

It was originally planned to select these two sub-group- from the same tribe; this proved impossible, because the influence of European contact has usually been more or less homogeneous in each tribal group. As a result, and because of other constraints, the best choice seemed to be two groups of Aborigines living in Central Australia, both West of Alice Springs, on the edge of the Great Western, or Gibson Desert. The "low-contact" group consisted of Pitjantjara Aborigines living at Areyonga Settlement; the "high-contact" group of Aranda Aborigines living at the Hermannsburg Mission.[1]

General background information about these two groups, together with the sampling procedures, will be provided in a later section.

The following hypothesis is therefore to be tested:

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[1] Throughout this report, these two groups are referred to, in short, as 'Areyonga' and 'Hermannsburg'.

Hypothesis 2: The rate of operational development is faster in the high-contact group (Hermannsburg) than in the low-contact group (Areyonga).

In addition to the two Aboriginal groups, a reference sample of Caucasian Australian children (hereafter called: 'Europeans') was tested in Canberra, A.C.T.

3. The comparison of the development of logico-mathematical and spatial concepts in relation to ecological and cultural factors

The present study is concerned with the passage from pre-operational to concrete operational thought. Among the many concrete operational concepts Piaget has studied, two appear to be particularly important: number and space.

This study includes a series of tests which are theoretically related to early logical and mathematical thinking (Piaget & Szeminska, 1941; Piaget & Inhelder, 1941): these are the now classical tests of conservation of Q, W, V and L[1], and the seriation of lengths. These will be referred to as the "logico-mathematical" tests.

Piaget and Inhelder's (1948) analysis of the development of the concept of space distinguishes between topological relations, which are acquired early in childhood, and projective and euclidean concepts, which develop conjointly, and relatively late in the period of concrete operations.[2] The following tests, which cover all three of these aspects of spatial relations, have been selected for this study: (1) Linear, circular and reverse orders, (2) Rotation of landscape models, and (3) Horizontality (the level of a liquid in a flask).

In European children, it is usually found that, on the average, logico-mathematical concepts are acquired relatively earlier than spatial concepts:

> At the age of seven years on the average the child is able to carry out logico-arithmetical operations (classifications, arrangements in series and one-to-one correspondences) but it is a year later that the time-space operations are achieved (Euclidean co-ordinates, projective concepts and simultaneity. (Tanner & Inhelder, 1956)

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[1] See list of abbreviations.

[2] See also, Bang et al., 1964; Pinard & Laurendeau, 1966; Laurendeau & Pinard, 1968.

As has already been stated (Chapter 1, Section B) Berry (1966a/b) found that perceptual and spatial skills are well developed in the Eskimos, for whom these skills are adaptive, whereas they are poorly developed in the Temne, an African, agricultural people who have little need for these skills.

This ecological functionalism may be extended to the Australian Aborigines (Berry, personal communication; Dawson, 1969a). Applying it to operational development, we might expect that the development of spatial operations would be relatively more advanced than the development of logico-mathematical operations. The contrary would be predicted to be true for Europeans.

Just as the Eskimos, the Australian Aborigines depend traditionally on hunting and food gathering, travelling for long distances in a relatively barren environment (Hellbusch, 1941; Elkin, 1943; Strehlow, 1965; and many others). Water is a rare commodity, and the journeys are usually organised to lead from one waterhole to the next. The Aborigine knows the location of these waterholes, and indeed of every other feature in the environment over a wide area, of which he seems to have a detailed "cognitive map", which enables him to find his way and to give directions to others.

Aborigines, however, do not use transportable maps, but draw symbolic maps on the ground or as rock-paintings.[1] These maps simply represent locations, usually waterholes, by circles, connected by lines which represent the journey between them. Analysed in Piagetian terms, these maps seem to contain topological and possibly projective, but certainly not Euclidean relationships.

On the other hand, the Aborigine does not measure distances, and his vocabulary has no word for area or distance.

> Aborigines know their good-gathering and water places and have some idea of clan and tribal boundaries; at least they know when they are in another tribe's territory. But they do not measure and have no terms for expressing size or distance. Ask an Aborigine about the size of a cattle station he knows, and he will probably tell you that it is a "little bit big"

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[1] I. Haynes, Prof. of Ethnotechnology, personal communication.

> or "properly big one". Ask him the distance to a place he knows and he will answer that it is "long way, might be", or it is "a long, long way" or perhaps that it is "close-up". If you are walking and tired, you must not place too much confidence in his "close-up". His ideas of area and distance are relative but not exact, for the time factor does not influence him. Consequently, an Aboriginal stockman reporting about cattle and grass refers to places by name, for his employer knows these and can estimate the distance for himself.
>
> Number. If however, Aborigines are to be assimilated into our economic system, they must grasp such matters, and they will do so in time. But their difficulty is very great. Full-blood Aboriginal school children learn the various measurement tables by rote and are shown what inches, feet, yards, square yards and so on are. And yet if they are asked the length of a line say twenty inches which has been drawn on the board, they might answer six inches, or half a mile. Such was my experience. The arithmetical table just has no relevance to anything in their camp life. Of course, the craftsman knows the length he wants to make his spear, but not in feet and inches. He works by sight, weight and balance.
>
> This matter of measurement is related to the problem of numbers - a real problem for Aborigines. Their languages have words for one and two, and indicate three and four by saying two-one and two-two respectively. Sometimes five is indicated by the open hand; seven by "marking off" two fingers on the other hand, and so on up to ten, and even twenty by marking the toes one by one. But this is not counting; it is only a concrete method of indicating individual persons or places. After five they usually say many, or a "mob" or a "big mob". And this is quite understandable. Individual persons are known by names and their tracks. A hunter only hunts and spears one kangaroo at a time. If he sees two or three or four he says so, if more, it is a mob, the individuals in which are not differentiated. Likewise he is lucky if he spears more than one wallaby, though he might see "plenty" or "big mob" wallaby. And as for witchetty grubs or nuts: who wants to enumerate them! Consequently, though children in school learn by rote to count up to a given number and to recite various tables, these numbers have no relevance to their parents' and grandparents' life - i.e. to hunting and food-gathering. (Elkin, 1943 - 4th edition, 1964, p.236-237).

This same explanation for the absence of a number system was put forward by Strehlow (1944) and while it may well be found to be unsatisfactory, (one would certainly wish to have more anthropological evidence concerning the use of basic concepts) the fact that the Aborigine is not concerned with number, measurement or quantities seems to be well established.

These observations give rise to the following hypothesis:

Hypothesis 3: Aborigines, because of their cultural background, will develop spatial concepts more readily than logico-mathematical concepts.

4. The relationship between operational level and the development of perceptual activities

Piaget makes a distinction between the figurative and the operative aspects of the acquisition of knowledge. Perception (Piaget, 1961, 1969a), together with certain aspects of mental imagery (Piaget & Inhelder, 1963a, 1966) and memory (Piaget et al. 1968), belongs to the figural aspect; it deals with configurations or states of transformations:

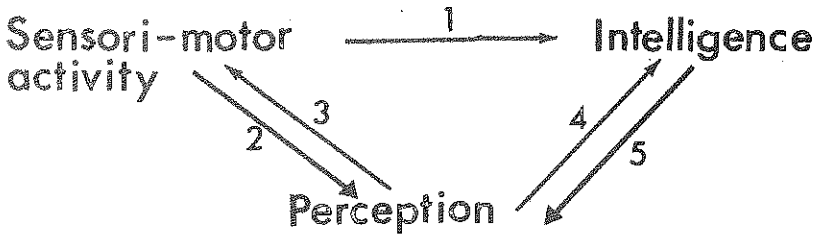
> Perception is not therefore the source of knowledge, because knowledge derives from the operative schemes of action as a whole. Perceptions function as connectors which establish constant and local contacts between actions or operations on the one hand, and objects and events on the other. Perceptual messages are transmitted in a figurative form, which is the only form available, and are decoded by being integrated, as far as possible, into the system of transformations.
>
> .. The figurative aspects of knowledge is tied with the here and now and consequently does not allow comparisons to be made at sufficiently great spatio-temporal distances for the transformations to be structured. It is therefore limited to the construction of approximations to objective configurations, approximations which are based on sampling (centration and encounters) and whose means of co-ordination are restricted (incomplete couplings). (Piaget, 1969a, pp.359-360).

Piaget's ideas about the relationships between perception and intelligence can be summarized in the diagram of Fig.2a (from Piaget's lectures in Genetic Epistemology, 19/11/1963).

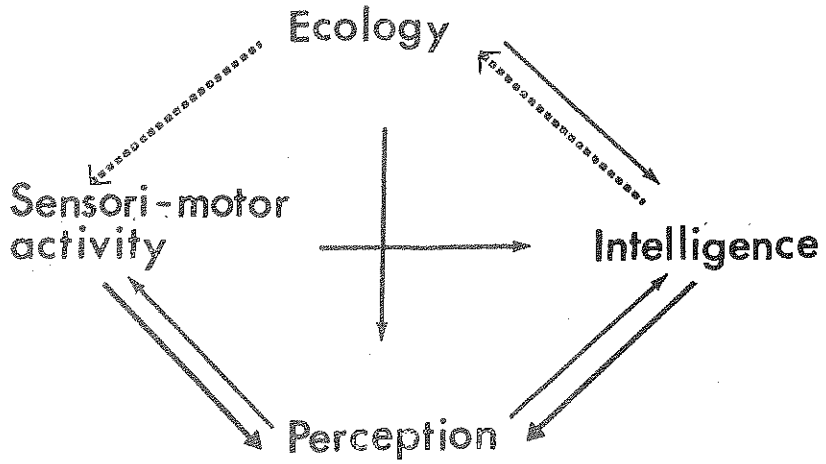
Intelligence does not develop from perception, but from a sensori-motor stage of action (arrow 1). The development of perception is parallel to that of intelligence, and also has its roots in sensori-motor activity (2) with which it is in interaction (3); however, perceptual development cannot be divided into stages. During the child's development, perception is also in interaction with intelligence (4), the most significant influence being the retroactive effects of intelligence on perception (5).

FIG. 2 Relationships between perception and intelligence

2a



2b



This retroaction influences the development of "perceptual activities":

> As the essential role of intelligence is to bring about comparisons at any distance in a mobile and reversible manner, and as the essential role of perceptual activity is to relate successive inter-field centrations at ever-increasing distances, it is very likely that sooner or later, depending on the domain involved, the perceptual activity will come under the direction of any representations which have already been organised in that domain. (Piaget, 1969a, p.334).

Based on this theoretical background, one might suppose that a direct and measurable relationship should exist between operational development and the results of developing perceptual activities, independently of chronological age. This seems to be a logical consequence from Piaget's theory, although Piaget has never stated it in such a simple form, and has not tried to examine it experimentally.

In fact, it seems hardly possible to subject this hypothesis to experimental verification within the confines of the usual developmental laboratory, because the variability in operational level at any one age is too small in European children. The cross-cultural setting, on the other hand, should provide us (from evidence of previous studies, e.g. de Lemos, 1966, 1969a/b) with a sufficiently large range of operational levels to make a verification possible.

Perceptual activities themselves cannot be measured, and Piaget measures them indirectly by their supposed effect on optico-geometrical illusions. He defines perceptual activities as follows :

> The collective term of perceptual activities (collective, because there is a large number of them, all of which do not necessarily relate to the same level of development) will be applied to those perceptual processes which occur when centrations or their effects have to be related across spatial or temporal intervals. These include activities of exploration, of transportation, of spatio-temporal or purely temporal transposition, of referral (to perceptual co-ordinates), of schematisation, etc.
>
> These activities increase in importance and in variety with age. They usually reinforce co-ordinations

> and reduce primary errors. However, they themselves often lead to new forms of systematic error because they relate previously unrelated elements; these new relations entail certain deformations which are similar to primary illusions. These new secondary illusions also increase continuously with age, up to a certain age. (Piaget, 1969a, p.133).

On the basis of this theoretical background, Piaget claims that the development of these perceptual activities can be traced indirectly by recording the following phenomena:

(1) A decrease with age of susceptibility to primary illusions.

(2) A decrease with practice of susceptibility to primary illusions.

(3) The initial increase and later decrease with age of the susceptibility to secondary illusions.[1]

Given the above theoretical discussion it follows that one should be able to detect differences in regard to the above phenomena between groups of subjects who differ in operational level. Specifically, the following hypothesis may be set up:

Hypothesis 4: The following phenomena are inversely related to operational level:

(a) The susceptibility to primary illusions

(b) The extent of the decrease with practice in susceptibility to primary illusions

(c) The age at which the maximum susceptibility to secondary illusions is reached.

The specific predictions based on Piaget's theory are summarized at the end of the next section.

5. The relevance of the ecological cue validity theory to perceptual development.

Only very crude developmental data have been obtained so far concerning the susceptibility to illusions of various ethnic groups. The present study is designed to provide a contribution in this respect.

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[1] See list of abbreviations and definitions for a definition of primary and secondary illusions.

It will be interesting to analyse these developmental data in relation to the ecological cue validity theory, which cannot account for the age-trends usually reported.

If small differences in the visual environment have an effect on susceptibility to illusions, as Segall et al. (1966) seem to think they do, the two Aboriginal samples should differ in specific ways.

The Aborigines in both samples live, or lived traditionally, in a very flat, open country. "The perceptual environment of both groups was remarkably "open vistaed". Vision to the horizon is but rarely interrupted by a solitary mulga or two and the cloudless sky permits unlimited visibility in all directions" (Gregor & McPherson, 1965). Thus the susceptibility to the H-V illusion of both Aboriginal groups should be markedly higher than that of the European group. Furthermore, because the Areyonga people spend more time out in the desert than the more settled, acculturated Hermannsburg people, they are hypothesized to be more susceptible to the H-V illusion, although previous research (Gregor & McPherson, 1965; Jahoda, 1966; Berry, 1968; Jahoda & Stacey, 1970) indicates that the latter part of the hypothesis is unlikely to be verified.

Similarly both Aboriginal groups have a much less carpentered environment than Europeans do, and, according to the ecological cue validity theory, their susceptibility to the M-L illusion should be low. Furthermore, because of the differences in living and housing conditions of the two Aboiriginal groups, the Hermannsburg sample should be more susceptible to the illusion than the Areyonga sample.

The following hypothesis derives from the above discussion:

Hypothesis 5:

(a) The order of susceptibility to the M-L illusion is the following (from highest to lowest): Canberra, Hermannsburg, Areyonga.

(b) The order of susceptibility to the H-V illusion is the following (from highest to lowest): Areyonga, Hermannsburg, Canberra.

It will be noted, of course, that the hypothesis based on Piaget's theory would not be identical with that set up

on the basis of Segall et al.'s (1966) theory.

In summary, the following predictions are based on the two theories:

Piaget		Segall et al.	
Susceptibility to primary illusions (e.g. M-L illusion):		Susceptibility to M-L illusion:	
High:	Areyonga	High:	Canberra
Medium:	Hermannsburg	Medium:	Hermannsburg
Low:	Canberra	Low:	Areyonga
Age of maximum susceptibility to secondary illusions (e.g. H-V illusion):		Susceptibility to H-V illusion:	
First:	Canberra	High:	Areyonga
Second:	Hermannsburg	Medium:	Hermannsburg
Third:	Areyonga	Low:	Canberra

6. Implications of de Lemos' study (1966, 1969a/b)

This study, as mentioned above, also provides a replication of a previous investigation on the development of concepts of conservation in Australian Aborigines, with one common population (Hermannsburg).

The following hypotheses can be set up on the basis of de Lemos' results:

Hypothesis 6: The order of difficulty usually found with the tests of conservation of Q and W is reversed in Australian Aborigines: W is found to be easier than Q.

Hypothesis 7: At Hermannsburg the performance of part-blood Aborigines is better than that of full-blood Aborigines.

B. METHODOLOGY

1. "Culture-free" tests

At the time when the only definition of intelligence was the result of a composite intelligence test (Binet), psychologists claimed that any test of factor 'g' would be culture-free, for the very reason that it was a measure of general intellectual capacity. It was soon recognized,

however, that the observed poor performance of all non-Western people might be due to the heavy verbal and educational loadings of most of these tests, and that they were culturally relevant only to the group for which they had been designed.

Attention therefore turned to non-verbal tests, mainly of spatial and perceptual reasoning (e.g. Raven's Matrices), correlating highly with general IQ tests. Some of these were designed specifically for cross-cultural use (e.g. Cattell's Culture-Fair (or -Free) Intelligence Test).

One such test, the Porteus Maze, has been widely used with Australian Aborigines (Porteus, 1917, 1931, 1965; Porteus et al., 1966, 1967; Bochner & David, 1968). Porteus concluded that Aborigines had an inferior intellectual capacity, and were therefore unable to adapt to our civilization.

Although these tests are still used, their failure has generally been recognized: the tests are foreign to non-Western cultures both in their form (paper/pencil; pictorial material; working to time limit), and in their content (reasoning according to symmetry, identity, seriation, etc.). Furthermore they consist mainly of rather artificial tasks, which are unlikely to motivate subjects who do not have the competitive values of Europeans.

2."Culture-fair" tests

Whereas "culture-free" tests are tests constructed by European psychologists, and applied to other cultures without modification of content, form, presentation or norms, except for the translation of the instructions, "culture-fair" tests will be defined as tests constructed by European psychologists, but adapted to suit a particular culture in their content and presentation; the norms, validity and reliability are established for the culture under study as well as for Europeans.

The best example of a "culture-fair" or "culture-reduced" test especially designed to be applicable to Australian Aborigines is the Queensland Test (QT) (Kearney, 1967), constructed under the direction of McElwain (1968a).

The QT has five sub-tests, administered in non-cyclic omnibus form similar to the Wechsler test; there is no time limit, and the mean time of testing is 45-60 minutes. The materials used are interesting to children and easy to handle. The test has the following additional advantages: (McElwain, 1968a, pp.13-14)

(i) the material is completely non-verbal in both administration and in response.

(ii) all the material is non-representational. There are no pictures, and no object used in the test has a common use or meaning.

(iii) in all the tests the goal of the test is clear. Generally the tester invites the subject to imitate some manipulation of material towards an overt goal. The tasks are then made progressively more difficult.

The findings with the QT:

> may be summed up by saying that the Aboriginal groups are inferior to Europeans, and in approximately the same degree as they have lacked contact with European groups. ... Not only are the mean scores lower but the rate of increase of score with age - the linear regression of score on age - in the range 7 to 12 years is also lower. (McElwain, 1968a, p.15).

The QT has proved to be a useful tool for practical purposes, although some doubts about its validity for Aboriginal subjects have been raised by Smith (1966); it is undoubtedly particularly useful in predicting the capacity of Aborigines to acquire European-type skills.

Theoretically, however, such a test is of little use. Firstly, it tells us nothing of the thought processes involved. Secondly, the five items retained for the test were the only ones out of a hundred measures of cognitive capacity to be judged valid to a satisfactory degree, and to give more or less identical results for Aborigines and for Europeans. McElwain (1968a, p.16) has not overlooked the fallacy which this contains:

> If we search among the range of psychological tests that are available and we reject those that indicate differences between two groups, we cannot then say that the groups are equal. By analogy we cannot reject all tests that show sex differences and then say that the 'sexes are equal in performance'.

It seems, however, that it would have been more interesting to investigate why Aborigines failed on the remaining 95 tests.

Considering the general failure of the culture-free and culture-fair approaches, we have to conclude that: (a) intelligence has to be defined as "the ability to adapt to one's environment" (e.g. Piaget, 1936; Berry 1969), and consequently that (b) that which constitutes intelligent behaviour for the members of one culture does not necessarily constitute intelligent behaviour for the members of another culture. (e.g. Faverge & Falmagne, 1962; Smith, 1966; Berry, 1966a/b, 1969).

One solution to this problem would be to compare only those fragments of intelligent behaviour which are demonstrated to be "functionally equivalent" (Berry, 1969); this, however, would very seriously limit the meaning of the global term intelligence.

Another alternative would be to devise intelligence tests for each culture separately, but comparability would then be lost.

3. The study of concepts

The methodology adopted for the present study is completely dissociated from the two approaches just described. The tests used in this study are not claimed to be culture-free, nor culture-fair, and the interpretation of the results will not be made in terms of intellectual capacity.

The purpose is to study certain specific cognitive functions, or concepts, which have been well described (in this case, by Piaget), and which have been found to be basic to the acquisition of scientific knowledge in the Western tradition. We are interested to find out whether these concepts develop also in a non-European culture, and, if so, whether this development follows the same stages, and proceeds at the same rate. Furthermore, we propose to study the relationship between the development of these concepts and cultural and environmental variables. It is recognized that this is an ethnocentric approach (cf. Introduction).

The only analogy between this methodology and that of the culture-fair movement lies in the adaptation of the materials, of the presentation of the tests, and of the testing situation, to the group under study. It is thought that this adaptation will ensure more valid and reliable results, but without eliminating the immediate disadvantage Aboriginal children have when they are subjected to European tests.

The interpretation of the results of the study will be limited to the particular concepts under investigation; they can be seen to reflect 'intelligence' only insofar as we accept to define intelligence in Aborigines as being equivalent to operational development, a step we are not readily willing to take. Insofar as the concepts under study are basic to a European type education, however, the results should be of practical as well as of theoretical significance.

C. GENERAL BACKGROUND AND SAMPLING

Since the design and the interpretation of the results of this study are based on the ecological and cultural characteristics of the two Aboriginal samples, an extensive description of the latter seems to be important. However, space prohibits a detailed report of all the observations we were able to make while living at Areyonga and at Hermannsburg. For the general introduction and the section concerning the Hermannsburg sample, an excellent summary of the necessary information has been given by de Lemos (1966, pp.127-141 and 155-156), and is still accurate at the present time. We will therefore quote from this, adding our own remarks where appropriate.[1]

The description will cover the following topics:

1. The general cultural background.
2. The present conditions of the Aborigines in the Northern Territory.

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[1] We gratefully acknowledge the permission to quote extensively from Dr. de Lemos' unpublished thesis. All direct quotes from her work will be indented and single spaced.

3. The environmental background of the children tested at:
   (a) Hermannsburg
   (b) Areyonga
4. Sampling procedures and sample characteristics.

1. General cultural background

De Lemos provides the following description of the general cultural background of Australian Aborigines:

> The Aboriginal culture has been extensively studied and reported. The earliest studies include those of Spencer and Gillen (1899, 1904, 1927) and Basedow (1925) on tribes in Central Australia. Later studies have been carried out by Elkin (1943), Kaberry (1939), Warner (1958), Meggitt (1962), and others.[1]
>
> No attempt can be made here to review this literature, but a brief outline of some of the main characteristics of traditional Aboriginal culture will be given.
>
> The Aborigines were basically a hunting and collecting nomadic people. They developed no agriculture, neither planting crops nor herding animals. Exchange of goods did take place, but this was mainly of social and ritualistic importance. No real trade or barter system was developed.
>
> The Aboriginal tribes were strongly attached to their own particular 'territory' so that movement of tribes and contact between tribes was relatively limited. While there seems to be some disagreement as to the basic constitution of the traditional Aboriginal community (see Elkin in Meggitt, 1962), the view appears to be generally held that the Aborigines lived in fairly large communities which hunted, camped, and performed corroborees together, but that smaller family groups would break away from the larger community for limited periods or in times of drought and food scarcity.
>
> The Aborigines did not have permanent villages or camp sites, but moved from place to place. The people slept in the open, or made rough shelters of branches, bark and leaves. Worldly possessions were limited to what could easily be carried when the tribe moved on to a new site.
>
> Weapons and implements made by the Aborigines include the throwing boomerang, spears, fighting sticks, digging sticks, shields, stone axes and fire sticks. Bags for carrying food and possessions were made by the women, usually from some kind of fibre string. Articles for adornment or for religious ceremonies

[1] E.g. Berndt and Berndt 1964, 1965 (present author's footnote).

were often made from human hair-string, fur or feathers. Sacred objects were generally made of wood or stone, decorated by simple designs, or, in north-east Arnhem Land, fairly elaborate paintings. The variety of material goods made by the Aborigines varied from tribe to tribe and from area to area, the north-east tribes generally having a richer variety of possessions and art forms.

The Aborigines had a complex social organisation and kinship system, and a rich variety of myths, totems, and religious ceremonies, rituals and beliefs. These aspects of Aboriginal culture haye been dealt with at great length in the works on Aboriginal culture referred to, and also by Strehlow (1947) and Berndt (1951, 1952).

Children were taught from an early age to observe and practise the rules and obligations of social relationships. They were also taught the myths and beliefs of the tribe. This occurred particularly at the initiation of the boys, when they were required to learn the special sacred myths and songs of their particular totem, which could not be passed on to the uninitiated or the women . Such learning was always by rote, and the children were not expected to question or discuss what they were taught (Strehlow (1947)). Boys and girls learnt hunting and food gathering skills at an early age, mainly by imitation and observation, and were expected to help in these activities as soon as they were old enough to do so.

Characteristics of Aboriginal Languages (de Lemos, 1966, 155-6).

Aboriginal languages are characterised by a wealth of specific concrete terms and a lack of abstract and collective terms. There are no terms for numbers exceeding four or five, and comparative terms are generally lacking.

Strehlow (1944) states that the Aranda language has three degrees of comparison; the positive, comparative and superlative. However, he points out that the superlative may often be used to mean 'very' or 'too', and is therefore not strictly applied. Our own experience in translating and interpreting the tests would suggest that these degrees of comparison are not often used in normal conversation, and the most common method of translating, for example, 'more' was the term used for 'big'.

Strehlow states that there are few conjunctions in the Aranda language. There are some copulative conjunctions, but disjunctive conjunctions such as 'either ... or' are entirely absent. He suggests that this characteristic may be due to the Aranda preference for short sentences using participles as connectives rather than conjunctions, and that this form is more suitable for a simple spoken language which

> prefers short sentences. However, it could also be related to an absence of the operational structures on which concepts of disjunction or conjunction must be based.
>
> Aranda has terms for one and two, and the terms for three, four and five are obtained by combining these terms. There are also terms for many and few. Carl Strehlow recorded terms for five, ten, twenty, thirty, and forty, but Strehlow states that these terms indicated only approximate values and were seldom used ..

Sharpe (1970) reports that traditional languages in the Northern Territory were able to handle most concepts, except numeration. Milliken (1969) collected information on cognitively relevant aspects of Aboriginal languages by sending questionnaires to linguists who had carried out work on Aboriginal languages; he provides the following summary of his findings:

> Only six cases were reported where Aborigines had words for numbers beyond 'two'. Six cases had words for 'three' and six for 'five'. One interesting report indicated that Aborigines had converted into their own language the equivalents of our number system going up to at least eleven and possibly beyond. Most had ordinal number words for first, second and last; they could discriminate between eldest and youngest, but this did not mean that there was necessarily a regular system throughout the language of comparatives and superlatives. No precise measuring scales existed in any of the languages. Time and distance, however, appear to have the greatest number of gross measuring words associated with them. All languages have devices for simple logical sequences. All languages have devices for critical thought and for challenging statements; but only four reports indicated that there was ever any questioning of religion or the explanation of the world and being. (Milliken, 1969, p.224).

2. Present conditions of the Aborigines in the Northern Territory

De Lemos' description of the present conditions of the Aborigines living in the Northern Territory is still accurate:

> The Aborigines' first contact with the Europeans began in the Nineteenth Century with the exploration and settlement of the Northern Territory. These contacts were at first limited, but with the establishment of missions, pastoral properties, ration depots, and more recently the government settlements, the

Aboriginal people have gradually come into closer contact with the European.

The first mission in the Northern Territory was established at Hermannsburg in 1877. Following this a number of missions were established, mainly in the northern part of the Territory, from 1886-1938. The government ration depots and settlements were established mainly after the Second World War, and many of the larger settlements were established only in the late 1950s.

Population and Distribution

The total full-blood Aboriginal population in the Northern Territory on 31 December, 1968 was recorded as 20,953, and on June 30, 1969 there were 5,308 Aboriginal children in Northern Territory schools (Northern Territory Administration, Welfare Branch, Annual Report 1968/69). The Aboriginal population has been increasing steadily over the last decade, although the infant mortality rates are extremely high (approximately 132/1000 live births); the life expectancy at birth of Aborigines is 50.0 years for males, and 50.7 years for females (Jones, 1965, 1970).

The large majority of the Aboriginal population is reported as being in contact with government settlements, mission stations, and pastoral stations.

To quote further from de Lemos' description:

Only 8.1 per cent of the Aboriginal population were living in or near the urban centres, including the government settlements at Darwin and Alice Springs. In comparison, 74.8 per cent of the non-Aboriginal population, mainly European, were living in the urban centres (percentages quoted from Tatz, 1964).

The missions and government settlements are generally situated hundreds of miles from the European living and communication centres. Some settlements and missions can be reached only by air or by sea, and during the wet season in the north access by air may be cut off. In other cases access by road may be limited by weather conditions. The Aborigines therefore have little opportunity to come into contact with the European centres.

Housing

On the older established missions most of the Aboriginals are housed in simple one or two-roomed houses, made from a variety of materials according to the area. On the newer settlements many of the Aboriginals live in 'humpies' or 'wurlies', rough

shelters made from whatever material happens to be available (Tatz, 1964). Most of the houses are completely unfurnished, and the utensils and material possessions of the Aborigines are few.

Health and Nutrition

Tatz (1964) points out that while reliable figures for the incidence of diseases among the Aborigines are not available, the available figures indicate a very high infant mortality, a high incidence of tuberculosis and leprosy and a high incidence of infections such as hook-worm, diarrhoea, gastro-enteritis, and eye and ear infections.[1] This he attributes largely to the poor housing conditions, lack of adequate water supplies and adequate sanitation, and an inadequate preventive health service. He also quotes figures by Crotty and Webb (1960) which indicate that malnutrition was a significant contributing factor in a high proportion of infant deaths (Tatz, 1964, pp.132 and 153).

While all missions and settlements provide either rations or cooked meals for the Aboriginals, figures quoted by Tatz suggest that in most cases their diet would be deficient, particularly in protein. Crotty (1958) reports that 'anaemia associated with a kwashiorkor-like nutritional disease is common between one and five years of age' (Crotty, 1958, p.325).

Increasing evidence of protein-calorie malnutrition resulting in growth retardation, anaemia, infections, malabsorption and infestation of the bowel has been accumulating over the past few years. In one study involving 2,250 children on six Aboriginal settlements in Queensland, retarded growth affected 50 per cent of Aboriginal children from six months to three years, and severe retardation affected 16 per cent of this group. The malnutrition was

[1] "School Medical Surveys in the Northern Territory have shown that many school children have defective hearing. The incidence is especially high in aboriginal children on mission and settlement schools, in fact, in some schools there are several children in a single class who have hearing defects of sufficient severity to affect their education. () Most N.T. children with defective hearing have conductive hearing losses associated with chronic ear troubles. The severity of these losses varies from very slight to moderate. Children with this type of loss are never extremely deaf but many are sufficiently hard of hearing that they will miss most of what is said when spoken to in a normal voice." (Commonwealth Acoustic Laboratory, no date, p.1-2). Bone conduction aids are issued to the children, but are never used for a long time. (present author's note).

accompanied by deficiencies in iron and in vitamins. (Jose & Welch, 1970). In another study, Maxwell and Elliott (1969) found a high incidence of malnutrition at all ages.

The seriousness of the nutritional state of Australian Aboriginal children has been described in a report by the Queensland Institute of Medical Research tabled recently in the Queensland Parliament (The Australian, October 7, 1970). Tatz (1970) has called for an urgent interdisciplinary approach to alleviate the situation. The main cause of malnutrition seems to lie in the inadequate nutrition of Aboriginal mothers during pregnancy and lactation, and inadequate infant feeding after weaning.

Another recently discovered threat to the physical and mental health of Aboriginal children is petrol inhalation(Nurcombe and Bianchi, in prep.). The habit apparently originated during World War II, and has been known on Elcho Island for about ten years before becoming a serious problem. Its effects are similar to glue inhalation psychosis, but the components of petrol are potentially more dangerous, and deaths have apparently occurred from petrol inhalation. Petrol-sniffing is invariably associated with other behaviour disorders and has been described by Nurcombe as a symptom of the stress in a society in transition.

On Elcho Island, petrol sniffing is reported to affect almost the entire school population, whereas at Hermannsburg, according to our own observations, it seems to be limited to adolescent boys.

Child rearing practices

The traditional methods of child-rearing of the Australian Aborigines have been described by anthropologists (e.g. Kaberry, 1939; Malinowski, 1963; White, 1969), and the contemporary scene is briefly mentioned by Nurcombe and Cawte (1967, pp.121-2):

> The childrearing environment today is characterized by close population, lack of privacy, large family size and a tendency for childhood peer groups to cohere beyond the control of overtaxed parents. This problem is intensified by the enforced absence of some of the fathers... Breast feeding tends to be relatively prolonged. It is provided on demand and used for

> pacification. Children are handled indulgently, permissively and with warmth. There is little parental check on emotional expression. Physical punishment when used at all tends to be inconsistent. Behaviour controls are predominantly social and group-oriented. Ridicule and shame appear more prominent than internalized conscience and guilt.

Very little is known, however, of aspects of child rearing which are likely to be directly relevant to cognitive development. It seems that motricity and exploration are actively discouraged in babies.

> Pitjantjatjara babies are usually smaller than white ones, but they learn to sit up earlier. It is normal to see the babies sitting unsupported before they are five months old,[1] but this early precocity is not sustained, and walking is not encouraged until the children are over a year old. Even crawling is discouraged and babies are sat into shallow holes dug out in the ground to prevent them from crawling into danger while their mothers are busy. (Hilliard, 1968, p.110)

According to another observer,[2] babies are allowed to explore freely within the boundaries of an area of approximately the size of the circle of light shed by the camp fire; if they crawl beyond they are immediately pulled back. This behaviour was probably adaptive in the traditional setting, but is likely to hinder sensori-motor development.

Subsequently, verbal exploration also seems to be discouraged, and Aboriginal children do not, apparently, go through the period of asking 'why'. This is probably due to the cultural norm of accepting the laws of nature, the social customs and the decisions of the elders without question.

> The ancient customs of the Pitjantjatjaras were not ways that could easily adapt to a changing world. They were essentially backward looking, and bound the people to the past and what had always been done. The tribespeople accepted, without question, many

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[1] This finding has recently been confirmed on part-blood Aboriginal babies (Nurcombe, personal communication) and follows the now well-established pattern of early motor development in non-European societies (e.g. Geber, 1958; Cravioto, 1968).

[2] Annette Hamilton, personal communication.

> practices, and if asked the reason for certain actions, were unable to say more than that they were tjaka, that is, the way they had always been done. (Hilliard, 1968, p.182).

It is well known that any form of competition is discouraged in Aboriginal culture, and this is probably also true of divergent, or creative thinking.

Many aspects of Aboriginal child rearing practices may thus be seen as inimical to an optimal cognitive development, in the Western sense, but much more research on this topic is needed.

De Lemos provides the following description of the education, general activities and employment of Aborigines.

> Education
>
> Prior to 1950 the only education available to Aboriginal children was that provided by the missions. The mission schools were generally handicapped by a shortage of staff and lack of finance, and in many cases one teacher with a minimum of equipment and space was responsible for a large amount of children. Since 1950 the government has established schools on settlements and pastoral properties, and has taken responsibility for supervising and assisting the mission schools.
>
> While education facilities for Aborigines have greatly improved since 1950, a recent report by Watts and Gallacher (1964) indicates that the educational achievement of Aboriginal children remains extremely low. Watts and Gallacher tested the children's reading comprehension, spelling and arithmetic and number concepts... On number concepts ... few Aboriginal children even up to 15 years of age appeared to have reached a level comparable to that reached by the majority of white Australian children at 5 to 6 years. Performances on reading and spelling were better, but still much below the white Australian levels, with the majority of children up to 15 years and over performing only at 7 to 8 year old levels or lower ... These findings indicate that the education of Aboriginal children cannot be equated with that of European children of the same age or the same period of schooling.
>
> General Activities and Employment
>
> Few Aborigines are employed in skilled or permanent positions. Apart from some of the stockmen on pastoral properties, and some of the Aborigines trained on the missions, they are generally employed in casual unskilled positions on missions or settlements, or remain unemployed. A large proportion of the adult

population have not received any schooling, and few have received any special training.

Contact with the European has led to some breakdown of the traditional Aboriginal culture and beliefs, but there is evidence that such beliefs still persist, and in many cases still exert a strong influence on the people, and customs and rituals such as the initiation ceremony are still carried out. While some still engage in traditional hunting and gathering activities, these are becoming less important and more intermittent as they are supplied with cooked meals or rations, clothes and tobacco on the settlements, missions and pastoral properties. It is therefore probable that their hunting skills are gradually being lost.

3. Environmental background of the children tested

De Lemos' account of the environmental background of the children tested at Hermannsburg is still accurate, and will be quoted extensively. It will be followed by our own description concerning the children tested at Areyonga.

1. Hermannsburg

The mission at Hermannsburg was established in 1877. It is situated in semi-desert country on the banks of the Finke River, which flows only after good rains. The people of this area are mainly from the Aranda tribe. Other tribes represented at Hermannsburg are the Loritja, and the Pitjantjara. These tribes have been extensively studied by the early anthropologists (Spencer and Gillen, 1927; Basedow, 1925). The Aranda language was recorded by one of the early Lutheran missionaries, Carl Strehlow,[1] and T.G.H. Strehlow has continued the study of the Aranda language, myths and traditions (Strehlow, 1944, 1947)..

About half the population at Hermannsburg is comprised of full-blood Aborigines; the others are part-bloods, the European ancestry being due to the contact, two to four generations removed, with Europeans living near or on the mission station. These Europeans have, apparently, never lived with the Aboriginal mother or their children for any length of time.

It seems that the part-blood children have been, and are still raised by the Aboriginal community in the same way as full-blood children. No difference could be detected between full-blood and part-blood children in

[1] Also Kempe, 1891 (present writer's footnote).

their living conditions, attention received, education, health or any other environmental condition.[1]

Activities on the Mission

Cattle raising is the main industry of the Hermannsburg Mission.

> ... attempts have been made to enable the Aborigines to acquire and herd their own cattle, but these have been largely unsuccessful. ... Other Aborigines are employed in essential activities on the mission; in the bakery, the kitchen (where meals are prepared for the school children), in cleaning and hygiene activities and in collecting firewood. A small number of women are employed in domestic activities and in sewing work, for which they are paid by piece rates. Several women are also employed in the hospital.
>
> A number of Hermannsburg Aborigines are water-colour artists. This art form was started by Albert Namatjira, who learned his technique from Rex Batterbee, a visiting artist Namatjira's success has popularised Aboriginal water-colours, and a ready market is found for them in the tourist trade. Other tourist objects and curios are also made - decorated boomerangs, spears, wooden carvings, bead necklaces and so on.

Games and leasure activities

> Since the everyday activities of the people are relevant to an assessment of their environmental background, and to the question of the extent to which operational thinking is required or expressed in their culture, a brief description of the most common leisure activities observed will be given.
>
> While a number of Aborigines are employed on the mission, a greater number remain idle. These people appeared to spend much of their time sitting in the shade in small groups of men or women and talking. The women often played a simple game of tossing a cotton reel. The object of the game was to make the cotton reel stand upright. Points were marked by each participant by strokes on the ground, and the participant scoring the greatest number of points was the winner. The men played a game called "nine sticks", which appeared to be an elaborated version of

[1] No stigma seems to be attached, in this community, to the fact of being part-blood, although, during fights, full-bloods may apparently accuse part-bloods of being "white fellows". On the other hand, it is apparently considered to be an honour for an Aboriginal girl to be approached by a white man.

> noughts and crosses. It is possible that this was European-introduced, since it was said to be similar to a German game, the early Lutheran missionaries being mainly German. Card games such as poker were said to be played by the men in the camp, but since this was discouraged by the mission authorities, it could not be confirmed. Card-playing was certainly known to be popular on neighbouring government settlements and pastoral properties. Observation of a poker game played on a pastoral property in this area indicated that the rules of poker were correctly followed, although the betting system appeared to be rather simple. Poker was played by both men and women on this property, and was very popular.[1]
>
> The children's games were very simple. One game was the 'bucking bronco', where one boy climbed on the back of another who attempted to unseat him by a realistic imitation of a bucking horse. This game was inspired by a rodeo which had recently been held on the mission. A game of 'cars' or 'trains' was played by boys from about three years up to fifteen years or over. In this game one or more empty tins were attached by wire to a long wire handle, and this was pushed around the mission. In some cases up to 13 tins were attached together. This game was apparently one which recurred periodically.[2] As it became less popular, a few girls were observed playing with the trains, presumably abandoned by their owners.
>
> The most popular activity of the girls appeared to be telling 'sand stories'. This was done by drawing figures in the sand by means of a long wire, each figure having a conventional meaning, and the girl accompanying the drawings by a verbal narration. These 'sand stories' are concerned mainly with everyday activities in the camp and with hunting, and have been described in greater detail by Munn (1963) ...

Both boys and girls enjoyed minor hunting expeditions into the neighbouring countryside, particularly along the Finke River, and, occasionally, they would bring rabbits or other animals they had found to the school. The boys sometimes practiced the throwing of small spears. On the other hand, western toys had begun to be introduced, and some children were seen looking at comic books or riding bicycles.

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[1] For a study of card playing among Aboriginals, see Berndt & Berndt, (1947). (present author's footnote).

[2] This game was very popular in 1969, particularly at Areyonga.

> Sport was encouraged by the mission and both the adults and the children participated. The men took part in football games and teams were selected to play those from neighbouring settlements. Athletics were organised by the school and competitions were held.
>
> Housing, health and nutrition
>
> Until recently the majority of Aboriginals at Hermannsburg lived in 'humpies' constructed of whatever materials were available, mainly scrap iron. A building programme in early 1964 has established a number of two-roomed aluminium houses which now house most of the Aborigines, although a number still live in humpies.[1] Furniture and utensils in these houses are limited.
>
> The hospital at Hermannsburg has been long established, and the nursing staff are known and trusted by the people. Consequently they are not reluctant to seek treatment at the hospital, as is often found in the newer settlements. The main health problems listed by Tatz (1964) at Hermannsburg are ear infection, sugar diabetes and high blood pressure, chronic nephritis in women, and a high incidence of tuberculosis. ...

The sister in charge at the Hermannsburg hospital reports that pneumonia is the major affection of adults, especially during the winter months. Babies from 6 months to 3 years of age are very prone to diarrhoea and chest infections. Older children are relatively healthy, although troubled by a variety of infections, especially of the skin and the eyes. The most wide-spread affliction is ear-infection. Some children, expecially the younger ones, receive daily treatment for their ear-infection; others do so once a week.

The diet of the children is relatively well balanced, since they receive their meals in common at the eating house, as well as oranges and milk during recess periods. This would not always be the case for parents, who are responsible for their own meals, and tend mainly to

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[1] By 1969, most of the Hermannsburg population lived in houses, some of which were built of locally quarried stone and comprised a large room, a kitchen and a bathroom. These were constructed by an Aboriginal building team under the supervision of a white builder. A small part of the population had vacated their houses because of the death of a relative, and lived in humpies near the Finke.

consume bread and tea with an enormous amount of sugar; however, they also eat meat, mainly beef, camp-pie and an occasional rabbit. What is more lacking, in their diet, is probably vitamins, since they cannot buy vegetables and only a limited variety of fruit. Very few Aborigines have their own gardens, but they sometimes have a small fowl-yard.

Education

> School activities at Hermannsburg go back to 1880, when the first school classes were held in the church building. A special school building was completed in 1896. Schooling was initially conducted in Aranda, and later partly in Aranda and partly in English, and the main subjects were religion, reading, writing and arithmetic. From the 1930s onward English became the more important, and finally the sole language of instruction, and the curriculum was widened.[1]
>
> In the early days the teaching was carried out on a part-time basis by the mission staff, and the school equipment was limited. In 1946 Beckenham (1948) reported that there was a total of 69 children at the school under one teacher, and that the school had no special equipment. The staff was gradually increased in the 1950s, and in 1964 there were five full-time teachers, and pre-school classes on a part-time basis were run by a member of the mission staff. ...

In 1969, there were 7 full-time primary school teachers, 1 full-time pre-school teacher, and two Aboriginal teaching assistants who were teaching their own classes.

The number of children enrolled at the Hermannsburg school at 30 June 1969 was 201 (101 male, 100 female), with an additional 39 at pre-school. The average daily enrolment over the 1968/69 school year was 196.6; the average daily attendance is reported as being 159.1 or 80.9% of the daily enrolment. (Northern Territory Administration, Welfare Branch, Annual Report 1968/69)[2].

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[1] Information on the early history of the school was supplied by T.G.H. Strehlow.

[2] The total Aboriginal population of Hermannsburg at 30 June 1969 was 554, of which 244 were classified as full-blood Aborigines.

In recent years the school equipment has been greatly improved and increased. A wide variety of activity materials are in use in the younger classes. There is a workshop containing tools for carpentry and craftwork classes, and regular art and craft classes are held where the children engage in constructive work. Sewing classes are also held for the girls.

Film sessions are held regularly in the evenings and attended by all the people on the mission. Various adult classes and activities are also organized.

Conclusion

Owing to their long contact with the Lutheran missionaries, and the relatively easy access to Alice Springs, the Aborigines at Hermannsburg have had a closer contact with the European culture than most other groups. Many of the older Aborigines have received education and training on the mission. Hermannsburg has frequently been visited by research teams, tourists, and other visitors, and during the Second World War there was extensive contact with the army personnel stationed in the Alice Springs area. The mission pays the workers in cash and has established a cash store where the Aborigines can buy at will. A second hand clothes shop has also been established. This, in addition to their contacts with Alice Springs and the tourists, has probably led to a greater understanding by the Hermannsburg people of Western values and culture than is achieved by most other groups of Aborigines.

2. Areyonga

The decision to establish a ration depot at Areyonga was made in 1943, in order to keep the Pitjantjara Aborigines from begging and foraging for food at military camps in the Alice Springs district and along the railway line. The Administration contracted to provide rations which the Finke River Mission (Hermannsburg) was to issue at Areyonga, in the Krichauff Ranges. Areyonga had traditionally been an Aboriginal centre because of its permanent water supply.

The first store and living quarters for the storekeeper were in operation in 1944. In 1950, the provision of additional wells made possible a minor expansion of the depot's facilities, which now included a make-shift school and an administrative building. A dining room, staff quarters and a medical clinic were established in 1952. (Finke River Mission, Hermannsburg, Central Australia. Welfare Branch, N.T.A., 1961).

"The 'local' population meanwhile remained nomadic, and attendance at the school by the children were irregular in the extreme as it was still the fashion for them to move out of camp on 'walkabout' whenever it seemed fitting to their parents to do so" (Finke ..., 1961, p.37). The population in touch with Areyonga then numbered more than 300 people, of which 120 were children.

Areyonga continued operations under the supervision of the Hermannsburg Mission until 1954, when it was taken over by the Welfare Branch of the Northern Territory Administration.

In 1969, the Settlement included a school, a pre-school, a hospital and infant-feeding clinic, a cash store, a kitchen with dining hall, a church, an administrative building and store room, and several houses for the staff. The total Aboriginal population was 325, of which 102 were children. (Northern Territory..., 1968/69).

Ecological and cultural background

The Areyonga school and other settlement buildings are situated in a valley, with steep, almost vertical rock walls; the Aboriginal camps are situated in the adjacent valleys, which are much wider. An extensive system of ridges and valleys extends to the South and East, the country to the North and West being flat desert.

The settlement is situated on Reserve 1028, which includes the Lake MacKay, Haast's Bluff and Petermanns Aboriginal reserves. The total area of this reserve is 44,800 square miles, and it comprises three other Government settlements; Papunya, Haast's Bluff and Docker River. The total Aboriginal population living on the reserve is estimated to be 1,725 (Northern Territory ..., 1968,69).

Although Areyonga is situated on Aranda country, it serves almost exclusively Aborigines from the Pitjanjara (or Pitjantjajara) tribe, which is part of the 'Western Desert bloc', and whose territory extends over a large part of the Northern Territory, South Australia and Western Australia. This is the most arid part of Australia, and it is generally recognised that the Western Desert people

had to have the greatest skills of all Aboriginal groups in order to survive (Berndt, 1959; Meggitt, 1962; Mountford, 1962; Hilliard, 1968).

> While it is true of all food-gathering communities living in arid regions that intimate local knowledge is needed in addition to the normal food-gathering skills, each local group in the Western Desert had to know all the habitats of the food plants, all the habits of the game animals, and all the locations of even the smallest rockholes and temporary waters in its own territory in order to survive ... During drought-enforced retreats from one safe water to the next, long distances had to be covered in the coolness of the night air, and shelter sought in dug-out shaded hollows during the day. Moves like these were made with uncanny assurance, and without the aid of a compass. ... We would often travel 'blind' through thick mulga scrub for several hours, and then halt suddenly before a soak or a rock-plate invisible even from a distance of fifty yards. ...
>
> The Western Desert tribesmen undoubtedly possessed more bush-craft than the Aranda, even though the latter were once counted among the finest trackers of the Australian bush. (Strehlow, 1965, p.126).

Because they were more or less constantly on the move, the Western Desert peoples appear to have lacked those elaborate songs and ceremonial cycles that were associated with the Aranda-speaking area.

> The Pitjantjara tribe, whose social structure is much simpler than that of the adjoining tribes, is divided into two intermarrying groups, or moieties, i.e. the Nananduraka (my people) and the Tananiltjan (the other folk.) The terms are reciprocal. (Mountford, 1962, p.27).

> The harsh economic environment is one of the possible reasons for the original absence of section systems among most of the Western Desert groups. The Aranda system was firmly based on the concept of inalienable land ownership by economically self-sufficient local groups. The Western Desert folk could not have used the Aranda system in their own arid environment ... (Strehlow, 1965, p.131).

In most parts of the Western Desert area these section and subsection systems have constituted only recent introductions, in the southern part even as recent as 1930 (Strehlow, 1965).

The Pitjanjara language, accordingly, is a language of

the Western Desert group (Elkin, 1943), but it is sufficiently related to Aranda to be able to be understood by the Hermannsburg people, and vice versa.

In summary, there are some important differences between the Pitjantjara and the Aranda cultures, languages and ecologies; for the purpose of this study, however, the difference in the amount of European contact seems to be the most important one.

European contact

Some contact between the Western Desert tribes and Hermannsburg Mission had existed since 1920, and regularly since 1930: "It was decided to attach native evangelists, trained at the Mission Station, to the nomadic tribes in an attempt to influence them towards a Christian way of life." This venture, however, proved difficult, because "the native missionaries, unaccustomed to the rigours of bush living, became so wasted physically as to require medical attention within a matter of months". They were then provided with rations, but these would not last long enough, because tribal law required that all food be shared. (Finke ..., 1961, p.81).

Thus, whereas the first baptism at Hermannsburg Mission took place in 1887, the early attempts to influence the Pitjantjaras were rather unsuccessful.

Even when the ration depot at Areyonga was established, contact with European culture was only sporadic, and mainly limited to the distribution of goods. In later years, with the expansion of the Settlement, a part of the Aboriginal population became more sedentary, but traditions and customs were constantly revived by the arrival from the desert of new groups. Evans and Long (1965) still found isolated nomadic groups living in the Western Desert during their patrols in 1957-1963, but most of these Aborigines are thought to have joined a Government Settlement by now.

Traditional culture is still relatively strong at Areyonga, although it is, of course, breaking down under the influence of schooling, the church, employment and

alcohol. Young people are still initiated, and the young men, during that time, live in a separate camp; however, they also play in a country-and-western pop group! Marriages among young people of the same age seem to become more frequent, and there seems to be what we may call a strong 'generation gap'.

The Pitjantjara still retain at least part of their hunting and tracking skills, since they are able to survive in the desert for several months during the yearly 'walkabout', during which adults and children travel hundreds of miles to visit sacred ancestral places in order to perform their ceremonies.[1]

Applying de Lacey's "index of contact" (de Lacey, 1970b) press, b) to the two samples, Areyonga has an index of .13 and Hermannsburg an index of .39 (maximum 1.00). This compares with .07 and .30 for de Lacey's low-contact groups (de Lacey, 1970a), and .71 and .98 for his high-contact groups. The difference in European contact between the Areyonga and Hermannsburg groups is therefore much smaller than the difference in de Lacey's study. In particular, both groups in the present study use the vernacular almost exclusively, whereas de Lacey's high-contact groups were speaking English as their main or sole language.

De Lacey's index, however, does not include the variables of length of contact, nor religious influence, on which our two samples differ widely.

Activities on the Settlement

Although most adult Aborigines on the Settlement have some form of employment or another, these jobs tend to be rather artificial because there is no real economic

[1] In 1969, while we were at Areyonga, one group started the 'walkabout' with a 4-wheel-drive vehicle; we met them again at Ayers Rock, but they soon ran out of petrol, and started walking towards the distant Docker River Settlement.

At that time, the attendance at the school dropped to about half its original level, and this explains why some children in the Areyonga sample have missed out on some of the tests, and others left before they could be tested at all.

reason for them. There is no productive industry at Areyonga, such as the cattle industry and the tannery at Hermannsburg the employment consists mainly of services to the Settlement: cleaning and garbage collecting, jobs at the kitchen and hospital, gardening (although the vegetables are rarely used) and pig raising (although Aborigines do not eat pork, and the pigs cannot be sold on the market, apparently for legal reasons), collecting wood, washing the school clothes etc. A few men work on the construction of a road across the ranges, but most of the building is done by outside contractors. There is little use for tourist objects and curios, since tourists do not have access to the reserve, and only a few are made for sale in Alice Springs.

It is not surprising, then, that no intrinsic motivation for work exists, except to get some money; many Aborigines are idle for most of the day.

Games and Leisure Activities

Card games and gambling seemed to be the major leisure activity of the men; it was not possible to observe the rules of the games. The women spent most of their time sitting in the camp or around the Settlement, and talking. They often went to collect bush foods and wood.

The children played the game of 'cars' described previously; a few had horses or donkeys to ride. The children were fond of taking walks into the surrounding countryside, collecting 'bush tucker' and small animals; they were extremely agile in climbing the surrounding hills. On week-ends they would often go 'rabbiting' with their parents. Girls were most often seen telling 'sand stories'.

The most popular activity on the Settlement was undoubtedly playing in the band; rehearsals were held twice a week, in the evening, and would attract everybody, young and old, black and white. The children, and sometimes the adults, enjoyed dancing ('twisting') to the band, usually in two groups, the girls on one side and the boys on the other.

The men also took part in football games and films were shown twice a week.

Housing, health and nutrition

Most of the aluminium and stone houses provided by the settlement remained unoccupied. The reasons given for this were that the houses were too cold in winter (and too hot in summer), and also that a relative had died, and therefore the area had to be vacated for some time. Thus, the majority of Aboriginals at Areyonga lived in humpies, and they shifted camp from time to time. They had, of course, no furniture and only very few utensils in these dwellings. The sanitary state of the camp was shocking to western minds.

Areyonga has a well equipped hospital and infant feeding clinic; unlike Hermannsburg, however, it does not receive a regular visit of the flying doctor, because the air field is not licenced. The main health problems were the same as those at Hermannsburg. It was noticed that the children at Areyonga were generally smaller than those at Hermannsburg, and appeared younger for their age, but it could not be established whether this was due to malnutrition or to the generally smaller stature of the Pitjantjaras.

Adults as well as children were provided with well balanced meals at the communal dining hall, but this did not seem to ensure that they had an adequate diet, because they would only eat some of the food; in particular, they seemed to leave the vegetables aside. Furthermore, when they ran out of money, they would revert to damper and tea until the next pay day. The children received at least one full meal at lunchtime, supervised by the teachers, but the attendance at the other meals was variable.

Education

School activities at Areyonga go back to about 1950, but have been rather sporadic because the pupils would often leave on 'walkabout' without notice. The school building is dark, and very cold in winter and, at the time this study took place, was extremely ill equipped. There was no school library, except a small, private one provided by a teacher, and even a football had to be borrowed from the local club.

In 1969, there were 4 full-time teachers at the school, and one full-time pre-school teacher; there were also a

number of Aboriginal teaching assistants, who sometimes took on the responsibility of looking after small groups of pupils.

The number of children enrolled at the Areyonga school on June 30, 1969 was 71 (23 male, 48 female), with an additional 12 at the pre-school. The average daily enrolment over the 1968/69 school year was 68.5; the average daily attendance is reported as being 61, or 89.0% of the daily enrolment. (Northern Territory Administration, Welfare Branch, Annual report 1968/69).

Conclusion

The Pitjantjara Aborigines of Areyonga are one of the few remaining groups of Aborigines who have only been minimally influenced by Western culture and values. They have kept the major part of their traditions and customs, and most of them live the traditional hunting-and-gathering life at least for part of the year. Contact with Europeans has been recent in time, and limited in extent, due to the isolation of Areyonga on an Aboriginal reserve. Furthermore, European influence has probably been rendered less pervasive by the large turnover in the Settlement's staff.

But traditional values are now breaking down quickly, without being adequately replaced by European norms and it may not be long before the skills associated with Aboriginal culture and ecology will be lost as well.

4. Sampling procedures and sample characteristics

(a) The Hermannsburg sample

A sample of 90 subjects was selected out of a total primary and post-primary school enrolment of 148. Ten subjects were chosen at each age from 6 to 12, and 5 subjects at each age from 13 to 16. The latter were grouped into the age-ranges 13-14 and 15-16 for all purposes.

In each group, an attempt was made to select 5 children of each sex, and 5 full-bloods, 5 part-bloods. These sampling procedures were based on immediately available Mission records. In the course of the research, however,

and when testing was almost finished, additional information on genealogy came to hand from older records, from Mission staff and from elderly Aborigines. It was then possible to document fully the ancestry of each child in the sample. This brought to light inconsistencies in the original sampling. It was established that a few children who had been thought to be full-blood Aborigines had in fact some remote European ancestry; these were therefore reclassified accordingly. In the case of 10 children and 3 adults, certainty could not be achieved, and it was decided to discard their results from the analysis concerning possible genetical differences (chapter 4 , section F). The characteristics of the final sample are set out in Table 1a and 1b.

Because it was impracticable to have the sampling done by an independent person, each child was attributed a number and the sampling was done without the experimenters' knowledge of names; the information about the proportion of European descent of each child was not recorded on the record-sheets, so that during testing the examiners were not aware of this information. (For a further discussion of this point, see chapter 4, section F).

Before the sample was selected, 5 children were excluded from the population because full details of their ages and/or tribal backgrounds were not available; 3 others were rejected because they were obviously deaf (2) or mentally retarded (1). At a later time, a further five subjects had to be excluded because they did not attend school regularly or left Hermannsburg before testing was completed; these were replaced by subjects of the same sex and age.

The sampling, because of these constraints, could not therefore be entirely 'random'. However, since more than half of all the pupils were tested, the sample is considered to be adequately representative of the whole Hermannsburg school population.

In addition to the school sample, 10 adults were tested on the tasks of Conservation of Q, W and V, Horizontality, and the M-L and H-V illusions. They volunteered because they were interested to see "what the children were doing" and/or because of the additional incentive of cool drinks or oranges. This sample would tend to be younger than average

Table 1a

Sample characteristics, Hermannsburg

AGE			SEX		SCHOOLING			
Age Group	Mean	Range	M	F	Years at school		Days in attendance	
					$\bar{x}$	S.D.	$\bar{x}$	S.D.
6	6;3	5;7 - 6;5	5	5	-		-	
7	7;2	6;7 - 7;6	5	5	1		not known	
8	8;1	7;8 - 8;6	5	5	1.6	0.5	282	85
9	9;1	8;7 - 9;5	5	5	3.2	0.6	560	132
10	10;1	9;7 - 10;6	5	5	4.8	1.0	856	204
11	10;11	10;7 - 11;4	5	5	4.8	0.4	882	78
12	12;0	11;8 - 12;6	5	5	6.7	0.5	1130	124
13/14	13;7	12;11 - 14;6	5	5	8.2	0.8	1432	174
15/16	14;7	14;8 - 16;6	4	6	9.1	1.1	1464	287
Adults	23;3	16;11 - 28;6	3	7	not known		not known	
			47	53				

Table 1b

Information on Aboriginal descent, Hermannsburg

Age Group	ABORIGINAL DESCENT (in 1/16 Aboriginal)		
	Part-bloods 10/16 to 15/16	Full-bloods 16/16	Uncertain*
6	7	3	0
7	6	3	1
8	5	3	2
9	7	3	0
10	5	3	2
11	6	2	2
12	5	4	1
13-14	5	4	1
15-16	3	6	1
Adults	3	4	3
	52	35	13

* rejected for analysis of genetic differences

for the adult population, and probably represents its better educated, more acculturated section.

(b) The Areyonga sample

At Areyonga, the school population was small because many Aborigines had left for Docker River, a settlement further West, which, although poorly equipped, attracted them because it is closer to their tribal grounds. Permission could not be obtained to test at Papunya or Yuendumu, two large neighbouring settlements, because another research project was in progress at these locations. Under these circumstances, the small Areyonga sample represents the best which could be obtained.

The total school enrolment of children aged 6 or more was 69; of these, 17 had to be excluded from the sample: 10 left (Walkabout) before testing was completed, 3 were untestable due to severe mental retardation, 2 were half-castes, 1 was an Aranda on a short visit from Hermannsburg, and 1 was enrolled, but did not attend school. Three other pupils left before the end of the testing, but since they missed only a few tests, they have been retained in the sample; in addition, three 15 year-olds, who were not attending school, were also tested, but not on the complete battery. The total Areyonga sample is therefore composed of 55 subjects, of which 49 have been completely tested. Full details of the characteristics of the sample are shown in Table 2.

In addition, 10 volunteer adults were tested; these came because they were interested and/or because of the additional incentive of cigarettes. They tend to represent the younger, better educated and more acculturated portion of the population.

Table 2

Sample characteristics, Areyonga

Group	AGE		SEX		SCHOOLING			
	Mean	Range	M	F	Years at school		Days in attendance	
					$\bar{x}$	S.D.	$\bar{x}$	S.D.
6/7	6;8	5;9 - 7;5	2	6	1.5*	0.7	162*	180
8/9	8;10	8;0 - 9;5	5	7	3.0	1.3	339	122
10/11	10;3	9;8 - 11;1	3	6	5.3	0.5	652	82
12/13	12;6	11;7 - 13;6	7	8	6.4	1.0	803	214
14/17	14;10	13;11 -17;3	3	8	7.8	1.8	1050	216
Adults	25;0	17;5 - 30	9	1	not known		not known	
			29	36				

* 7 year-olds only

Table 2 (continued)

UNGROUPED AGES			SEX	
Age	Mean	Range	M	F
6	6;0	5;9 - 6;1	1	2
7	7;0	6;7 - 7;5	1	4
8	8;3	8;0 - 8;5	1	3
9	9;1	8;10 - 9;5	4	4
10	10;0	9;8 - 10;3	1	6
11	11;0	11;0 - 11;1	2	0
12	11;11	11;7 - 12;2	2	4
13	13;0	12;7 - 13;6	5	4
14	14;2	13;11 - 14;5	2	4
15/17	15;9	14;9 - 17;3	1	4
Adults	25;0	17;5 - 30	9	1
			29	36

(c) The Canberra sample

A sample of 80 children was selected from a local primary school. The classes in this school were not graded according to performance; on the contrary, care was taken to include in each class a cross-section of abilities. Thus, one class could be selected at random from each grade. Within these classes, all subjects who were not in the appropriate age range ((n-1);7 to (n);6 : e.g. for 12 year-olds, 11;7 to 12;6) were excluded, as well as those who had a serious visual defect and those, of migrant origin, who were not completely fluent in English; of the remainder,

5 boys and 5 girls were sampled randomly, approximately in equal numbers in the lower and upper halves of the age range. When they were available, I.Q. scores (as assessed by the school guidance officer) were recorded, but not used in the sampling procedures. Details of the sample characteristics are given in Table 3.

The Canberra sample is considered to be reasonably representative of an average, urban caucasian Australian population. Although Canberra tends to have a large proportion of its population in the higher income bracket, care was taken to select a state school in a lower middle-class suburb. For 39 subjects in the sample, information was available on the father's occupation: 41% were blue-collar and 54% white collar workers; 5% were in the professional or academic category. It should also be borne in mind that the representativeness of this sample is not crucial to the present study.

In addition, 20 adults, 10 of each sex, were tested; these were volunteer first-year University students, who came either because of interest in the research and/or to obtain a small credit towards their annual class mark. Preference was given to part-time students.

Table 3

Sample characteristics, Canberra

Group	AGE Mean	AGE Range	SEX M	SEX F	IQ Mean
5	5;0	4;10 - 5;2	5	5	N.A (Not available)
6	6;0	5;11 - 6;3	5	5	N.A
7	7;1	6;11 - 7;7	5	5	N.A.
8	8;0	7;10 - 8;2	5	5	N.A.
9	9;0	8;9 - 9;3	5	5	N.A.
10	10;1	9;10 - 10;5	5	5	111.6
10B*	10;1	9;9 - 10;2	5	5	N.A.
11	11;1	10;11 - 11;6	5	5	111.3
12	12;0	11;7 - 12;3	5	5	109.3
Adults	21;9	16;11 - 31;5	10	10	N.A.
			55	55	

*Group 10B represents the second sample of 10 year-old children selected for the check-up described in Appendix 2.

CHAPTER III : THE TESTS : TEST-MATERIALS, PROCEDURES AND SCORING

The tests included in this study can be subdivided into three groups according to the cognitive areas they are designed to assess:

A. Logico-mathematical operations
   1. Conservation of Quantity (Q)
   2. Conservation of Weight (W)
   3. Conservation of Volume (V)
   4. Conservation of Length (L)
   5. Seriation

B. Spatial operations
   1. Orders: linear, reverse and circular
   2. Rotation: of two landscape models
   3. Horizontality: level of water in a tilted bottle

C. Perception
   1. Müller-Lyer illusion (M-L)
   2. Delboeuf illusion (Delb.)
   3. Horizontal-Vertical illusion (H-V)
   4. Oppel-Kundt illusion (O-K)
   5. Size-Weight illusion (S-W)

Sections B, C and D of Chapter 3 are devoted to a detailed description of the tests coming under the three respective headings. Each test will be discussed under the following headings:

1. Test materials
2. Procedures
3. Piaget's description of the stages
4. Notation of subjects' behaviour
5. Scoring: (a) in stages
   (b) in points

The general principles underlying the selection of the tests and test-materials, the procedures and the scoring are discussed in Section A of this chapter.

A. GENERAL PRINCIPLES UNDERLYING THE SELECTION OF THE TESTS AND TEST-MATERIALS, PROCEDURES AND SCORING

1. Selection of the tests

The tests were selected after an extensive pilot-study, the details of which are provided in Appendix 3. From the tests probed in the pilot-study, 13 were retained for the main study. Another one, the test of Rotation, was added later to increase the number of tasks in the spatial field.

The tests of concrete operational development were chosen to cover a wide age-range. The conservation tasks were included to provide a comparison with the previous study in Hermannsburg by de Lemos (1966, 1969a/b) and the task of seriation was added to assess logico-mathematical operations outside the conservation area. The tests of spatial operations were selected to cover topological, projective and euclidean concepts of space.

The perceptual illusions were selected so as to include two primary (Müller-Lyer; Delboeuf) and two secondary (Horizontal-Vertical; Öppel-Kundt) optico-geometric illusions as well as one illusion (Size-Weight) which involves tactilo-kinaesthetic as well as visual information.

2. Test-materials

The following criteria were used for the selection of the test material:

1. The material had to be suitable for cross-cultural use.
2. Where possible, standardized material (Vinh Bang, in prep.) was used.
3. It had to be attractive to children, both Aboriginal and European.

For the conservation tasks, and in relation to principles 1 and 2, it will be recalled that the practice in a few cross-cultural studies has been to use materials thought to be more familiar to non-western subjects than the classical plasticine or water. Price-Williams (1961) used fine earth, or nuts, and de Lemos (1966) used sugar for the conservation of Q; de Lemos used tea in plastic bags of different sizes for the conservation of W, and Waddell

(1968) employed tobacco sticks for conservation of L.

Adapting the content of a test to the experience of the subjects is certainly an acceptable procedure where it does not change the test's structure; it should be adopted whenever the standardized materials would be meaningless to the subjects, puzzle them, increase the unfamiliarity of the situation, or distract them from the purpose of the test. On the other hand, if there is no reason to believe that the use of the standardized material will have any adverse effect, it would be a mistake to introduce an extraneous variable.

It could, moreover, be argued that such an adaption of the contents is of very limited value, since so many other factors tend to make the testing situation artificial. It is true, for instance, as Waddell (1968) has pointed out, that the use of containers (for the conservation of Q), especially transparent ones, is foreign to certain cultures. At the same time, experiences such as being asked to sit down at a table by a relatively strange European, receiving individual attention, being asked to perform a novel task, being asked his opinion, are sufficiently foreign to an Aboriginal subject to render a direct comparison between European and Aboriginal results difficult, irrespective of the care taken with the adaptation of the test materials.

In the pilot study, it was found that Aboriginal children attending school were quite familiar with plasticine; in fact, some of them even liked to eat it! Tea in plastic bags was also used during the pilot study, but failed to provoke any interest, and, in addition, was very difficult to pour from one bag into the next without spilling a large part on the table. In any case, the handling could not be performed by most subjects, and this was thought to be a major disadvantage. The classical use of plasticine was therefore retained for the conservation of W.

Similarly, the use of sugar for the conservation of Q proved to be less satisfactory than the traditional coloured water. In the pilot study, the children failed to

show any particular interest in sugar. Furthermore, its use precludes the question: "How much is it to drink?", which is very useful in making the test meaningful. However, in the main study, a minor departure from the standardized technique was made, insofar as orange cordial was used instead of water. This also helped to make the situation very concrete, since the subjects could actually drink it, and, as will easily be guessed, added to the popularity of "Mr. Dasen's games"![1]

Not much had to be done to comply with principle 3, since Piaget's tasks seldom fail to be intrinsically interesting to children. Most of the material was painted in bright colours, mainly red.

For the perceptual tests, the principles governing the manufacture of the stimulus cards were based on those described by Campbell (1964) and Segall et al. (1966), namely:

1. Two colours, red and black, were used, to help make it clear which parts of the figure were to be compared.[2]
2. Lines, in the Müller-Lyer and the Horizontal-Vertical illusions, were not joined, as is usually the case in these figures, but were separated by spaces of 1 or 2 mm. This, again, was devised to make it clear what was asked of the subject.[2]
3. In addition to the actual stimulus cards, check items were used for each illusion. These were devised:

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[1] An additional disadvantage of using sugar or earth, which seems to have gone unnoticed, is that the content is thus no longer continuous: the fine granules of sugar or earth can be considered to be an intermediate step between the classical case of continuous quantity (any liquid) and the test of discontinuous quantity (usually beads). Both of these have also to be distinguished from the use of plasticine (usually referred to as 'substance'). Although all these tests have the same structure, it is well known that for European subjects the different contents are not of the same difficulty, the conservation of discontinuous quantity being generally acquired about one year before the conservation of continuous quantity.

[2] These adaptations are known to weaken the illusions substantially (Segall et al., 1966, pp.239-240), but this does not matter, since the same stimulus figures are presented to all subjects.

(a) to train the subject for the particular task, making it perfectly clear which parts were to be compared, and which one (the 'big' one, or the 'small' one) was to be pointed at.

(b) to check that the subject was following these instructions. This was achieved by presenting an extreme case of the illusion (f. ex. an illusion of 500%); if the subject showed the 'wrong' answer, it was assumed that the subject was not exhibiting an unusually large illusion, but that there was a failure in communication. Campbell (1964, pp.325-327) discusses in some detail the epistemological implications of this assumption.

3. Testing procedures: general principles

The following general principles were applied in devising the testing procedures:

1. The procedures were adapted for cross-cultural use whenever it seemed necessary; the following rules were used in making these adaptations:[1]

(a) The verbal content of the tests was reduced, sometimes to a point where the test became almost completely non-verbal (Seriation, Rotation). In these cases, the instructions simply required the subject to imitate the experimenter or a model presented by him.

(b) When this was not possible, because of the loss of information that would result, the tests used only very simple vocabulary (see next chapter). Before actual testing began, the subject's understanding of this vocabulary was tested, and, if necessary, the instructions were adapted accordingly.

(c) The tests were always preceded by a training sequence,

[1] Although no attempt was made to make the tests "culture free" or "culture fair", some principles of procedure were influenced by the methodology of the Queensland Test (McElwain, 1968a). Many points discovered during the pilot study were confirmed by similar observations and recommendations made by McElwain (1968b) and were applied in the main study.

and by check items to ensure adequate communication.

(d) No pictorial material was used (except for outline drawings of the bottle in the Horizontality test).

2. However, changes in the standardized procedures developed by Vinh Bang (in prep.) were kept to a minimum whenever possible.

3. The testing procedures were devised to be suitable for the low-contact group (Areyonga); the same procedures were then used for the two other samples, except that, for the Canberra sample, a more sophisticated English was used.

4. A time limit was never used and the subjects were never led to believe that they had to answer or to work quickly.

5. The testing was done in English. It would have been impossible to learn the Pitjantjajara and the Aranda languages to any sufficient degree of fluency in the time available for this study. However the experimenters were familiar with a few key words of the vernaculars, and used these to establish contact or to trigger a response. Translations were cross-checked with several Aboriginal and European informants.

As English is the only language used in settlement and mission schools, most subjects understood simple orders and questions, and could speak at least a few words (cf. 1b).

It proved impracticable to use an interpreter for the following reasons:

Europeans speaking these Aboriginal languages are extremely rare; they would not have been able to spend a sufficient time on this project, and in any case, would not have had the proper training in psychological testing. Nor were Aboriginal interpreters suitable for this task available. A short attempt was made in Areyonga to secure the help of a native teaching assistant when a couple of young subjects could not, or would not communicate in English. This was a failure in many respects: the subjects would not communicate with the teaching assistant any more than with the experimenter, which seems to show that it was the unfamiliar testing situation rather than language

difficulties which caused the blockage. Furthermore, the experimenter felt that he had no real control over the communication between the child and the experimenter. (The interpreter proved to be a non-conserver herself, and might have influenced the subjects against a conserving response). The experiment was discontinued immediately. The same observations had been made by de Lemos (1966, pp.372-373).

4. The general testing situation

Testing was always performed during normal school hours (usually about 9 a.m. to 3 p.m.) except with adult subjects.

While lighting and seating arrangements could not be kept absolutely standard for all subjects, they were always appropriate to the situation. Various rooms were used, as available.

At Hermannsburg and Areyonga, two subjects were tested at the one time in the same room by separate experimenters,[1] but facing away from each other. They usually came from the same class and were of the same sex. This greatly helped to overcome shyness and to establish rapport, and doubled the speed of testing. Each subject was tested successively by both experimenters.

It was not possible to test two subjects at a time in Canberra, but the younger subjects came in groups of two, one drawing or reading while the other was being tested.[2]

Total testing time varied greatly with age and among subjects, and occupied from one to three hours, with an average of approximately two hours for Aboriginal subjects and 75 minutes for Europeans. This total time was subdivided into several sessions (from 2 to 6) of varying

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[1] The second experimenter was Mrs C. Dasen, Lic. ès Sc., who is not a psychologist, but was especially trained for the situation and had been in contact with Piagetian tests and ideas for several years. However, the conservation tasks were always conducted by the author to ensure consistency in the clinical method.

[2] This procedure was introduced after a 5 year-old girl went home after school, and on being asked by her mother what she had done at school that day, replied "Oh, it was fun - I played games with a bearded man in a caravan"!

length (15 to 45 min.) depending on the subject's motivation and the school's time table; the sessions were usually separated by one or two days. Testing in Canberra took place intermittently in November and December 1968, February, March, October and November 1969; at Areyonga in April and May 1969, and in Hermannsburg from June to August 1969.

At Areyonga and Hermannsburg, a great deal of time had to be spent on establishing rapport with the children. This was accomplished as follows:

(1) At first, the examiners attended school activities, moving from one class to the next, asking questions, making comments, taking small groups for reading or maths lessons, showing slides, organising drawing contests and going for walks with the children during or after school. This initial 'public relations' period took more than a week at Areyonga, and three or four days at Hermannsburg. That this procedure was successful is attested to by the fact that from thereon children came spontaneously to the experimenter's house after school (in Areyonga every day!) to look at books, drink cordial, play games or "help" around the garden with the hope of receiving an orange.

(2) In a second stage, the subjects came to the experimental room and were allowed to play with a puzzle or Lego (a plastic construction set), to look at photographic books dealing with Aboriginal children, to make a drawing, and, if possible, to take a first test.

In most cases, no reinforcement had to be given; it was considered a reward to be able to "play the games". The children were allowed to drink the cordial during or after the conservation of Q test, and sometimes occasional shyness was overcome with a sweet or by verbal encouragement. Aboriginal adults were given cigarettes or an orange.

Subjects were encouraged by words such as 'good boy' (etc) irrespective of their actual performance. No feedback was given, except to some older subjects and adults after the testing was completed.

5. Test sequence

The order in which the tests were administered was flexible, but subject to the following principles:

1. The tests of Q, W and V were presented in a predetermined order, such that in the overall sample as well as in each age group, the number of subjects taking each test first, second or third was approximately equal.

2. Conservation tests were usually distributed over different sessions to avoid response persistence.

3. The testing was usually introduced by a perceptual test, Orders or Seriation. The idea was to start with a test where verbal communication was reduced to a minimum, where the subject could be actively playing (Orders), and which was easy enough to provide the subject with an initial feeling of success.

4. Perceptual, spatial and logico-mathematical tests were usually alternated, to provide variety.

All the tests were not administered to all age groups.

The logico-mathematical tests (conservations and seriation) were presented to all Aboriginal children, whereas, in the European sample, testing was discontinued if 100% conservation had been attained in the previous age-group. In Areyonga, the conservation tests were not administered to the 6 and 7 year-olds, and in the European sample, conservation of V was not administered to the 5 year-olds.

The spatial tests of Rotation and Horizontality were administered to all children of all three samples. The test of Orders was presented to the following age-groups: 5 to 8 in Canberra, 6 to 10 in Hermannsburg, and 6 to 11 in Areyonga.

The five perceptual tests (illusions) were administered to all the children.

Adults in the Aboriginal sample were presented with the following tests: Conservations of Q, W and V, Horizontality, M-L and H-V illusions. European adults were presented with the five perceptual tests.

6. Classification of responses and scoring

For each test, the following three ways have been used to categorize the subjects' responses:

(a) Description of behaviour ('notation'): For each part of a test, the subjects' reactions have been recorded according to certain rules, and using symbols (usually: A,B,C and D). For each test, these will first be described in detail.
These symbols, or notations, are then used to score the subjects' performance in two different ways: by stages, and by a system of points.

(b) Scoring by stages:
The notations of the different parts of each test are combined into a classification by stages, which corresponds as closely as possible to that originally described by Piaget. (A summary of Piaget's stages is provided for each test.)
Stage 3 always represents the concrete operational stage. It is sometimes subdivided into two substages: 3A indicating a formative period in which the concrete operations have not yet reached a complete state of equilibrium, and 3B, in which the reactions are immediately operational.
Stage 3 is preceded by a variable number of lower stages, typical of pre-operational thinking, but indicating a progressively more complex structural organisation.

(c) Scoring by points:
Each 'notation' is also attributed an arbitrary number of points; these are added to form the score, in points, for each test. The scores of the logico-mathematical tests are added to form the 'logico-mathematical score', and the scores of the spatial tests are added to form the 'spatial score'.
In addition to providing the possibility of adding the performance of different tests, the system of points reflects performance in a somewhat different way than the classification by stages.[1] In the latter the results are usually expressed as percentages of

[1] Slightly different results may be obtained with the two scoring systems; see, for instance, p.238 and 249 .

subjects reaching stage 3, whereas in the former, the pre-operational reactions are taken into account as well. This is why the results will always be reported in both scoring systems.

B. TEST MATERIALS, PROCEDURES AND SCORING: LOGICO-MATHEMATICAL TESTS

Since the four conservation tasks have the same structure and since the procedures and scoring which apply to them follow a similar pattern, they will first be described conjointly. The reader should have little difficulty in applying the general description to each particular content. The test materials and details of the procedures will then be described for each test separately. The test of seriation is also described in a separate section.

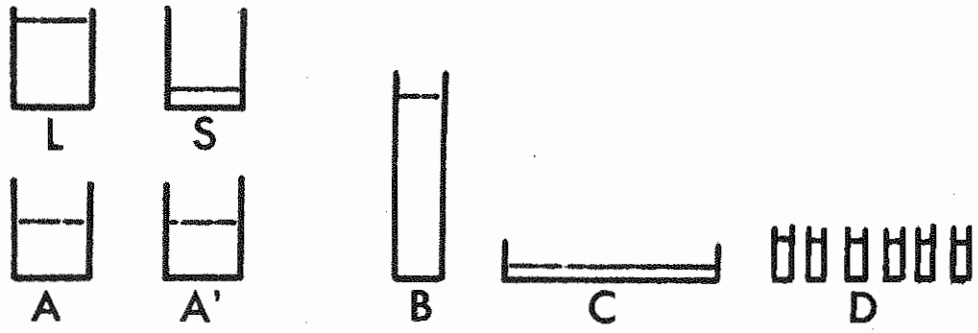
1. Conservation tests: general procedures

Piaget's clinical method was used throughout. This means that the questioning was adapted to the child's answers, rather than being laid out in advance. This method also enables the experimenter to introduce spontaneously any modifications which are likely to clarify the diagnostic of the child's thought, and its flexibility is obviously of great advantage in cross-cultural testing. This does not mean, however, that the procedures need be unsystematic or unstructured, nor necessarily in contradiction with the term 'standardized'. What the standardized procedures (Vinh Bang, in prep.) establish is a set of questions about the child's thinking which have to be answered during the testing; the standardization also suggests the best order for asking these questions, and suggests the best wording for the instructions, but leaves the experimenter free to change these if necessary.

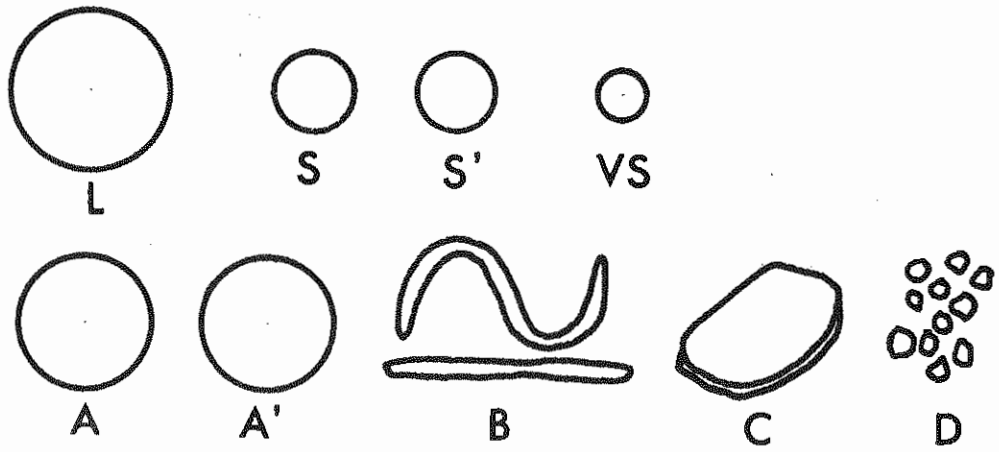
Our procedures can be subdivided into 5 parts. The symbols used are illustrated in Fig. 3.

FIG. 3 Symbols used for Conservation tests

Quantity (Liquids)



Weight & Volume



Length

Part 1 serves to 'initiate the programme'. One of the conservation tasks is selected according to the previous determination of the sequence (counterbalancing of the order of conservation of Q, W and V).

It is made sure that the child understands the test material and is familiar with it. (For example, he may be asked how a balance works, or what will happen if a plasticine ball is put into the water). If there is any doubt on his part, or if he appears not to comprehend, these phenomena are demonstrated and explained.

Part 2 establishes the subject's understanding of the inequality over a variety of situations. For example, the subject is asked what would happen if two different plasticine balls (for example L/VS, S/VS, L/S, etc.) were put on the balance or into the water, or how much there is to drink when the cordial is poured in varying amounts into two identical glasses (A and A').

Part 3 is used to check the subject's understanding of equality (for example S/S', A/A', etc.) in at least 2 situations. If this fails at first, inequality items are repeated before items testing for comprehension of equality are tried again.[1]

Phases 1, 2 and 3 therefore serve as pre-training. Typically, each item consists of a prediction (anticipation) and a demonstration, the latter providing the subject with the necessary feed-back. This training sequence can be performed, if necessary, almost without language. However, these 3 parts are also used to check the subject's vocabulary, namely the level of relational terms he is able to understand and use. If any doubt remains, additional items are introduced to this end.

If the subject fails to understand either inequality or equality, or both, the test is discontinued and scored F (for "Failure to communicate"). The convention used is that the subject had to be successful on at least 4 successive

[1] Thus, in practice, items of parts 2 and 3 are often alternated.

check-items, two inequalities and two equalities for the testing to continue.

For those subjects who pass the check-items, part 3 also serves to initiate the actual testing phase in establishing the initial identity between A and A'.

Part 4 is the critical test phase during which the main results are obtained. It consists of three sub-parts.

(1) First, the subject is asked to transform A' into B. As much as possible, all transformations are performed by the subject and not by the experimenter, although the latter may have to demonstrate or to help. This is designed to avoid the occurrence of what Greenfield (1966b, pp.245-263) has called 'action magic'.[1] In any case, and although this may not be obvious from publications, it is a principle of the Genevan methodology to let the child handle the material whenever possible.

The subject is then asked whether the particular physical peroperty (quantity, weight, volume, length) of A and B are still the same, or whether they have changed. The most common wordings which were used are described separately for each test, later in this chapter.

Some subjects find an easy escape in simply repeating the last word of the experimenter's question. To check on this subterfuge, the question is often repeated, changing the order of the relational terms. (For example: "Do we have the same amount to drink, or do you have more, or do you have less?"; the next question would then be: "Do you have less to drink, or do you have more, or do we have the same amount?")

Another possibility is to avoid suggesting any

[1] 'Action magic' refers to the attribution of 'magical' powers to an authority figure, such as the experimenter; in this case, non-conservation could be rationalized as having been produced by adult magical power in addition to the physical transformation. Greenfield demonstrates large differences in results between the 'passive' and the 'active' do-it-yourself' versions of the conservation of Q. She even concludes that "Active participation by the child is superior to screening as a pedagogical device" (p.247).

possibility, in asking: "How is it?" or "How much is it to drink?", or "What will the balance do?", "How much will the water come up?" etc.
After the subject gives an answer, he is asked to explain it, but no attempt is made to question him further, or to interfere in any way. Whether or not the subject is able to justify his answer, the testing proceeds.

(2) If the subject has answered that A and B are no longer equal, he is asked how it would be if the state A-A' were restored. (For example: "How is it if we make a ball again?", or "How long is it if we push the stick back here?") This question is used to assess whether the subject reasons according to what Piaget has called 'renversabilité' or 'retour empirique'. This has sometimes been mistakenly translated and interpreted as 'reversibility'; Ginsburg and Opper (1969, pp.151-2, 167) more correctly use the term 'empirical reversibility'. The distinction indicates that it is a non-operational, weak form of reversibility, since the subject believes that B is different from A, but could be made equal if the reverse transformation into A' were performed. In contrast, the operational child who uses a reversibility explanation claims that B is equal to A because the transformation could be reversed.
The equality between A and A' is established again through an adequate demonstration.

(3) The subject is asked to transform A' into C, and the same questions are asked (see details below). The child is also asked for as many explanations as possible, and if any doubts about his answers remain, additional checks and questions are introduced.

Part 5 is a multi-purpose additional inquiry, and is even more flexible than the previous parts, insofar as any deviations which the experimenter needs to introduce are considered admissible. The most common sub-parts are as follows :

(1) If the subject does not give a clear answer on either question of part 4 (AB or AC), a third transformation is used (AD); this is also the case if the first two answers are inconsistent.

(2) If the subject has consistently given conservation answers on the previous items, an additional transformation CD is used, in which both A and A' are changed; this double transformation is achieved by starting with item AC and, without the usual return to the identity A-A', changing A into D.

(3) With all European subjects, their confidence in their replies is tested by counter-suggestions (c.s.), in which it is suggested that some other child has given the opposite reply.

(4) In a few cases, and only with European subjects, a 'counter-experiment' (c.e.) is used, in which the experimenter surreptitiously removes some plasticine (in the tests of W and V) and asks to check the predicted equality empirically. Any surprise shown by the subject at the unsuspected inequality is taken as final proof of the reality of his notion of conservation.

(5) If the subject has given inconsistent answers, this is pointed out to him, and he is asked to clarify his position. Sometimes, previous items are repeated.

(6) The subject is pressed to find as many explanations as possible. He is asked: "What else could you say?; Can you find another explanation for this?; What you say is right, but how else could you explain it?; This is a game on explaining things: what else can you think of?", etc.

(7) For the conservation of L, part 5, presented to all subjects, consists of an item AD, in which two pipe cleaners are presented, a straight one (A) and a longer one (D), bent several times to bring its ends into correspondence with the extremities of A.

Discussion

The flexibility inherent in part 5 enables the experimenter to go on until he is perfectly sure about his assessment. A well trained experimenter can also collect a wealth of additional information about the child's reasoning, which goes well beyond the simple assessment of the presence or absence of the concept of conservation.

As Goodnow (1969a, pp.440-452) has pointed out, the Genevan school is more stringent in its assessment of an operational level than is commonly believed. The child cannot simply say 'yes' when asked if A and B/C are still the same weight, but has to fulfil at least three additional requirements:

(1) He has to be able to verbalise an adequate explanation for his answer. However, he is not required to give all three possible justifications (identity, compensation and reversibility).

(2) He has to generalize conservation to a variety of situations (with the same content).

(3) He has to resist 'counter suggestions' or 'counter experiments'.

The Genevan school assumes a fourth theoretical requirement which is generally not tested: the conservation answer has to be stable over time.

The above methodology, however, presents difficulties in cross-cultural research. For one thing, it requires a relatively high level of verbal fluency. With many of our Aboriginal subjects, such an interview would go quite well; with many others, however, it was only possible to record a simple answer on part 4, any additional discussion being impossible. Secondly, there is a more subtle difficulty: the Aboriginal child is not used to expressing and maintaining his own opinion. Any further questioning is likely to be taken as criticism, and the subject will change his answer. Very few resist a counter suggestion. Whether the child actually changes his mind or not is difficult to say: he could well give an answer which he knows to be wrong, but which he thinks will please the European authority figure.

Because of this, the results reported in this study are based on part 4 and sub-parts 1, 5, 6 and 7 of part 5 only, it being thought that the inclusion of this additional data would tend to underestimate the performance of the Aborigines relative to Europeans, and of the low-contact Aborigines relative to the high-contact Aborigines.

2. Conservation tests: description of stages

The conservation tests are so widely known that we will not devote much space to the description either of the stages on these tests or of the operational structures involved. Details are available in Piaget et Szeminska (1941), Piaget et Inhelder (1941), Flavell (1963), de Lemos (1966), Ginsburg and Opper (1969) and elsewhere.

Usually a classification into three stages is used. Recently, Pinard et al. (1969) have proposed a five-stage classification which enables finer distinctions, and which, we suggest, should be adopted widely. In this study, however, we shall use the classical three stage classification.

Stage 1: Non-conservation (NC)

The child's answers are based on his immediate perception; at any one time he is focussing his attention on one dimension only but may switch from one to another. This gives rise to contradictions which he is unable to resolve because he cannot co-ordinate the relationships involved.

The child thinks that a transformation in the shape or spatial disposition of an object entails a change in its physical characteristics. He may, or may not reason according to 'empirical reversibility' (cf. p.109).

Stage 2: Transitional (T)

The child is more likely than before to take two dimensions into account, either successively or at the same time. He accepts conservation in some cases but not in others, without being aware of the contradictions in his judgments. Usually the child conserves in simple situations, but if the perceptual features of the situation are

exaggerated, or if his answers are questioned, he reverts to non-conservational answers.

Stage 3: Conservation (C)

The child shows immediate conservation throughout any particular test. He now thinks that the transformations change only the appearance but not the particular physical property, and justifies his answers with at least one of three explanations:

(1) identity: it is still the same because it was the same before, and nothing has been taken away or added.

(2) compensation: the change in one dimension is compensated by a corresponding change in another dimension (for example, B is now much longer, but also much thinner).

(3) reversibility: it is the same because it could be returned to its original state (for example: "We could make a ball again").

These three stages apply equally to all the conservation tests used.

3. Conservation tests: classification of responses and scoring

(a) Description of behaviour (notation)

For each conservation test, the reactions to the two items of part 4 (items AB and AC) were recorded separately using the following notation:

NC : The subject gives a non-conservation answer

T : The subject gives a transitional answer, i.e. he is not consistent, and gives successively conservation and non-conservation answers

C : The subject gives a conservation answer

F : The subject fails to give an answer, or does obviously not understand the question, or his answer cannot be classified.

(b) Scoring in stages

For each test, the two items were then combined into a final stage, according to the following rule:

Stage 1 : Non-conservation answers (NC) on both items

Stage 3 : Conservation answers (C) on both items

Stage 2 : All other combinations

If, on one of the the two items, the notation was F, the third item (AD, in part 5) was used instead to determine the final stage. If F was recorded on at least two items, or if the subject failed the check items, the final stage was also called 'F'.

For the conservation of L, the three parts are reported separately.

(c) Scoring in points

For each conservation test the two items of part 4 (AB and AC) were scored separately in the following way:

Notation	Score in points
F	0
NC	0
T	1
C	2

The scores of both items were then added to give the total score for each test; the maximum score is thus 4. For the conservation of L, the maximum score is 6, since there are 3 items for that test.

In summary, the following scoring system applies:

Notation on AB	Notation on AC	Final stage	Final score (points)
NC	NC	1	0
NC	T	2	1
NC	C	2	2
T	NC	2	1
T	T	2	2
T	C	2	3
C	NC	2	2
C	T	2	3
C	C	3	4

4. Details of test materials and procedures for each conservation test

Conservation of Quantity (Q)

1. Test materials:

2 standard beakers, 250 cc (A and A')
1 long, narrow measuring glass (B)
1 wide culture dish (C)
6 small, flat-bottom test tubes (D)
orange cordial

2. Procedures: The description follows the parts outlined earlier in this chapter (section B,1).

Part 1: The subject is shown the standard glasses (A and A') and the orange cordial, and is asked whether he likes to drink orange cordial. He is allowed to drink some if he wishes.

Part 2: The subject is asked to pour more (a lot, big, full)[1] cordial into one glass, and less (little, small, little bit) into the other. This procedure may be repeated several times until the experimenter is sure of the child's consistent use of vocabulary.

Part 3: The subject is asked to pour the same amount (same/same) of cordial into each glass, and several checks are made, as above.

Part 4: (1) The subject is asked to pour A' into B (see Fig. 3 for symbols). He is asked one or more of the following questions, or any variation thereof:
- How much is it to drink (now)?
- Do we have the same amount, or do you have more, or do you have less (changing the order of the the relational terms, and using the appropriate vocabulary)

[1] Most of the wording given below applies to Aboriginal children; for European children a more sophisticated English was used, although the questions and answers were basically the same.

- Does one have more (lot, big, full - or less, little, etc.) cordial (or: to drink)? (if 'yes':) Which one has more?
- Is it the same amount?

The child is asked to explain his answer. The most common wordings of the instructions were:

- Why is it .....? ("Why do you think .....?" was avoided most of the time because it could be interpreted as criticism.)
- How can you explain? How can you tell me? (or: show me)
- How do you know?
- What else could you say? Yes, good, go on!

(2) The child is asked: "How much would it be if we poured this one (B) back into that glass (A')?" The equality between A and A' is re-established.

(3) The subject is invited to pour A' into C, and the same questions are asked.

Part 5: Additional questioning follows the pattern described earlier in this chapter. Part AD corresponds to the pouring of A' into 6 small glasses (D).

Conservation of Weight (W)

1. Test materials:

2 standard plasticine balls, Ø 4 cm (A and A')
1 large plasticine ball, Ø 5 cm (L)
2 small plasticine balls, Ø 3 cm (S and S')
1 very small plasticine ball, Ø 2 cm (VS)
balance similar to those used in the school for mathematics

2. Procedures:

Part 1: The subject is shown the balance, and is asked: "What is this? What is it for? How does it work?" If he cannot give an adequate explanation, the working of the scale is explained and demonstrated.

Part 2: Several combinations of unequal plasticine balls (L/S, L/A, A'/S, etc) are presented. Each time the child is asked:

- How are these? Which one is heavy? Are they the same weight?

The balls are then put on the balance by the child, while the experimenter keeps it from moving. The child is asked: "What will the balance do if I let it go? Will it stay level, or will it go down?"

Part 3: The same procedures are repeated with equal balls (S/S', A/A'). The child is required to make at least 4 successive correct predictions, two on part 2 and two on part 3.

Part 4: (1) The subject is asked to roll A' out into B; A and B are placed on the balance, while the experimenter keeps it from moving. The child is asked one or more of the following questions, or any variation thereof :

- How is the weight?
- Are the balls the same weight, or is one of them heavier (lighter)?
- Are the balls the same weight?
- Is one of the balls heavier (lighter)?
- What will the balance do?
- Will the balance stay level?
- Will the balance go down? (if 'yes':) On which side will it go down?

The child is also asked to explain his answer, in the same way as for the conservation of Q.

(2) The child is asked: "How is the weight if we make a ball again?" and he is invited to roll B back into a ball (A'). The equivalence of A and A' is established on the balance.

(3) The child is requested to flatten A' into C, and the same procedures and questions are applied.

Part 5: Additional questioning is modelled on the pattern described earlier in this chapter. Part AD

corresponds to the breaking up of the ball (A') into little pieces (D).

Conservation of Volume (V)

1. Test materials:

2 beakers, 300 cc
2 standard plasticine balls, Ø 4 cm (A and A')
1 large plasticine ball, Ø 5 cm (L)
2 small plasticine balls, Ø 3 cm (S and S')
1 very small plasticine ball, Ø 2 cm (VS)
2 rubber bands
2 pieces of wire
water

2. Procedures:

Part 1: The child is asked if the level of the water in the two glasses was the same, and to rectify it if necessary. The rubber bands are adjusted to the water levels. The subject is asked to predict what would happen if one of the balls was put into the water. The wire is then run through the ball, and the latter immersed. The child is asked: "Why does the water come up?" If the child does not answer correctly, he is told: "The ball takes up room in the glass, so the water is pushed up." These procedures are repeated in various ways until the experimenter is satisfied that the child understands the problem.

Part 2: The subject is asked to predict how the water would come up when balls of different sizes (L/VS, A/S, etc.) are immersed. Each time the outcome is demonstrated. The vocabulary of the child is assessed.[1]

[1] Much care had to be taken in this respect, and each answer had to be checked by asking the child to indicate his prediction by showing the level with his finger. Some Aboriginal children tended to express the prediction of equal levels by saying that the water would come up 'big' in both glasses. Others used a quite original system of numbers: "It comes up 1 here, and 4 here" (small and big) or "It comes up 2 and 2" (equal).

Part 3: The same procedures are repeated with two identical balls (S/S', A/A'). The child is required to make at least 4 successive correct predictions, 2 on part 2, and 2 on part 3.

Part 4: (1) The subject is invited to roll A' out into B, which is bent into an S shape, so that it could fit completely in the water. The child is asked one or more of the following questions, or any variation thereof:

- How will the water come up?
- Will the water come up to the same level, or will it come up more (big, full), or will it come up less (little, little bit, small)? (The order of the relational terms is varied from one question to the next.)
- Will it come up to the same level? (same high, same/same)
- Will one come up higher? (big, full)

The child is asked to explain his answer, in the same way as for the conservation of Q and W.

(2) The subject is asked: "How would the water come up if we made a ball again?" and is invited to roll B back into a ball (A'). A demonstration of the equality of A and A' follows.

(3) The child is requested to flatten A' into C, and the same procedures and questions are applied.

Part 5: Additional questioning follows the pattern described earlier in this chapter. Part AD corresponds to the breaking up of the ball (A') into little pieces (D).

Conservation of Length (L)

1. Test materials:

Sticks of polished wood, section 3 x 3 mm
1 stick of 18 cm (L)
2 sticks of 16 cm (A and A')
1 stick of 14 cm (S)

5 sticks of 4 cm (a's)

1 pipe cleaner of 15 cm, bent in S shape; distance between extremities 11 cm (D)

1 pipe cleaner, straight, 11 cm (A)

1 pipe cleaner, straight, 15 cm (L)

2. Procedures: The procedures for the test of conservation of L follow a slightly different pattern from the other conservation tests, although the outline (p.107-110) still applies in respect of its principal elements: the check items are designed to test the subject's vocabulary and the consistency of his reactions to identity and non-identity situations. The test then comprises three parts, each of which is scored and analysed separately.[1]

Check items: The child is presented with all the sticks and is told: "Give me a long (big) one and a short (small, little) one." Once he has done that, he is asked: "Which one is longer? and which one is shorter?". the experimenter then takes two sticks of differing lengths himself, and repeats these questions. The child is then told: "Give me two sticks which are the same length (the same long, equal)". Such questions are repeated until the experimenter is satisfied that the subject uses a certain vocabulary consistently.

Part 1: Two sticks of equal length (A and A') are presented in a position horizontal to the child, parallel and with the end points coinciding; they are separated vertically by 5 cm. The child is asked: "How are these two sticks? Are they the same length? Or is one longer?". Once the equality between A and A'

[1] Part 1 of our test corresponds to part II(i) of de Lemos' (1966, p.185) procedures, and to part 1 of the standardized test on displacement of length (Vinh Bang, in prep.).
Part 2 of our test corresponds to part 2 of the standardized test on sectioned length (Vinh Bang, in prep.).
Part 3 of our test corresponds to part I(i) of de Lemos' (1966, p.184) procedures.
The original form of these tasks is described in Piaget, Inhelder et Szeminska (1948).

is established, the top stick (from the child's point of view) is pushed to the right so that its end point overlaps that of the bottom stick by about 5 cm. The child is asked one or more of the following questions, or variations thereof:

- Are the sticks the same length, or is one longer?
- Are the sticks the same length?
- Is one stick longer? (If 'yes') Which one is longer?

The problem can also be presented in terms of 'two roads': "If these are two roads, and you walk (drive) along this one, and I walk along this one: Will we both walk the same length (same long, same distance, same far)? Or does one walk longer (big)?"[1])

The child is then asked to explain his answer, in the same way as for the other conservation tests.

Part 2: The subject is given one of the sticks of 16 cm (A) and the four small sticks of 4 cm (a's) and he is asked to align the latter with the former. It is made sure that he understands that the four short lengths add up to the length of A. The story of the two 'roads' (as in part 1) is used in every case. The 4 a's are then displaced to form an M shape (now symbolised by the letter C; see Fig. 3). The left extremities of A and C coincide, whereas the distance between the right ends is about 5 cm. The child is asked one or more of the following questions, or variations thereof:

- Are the two roads the same length, or is one longer than the other? (or is one shorter? - the order of the relational terms being varied from one question to another.)
- Are the two roads the same length (same long)?
- Is one road longer (big)? (If 'yes) Which one is longer?

---

[1] We did not put this question in the form of "the time it takes to walk", as was done by de Lemos (1966).

- If you walk on this road (A), and I walk on this road (C), do we walk the same distance (same far, same long, same length)?
- Or does one of us walk longer (big, long)? (If 'yes') Which one?
- Or does one of us walk shorter (small, little)? (If 'yes') Which one?

The child is asked to explain his answer, as on the other conservation tests.

Part 3: Two unequal-length pipe cleaners, a straight one (A) and a curved one (D) are placed in front of the child in such a way that the ends coincide (Fig. 3). The child is asked one or more of the following questions, or variations thereof:

- Are these the same length (same long)?
- Or is one of them longer (big, long)? (If 'yes') Which one?
- Or is one shorter (small, little)? (If 'yes') Which one?

The following supplementary procedures are used, but not with every subject: (In fact, they were used with Aboriginal subjects in very few instances only, to clarify a previous answer).

(1) The curved pipe cleaner (D) is straightened, so that its ends extend beyond those of (A), and the same questions are asked. D is then returned to its original form, and the questions are repeated.

(2) The curved pipe cleaner (D) and the long, straight one (L) are placed in front of the child, and the same questions are repeated.

In every case, the child is asked to explain his answer. The 'why' questions follow the same form as in the case of the other tests, except that the following question is used more often: "What could

you do to explain that .....?"[1]

5. Seriation: test materials, procedures, stages and scoring

1. Test materials

(A) 1 set of 10 sticks of polished wood, section 3 x 3 mm, increasing from 10.6 to 16.0 cm by steps of 0.6 cm, glued on a white cardboard of 29.5 cm x 20 cm, with a distance of 2.1 cm between the sticks.

(B) 1 set of 10 loose sticks (as above), increasing from 10.3 cm to 15.7 cm by steps of 0.6 cm.

2. Procedures:

The following procedure is used:

Part 1: The subject is given set B and shown the model A.[2] The experimenter says: "Do you see what I have done with my sticks? I have made a staircase. (The subject is usually familiar with this word from the Cuisenaire method.) It goes up, and up, and up. (The increasing order is pointed out.) Now you make the same staircase here on the table."
If the subject does not react immediately, the instructions are repeated in different words, and the experimenter starts the seriation with the first 2 elements, pointing out to the subject that he is to continue. The model is removed once the subject has started working, but can be presented again any number of times if necessary. In particular, the subject is asked whether his seriation corresponds with the model (which may be shown again) and, if

---

[1] The usual 'why' questions often failed to provoke an explanation with Aboriginal children, whereas many were able to demonstrate their point, especially for the conservation answers: in parts 1 and 2, they would usually restore the original state, and in part 3 they would straighten the curved pipe cleaner (D) to prove that it was longer. Non-conservation answers were usually substantiated by the child's pointing to one extremity. (See also p.173)

[2] The only departure from the standardized technique (Vinh Bang, in prep.) is the presentation of the model, which minimizes the importance of language in the instructions.

not, to modify his construction accordingly. If difficulties arise, the subject is helped along to some extent. For example, if he forgets a stick and makes no attempt to insert it, the experimenter asks: "Where does this one go? Where is a good place for this one?" or, if a mistake occurs, the experimenter says: "Is this the right place?; Is this a nice staircase?; Is it like mine?; Does it go up, and up, and up?" etc.

Part 2: The subject is given the model. The experimenter says: "Now you can play with mine. Put your sticks in the right place." (The subject's sticks are designed to fit between those of the model.) If the subject does not react properly, the experimenter takes one stick from the middle of the series, and puts it in a place where it is obviously too long, and asks: "Is this a good place?". The same procedure is repeated in a location where the stick is obviously too short and then in the correct position. It is pointed out that the stick is longer than the preceding one, but shorter than the following one. If the subject still does not seem to understand, the same procedure is repeated with a second stick, but no more. If the subject makes a mistake, he is not corrected, but is asked: "Is this a good place for it?" When the subject has placed all the sticks, he is given another chance to correct it if he wants to and is able to do so.

The main departure from the standardized procedure is that the sticks are handed to the subject in a random, instead of predetermined order. This makes the experimenter's task easier and is not expected to influence the results.

The standardized technique calls for a third part, in which the subject has to hand the sticks successively to the experimenter, who aligns them behind a screen. This was not done in the present study.

3. Piaget's description of the stages for seriation

According to Piaget (Piaget and Szeminska, 1941; Piaget 1952) :

> there are three distinct stages in the seriation of the sticks (Questions I and II).
>
> 1. First comes a period during which the child always fails to make the complete series, ... succeeding only in making several short series which he puts side by side without regard to the order of the whole series. Or else he succeeds in building the staircase, but only considers the top of each stick, and disregards the base, and thus the total length of each element, so that his staircase is only regular at the top, and as the sticks are not placed in a horizontal line they are not in the correct order of size.
> 2. In the second stage, the child succeeds, by trial and error, in making a correct staircase, but has not acquired a system of relationships by means of which error is eliminated and extra sticks can be inserted at once in their right place. (1952, p.124)
>
>   Once the first series had been made, none of the children was able to insert the extra sticks without mistakes and continual trial and error. The present level appears to be characterized by this opposition between success with the first series and failure to insert new elements. (1952, p.129)
>
> 3. In the third stage, each element is without hesitation placed in a position in which it is at the same time bigger than the preceding elements and smaller than those which follow. (1952, p.124).

4. Notation of subject's behaviour

The following is a description of the notations used in recording the subjects' behaviour, and of the actual behaviour subsumed under each notation.

Part 1

Notation:	Description of behaviour:
A	The subject completes the whole seriation spontaneously, adjusting the base line and selecting the sticks in increasing (or decreasing) order; if he misses one, he is able to insert it correctly. One or two hesitations or errors are allowed if they are due to inattention and are corrected without difficulty.

The subject can use one of three methods in seriating the sticks, and these are recorded separately:

A 1 The child can use the so-called 'operational' method: he takes all the sticks in his hand, forming a bundle, which he rests on the table to insure a common base, and he proceeds as described above.

A 2 He can also use the 'perceptual' method: the sticks are left in random order and various orientations on the table; the subject judges their length perceptually, and selects them in order, as described above.

A 3 A third method, which could also be considered as an intermediate stage, is the following: the subject selects a stick at random, checks if it fits, and puts it back if it is too long. If the stick fits into the already established series, he inserts it. Thus the series does not have to be destroyed or restarted at any time.

B The seriation is completed, or nearly so, but the method of achieving this is different. Generally it is more cumbersome and non-systematic. The subject does not select the sticks in an increasing (or decreasing) order. If a stick is found to be too long, it is rejected (as in A 3); if it is too short, the child cannot insert it (which distinguishes B from A 3), but has to demolish part of the already established series, and start anew, so that completion often takes a very long time.

C The seriation is not completed (i.e. more than 4 errors are made), or the base line is not sufficiently adjusted. Typically, the subject makes small, unrelated series.

D The subject completely fails at the task. This includes the case where the top line is adjusted into a 'staircase', but no attention is paid to the length of the sticks.

Part 2

Notation: Description of behaviour:

A Complete success: the subject completes the seriation, and his method is systematic. He is consistent in the direction of scanning: for example, once the stick which is to be inserted (X) is found to be smaller than one of the sticks in the model (N), he does not compare it to N+1, but moves in the direction N-1. (He thus understands the transitivity of asymetrical relations: if $X < N$, and $N < N + 1$, then $X < N + 1$, as well as $N - 1 < X < N$ and $N > X > N - 1$).

One or two errors are not counted if they are due to inattention and are easily corrected.

B Partial success: the subject completes the seriation, or nearly so (i.e. he makes no more than 4 errors), but his method is unsystematic and clumsy.

C The subject attempts to solve the problem, and succeeds in inserting correctly some elements (at least 2 and up to 5), but he clearly does not understand the relations involved.

D Complete failure: the child makes no attempt to insert the sticks and does not understand the problem.

5. Scoring

(a) Scoring in stages

To obtain each subject's classification into one of the three stages, the notations of the two parts are combined according to certain rules. These stages are thought to correspond exactly to Piaget's description, although our scoring method has the advantage of being more precisely defined. The scoring system is as follows :

Notation part 1	Notation part 2	Final stage
C or D	C or D	1
A or B	B, C or D	2
A	A	3

For some children (26 out of 183 in this study), inserting the extra sticks (part 2) appears to be easier than constructing the original series (part 1). This seems to represent a reversal in Piaget's second stage, and is scored separately:

Notation part 1	Notation part 2	Final stage
C or D	A or B	Rev. 2 a
B	A	Rev. 2 b

These 'reversals' are further discussed in chapter 4, section A,7 (pp.185-188).

(b) Scoring in points

On both parts, the following conventional scores are used:

Notation	Score
A	3 points
B	2 points
C	1 point
D	0 points

The points on both parts are added, leading to a possible maximum of 6.

C. TEST MATERIALS, PROCEDURES AND SCORING: SPATIAL TESTS

The following tests of spatial operations were used:

1. Orders: linear, reverse and circular
2. Rotation: of two landscape models
3. Horizontality: level of water in a tilted bottle

These tests will be described successively under the following headings:

(1) Test materials
(2) Procedures
(3) Piaget's description of the stages
(4) Notation of subjects' behaviour
(5) Scoring: (a) in stages
(b) in points.

1. Orders

(1) Test materials

The test materials consisted of:

Miniature clothes, cut out of coloured cardboard or heavy paper, so as to form an inverted V shape which enables them to hang on a string; the following items were available:

Code	Number	Description
A	3	Blue trousers
B	3	Handkerchief (green)
C	3	Red dress
D	3	Shorts (white and blue)
E	3	Blue skirt
F	3	Blue apron
G	3	Yellow jumper
H	3	Green jumper
I	3	Orange towel
J	3	Shirt (white and red)
K	2	White sheet
L	1	Yellow dress

"Clothes line": a wooden frame, 40 cm long and 18 cm high, with two strings joining the ends;
A basket to carry the clothes.

(2) Procedures

The child is presented with the test material, the clothes being poured from the basket onto the table. He is asked to name the clothes, although this serves only as an introduction and is not scored in any way. The experimenter says: "We are going to wash these clothes and hang them up to dry".

Part 1: Linear order

The experimenter hangs items A to I on the top line, always in the same order. When this is completed, he says: (pointing to the lower string)

- Now you hang the clothes in the same way on this line!

or sometimes simply:

- Now you make same!

If the subject does not react immediately, the first element (A) is put on the string and the subject is asked to go on. If this still fails to elicit the proper response, a second item (B) is placed on the line by the experimenter, and the instructions are repeated.

If a mistake occurs, the experimenter says:

- Is this the right one? Is yours just the same?

but the error is not corrected, unless the child does so himself. At the end, the subject is given another chance to check his line and to correct it if necessary.

The experimenter shows the child how to "make wind to dry the clothes", namely by blowing; thereafter the clothes are declared dry, and the bottom row is removed, but not the top, which serves as model for part 2.

Part 2: Reverse order

The child is asked to choose exactly the same clothes as those on the top line, but to reverse their order. This rather difficult instruction is formulated in different ways, until the experimenter is sure that the child has understood the problem.

The following is an example of one of the possible formulations:

The experimenter points to the lower line from right to left, and says:

- Now you are going to put your clothes the wrong way around. I have put my trousers (A) here (The experimenter points to the location of A on the top line) and you are going to put yours here! (The experimenter takes A from the table, and puts A on the lower line under I.)

The experimenter then points to B, and shows where it is supposed to go, namely under H; he also points out that C should go under G, and D under F.

If the subject does not react immediately, or if he starts a direct order again, the instructions are repeated, and a second item (B) is put on the bottom line by the

experimenter, but no more.

If a mistake occurs, the experimenter asks: "Is this the right one?" and encourages the child to establish the inverted one-to-one correspondance. The experimenter may also say: "Which one comes next?" to encourage the subject to go on, but he does not suggest any answer.

At the end, the child is given another chance to make corrections, and the clothes are 'dried' again; they are all taken from the line.

Part 3: Circular order

The experimenter puts 9 items chosen from elements A to J (in any order) into a circle on the table, and says:

- Now you put your clothes in the same order as mine, but on the line. Which one do you want to start with?

The child usually starts with the red dress (C); if he does not react, C is put on the left extremity of the line, and the experimenter says:

- Good, now put yours in the same order. Which one is next? ... Good, now which one is next? ... Good, now go on!

If the child makes a mistake with the first four elements, he is corrected and the instructions are repeated until it is ascertained that they have been understood. If mistakes occur later on, they are not corrected, but the experimenter asks: "Is this the right one?" and he encourages the child to establish the one-to-one correspondance. The experimenter can also say: "Which one comes next?" to encourage the child to go on, but he does not suggest any answer.

At the end, the subject is given another chance to check his performance.

The subject is then told that he can hang up any clothes he likes, and he is left to play for a while, until he is asked to put the clothes back into the basket.

The three parts of the test are always presented in this order.

(3) Piaget's description of the stages

The following stages are summarized from Piaget and Inhelder (1948, pp.105-128; 1956, pp.82-103).

Stages	Description
0	The child makes no attempt to copy the model; there is no correspondence, even by resemblance of the items and irrespective of order.
1 A	The child copies the model, but independently from order: he simply matches each element with a similar one, in any sequence.
1 B	The child can use the relation of proximity to form pairs, but cannot co-ordinate these into more than very small series.
2 A	The child can understand the notion of order when he can check it constantly, and he establishes an exact one-to-one correspondence between the objects. (The child is not able to space one series differently from the other)
2 B	The child can copy a linear order with any spacing. In addition, the transformation of a circular order into a linear one becomes possible, though a reversed order cannot yet be completed successfully.
Intermediate (Int.)	The reverse order is gradually achieved by a trial and error method.
3	The child immediately succeeds on the reverse order; this is an indication of the reversibility of his thought processes and is thus typical of concrete operations.

(4) Notation of subjects' behaviour

For all three parts the following notations were used to record the subjects' behaviour:

Notation	Description
A	Complete success: the alignment is successfully completed through a systematic method. One or two errors are disregarded if they are due to inattention and if they are spontaneously corrected.
B	Success after trial and error: the alignment is completed, or nearly so, but only after many mistakes and corrections.
C	Some attempts: some elements (at least 3) are spontaneously placed correctly, but the alignment is not completed. On part 2 (reverse order), the child typically reversed the first four elements, but is surprised that the central elements are identical, and he goes on with the linear order.
D	Failure: complete failure is recorded when only one or two elements are placed correctly, or when the child simply matches each element with a similar one, irrespective of order.

(5) Scoring

(a) scoring in stages

The stages were obtained by combining the notations on the three parts of the test. The stages are thought to correspond to those described by Piaget, although the following scoring system has the additional advantage of being more precisely defined.

Notations			Final stage
Part 1 (linear)	Part 2 (reverse)	Part 3 (circular)	
D	D	D	0 / 1A
C	C or D	C or D	1 B
A or B	C or D	C or D	2 A
A	C or D	A or B	2 B
A	B	A or B	Int.
A	A	A or B	3
A or B	A or B	C or D	Int. reversed[1]

(b) scoring in points

For each item, the scores have been arbitrarily set at:

Notation	Score (in points
A	6
B	4
C	2
D	0

These are summed for the 3 parts, leading to a maximum possible total score of 18.

2. Rotation

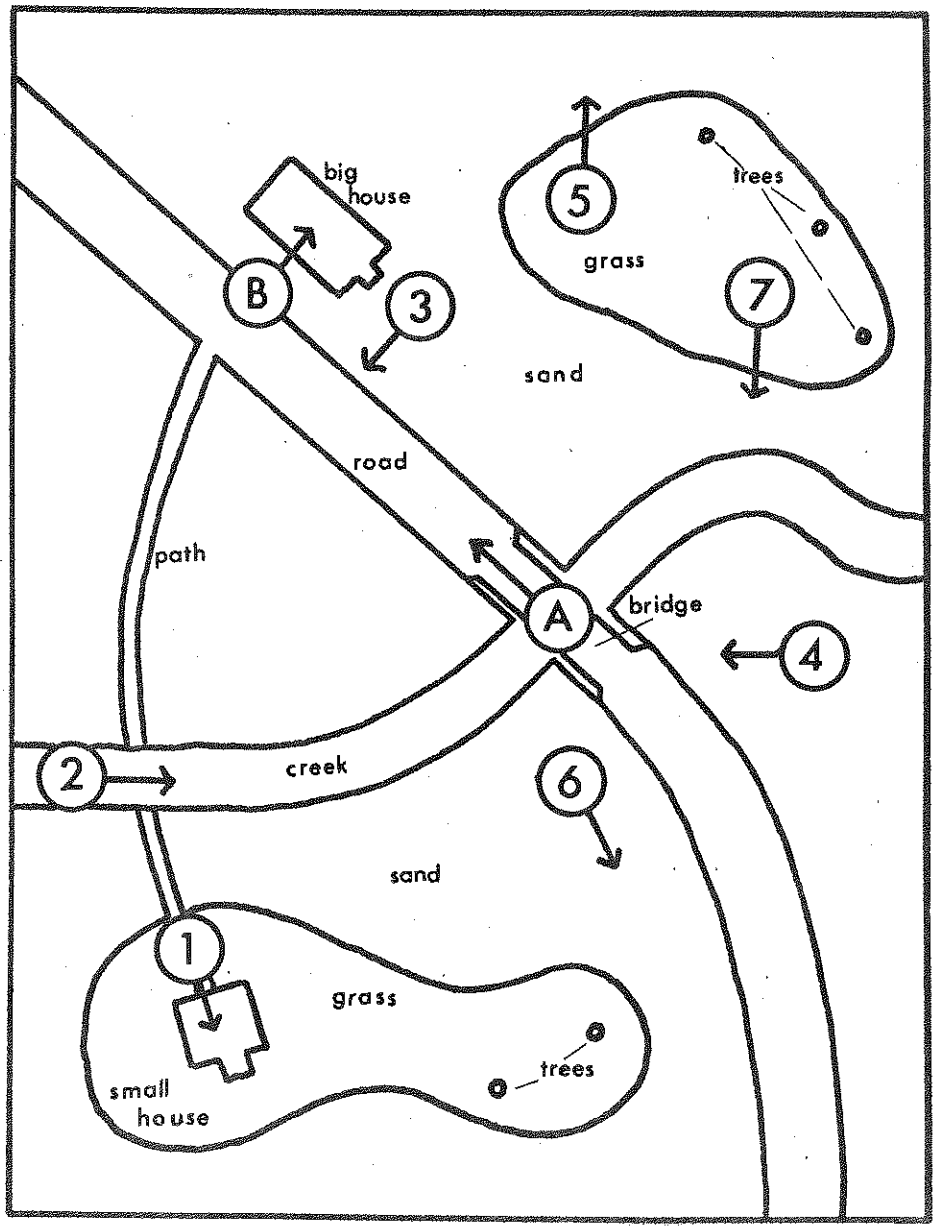
(1) Test materials

Two identical landscape models were made on plywood with sand, glue and paint. They included model-train trees, houses and bridges. The spatial features were identical to those used by Piaget (1948; 1956, p.421), and are depicted in Fig. 4. The models have been adapted to be more appropriate to the Central Australian landscape: yellow and brown colours are predominantly used, and, except for two patches, the green grass is replaced by sand, and shrubs are used

[1] According to Piaget, the reverse order should be acquired after the circular one. This was found to be true except in two cases where the children succeeded on part 2 but not on part 3. These have been classified at a stage called 'Intermediate reversed'. (See also p.190-195)

FIG. 4 ROTATION

Spatial features of the lanscape models and positions used



instead of pine trees. The houses closely resemble shearing sheds, or aluminium 'Kingstrand' huts provided to Aborigines on settlements.

Two toy sheep.[1]

A cardboard or plywood screen (about 100 cm x 70 cm), with a base to hold it upright.

(2) Procedures

The two landscape models are placed side by side on a desk, in the same orientation; the subject and the experimenter are standing in front of the desk.

The child is asked to name the elements (houses, river, roads, trees, bridge, grass, etc.) on one of the models and to show the corresponding elements on the other. The fact that the two models are identical is pointed out. The child is given a toy sheep, and he is asked which landscape model he wants to play with (thereafter denoted: B); the experimenter then takes the other model (A) and the other sheep.

Check items

The experimenter places his sheep on the bridge of model A, and tells the child: "Put your sheep in exactly the same spot on your farm; and your sheep has to look at exactly the same thing as mine!"

If the child makes a mistake he is corrected, and the instructions are repeated and explained further. Another position ('on the road looking at the big house') is used in the same way.

Once the child understands the position, model B is turned around by 180°, and the same check-items are repeated. Additional positions are used if necessary.

Test items

The screen is placed into position between the two models. The child is told that he is not to look at both models at the same time, but that he can go back to look

[1] The sheep gives a clearer indication of the direction in which it looks than the doll used in the original technique, where the direction has to be abstracted from the single cue of the face.

at A whenever he is not sure where the sheep is. The experimenter and the subject are always side by side in front of the table, and the subject is not allowed to move around the models.

The sheep is placed successively in 7 standard positions; these are depicted in fig. 4.[1] As much as possible, the child is kept from seeing the trajectory from one position to the next.

If the child makes a mistake in position, direction, or both, he is told:

- Look again! Are you quite sure this is the right place?

or - Yes, this is the right place, but are the sheep looking at the same things on the farm?

If this does not trigger a correct response, the subject is helped further:

- Where is my sheep? ... Yes, and where is yours? Is yours at the same place as mine? What is my sheep looking at? It's looking at the .....; what should yours look at? (etc.).

After two unsuccessful attempts, testing goes on with the next position without telling the subject that he was wrong.

The child is not asked to express his reasoning. It is realized that a lot of useful information is thus lost, but taking verbalization into account would have unduly advantaged some subjects over others. As it stands, the test can, if necessary, be conducted almost completely non-verbally, through imitation.

(3) Piaget's description of stages

The stages for the test of rotation can be described shortly as follows (Piaget, 1948: 1956, pp.421-426):

Stage I: The positions are located mainly through topological relationships of proximity and surrounding or enclosure. The sheep is located in a similar

[1] These positions correspond to, but are not exactly those of the standardized procedure (Vinh Bang, in prep.) because these were not available at the time testing began.

'setting' (on the grass, in the river, etc.) or next to the same object without the child concerning himself with left-right, before-behind relations, distances, and so on. Thus if the sheep is next to the yellow house on the grass, the child will concentrate either on the grass and ignore the house, or disregard the grass and put his sheep somewhere near the house - in which event he may place it near the big or the small one. In neither case does he attempt to logically multiply one property by the other. There is a complete failure to co-ordinate projective viewpoints (rotation), and euclidean relationships (such as distances in a straight line, angles, etc.) are disregarded.

It is during Stage 2 that disparities most frequently occur between answers for the various positions. The reason for this is that the responses at this stage are transitional in character and result from the interplay of perceptual and conceptual factors.

Substage 2 A: The child begins to establish a few relationships which involve reference objects more distant than hitherto.
He starts to co-ordinate the relative positions of a number of items, and left-right, before-behind relations increasingly influence his decisions. However, there is still a failure to co-ordinate the whole complex of these relationships in terms of a specific 'point of view', since the child does not yet understand the effect of rotating the model and judges the orientation of the objects relative to his own position. Typically he chooses the same absolute position, or hesitates between various relations, which he takes into account successively without being able to co-ordinate them.

Substage 2 B: Piaget has described this substage in the following way:

> Unlike the children belonging to Stage 2A, who ignore the effects of rotation, the present subjects are able to take these effects into account, though only step by step, reversing a single relationship to begin with and only later multiplying it by another. The child's progress in logic often has somewhat paradoxical results, causing him to overlook obvious proximities ...

> in the course of dealing with more distant features, so that the various relationships tend at first to remain disconnected and consequently incomplete. These momentary incongruities are particularly apparent when it is a matter of taking two distances into account at the same time. The child attends to the first and overlooks the second, then does the opposite. Only after a number of attempts does he hit on an acceptable compromise. In short, the picture presented by this substage is one of gradual progress in co-ordination. But this is achieved only through constant trial and error, often attended by sudden changes of mind leading to alterations, both of projective (left-right, before-behind) and euclidean relationships (order and distance along the two dimensions concerned). These early attempts at co-ordination of viewpoints and use of systematic comparisons both stem from the logical multiplication of increasingly numerous relationships. At the same time, this process remains purely intuitive and is not yet governed by set operations. (Piaget, 1956, p.425).

Typically, the child at this stage finds the correct position and takes rotation into account, but he does so in successive approximations, by trial and error.

Stage 3: The last stage is characterized by a complete control over all relationships. The rotation of the model no longer has any effect on the child's judgment, the sheep being placed in a position determined in accordance with the dual system of reference provided by the two dimensions of the layout.
Typically, the child places the sheep in the correct position and direction every time.

(4) Notation of subjects' behaviour

The position and direction errors were recorded exactly as they occurred on duplicated record sheets representing the model landscapes schematically.

(5) Scoring

(a) scoring in stages

As Piaget has pointed out:

> the stages of development thus exhibited can only be identified on the basis of the hole of the child's responses, or his average response. For although the sequence of responses is the same in each of the ... positions, considerable disparities exist between different solutions offered, due to variations in the difficulty of the problem. (Piaget, 1956, p.422)

Thus the protocols (duplicated record sheets) were examined by two independent judges, and were classified as to the stage most nearly corresponding to the behaviour on the whole test. The description of the stages provided in section (3) was used for this purpose.

Agreement between the two judges was 85 per cent.

(b) scoring in points

The child could make a maximum of 14 errors on position, and the same number on direction, since 7 positions were used, with a maximum of two trials for each position.

The number of correct responses (maximum 28) was used for the scoring in points.

3. Horizontality

(1) Test materials

1 spherical bottle[1], 500 cc, Ø 11 cm, half filled with blue coloured water
1 opaque cloth bag, to contain the bottle (same shape)
1 base, approximately adjustable to the subjects' eye height
Blue pencils
Duplicated record sheets, with outline drawings of the bottle placed in 6 different positions, folded so that only one drawing appears at any one time.

(2) Procedures

The round bottle is placed in the vertical position on a stand in front of the child, and care is taken to have the level of the water in the bottle at the height of the child's eyes, or a little above, so that he can see the edge of the surface clearly as a straight line. The subject is also presented with the corresponding outline drawing, and

[1] In the standardized version of the test (Vinh Bang, in prep.), a rectangular jar is used; the test with the spherical bottle tends to be slightly easier.

he is told:

- I have made a drawing of the bottle. Show me where this is on the bottle! (The experimenter points at the cork on the drawing, and makes sure that the child can show it on the bottle).
- And what is this?

The experimenter points at the bottom line of the drawing, representing the stand. The examiner ensures that the subject establishes the correspondence between the line and the horizontal edge of the box (stand) or the table, in such a way that this horizontal, which remains visible throughout the experiment, can assist in judging the position of the liquid. The instructions continue:

- But I forgot to draw something, what is it? ... Yes, the water! I'm going to draw the water. (The examiner draws the water; surface line first.) And now, would you like to draw the water, too?

The subject is given a second outline drawing, and a blue pencil, and it is made sure that he understands what he has to do.

When this first direct copy is successfully completed, the bottle is hidden in the bag; thus the shape of the bottle is still apparent, but the water is no longer visible. The bottle is again placed into the vertical position, and the subject is asked to draw the water again, on a new outline drawing. Again, it is made sure that the child understands the instructions precisely.

Part 1 : Anticipation (A)

The bottle is placed successively in 5 different positions, always in the same order: (all orientations refer to the subject's point of view).

1. tilted to the right
2. on its side, cork to the right
3. upside down
4. tilted so that the cork touches the stand on the right
5. tilted to the left

Each time the child is given the corresponding outline drawing, the record sheet being folded so that only one is visible at any one time. The subject is asked to guess (anticipate) where the water level is, and to draw it. If a hesitation occurs, or a doubtful drawing is executed, the child is asked to indicate the level of the water with his hand or pencil or by another appropriate gesture or verbal explanation.

Part 2 : Copy (C)

The bag is removed, and the same procedure is repeated for the positions on which the child was not successful (scores C, D or E; see below) during the first part of the test. In each case, before the child is allowed to draw, he is asked to look very closely at the water level and to indicate its position with his hands or pencil. (If the child is not held back for a while in this way, he tends to repeat the previous drawing without actually observing the water level).

Part 3 : Anticipation after Copy (AC)

The same procedure is repeated once more, the bottle being again hidden in the bag. However, this is done only for the position on which the subject, in part 2, improved on his performance in part 1.

If, on any position, the child has made a different drawing in part 1 and parts 2 and 3, he is shown the two conflicting pictures and is asked which one is correct.

(3) Piaget's description of the stages

The following stages are summarized from Piaget (1948, pp.443-496; 1956, pp.382-412):

Stage 1: The child does not only lack the notion of the horizontal plane, but of the surface plane in general. He scribbles, or draws the water as a ball inside the bottle, without defining a straight line or locating the water relative to the jar except with the purely topological relations of proximity and surrounding. He may also avoid drawing the surface in representing the bottle completely filled.

Stage 2: The child now has the notion of the surface plane and draws it in reference to the bottle, but does not make use of an outside reference.

Substage 2 A: The water level always stays parallel to the base of the jar. The child seems to think that the water-line stays constant, not in relation to an external referent, but to the bottle itself; he assumes that the surface of the water tilts with the jar and can occupy any position, including the vertical.

If the water is thought to move, it is imagined as simply expanding or contracting, increasing or decreasing in volume; the child imagines that the surface of the water remains parallel to the base.

Not only does the child of this stage fail to predict horizontality, but is incapable of noting the result of the experiment (part 2 of the test). The child does not have the necessary structures (i.e. a co-ordinate system, and an external reference system where stationary objects serve as reference points for mobile ones) to evaluate the perceptual data correctly.

Substage 2 B:

> Although the child cannot draw the water in the tilted jar as level (though he indicates its direction with his finger) he is nevertheless able to show it as no longer parallel with the base of the vessel. But he still fails to co-ordinate his predictions with any fixed system outside the jar (i.e. with the table or the stand) and merely connects the water-line with the corners of the jar, tilting it at an angle (and sometimes, accidentally, making it horizontal), though when the jar is inverted he makes the level horizontal. (1956, p.384).

Again, these children cannot derive any information from seeing the result of the experiment. They sometimes "discover that it 'stays straight' when the experiment takes place. But their grasp of the data is so inadequate in the absence of any system of co-ordinates that they are unable to apply it in predicting the outcome of further experiments." (1956, pp.397-8).

Intermediate stage: The only novel feature of this stage is the discovery of the horizontal when the bottle is lying on

its side. "The child is beginning to establish a connection of some sort with a reference system external to the jar, at any rate in this particular position". (1956, p.401). It constitutes the first authentic expression of the concept of horizontality, as distinct from the inverted position where the liquid is shown horizontal only because it lies parallel with the base of the jar.

Stage 3: The idea of the horizontal is effectively applied to all positions. As a result of concrete operations, the child is able to interrelate the different parts of the pattern: the mobile reference system within, and the fixed systems outside.

Substage 3 A: The child still makes mistakes during the first part of the test, but he is able to learn from the second part (copy), and the horizontal is applied in all positions of the bottle in the third part of the test.

Substage 3 B: The child is able to make an immediate prediction of the horizontality of the water level in any position of the bottle.

(4) Notation of the subjects' behaviour

The children's drawings are assessed according to the following notational system: (see Fig.5a for some typical illustrations of each).

Notation	Description
A	Correct; line absolutely horizontal
B	Probably correct; the surface line shows a slight deviation from the horizontal, but this seems to be due to factors such as drawing difficulty or lack of attention.
C	The water is not drawn horizontally, nor is it drawn parallel to the base of the bottle. In other words, there is an indication of water movement, but not necessarily in the right direction.
D	The water is drawn parallel to the base of the bottle.

Notation	Description
E	No straight line is defined for the surface: the child scribbles, draws a ball inside the jar, or draws a completely filled bottle.

(5) Scoring

(a) classification in stages

The stages used for the scoring follow those described by Piaget as closely as possible. However, because of the complexity of the perceptual and conceptual factors involved, the diversity of the positions, or attentional factors, inconsistencies occasionally occur. For example, the children sometimes respond differently to the three oblique positions, giving both D and A, B or C answers, thus indicating that they are somewhere between stage 2A and 2B; or they make a correct drawing for the bottle put on its side, but not for the inversed one, which, strictly speaking, represents a reversal in Piaget's stages.

To avoid a further multiplication of substages, intermediate or reversal stages, a sequential scoring procedure is used to attribute a stage to each child (see Fig. 5b).

(b) scoring in points

The scores are added for each of the five positions on parts 1 and 3 (A and AC), leading to a possible maximum sum of 15 points for each of these parts, and a total of 30 for the test. The scores are obtained as follows:

Notation	Score (in points)
A, B	3
C	2
D	1
E	0

FIG. 5a HORIZONTALITY

Typical reactions and scoring conventions

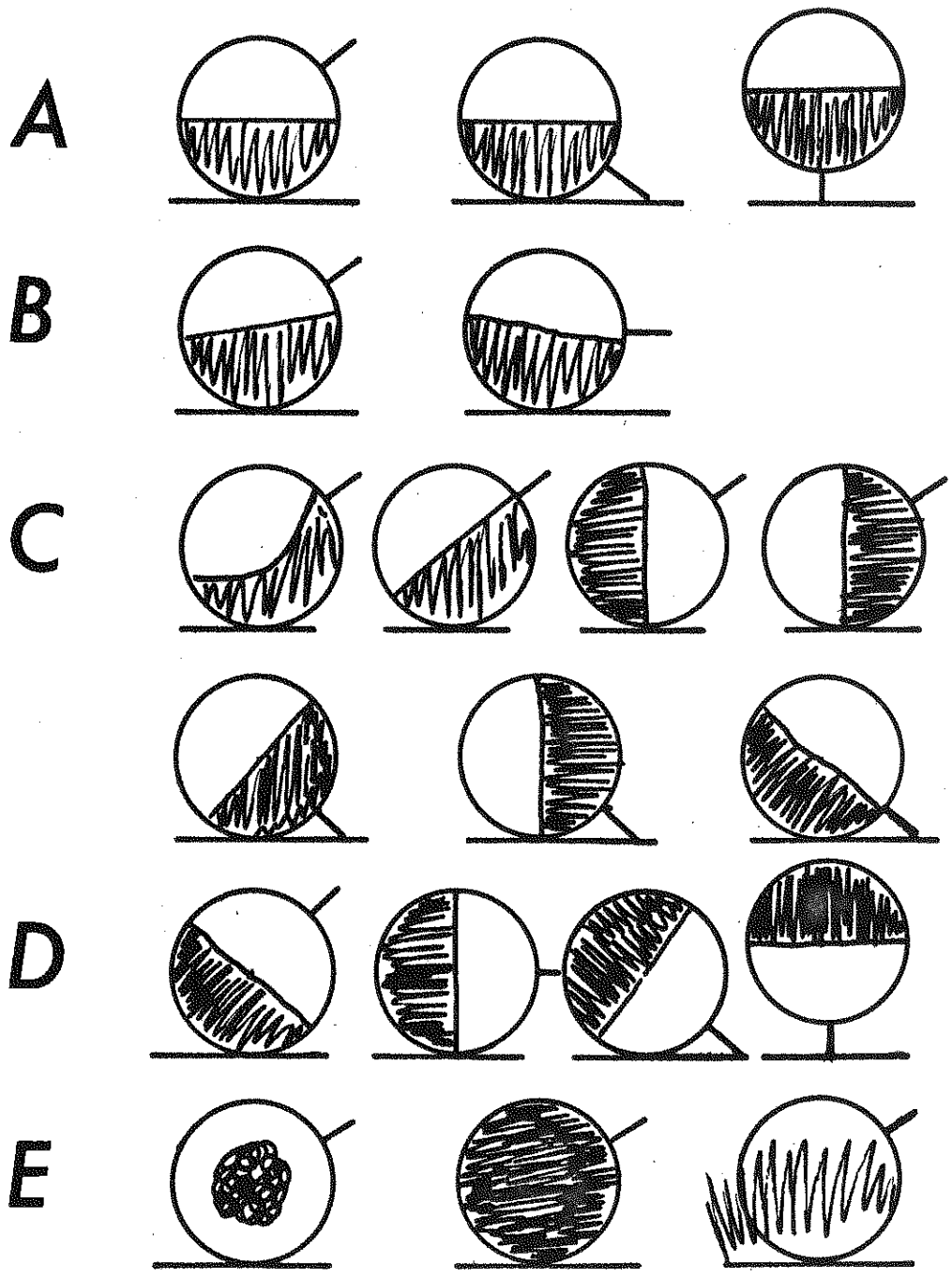


FIG. 5b HORIZONTALITY

Flow chart of scoring procedure

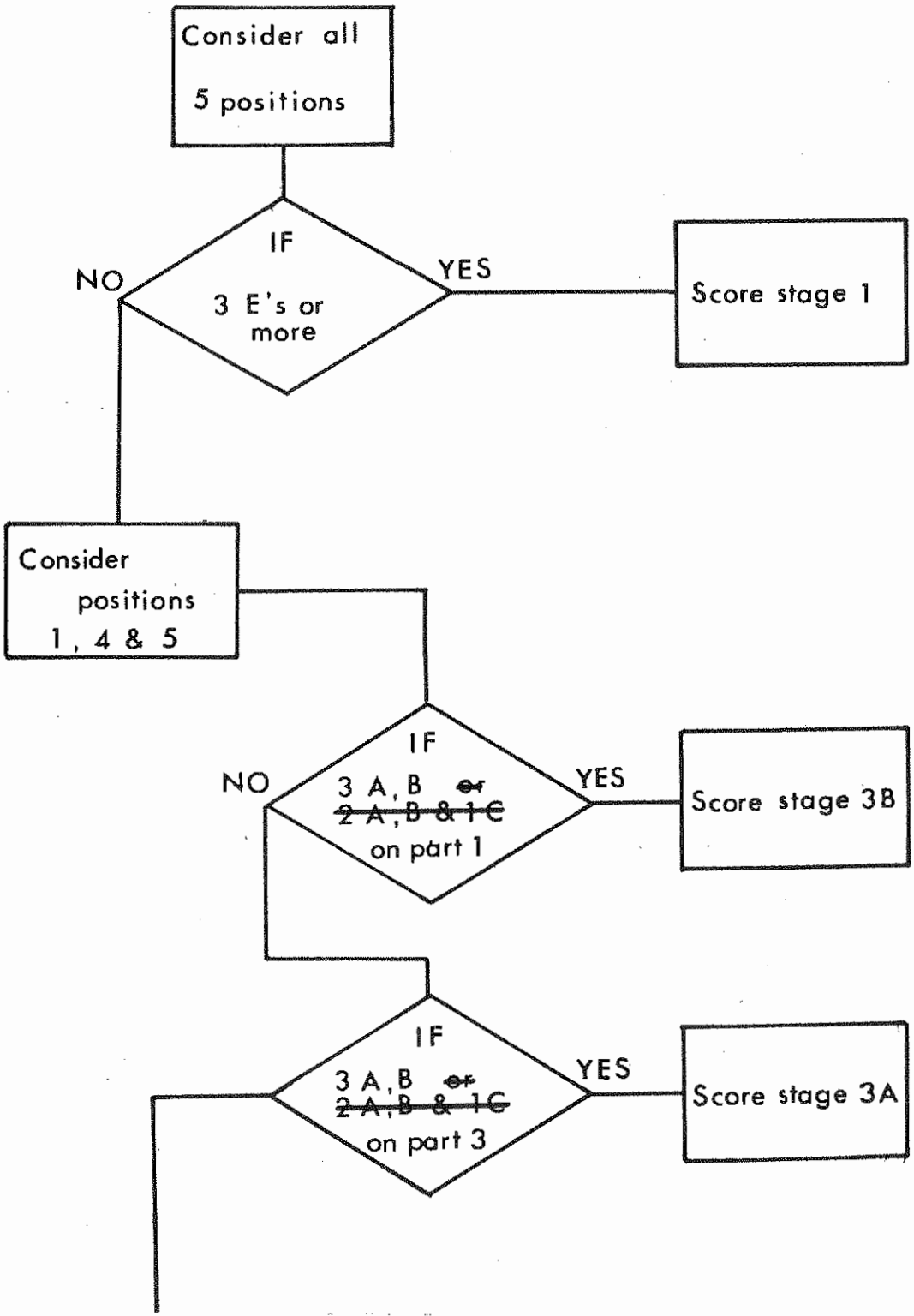
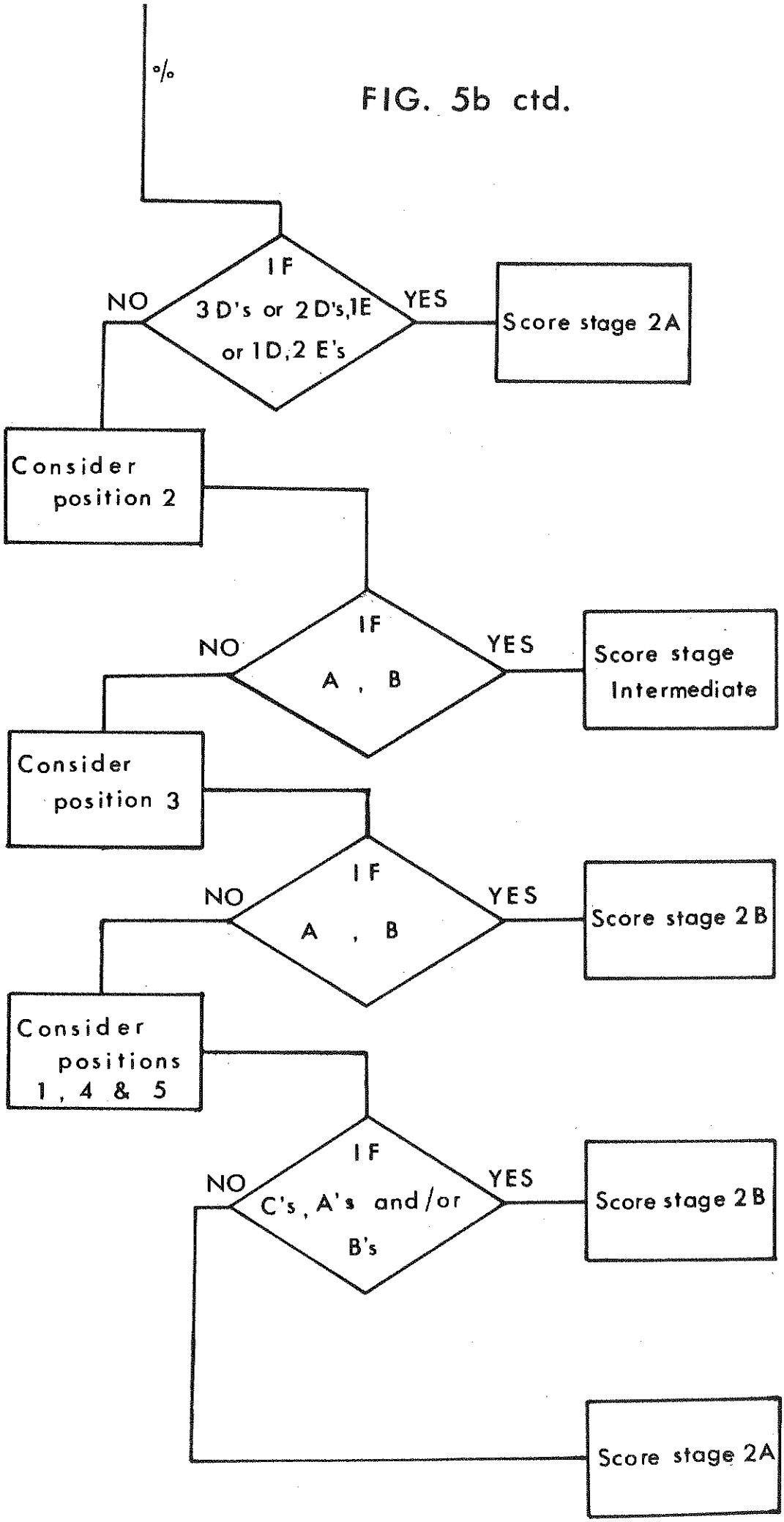


FIG. 5b ctd.


%
IF
3 D's or 2 D's, 1E
or 1D, 2 E's
NO
YES
Score stage 2A
Consider
position 2
IF
A , B
NO
YES
Score stage
Intermediate
Consider
position 3
IF
A , B
NO
YES
Score stage 2B
Consider
positions
1 , 4 & 5
IF
C's , A's and/or
B's
NO
YES
Score stage 2B
Score stage 2A

D. TEST MATERIALS AND PROCEDURES: PERCEPTUAL TESTS

The following five perceptual illusions were included in this study:

1. Müller-Lyer illusion (M-L)
2. Delboeuf illusion (Delb.)
3. Horizontal-Vertical illusion (H-V)
4. Oppel-Kundt illusion (O-K)
5. Size-Weight illusion (S-W)

For this group of tests, the procedures were the same in each case, disregarding minor adjustments. Therefore they will be described conjointly in a later section. The test materials, on the other hand, will be described separately for each illusion.

(1) Test materials

The general principles governing the manufacture of the stimulus cards have been described in section A (p.98). Basically the test materials are similar to those devised by Segall et al. (1966) for measuring the M-L and H-V illusions cross-culturally.

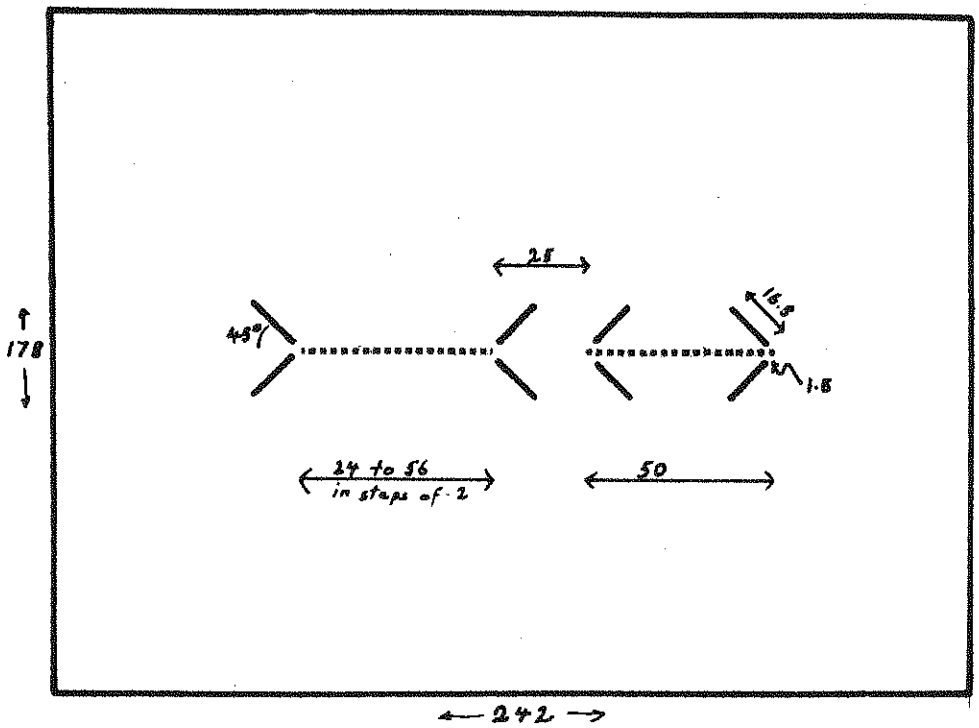
All figures are drawn on white Bristol, 'Imperial', 4/sheet paper with a Staedtler Mars Precision drafting equipment. The inks used are Pelican no 3 (vermilion) and no 17 (black). The thickness of all lines is as closely as possible 1 mm. The figures are sprayed with a protective plastic coating of 'Letraset', and were cleaned or replaced as soon as a spot or fingermark would have enabled a subject to recognize a particular card. The use by the subjects of the distance between the figures and the edge of the cards is made more difficult by centering all the figures; this cue was occasionally pointed out by European psychology students, but it is doubtful whether children would have noticed it. All cards are of 242 x 178 mm, except for the Oppel-Kundt illusion (180 x 120 mm).

Müller-Lyer illusion

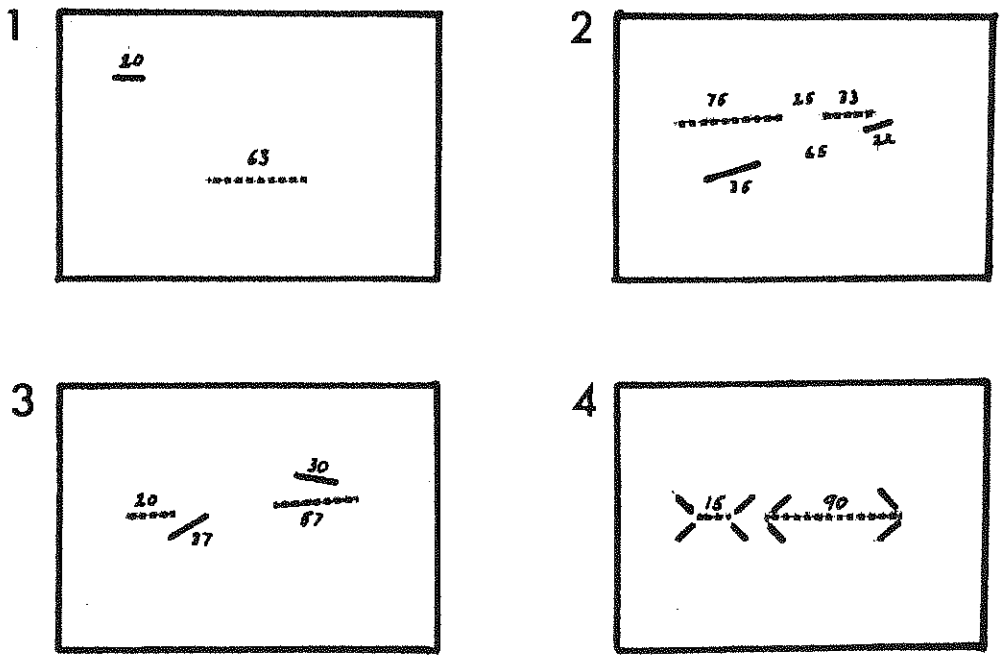
The material was based on Segall et al. (1966): identical check-items are used, and the same principles, if not dimensions, have been applied in designing the stimulus cards. The material is illustrated in Fig.6a, in Campbell (1964,

FIG.6a MÜLLER - LYER ILLUSION

Stimulus figures (scale: 1/2)



Check items (scale: 1/5)



all measures in mm

red ——— black

pp.319-321) and in Segall et al. (1966, pp.86, 107-110).

Delboeuf illusion

(a) Cards:

The Delboeuf illusion was measured by presenting a single standard card in conjunction with 16 variable ones.

The standard card comprised two concentric circles: a red one, with which the comparisons were made, with a diameter of 75 mm and a black one with a diameter of 100 mm.

The variables were single red circles, varying in diameter from 55.9 mm to 96.4 mm in steps of 2.25 mm (except at the lower end of the range, where two steps of 4.5 mm were used and at the upper end, where there was one such step.)

In percent of the standard, the illusion could thus be measured from -25.5% to 28.5% in steps of 3% (except at the extremities, where the steps are 6%).

In addition, 6 cards have been drawn for use as check items; these were:

A. A red circle, Ø 112.5 mm (50% illusion if subjectively equal to standard circle)
B. A red circle, Ø 37.5 mm (-50% illusion if subjectively equal to standard circle)
C. A red circle, Ø 75 mm (0% illusion if subjectively equal to standard circle)
D. A red circle, Ø 100 mm, intersecting a black circle, Ø 40 mm.
E. A red circle, Ø 50 mm, on the left side of the card, and a black circle, Ø 100 mm, on the right; the 2 circles are separated by 35 mm.
F. Two concentric circles, a red one, Ø 50 mm, and a black one, Ø 100 mm.

These cards were presented in the following combinations to serve as check items:

Check 1 : A and B
Check 2 : C and D
Check 3 : C and E
Check 4 : C and F
Check 5 : A and Standard
Check 6 : B and Standard

Horizontal-Vertical illusion

The material is based on that used by Segall et al. (1966). The check items and stimulus figures are illustrated in Fig. 6b.

Oppel-Kundt illusion

The size of the cards used for this illusion was 180 x 120 mm. The figure representing the standard, and the lines used as variables, were drawn on individual cards. The standard consisted of a horizontal, black line, centered on the middle of the card, 50 mm long, and segmented by 11 vertical, red lines, 8 mm long, and 1 mm thick, spaced at 4 mm.

The 23 variables were black horizontal lines, centered on the middle of the cards. They ranged from:

(a) 32.5 to 44.5 and 55.5 to 65.5 mm in steps of 2 mm, and from
(b) 44.5 to 55.5 mm in steps of 1 mm; there was also one card of
(c) 70 mm.

The corresponding illusions, in percent of the standard, were:

(a) -35% to -11%, and 11% to 31% in steps of 4%
(b) -11% to 11% in steps of 2%
(c) 40%.

In addition, three cards were used for the check items:

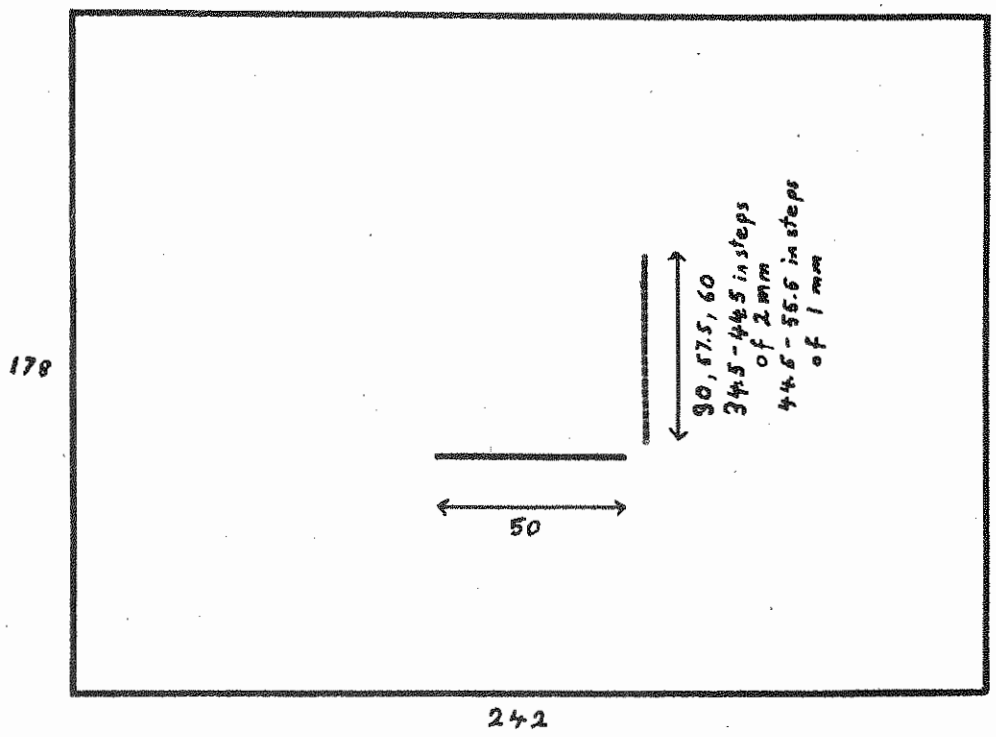
A. A horizontal black line of 75 mm
B. A horizontal black line of 25 mm
C. A horizontal black line of 30 mm, segmented by 3 vertical red lines of 11 mm each, and surrounded by 3 vertical red lines of, respectively, 10, 12 and 100 mm.

These cards were presented in the following combinations to form the check items:

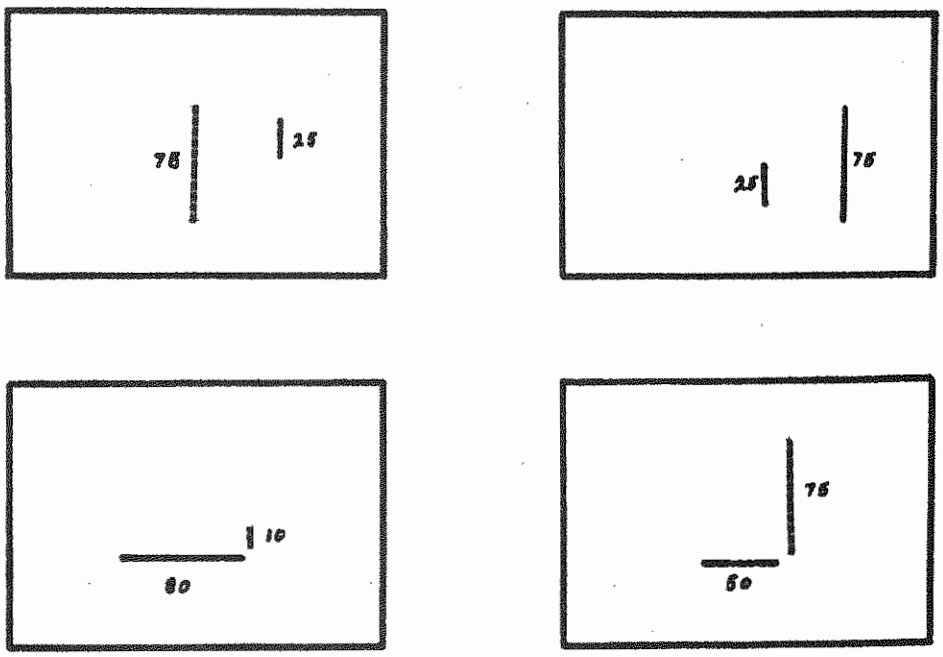
Check 1 : A and B
Check 2 : A and C
Check 3 : B and Standard (illusion 50%)
Check 4 : A and Standard (illusion -50%)

FIG.6b HORIZONTAL-VERTICAL ILLUSION

Stimulus figures (scale: 1/2)



Check items (scale: 1/5)



all measures in mm

red

black

Size-Weight illusion

The S-W illusion was measured by asking the subject to lift two pharmaceutical containers of differing size. The larger one of these (height: 10 cm; Ø 9 cm) was the standard, weighed at 480 grams; the smaller variables (height: 8.5 cm; Ø 5 cm) increased in weight from 150 to 690 grams in steps of 60 grams; in addition, there was a jar weighing 120 grams.

It was thus possible to measure an illusion ranging from -43.75% to 75% in 9 steps of 12.5% and one step of 6.25%.[1]

For easier identification, the jars were marked at the bottom with numbers from 1 to 11 (heaviest to lightest), but the subjects cannot see these numbers.

For the check items, two variables were presented at a time, respectively in the left and right hands; represented by their numbers, these are: 3 and 10, 11 and 4, 10 and 5, 6 and 11, 3 and 8, 9 and 4 etc., until five successively correct judgements were obtained.

(2) Procedures

The perceptual tests were presented under the same conditions as the operational tasks (see section A, p.101). The stimulus cards were presented as closely as possible in the fronto-parallel plane, at a distance of approximately 40 to 50 cm from the subject. No attempt was made to limit the subject's eye or head movements, except that he was not to tilt his head too much (which could have been important for the H-V illusion). The subject was thus free alternatively to fixate the standard and the variable, and this behaviour was especially noticeable with the rather large Delboeuf figures. Due to the difficulties created by the cross-cultural setting, strict laboratory conditions characteristic of perceptual research could not be adhered to; however, the testing conditions and procedures were

[1] The illusion, in percent of the standard, may be obtained by the formula:

$$i = \frac{(480 - \text{Weight of variable})\ 100}{480}$$

sufficiently similar for the three samples to be validly compared.

The testing procedures followed the same pattern for all the illusions:

1. The check items were presented first, if necessary twice in succession, to make sure that the subject understood which elements he had to compare and what the convention for the answer was to be; if this could not be achieved after two sets of check items, testing was discontinued.

For the M-L, the H-V and the O-K illusions, the instructions were:

- Show me which (red, black) line is longer![1]

If the child did not understand the comparative form, 'big' was used instead:

- Show me which line is big!

For the Delb. illusion, the instruction was:

- Show me which red circle is bigger (big)!

When being tested for the S-W illusion, the subject was asked:

- Which one is heavier (heavy)?

If the subject did not understand 'heavy', the experimenter took two jars in his hands, holding them out at equal heights, and letting the arm with the heavier jar move downwards; the child was trained to do the same, and was asked: "Which one goes down?".[2]

The universal word 'big', so useful in all other instances, could not be used for the S-W illusion, since it would have been difficult to distinguish between subjects paying attention to weight and those considering only size. Furthermore, the vernacular could not be used, since it does not distinguish clearly between big and heavy.

---

[1] This formulation excluded equality answers almost automatically. If the subject did answer that the standard and variable were the same, he was asked: "Isn't one just a little bit longer (big)?" An equality answer was only recorded on the subject's insistence.

[2] This procedure was inspired by the non-verbal technique devised by Furth (1966) for testing deaf children on the conservation of W.

2. After the subject had successfully completed the check items, five PSE's were determined successively by the concentric and clinical method. A brief description of this method, based on a manuscript by Matalon, is contained in the appendix to Piaget (1969a). In short, only the first stimulus card is chosen at random, the following choices being determined by the subject's answers. This enables a determination of the PSE with the least possible number of trials. This method was devised by Piaget for experimentation with children, where a large number of presentations would be very difficult to carry through; for the same reason it is a suitable method for cross-cultural research.

The concentric and clinical method is sometimes criticized on the following grounds:

1. The assumption of the consistency of the subject's answers is obviously wrong. It is well known that, within the 'region of uncertainty', by definition, the answers are not necessarily consistent.

2. The choice of the succession of stimulus cards is left to a great extent to the experimenter's judgment, and thus the process is subject, to some degree, to conscious or unconscious personal influence.

These objections are quite valid. However, each psychophysical method has one disadvantage or another; the concentric and clinical method may have more drawbacks than others, but its advantages in cross-cultural research would appear to us to outweigh these. The inconveniences are also overcome by the possibility of multiplying the number of PSE's which can be measured within a short time.[1]

Several precautions were taken to increase reliability: (1) To avoid a possible position effect, the side on which the variable is presented is alternated with each PSE determination (about every 5 stimulus presentations). Half the subjects in each sample and each age-range start with one position, half with the other. The position chosen to initiate the series is predetermined at random. Only for

[1] The results reported in this study represent averages of 5 PSE's for each subject on each test.

the H-V illusion is this alternation impracticable, and the variable, the red vertical line, is always on the right of the standard.

(2) As an addition to the check items, the series is usually started with the two extreme variables of the range, and it is expected that these will be perceived veridically. If this is not so, the check items are repeated.

(3) If several stimuli in a narrow range have to be presented successively, these are interspersed with an occasional extreme variable to maintain motivation.

(4) A few subjects adopt perseverative escape response patterns, pointing always to the same side, or alternatively left and right. With the concentric clinical method, it is extremely easy, for an experienced experimenter, to detect such oppositional tendencies very quickly, and to select variables so as to be sure what the subject is doing before correcting him. If this occurs once, the instructions are repeated and the testing is resumed, discarding the unreliable measurements. If this happens again, testing is discontinued.

CHAPTER IV : RESULTS AND DISCUSSION : OPERATIONAL TESTS

In view of the large amount of data, and their heterogeneity, it would be inconvenient to present the results separately from the discussion. Each section thus comprises both the data and a detailed commentary thereon, including some digressions and pertinent comments. Chapter 6 is reserved for a more general discussion.

The results of the operational tests will be presented as follows :

For each test, the percentage of children at each age level classified at the three stages of development will be tabulated for each sample. Results obtained on European children in Geneva (Piaget and Inhelder, 1963b, pp.121-122; Inhelder, 1963, pp.xvi-xvii) and with Aboriginal children in Hermannsburg (de Lemos, 1966, 1969a/b) will be included for comparison, if available.

The tables include under F the percentages of children who could not validly be classified into any one of the stages. In other publications (e.g. Heron & Simonsson, 1969), these cases have been discarded from the sample. In the present study, the inclusion or exclusion of F cases makes little material difference.

The percentage of children at each age level attaining the concrete operational stage (stage 3) will then be graphed.

The results expressed in average scores in points for each individual test are given in Appendix 5.

After the quantitative results have been presented and discussed, a brief description of the children's reactions to the tests (qualitative analysis) will be given.

The results will show that hypothesis 1 ("The qualitative aspects of operational development (i.e. the stages) are identical in Australian Aborigines and in Europeans, but the rate of development is slower in Aborigines") is confirmed for each operational test.

A. LOGICO-MATHEMATICAL TESTS

1. Conservation of Quantity

The results are set out in Table 4 and in Fig. 7.

The results obtained in Canberra are similar to those reported from Geneva.

The performance of the Aboriginal children is much lower; the 50% conservation level is achieved at age 12 in the Hermannsburg group, but is not reached at any age in the Areyonga sample. The 100% level is not reached in either sample, even at age 15/16, and more than half of the adults in both samples fail to display the concept of conservation of Q.

The percentage of children attaining conservation in the Hermannsburg group is slightly higher than those obtained by de Lemos; the difference is especially noticeable in the older age group, where 70% of the children attain conservation as compared to only 40-50% in the previous study. The difference, however, is not statistically significant (see Table 8).

2. Conservation of Weight

The results are reported in Table 5 and in Fig. 8.

The similarity between the Swiss and the Australian results is less close for this test than for the conservation of Q, mainly because of a sharp drop in performance of the Canberra group at ages 10 and 11. Further facts and hypotheses concerning this finding are set out in Appendix 2.

In the Aboriginal groups, conservation of W is almost absent. The two groups have almost identical results, except in the higher age groups (13-16). The 50% level is reached by the Hermannsburg group at age 15/16, but for the Areyonga sample, the percentage of children reaching the concrete operational stage is almost constant at about 10%.

Only two out of ten adults in Hermannsburg, and only one out of ten in Areyonga displayed the concept of conservation of W.

The performance obtained in Hermannsburg with this study

TABLE 4

CONSERVATION OF QUANTITY (LIQUIDS) : PERCENTAGE OF SUBJECTS CLASSIFIED AT EACH STAGE.

Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.
Geneva													
N=25 per age													
C	4	18	74										
T	11	42	22										
NC	85	40	4										
Canberra													
N=10 per age													
C	0	30	70	90	100	100	-	-					
T	10	10	20	0	0	0							
NC	90	60	10	10	0	0							
Hermannsburg													
N=10 per age													
C		0	0	20	40	30	10	50	70		70		40
T		10	10	40	10	0	30	10	10		10		20
NC		60	80	30	50	70	60	40	20		10		40
F		30	10	0	0	0	0	0	0		0		0
De Lemos Hermannsburg													
C				8	11	36	20	44	40	43	50		
T				17	33	0	30	0	50	14	33		
NC				75	56	64	50	56	10	43	17		
N				12	9	11	10	9	10	7	12		
Areyonga													
C				17		0		20		30			30
T				0		0		27		10			20
NC				75		89		40		60			50
F				8		11		13		0			0
N				12		9		15		10			10

C=Conservation T=Transitional NC=Non-conservation
F=Failure to communicate N=Number of Ss

FIG: 7 CONSERVATION OF QUANTITY

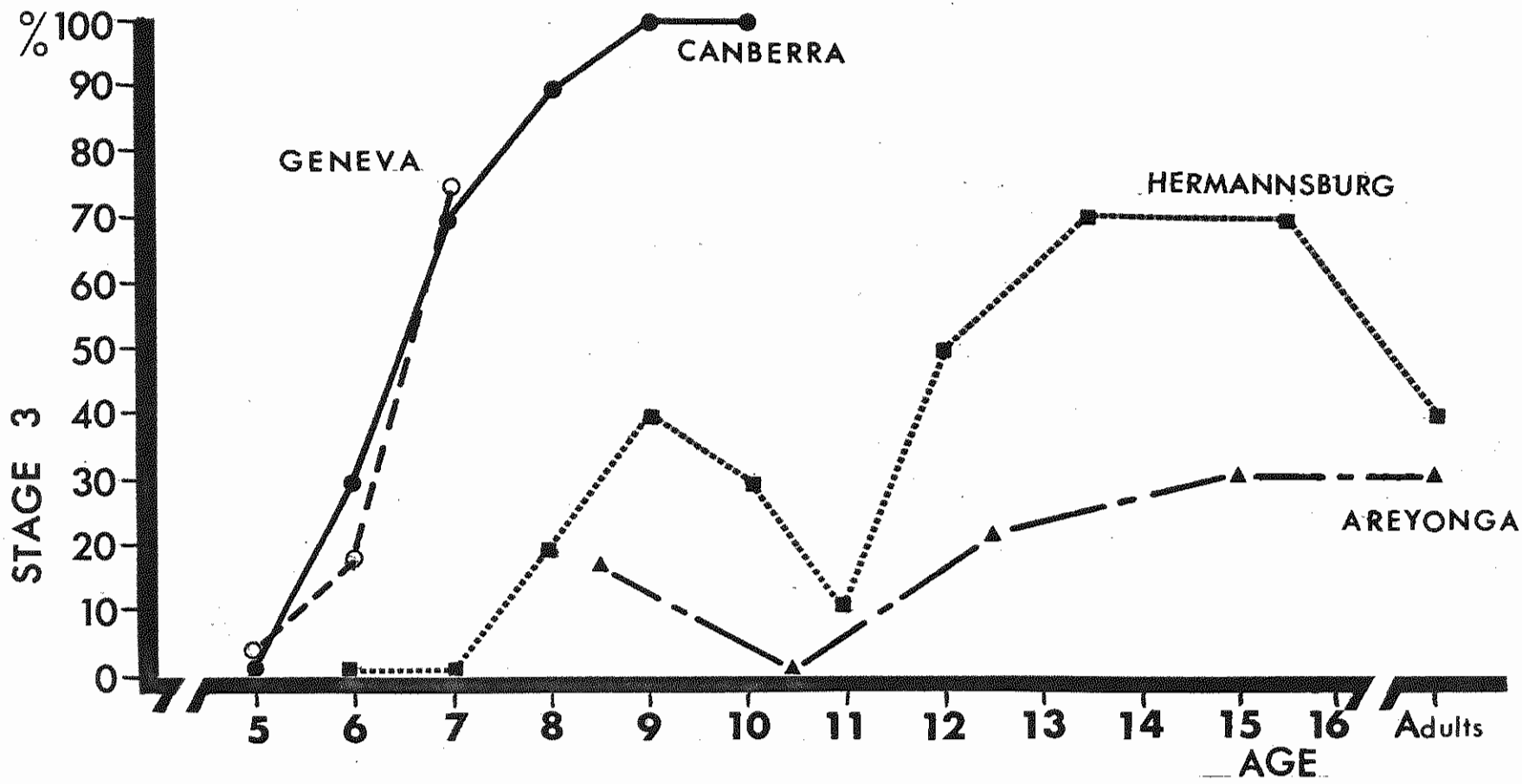


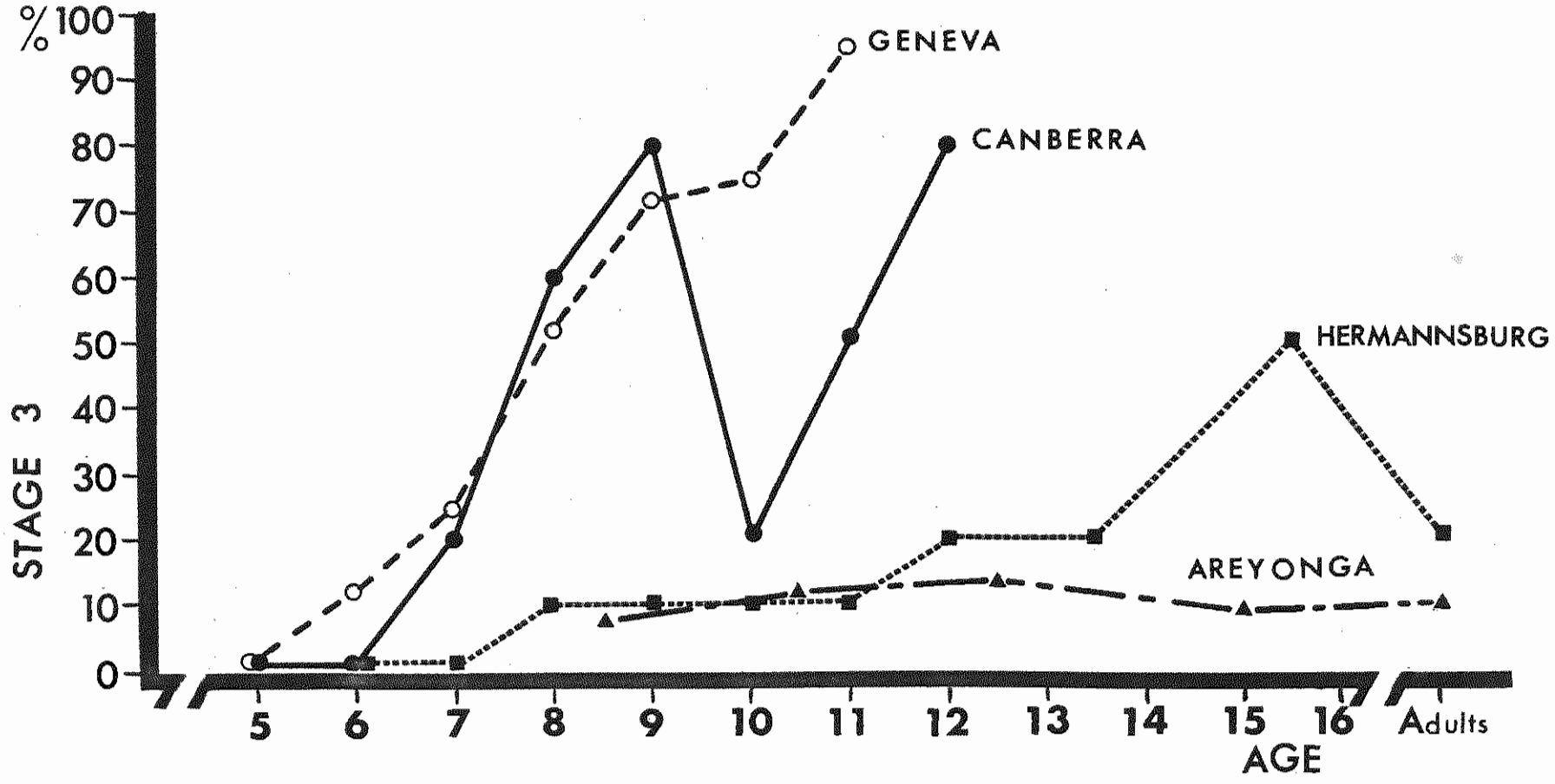
TABLE 5

CONSERVATION OF WEIGHT : PERCENTAGE OF SUBJECTS CLASSIFIED AT EACH STAGE

Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.
Geneva													
N=25 per age													
C	0	12	24	52	72	76	96						
T	0	4	0	8	12	8	4						
NC	100	84	76	40	16	16	0						
Canberra													
N=10 per age													
C	0	0	20	60	80	20	50	80					
T	0	30	40	30	0	20	20	20					
NC	100	70	40	10	20	60	30	0					
Hermanns-burg													
N=10 per age													
C		0	0	10	10	10	10	20	20		50		20
T		10	20	0	20	0	20	10	40		40		0
NC		70	50	60	70	90	70	70	40		10		80
F		10	40	20	0	0	0	0	0		0		0
De Lemos Hermanns-burg													
C				25	33	73	60	67	60	57	67		
T				8	33	9	10	11	30	0	0		
NC				67	33	18	30	22	10	43	33		
N				12	9	11	10	9	10	7	12		
Areyonga													
C					8		11		13		9		10
T					25		22		20		37		10
NC					42		56		60		27		80
F					25		11		7		27		0
N					12		9		15		11		10

FIG. 8 CONSERVATION OF WEIGHT

Percentage of subjects conserving



is much lower than that reported by de Lemos. This finding is further discussed in Sections A,6 and C,2 of this chapter.

3. Conservation of Volume

The results are set out in Table 6 and in Fig. 9.

Up to the age of 9, Canberra children seem to acquire the concept of conservation of V at about the same rate as Geneva children; after this age, the figures show large fluctuations. It is difficult to say whether these fluctuations are due to the small number of subjects in our sample, compared to the Genevan one (N = 25 per age group), or whether the sharp fall of performance which seems to be evident at age 10 is due to the same or a similar cause as the drop on conservation of W.

The performance level of the two Aboriginal samples differed markedly only at the higher ages and for adults. The results of both groups are slightly better than those obtained by de Lemos in Hermannsburg (see Table 8).

4. Conservation of Length

The results for the conservation of L are set out in Table 7 and Fig. 10, 11 and 12.

For the purpose of comparison with other studies, the three parts of the test are treated separately.

For the Genevan sample, only the results of the first part have been published (Inhelder, 1963); the results obtained by de Lemos are also included under part 1, although the technique she used differed somewhat from the present one.

On part 1 of the test (Fig. 10), the Swiss and the Australian European samples give very similar results; the curve for the Canberra sample is slightly above the Genevan one up to the age of 8, but then flattens out. One child still failed to conserve length at age 10, but this is also the case of a 9 year old child in the Swiss sample.

The increase with age in the percentage of Aboriginal children achieving conservation is only small. This is partly due to the relatively high concept achievement of the younger subjects. In the Hermannsburg sample, the 50% level is reached at age 7, which is comparable to the Canberra results, but this performance is not maintained at all ages.

In spite of rather large fluctuations, it is certainly correct to say that the results we have obtained in

TABLE 6

CONSERVATION OF VOLUME : PERCENTAGE OF SUBJECTS CLASSIFIED AT EACH STAGE

Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.
Geneva													
N=25 per age													
C	0	0	12	28	32	56	80						
T	0	0	0	28	12	20	4						
NC	100	100	88	44	56	24	16						
Canberra													
N=10 per age													
C		10	10	10	50	10	60	50					
T		20	40	50	30	10	10	40					
NC		70	50	40	20	80	30	10					
Hermanns-burg													
N=10 per age													
C		10	10	0	30	30	10	20	20		60		30
T		10	20	40	30	60	20	30	30		30		0
NC		40	40	20	40	10	70	50	50		10		70
F		40	30	30	0	0	0	0	0		0		0
De Lemos Hermanns-burg													
C				8	11	9	20	0	10	29	25		
T				0	33	18	10	33	30	29	42		
NC				92	56	73	70	67	60	43	33		
N				12	9	11	10	9	10	7	12		
Areyonga													
C					25		22		13		30		0
T					42		56		13		20		0
NC					17		22		53		50		100
F					17		0		20		0		0
N					12		9		15		10		10

FIG. 9 CONSERVATION OF VOLUME

Percentage of subjects conserving

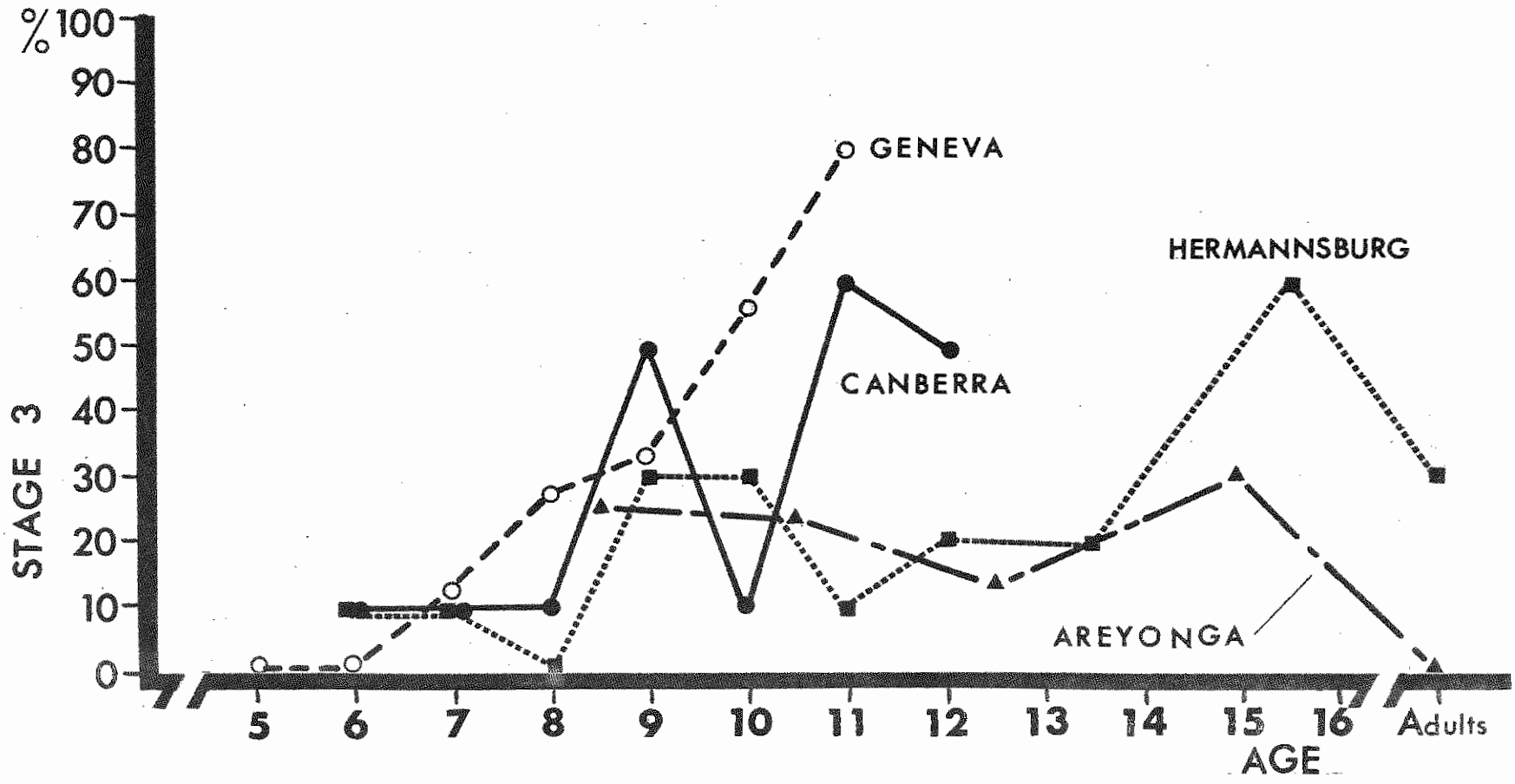


TABLE 7

CONSERVATION OF LENGTH : PERCENTAGE OF SUBJECTS CLASSIFIED AT EACH STAGE

Age		5	6	7	8	9	10	11	12	13	14	15	16
Geneva													
N=25 per age													
Part 1	C	8	4	20	68	96							
Canberra													
N=10 per age													
Part 1	C	0	10	60	70	80	90						
	T	10	0	30	10	0	0						
	NC	90	90	10	20	20	10						
Part 2	C	0	10	40	70	100							
	T	0	30	30	20	0							
	NC	100	60	30	10	0							
Part 3	C	10	50	40	100	100							
	T	10	0	30	0	0							
	NC	80	50	30	0	0							
Hermannsburg													
N=10 per age													
Part 1	C		20	50	40	30	50	50	60	20		70	
	T		0	0	0	10	10	20	10	10		0	
	NC		70	40	50	60	40	30	30	70		30	
	F		10	10	10	0	0	0	0	0		0	
Part 2	C		0	10	10	10	40	40	50	20		40	
	T		0	0	0	0	10	0	0	0		0	
	NC		80	80	80	90	50	60	50	80		60	
	F		20	10	10	0	0	0	0	0		0	
Part 3	C		0	10	20	30	30	0	10	10		20	
	T		10	10	0	0	0	0	10	20		0	
	NC		70	70	70	70	70	100	80	70		80	
	F		20	10	10	0	0	0	0	0		0	

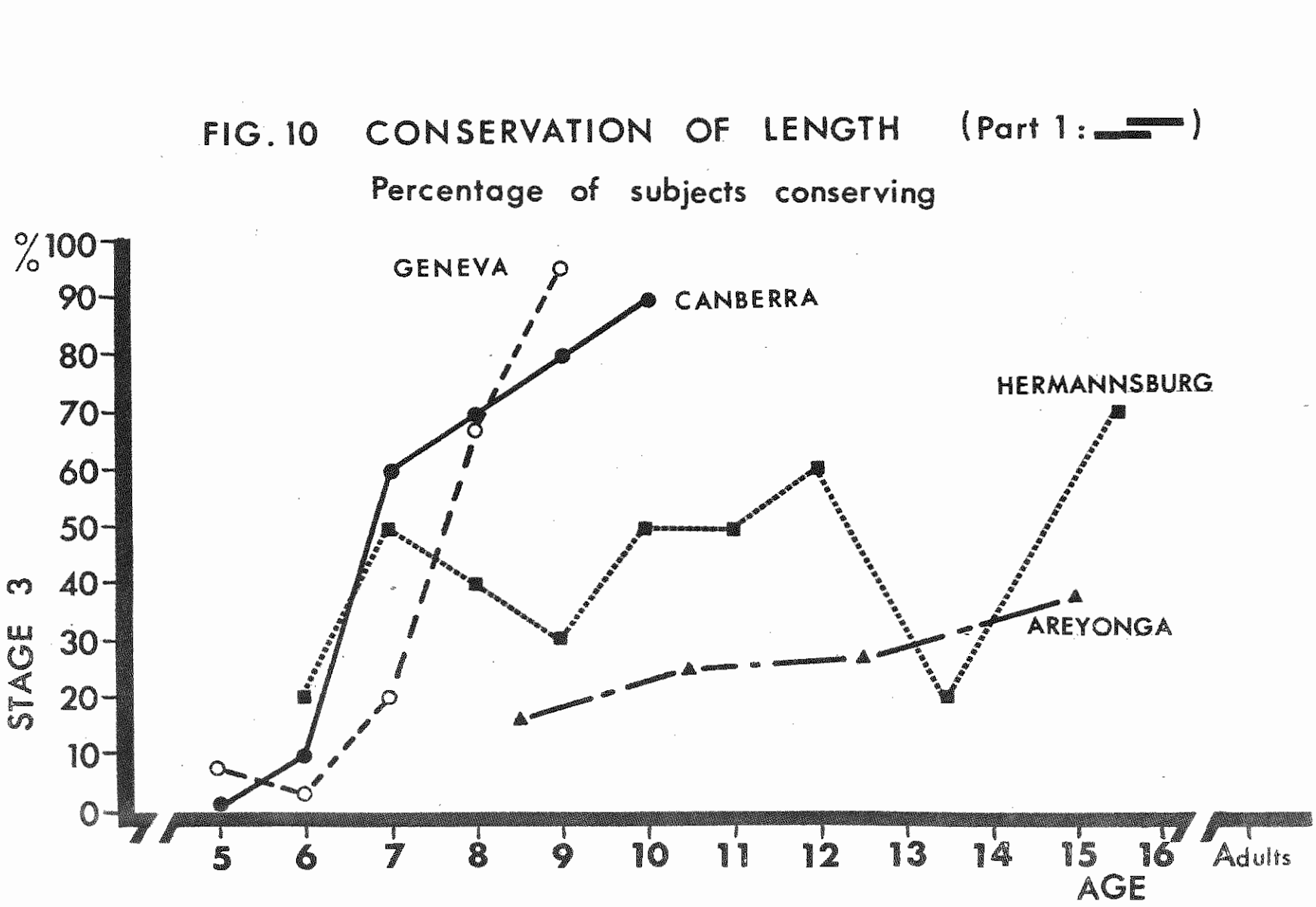
Cont'd

TABLE 7 (Cont'd)

CONSERVATION OF LENGTH:

Age		5	6	7	8	9	10	11	12	13	14	15
De Lemos Hermannsburg												
Part 1 and other items												
	C				33	67	54.5	50	22	50	57	42
	T				8	0	9.5	10	33	40	0	42
	NC				58	33	36	40	45	10	43	16
	N				12	9	11	10	9	10	7	12
Areyonga												
Part 1	C					17		25		27		37.5
	T					25		12.5		0		12.5
	NC					58		62.5		67		37.5
	F					0		0		7		12.5
Part 2	C					8		0		20		25
	T					17		0		0		12.5
	NC					75		87.5		73		50
	F					0		12.5		7		12.5
Part 3	C					17		12.5		13		50
	T					0		12.5		27		0
	NC					83		75		53		37.5
	F					0		0		7		12.5
	N					12		8		15		8

FIG. 10 CONSERVATION OF LENGTH (Part 1: ▬▬)



Hermannsburg are identical to those of the previous study by De Lemos.

The performance of the Areyonga sample is, again, very poor.

Part 2 of the test (Fig. 11) is of about the same difficulty as part 1 for the European subjects. For the Aboriginal children, however, it seems to be slightly more difficult, especially for the younger ones. In the Hermannsburg group it is only at age 10 that the percentage curve starts to rise. Conservation is almost absent in the Areyonga sample.

According to Piaget, Inhelder and Szeminska (1948), the third part of the test (Fig. 12) should be easier than the two others. This is so for our European sample where the 50% level is reached at age 6, and the 100% level at age 8, which is between one and two years earlier than on the two other parts, but was not confirmed for the Aboriginal groups.

5. Conservation tests : qualitative results

There was a remarkable consistency in the individual responses to the various tests. It is therefore possible to describe them together. This will be done only briefly, because it does not add anything of importance to this study, nor to that of de Lemos (1966, chapter VII). The uniformity between all studies is indeed remarkable.

Extensive descriptions of protocols are given in the literature and in de Lemos' study, and will not be repeated here. All interviews were tape-recorded, but the transcription was discontinued when it was realized that no additional information would be gained.

The most important feature of the qualitative analysis of the results is the exact correspondence between the answers given by the European children in Canberra and by the Aboriginal children. The latter may use only a word or two, or a gesture, instead of a long verbal explanation, but the reasoning they express is indeed precisely the same. In de Lemos' words:

FIG. 11 CONSERVATION OF LENGTH (Part 2: $\overline{w}$)

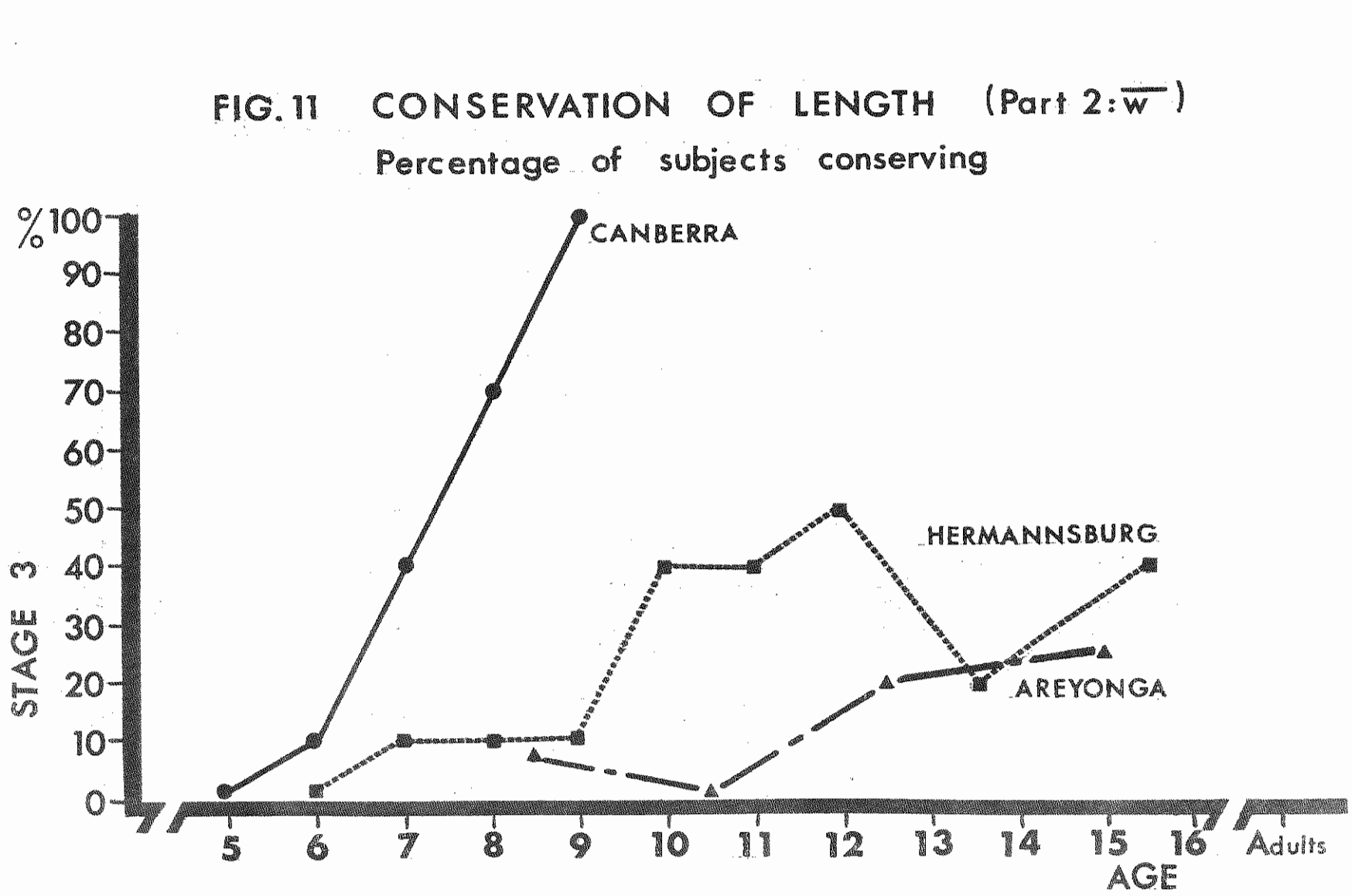
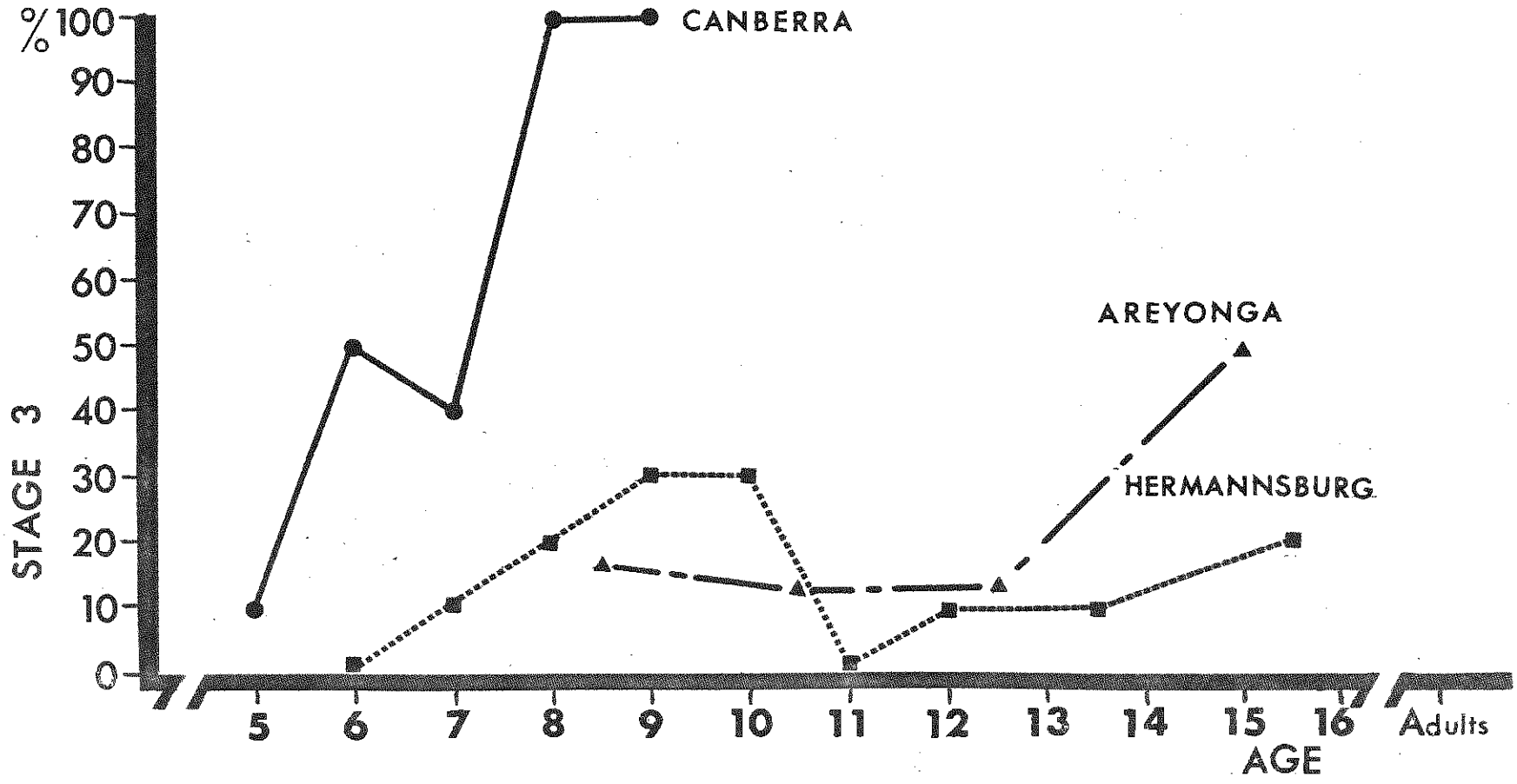


FIG. 12 CONSERVATION OF LENGTH (Part 3: ⌒)

Percentage of subjects conserving



> In general, the responses and explanations given by the Aboriginal children reveal the same processes of development which Piaget has described for European children. Non-conservation responses are invariably justified with reference to the perceptual features of the present situation, while conservation responses are justified with reference to past or future situation, indicating the child's ability to link these together in a system of reversible transformations. While the explanations given by the Aboriginal children were in general more limited than those of European children, the fact that a few children gave explanations illustrating precisely the same processes of thinking that Piaget has described seems to be in itself significant. (de Lemos, 1966, p.286-7)

As with the European children, the most frequent explanations of conservation are in terms of identity, compensation and reversibility, the latter two occurring less frequently than the first. Some children, in all samples, were able to give all three justifications. The difference between the Aboriginal children and the European children lies mainly in the amount of prompting required (and in the patience of the experimenter!). A few Aboriginal children did not give any explanation at all.

Reversibility justifications were rare, but relatively more frequent than reported by de Lemos. In particular, if other questions failed to provoke an explanation, the experimenter would often ask: "What could you do to explain to me that it is the same?". This often prompted the subject to demonstrate reversibility by action: the child would pour the cordial back into the original beaker, or would remodel the plasticine into a ball. Sometimes this could have been meant as 'empirical return' (in Genevan terminology: 'retour empirique' or 'renversabilité'), but usually it was quite clear that equality applied to the objects when transformed as well as when returned to their original state.

Another type of explanation, linked to reversibility, was given on a few occasions by children of all three groups; as it does not appear to have been discussed previously in the literature, we shall refer to it as 'correlative transformation'. The child would say, for example: "It's the same, because we can roll this ball (A) out as well"

(to make it similar to B). Thus, instead of reversing the transformation (B → A = A'), the child thinks that applying the same transformation to the remaining object will prove the point. (If A = A', and A' → B, and A → B', then B = B').

This type of explanation was also given several times for the conservation of L (part 1), where the subject would push the stick which had remained stationary to the side of the one which had been moved, instead of pushing the latter back to its original position.

The general conclusion that justifications given by Aboriginal and by European children are identical needs one qualification. By about age 10 years, and thereafter, European children begin to give more complex statements for both conservation and non-conservation, which seem to reflect a new way of thinking about the problem. Some examples of these explanations are given in Appendix 2, where it is also argued that the children start to use formal concepts, sometimes without fully comprehending them. They also tend to formulate their explanations into general laws ("It is always the same weight, whatever you do to it, unless you take some off").

No such generalizations or complex explanations were given by Aboriginal subjects. This may be due partly to the lack of verbal fluency. However, even the older subjects and the adults who had acquired a very good command of the English language did not make any of these involved statements. The formal properties of thought, which are evidenced by some of the formulations the European children use, are absent from the explanations the Aborigines give. Each one of their justifications seems to be independent from the others, and applies only hic et nunc.

Another peculiarity of the Aborigines' reactions to the conservation tests is the occurrence of contradictions and ambiguities in their explanations. Whereas every effort was made to elucidate the cause of inconsistent answers, this was not always possible, and it may well be that some answers which appeared to be contradictory to the experimenter were not seen as such by the subjects.

De Lemos has analysed most of these ambiguities, and

her observations apply fully to our study. We shall therefore only mention a few important ones.

For the conservation of Q, difficulties arose with those subjects who could not use relational terms, such as 'more' and 'less'. In these cases, phrases like 'big to drink' or 'little to drink' were used instead. This usually solved the problem, but on occasions it made it difficult to decide whether the subject was referring to the quantity of liquid or only to its height in the glass. Extensive questioning usually clarified the situation.

Similarly, some children were unable or reluctant to use the word 'same'. One way of expressing the idea was to say that both had 'big' to drink (or both 'little'). In such a case, only further questioning could resolve the ambiguity.

Other possible linguistic misunderstandings, partly based on the corresponding usage of the relational terms in the vernacular, are described by de Lemos. A typical example is the use of the word 'level' instead of 'same'; this works extremely well for the conservation of W, where it can express at the same time the equality between the two balls and the fact that the balance will not go down on either side, but in the case of the conservation of Q, it may lead to confusion with the reference to 'water levels' in the two beakers.

Very few ambiguities occurred on the test of W, where the subjects could clearly indicate, by gestures if needed, whether the balance was to go up, or down, or stay level, so that the test was meaningful even to those who did not spontaneously use, or understand, the words 'heavy', 'light' and 'same weight'.

The persistent inconsistencies mentioned by de Lemos between the judgments as to which ball was heavier, and which would make the scale go down, were not frequent, except in those subjects who did not understand the working of the balance (scored 'F').

For the conservation of V, de Lemos' descriptions apply without modification, and the test generally presented no special problems.

Almost all Aboriginal children gave some categorical answer in one direction or the other for part 3 of the conservation of L, but few were able to explain their choice, in spite of extensive questioning. The problem did not seem to interest them, and often the experimenter did not feel sure that the children had understood the question completely.

On parts 1 and 2, some Aboriginal children could not give any explanation for their answer, but many others who were not able to give extensive verbal explanations simply pushed the stick(s) back into the original position (reversibility).

Others gave the usual identity explanation, whereas compensation was rare. Non-conservation was clearly explained (sometimes by gestures) by the exclusive consideration of the extremities of the sticks.

As Piaget and de Lemos had found previously, the stick which is moved was usually considered to be longer by most non-conserving children.

6. Replication of a previous study in Hermannsburg (de Lemos, 1966, 1969a/b)

Before considering the results of this test of seriation, it is convenient to compare the results we have just described for the Hermannsburg group with those obtained 5 years previously at the same location, by de Lemos. Only the age groups from 8 to 15, which are common to both studies will be used.

The number of subjects attaining stage 3 (conservation) in the two studies, and on the 4 tests which are common to these, are presented in Table 8. Since the samples differ slightly in size, the corresponding proportions are also given.

The proportion of subjects classified at stage 3 is somewhat higher in our study for the tests of Q and V, but the differences are not statistically significant on chi-square tests. The proportion of subjects conserving L in the two studies is almost identical, whereas on W the proportion of subjects classified at stage 3 is significantly lower in the present study than in de Lemos' study.

TABLE 8

CONSERVATION TESTS : CHI SQUARE TESTS ON TOTAL FREQUENCIES

(Number of subjects attaining stage 3 in the Hermannsburg samples (age 8-15) of the present study and of that of de Lemos, 1966).

Tests		Quantity		Weight		Volume		Length (1)	
Stage 3		N	prop.	N	prop.	N	prop.	N	prop.
Hermannsburg (Dasen)	N = 65	26	.40	11	.17	15	.23	29	.45
Hermannsburg (de Lemos)	N = 80	25	.31	44	.55	11	.14	37	.46
χ^2		1.1890		22.0690		2.1170		0.0290	
Significance level (two-tailed test)		NS		.001		NS		NS	

These figures confirm the trends which are noticeable from an inspection of the tables and graphs presented in paragraphs 1 to 4 (see in particular Fig. 7-10).

Leaving the results of the conservation of W aside for the moment, we conclude that the overall results of the previous study have been confirmed. The two studies are also very similar in quantitative and qualitative terms.

On the other hand, the results obtained in this study for the conservation of W do not confirm de Lemos' Quantity/Weight reversal. This question is discussed in detail in Section C of this chapter. Furthermore the difference de Lemos found between the performances of part-blood and full-blood Aborigines was not replicated either. The results and discussion of this topic forms Section F of the present chapter.

Relatively more space will be devoted to these two failures to replicate previous findings, because their interpretation is far from being clear and will need extensive discussion. However it should be kept in mind that they represent a rather minor exception to the general comparability in results.

Retest of de Lemos' subjects after 5 years

The fact that the present investigation and that of de Lemos (1966) share one common sample (Hermannsburg) provides us with a quasi-longitudinal study.[1] Of the children tested by de Lemos in 1964, 22 were retested in 1969, ranging in age from 12 to 16, with approximately an equal number of subjects at each age. (Two subjects who had left school in 1969 were included in the adult group, and were therefore not subjected to the test of conservation of L.)

The results are presented in Table 9. On the tests of Q and V, the shift to higher stages is dramatic, and reflects partly the fact that these 12 to 16 year-olds are now performing slightly better on these two tests than the group of the same age did in 1964 (cf. Table 8).

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[1] We wish to thank Dr. de Lemos for making the individual results of her subjects available.

TABLE 9

CONSERVATIONS : RETEST AFTER 5 YEARS (see text)

Quantity

		de Lemos (tested 1964)			
	Stages	1	2	3	Σ
Dasen (tested 1969)	1	2	1	0	3
	2	2	2	0	4
	3	10	2	3	15
	Σ	14	5	3	22

Weight

		de Lemos (tested 1964)			
	Stages	1	2	3	Σ
	1	6	0	0	6
	2	2	1	5	8
	3	1	2	5	8
	Σ	9	3	10	22

Volume

		de Lemos (tested 1964)			
	Stages	1	2	3	Σ
Dasen (tested 1969)	1	4	1	0	5
	2	5	1	0	6
	3	8	2	1	11
	Σ	17	4	1	22

Length (1)

		de Lemos (tested 1964)			
	Stages	1	2	3	Σ
	1	5	1	3	9
	2	1	0	0	1
	3	2	1	7	10
	Σ	8	2	10	20

On the contrary, there seems to be no improvement on conservation of W and L over the 5 years.

The interesting fact is that on Q and W only 1 subject out of the 22 'regressed' during the 5 years, namely from the transitional to the non-conservation stage. All others either remained at the same stage, or moved to a superior stage. The number of 'regressions' is slightly higher for the two other tests. On W, 5 subjects who had been classified at the third stage were now giving transitional answers, and on L, three subjects even reverted from stage 3 to stage 1. Although not numerous, these cases present an interesting problem. Were these children truly at the conservation stage 5 years ago, and did they for some unknown reason 'lose' the particular concepts? Or had they displayed conservation on a superficial basis only, "a particular type of conservation ... which would not have a complete operational status, and which cannot be considered as a symptom of a structure implying additive and multiplicative operations, which are necessary to the understanding of reversibility"[1], as Bovet (1969, p.192) puts it to explain the 'regressions' she found in Algerian children?

Or were these subjects simply misclassified in one of the studies, pointing to the relative unreliability of these two tests? Our data, at the moment, does not enable us to answer these questions.

Generally speaking, the longitudinal comparison thus does not provide us with any interesting new facts, but confirms the results discussed previously. It also raises the following question.

What happens when the children leave the relatively stimulating school environment? Our cross-sectional data suggests a regression in concept-attainment from adolescence to adulthood, which, if verified, would be of utmost interest for both theory and practice. The longitudinal data suggests

---

[1] "Il nous semble justifié de conclure à une forme particulière de conservation à 7-8 ans qui n'aurait pas un statut opératoire complet, et qui ne peut être considerée comme le symptôme d'une structure impliquant les opérations additives et multiplicatives nécessaires à la compréhension de la réversibilité."

rather the more plausible hypothesis that the adults of today had never acquired the concepts, whereas those adoloscents of today who have, are unlikely to 'lose' them as they become adults.

7. Seriation

The results for this test are presented in two different ways:

1. In Table 10 and Fig. 13 and 14, the results for the two parts of the test are given separately as the percentage of subjects classified according to the four scoring conventions (see chapter 7). This follows the format in which the results of the Genevan standardization have been published (Piaget and Inhelder, 1963b; p.130).

2. The performances on both parts of the test are then combined into stages. The percentage of subjects classified at each stage is given in Table 11; the percentage of those attaining stage 3 is represented graphically in Fig. 15.

The first method of presentation enables us to compare the Canberra with the Geneva results: the fit is extremely close for both parts of the test.

The results of the Aboriginal samples present the following interesting findings:

1. In contrast with the conservation tasks, seriation is achieved by all or nearly all older Aboriginal subjects. In terms of the differentiation we have made in chapter 1,A between c-type and d-type ogives, the results of the conservation tasks conform to the latter, whereas the results of the seriation test are a case of the former. This is particularly clear for the Hermannsburg group.

2. In contrast with the conservation tasks, the performance of the younger children in the Areyonga sample is actually superior to that of the younger children in the Hermannsburg sample, especially on part 2 of the test. If our previous hypothesis is true, this could, of course, be a reflection of the perceptual rather than operational approach.

In the overall results, however, the same general trends as observed before are present, namely a clear separation between the European and Aborigianl performance, and a less

TABLE 10

SERIATION : PERCENTAGE OF SUBJECTS CLASSIFIED ACCORDING TO THE FOUR SCORING CONVENTIONS ON BOTH PARTS OF THE TEST

Age		4	5	6	7	8	9	10	11	12	13	14	15	16
Geneva														
Part 1	A	0	9	34	63	95								
	B	0	12	25	15	5								
	C	47	61	34	22	0								
	D	53	18	7	0	0								
Part 2	A	0	9	28	63	95								
	B	20	32	54	37	5								
	C	20	16	12	0	0								
	D	60	43	6	0	0								
N		15	34	32	32	21								
Canberra														
N = 10 per age														
Part 1	A		0	50	70	100								
	B		30	30	30	0								
	C		40	20	0	0								
	D		30	0	0	0								
Part 2	A		0	30	70	100								
	B		30	50	0	0								
	C		20	20	30	0								
	D		50	0	0	0								
Hermanns-burg														
Part 1	A			0	0	20	50	80	80	90	100			100
	B			0	40	40	50	20	20	10	0			0
	C			60	50	40	0	0	0	0	0			0
	D			40	10	0	0	0	0	0	0			0
Part 2	A			0	10	30	20	40	60	90	100			100
	B			30	40	20	70	30	20	10	0			0
	C			50	40	50	10	30	20	0	0			0
	D			20	10	0	0	0	0	0	0			0

Cont'd

TABLE 10 (Cont'd

SERIATION

Age		4	5	6	7	8	9	10	11	12	13	14	15	16
Areyonga														
Part 1	A				12.5		25		44		73		100	
	B				12.5		33		33		13		0	
	C				25		25		22		7		0	
	D				50		17		0		7		0	
Part 2	A				37.5		42		44		33		75	
	B				25		42		33		47		25	
	C				37.5		17		11		13		0	
	D				0		0		11		7		0	
N					8		12		9		15		8	

FIG. 13 SERIATION (Part 1)

Percentage of subjects scoring 'A'

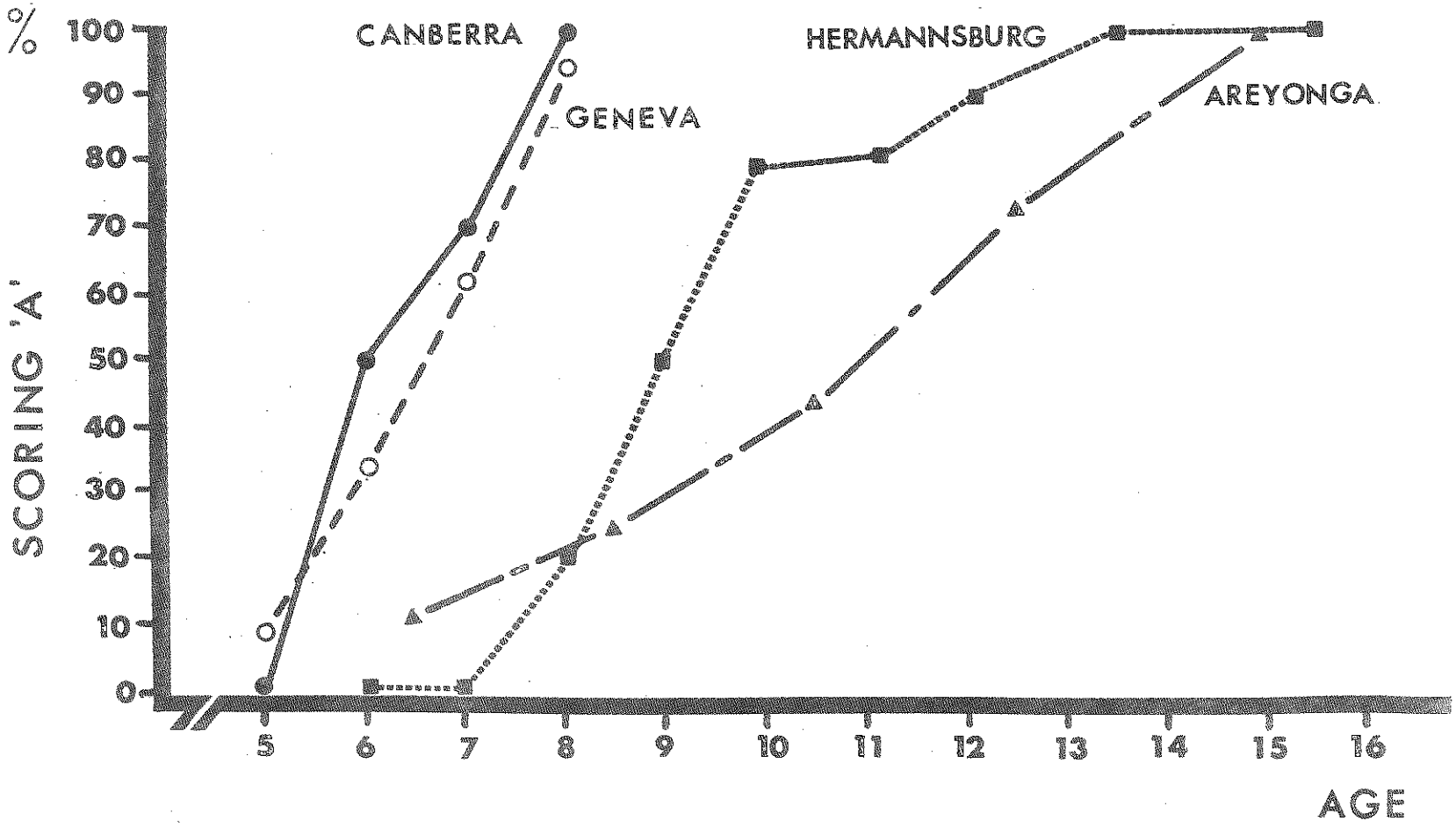


FIG. 14 SERIATION (Part 2)

Percentage of subjects scoring 'A'

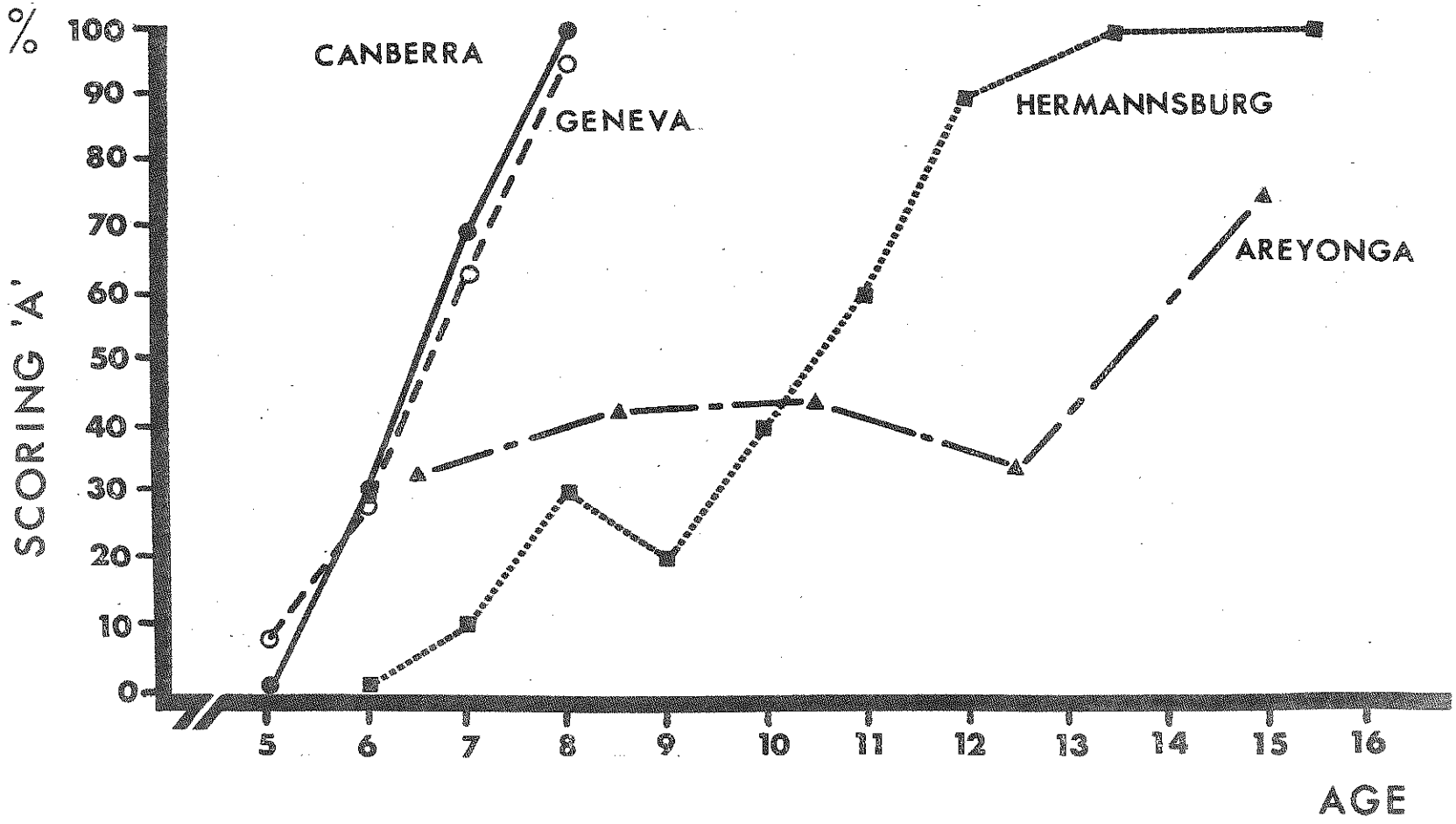
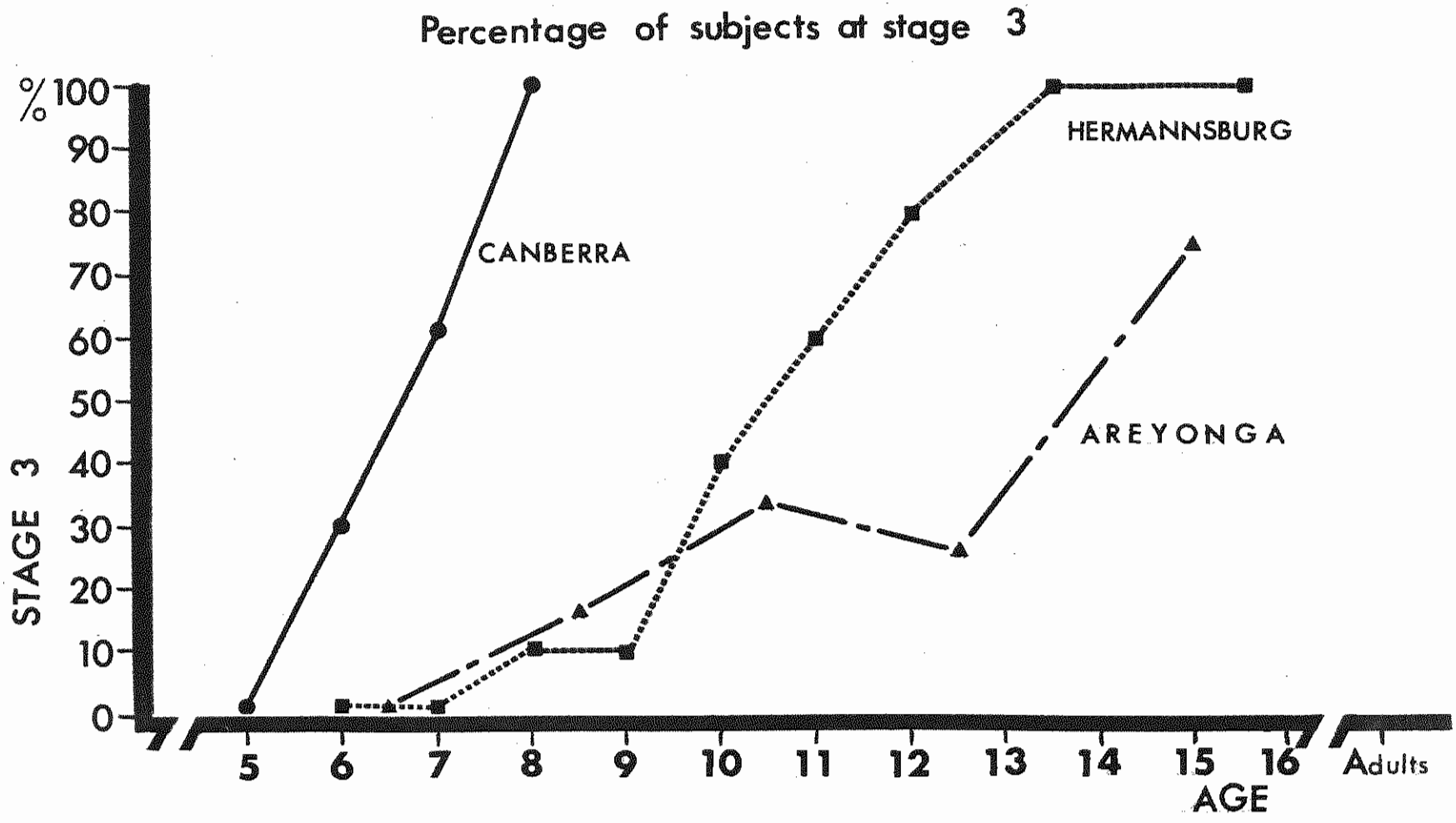


TABLE 11

SERIATION : PERCENTAGE OF SUBJECTS CLASSIFIED AT EACH STAGE

Age	5	6	7	8	9	10	11	12	13	14	15	16
Canberra												
N = 10 per age												
3	0	30	60	100								
2	30	50	30	0								
Rev. 2b	0	0	10	0								
Rev. 2a	10	10	0	0								
1	60	10	0	0								
Hermannsburg												
N = 10 per age												
3		0	0	10	10	40	60	80	100		100	
2		0	30	40	80	60	40	10	0		0	
Rev. 2b		0	10	0	10	0	0	10	0		0	
Rev. 2a		30	30	30	0	0	0	0	0		0	
1		70	30	20	0	0	0	0	0		0	
Areyonga												
3			0		17		33.3		27		75	
2			12.5		33		33.3		53		25	
Rev. 2b			12.5		8		11.1		7		0	
Rev. 2a			37.5		25		11.1		0		0	
1			37.5		17		11.1		13		0	
N			8		12		9		15		8	

FIG. 15 S E R I A T I O N



marked, but definite superiority of the Hermannsburg over the Areyonga performance.

Another finding concerning the relative difficulty of the two parts of the test is of little importance to our main argument, but is interesting as such, especially insofar as the relationship between 'perception' and 'operation' is concerned.

Piaget has claimed that part 2 is more difficult than part 1, since the successful inserting of the sticks can be seen as the mark of a complete and flexible handling of the asymmetrical relations involved, Part 1 being supposed to have a greater perceptual component (Piaget and Szeminska, 1941, pp.162-163; Piaget, 1952, p.130).

However, the notion that part 1 is more subject to a perceptual solution than part 2 could be questioned. Is it not true that, on part 2, the whole configuration of the 'staircase' is immediately given to the child, whereas on part 1, he has to construct it himself (with the exception, in our technique, of being allowed to look at it for some time)? Piaget objects that "a completed figure constitutes a closed configuration and it is therefore more difficult to compare a new element with those already forming part of this global structure than to measure it against isolated elements" (Piaget, 1952, p.130).

On the other hand, Piaget and Inhelder, in their study of visual imagery (1963a; 1966), have shown that a 'global anticipation of the seriation is possible at the pre-operational stage, whereas an 'analytic anticipation' seems to be linked to the concrete operational structures. Such a 'global anticipation image' is, if we interpret Piaget and Inhelder correctly, an interiorised perceptual configuration, whereas the 'analytic anticipation image' is an internal representation of actions. The former may well assist in the solution of part 2 (even if it is then not a 'truly operational' solution), whereas the latter seems to be closer to the operations involved in part 1.

It thus seems just as reasonable to argue that a greater reliance on perception would facilitate the solution of part 2, relatively to part 1.

We could further hypothesize that there are different ways of solving the seriation task. It is quite natural that the child, at an early developmental level, should approach the problem perceptually, as is evidenced by his reactions to many other tasks. This perceptual approach usually leads him into the errors which are so typical of the pre-operational period (for example, non-conservation), but in this case, it could well help him to solve part 2 of the test.

Possibly this perceptual solution should therefore not be considered to indicate concrete operational thinking.

At an intermediate developmental level, but still within the pre-operational stage, it is likely that the child would progressively discard his perceptual approach and turn to an attempt at an operational solution. For these children, then, part 2 would become more difficult than part 1, just as Piaget has described.

At a third level, once the child has acquired concrete operational thought in respect of this problem he is able to solve both parts equally well, and the results of parts 1 and 2 can be expected to be the same.

Our results do not confirm Piaget's contention: part 1 appears to be easier than part 2 only for the 6 year-olds in Canberra, the 9-11 year-olds in Hermannsburg and the 12-16 year-olds in Areyonga. In most other instances the two parts seem to be of the same difficulty; in the Hermannsburg sample, the results of part 2 are even superior to those of part 1 for the age group 6-8 years, and in Areyonga this is so from age 6 to 10/11.

This is not only true when the ogives for the overall results are considered, but also if we look at the performance of individual subjects.

The fact that some of these succeed on part 2 but not on part 1 is reflected in the number of children who had to be classified at the 'reversal stages' (Rev. 2a and Rev. 2b; see Table 11). The percentage of these reversals is especially high in the younger age groups in the Aboriginal samples, but some cases have also occurred in the European sample.

If we turn to the Swiss results, we notice that the difference in difficulty between the two parts has not been verified either. Moreover, a close inspection of the percentages leads one to think that at least a few isolated cases of reversals (of the type we have labelled 'Rev. 2a') must have occurred.

On the other hand, our data fits our hypothetical elaboration extremely well, and could be interpreted in the following way:

Level 1 would occur at about age 5 and below in the European group, from 6 to 8 in Hermannsburg, and from 6 to about 11 in Areyonga. (These ages being, of course, average values, resulting from a comparison of Fig. 13 and Fig. 14). It is at these ages that part 2 of the test is generally easier than part 1. The differences between the samples reflect their differential level of operational development.

Level 2, where the solution of part 2 is more difficult than that of part 1, would be attained at approximately age 5 or 6 in Europeans (although this study cannot provide data for this, since the younger ages were not studied), age 9 to 12 in Hermannsburg, and age 12 to 15(+) in Areyonga.

As evidenced by the equal difficulty of both parts, level 3 would occur at age 7-8 in our Canberra sample, 12 to 15(+) in Hermannsburg, but is not reached in Areyonga within the age-range of our study.

It should be noticed that we are speaking in terms of levels, and not stages, because our hypothesis is based on interaction between the child's tendency to adopt a perceptual approach and his operational level, and not on clearly defined structural properties of his reasoning. These levels could well be integrated into a slightly modified version of Piaget's stages on this test, but such a reformulation is outside the range of this study. It would have to be based on further experimental evidence, especially in regard to the behaviour of very young European children on this task.

Alternatively, the 'reversals' could be due to the simple fact that part 2 is always preceded by part 1. Whether such an order-effect is interfering could easily

be established by an experiment in which the order of the two parts were counterbalanced. This was not done in the present study because we wanted to follow as closely as possible the procedure standardized in Geneva.

Qualitative analysis

The reactions to this test of both European and Aboriginal children were exactly those described by Piaget, with the two following qualifications:

1. Almost none of the children arranged the sticks in pairs, which is described as one of the most typical reactions of stage 1.

2. As shown in Table 12, some of the children who were clearly at the concrete operational stage did not use what Piaget has called the 'operational' method (here called A1; see chapter 3, section B,5).

Significantly more Aborigines (Hermannsburg and Areyonga combined) than Europeans use the 'perceptual' method (A2) rather than the 'operational' one (see Table 12b).

We consider that the 'perceptual' method (A2), contrary to the 'random' method (A3), should not necessarily be regarded as an inferior way of achieving seriation. As a matter of fact, the perceptual method represents a considerable achievement, since the sticks have to be compared in their random positions, without the help of a common base. Piaget (1961) remarked that this sort of comparison was easier for children than for adults, because the former have not yet developed a system of coordinates which makes the comparison of slants (inclination) easier, but the comparison of lengths in various orientations more difficult.

Our results on two of the spatial tests (see chapter 4, section B) show that Aboriginal children do not develop a system of coordinates as readily as Europeans do. This may help them in using the perceptual method for seriation, but does not preclude the hypothesis of a generally stronger perceptual orientation in Aborigines:

Reliance on visual perception seems to be a natural cultural adaptation for hunting and gathering people. It could be expected that Aborigines would tend to apply this

TABLE 12

SERIATION ; Part 1 :

METHODS USED FOR SUCCESSFUL SERIATION

(a) General results

	A1	A2	A3	Σ	(Tot.N)	(Age range)
Canberra	7	5	10	22	40	5 - 8
Hermannsburg	6	21	25	52	90	6 -16
Areyonga	0	21	6	27	52	6 -16
Σ	13	47	41	101		

$\chi^2 = 21.538$ ($p < .001$)

(b) Comparison of operational (A1) and perceptual (A2) methods

	A1	A2	Σ
European	7	5	12
Aboriginal	6	42	48
	13	47	60

$\chi^2 = 11.880$

$p < .001$ (df.1)

(c) Comparison of operational (A1) and random (A3) methods

	A1	A3	Σ
European	7	10	17
Aboriginal	6	31	37
	13	41	54

$\chi^2 = 3.942$

$p < .05$ (df.1)

perceptual approach, and perceptual skills not only to the problems they have been used to solving, but also when confronted with a novel situation.

B. SPATIAL TESTS

1. Orders

The results of the three parts of this test are presented in Table 13.

The linear order is by far the easiest of the sub-tests; all subjects, except one at Areyonga being able to copy the model in the correct order.

In all samples the sub-test of circular order is easier than that of reverse order, although the differences are not large. This confirms the order of difficulty described by Piaget (1948, 1956). This order is not only verified by the proportion of subjects succeeding on the three sub-tests, but also for each individual (except for two subjects who succeeded on part 2 but failed part 3; these were classified as being at a stage called 'Intermediate reversed').

In Table 14, the three sub-tests have been combined into stages (see Chapter 3, section C). Fig. 16 shows the percentage of subjects reaching stage 3.

The Canberra results are similar to those obtained in Geneva, but not yet published (Vinh Bang, in prep.). In contrast to the results obtained with the logico-mathematical tests, the difference between the European and the Aboriginal results, and between the Hermannsburg and Areyonga results, is much less. Only at ages 6 and 7 is there a noticeable difference between the three groups.

The qualitative reactions to the test were the same in all samples and correspond exactly to those described

TABLE 13

ORDERS : PERCENTAGE OF SUBJECTS CLASSIFIED ACCORDING TO THE SCORING CONVENTIONS ON THE THREE PARTS OF THE TEST

Age		5	6	7	8	9	10	11
Canberra								
N = 10 per age								
1. Linear								
	A	100	100	100	100	-	-	
2. Reverse								
	A	20	80	90	100	-	-	
	B	0	0	10	0			
	C	80	20	0	0			
	D	0	0	0	0			
3. Circular								
	A	30	90	50	100	-	-	
	B	40	0	40	0			
	C	30	10	10	0			
	D	0	0	0	0			
Hermannsburg								
N = 10 per age								
1. Linear	A	100	100	100	100	100	-	
2. Reverse	A	50	70	80	100	100	-	
	B	10	20	20	0	0		
	C	10	10	0	0	0		
	D	30	0	0	0	0		
3. Circular								
	A	70	90	90	100	100	-	
	B	20	10	10	0	0		
	C	10	0	0	0	0		
	D	0	0	0	0	0		

Scoring:

A. Immediate success

B. Trial and error method, finally correct result.

C. Partial success

D. Complete failure

Cont'd

TABLE 13 (Cont'd)

ORDERS:

Age	5	6	7	8	9	10	11
Areyonga							
1. Linear							
A			87.5	100		100	
B			12.5	0		0	
2. Reverse							
A			25	92		100	
B			37.5	0		0	
C			12.5	8		0	
D			25	0		0	
3. Circular							
A			75	100		100	
B			12.5	0		0	
C			12.5	0		0	
D			0	0		0	
N			8	12		8	

TABLE 14

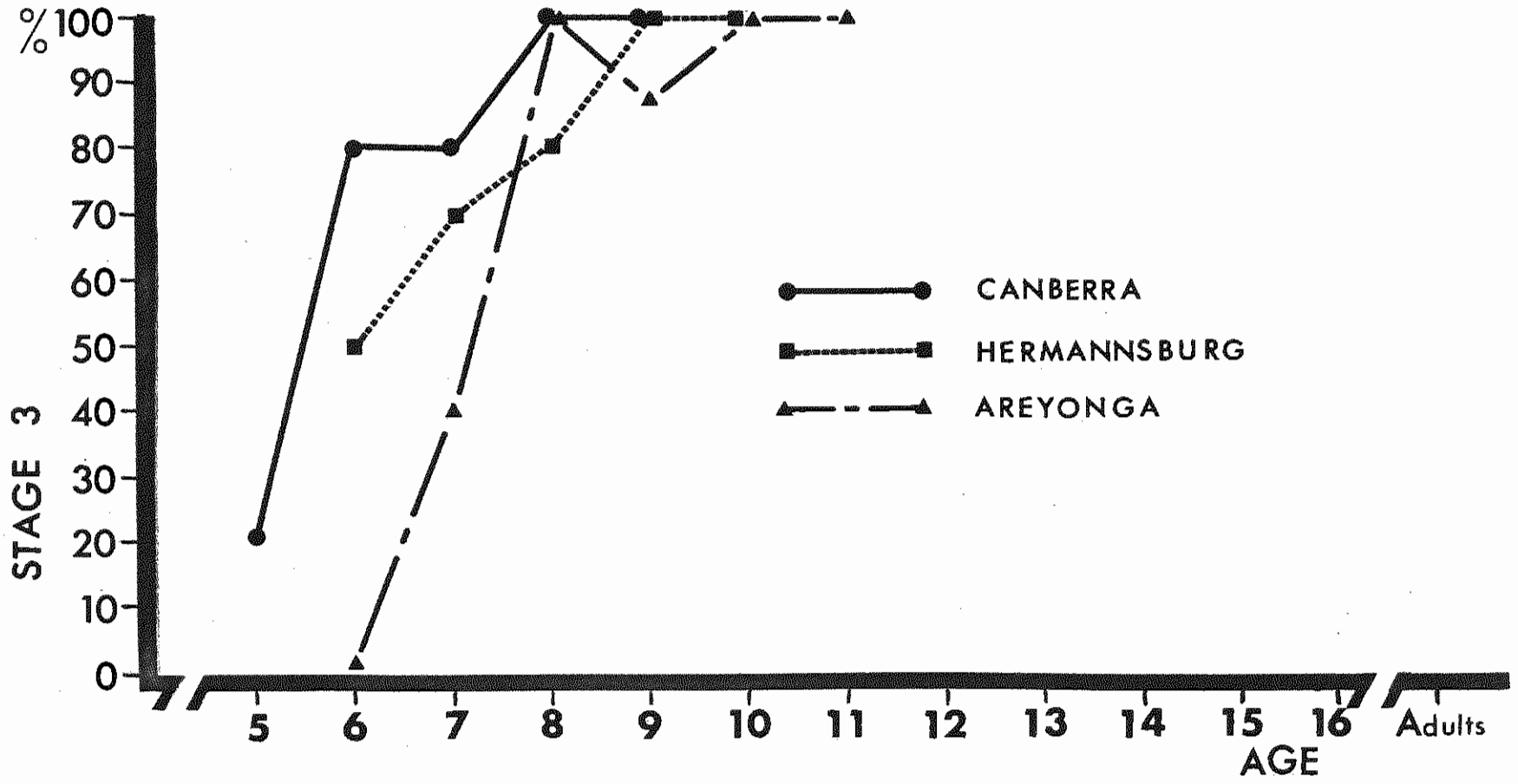
ORDERS : PERCENTAGE OF SUBJECTS CLASSIFIED AT EACH STAGE

	Age	5	6	7	8	9	10	11
	Stages							
Canberra								
N = 10 per age	3	20	80	80	100	100	-	-
	Int.	0	0	20*	0	0		
	2b	50	20	0	0	0		
	2a	30	0	0	0	0		
Hermannsburg								
N = 10 per age	3	-	50	70	80	100	100	-
	Int.		10	20	20	0	0	
	2b		30	10	0	0	0	
	2a		10	0	0	0	0	
Areyonga								
	3		0	40	100	88	100	100
	Int.		33.3*	40	0	0	0	0
	2b		66.6	10	0	12	0	0
	2a		0	0	0	0	0	0
	N		3	5	4	8	6	2
Areyonga								
Ages grouped								
	3			25		92		100
	Int.			37.5*		0		0
	2b			37.5		8		0
	2a			0		0		0
	N			8		12		8

* indicates one subject classified at stage "Interm. reversed' (see text).

FIG. 16 O R D E R S

Percentage of subjects at stage 3



described by Piaget.[1]

The results of the test of Orders confirm Piaget's hypothesis that the topological properties of space are acquired early in the development of the child. "The existence of initial topological structures having nothing to do with either metrics or the coordination of viewpoints is fairly normal; such forms of spatial organization express the most general properties of space and the properties most dependent on the conditions of the subject's own actions" (Piaget, introduction to Laurendeau and Pinard, 1968).

In an analysis of the spatial properties of various items of Cattell's "culture-free" test, Kidd and Rivoire (1965) found "that elementary topological properties are basic to all of the items ... and that, in culturally-weighted items, the basic concepts are obscured by more complex aspects of spatial perception. These data suggest that the most elementary forms of spatial perception (topology) are common to all cultures" (Kidd and Rivoire, 1965, p.108). The results of the present study also suggest that the topological properties of space are acquired at about the same time, and at the same rate, by European and by Aboriginal children.

2. Rotation

The results of the test of the rotation of a model landscape are set out in Table 15 and Fig. 17.

Standardized data for Swiss children are not available, but Piaget mentions that "out of 41 children taking part in these experiments, we did not find any below the age of 7 who could determine the 15 positions at all accurately,

---

[1] At the lower ages the test was most popular with both boys and girls. The only difference between the European and the Aboriginal children was that the latter continued to be interested in the test at ages 10 and 11, which would not be the case with European children. An interesting observation is that the European children, when left to play alone at the end of the test, liked to put those items on the washing line which had not been used during the test; Aboriginal children, on the other hand, although they were just as delighted with the game, tended to be more hesitant, and many repeated the pattern used in the test.

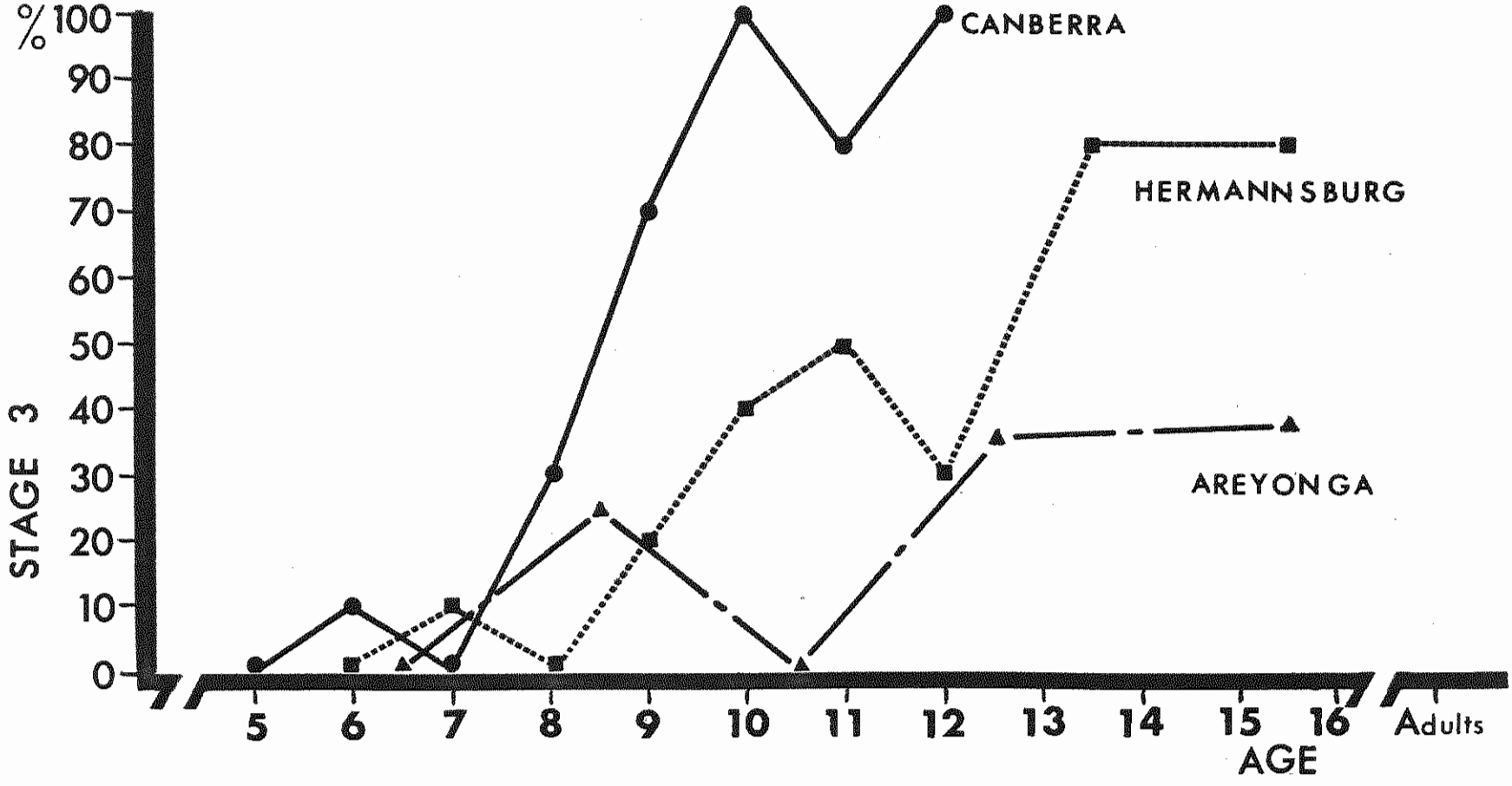
TABLE 15

ROTATION : PERCENTAGE OF SUBJECTS CLASSIFIED AT EACH STAGE

	Age	5	6	7	8	9	10	11	12	13	14	15	16
	Stages												
Canberra													
N = 10 per age	3	0	10	0	30	70	100	80	100				
	2b	40	50	70	70	30	0	20	0				
	2a	40	30	30	0	0	0	0	0				
	1	20	10	0	0	0	0	0	0				
Hermann-sburg													
N = 10 per age	3		0	10	0	20	40	50	30	80		80	
	2b		50	40	70	80	60	50	70	20		20	
	2a		40	40	30	0	0	0	0	0		0	
	1		10	10	0	0	0	0	0	0		0	
Areyonga													
	3			0		25		0	36		37.5		
	2b			75		58		67	64		62.5		
	2a			0		17		33	0		0		
	1			25		0		0	0		0		
	N			8		12		9	14		8		

FIG.17 ROTATION

Percentage of subjects at stage 3



whereas between 7 and 8 years of age correct answers are obtained for all positions". (Piaget, 1956, p.425).

In our Canberra sample, all 7 year-old children were still at stage 2; after that age the cumulative frequency curve of children reaching stage 3 rises rather sharply, but not as suddenly as Piaget has found. It is not until 10 years of age that a 100% stage 3 performance is found, and this is followed by a small drop at age 11. This does not necessarily mean that the Canberra children develop the concepts of projective and euclidean space more slowly than Swiss children, but probably that we have been more stringent than Piaget in the scoring and/or in the application of the procedures (in our case, for example, the screen was always used, whereas this was not the case in the original work). Other differences - for example, the choice of the positions - render a detailed comparison with Piaget's results difficult.

In contrast to the results on the previous test, Aboriginal performance is again relatively poor. If we look at the proportion of children reaching stage 3, the 50% limit is never reached by the Areyonga group, although at Hermannsburg a steady 80% is reached after the age of 12 years.

It should be noticed that most Aboriginal children after the age of 8 or 9 have reached stage 2b, whereas in the conservation tasks we find that the proportion of children classified at the transitional stage does not increase markedly with age.

Thus it seems that many Aboriginal children are able to achieve this progressive coordination between two variables in the case of this spatial task, but not in the case of the conservation problems.

Again we found that the reactions to the test of the Aboriginal children were exactly the same as those of the Australian Europeans and as those described by Piaget. The types of errors which occurred were identical, and so was the strategy used to solve the problem.

3. Horizontality

The results are presented in Table 16 and in Fig. 18. The test proves to be very difficult. Only at age 11 can all Canberra children solve the problem, and this only after learning on part 2 has occurred. Had we asked for an immediate understanding (stage 3b), only 70% at age 11 and 50% at age 12 would be considered to have reached the concrete operational stage (Table 16).

This shows that the task is not greatly influenced by previous experience: it is quite clear that any child (European or Aboriginal) aged 9 or 10 would have had countless opportunities to witness water (or, more likely, some other liquid) being poured from a bottle, a glass or a cup. Nevertheless, he does not seem to have noticed that the level of the liquid always stays horizontal. Before the child has the conceptual framework to understand the phenomenon, he can watch it time and time again without being able to draw the necessary conclusion. This is evident in our 8 to 10 year-old Europeans, who can perfectly well copy the level of the water in all positions (part 2, Table 16), but revert to erroneous drawings on part 3 of the test.

The Areyonga and Hermannsburg curves are not noticeably different, although the Hermannsburg performance seems to be better at ages 10 to 13, and the Areyonga performance after that age. This cross-over becomes clear if we look at the percentage of subjects who improve their performance during the test (Table 16). In Hermannsburg, it is the 10 to 12 year-olds who seem to take advantage of part 2, whereas adolescents and adults succeed on part 2, but revert mainly to the Intermediary stage on part 3. In Areyonga, on the other hand, very little improvement over the 3 parts of the test occurs up to the age of 12/13, whereas older children and adults show a relatively poor performance on part 1, but succeed on part 2 and are able to learn through this procedure.

This is the only case in all the experiments of this study where adults perform better than the older school-children and the only case where the low-contact group

TABLE 16

HORIZONTALITY : PERCENTAGE OF SUBJECTS CLASSIFIED AT EACH STAGE ON THE THREE PARTS OF THE TEST

	Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.
Canberra N = 10 per age														
Part 1 (A)	(3b*	0	0	0	30	10	20	70	50					
	(Int.	10	20	30	40	70	70	30	50					
	(2b	30	10	50	30	20	10	0	0					
	(2a	60	50	20	0	0	0	0	0					
	(1	0	20	0	0	0	0	0	0					
Part 2 (C)	(3	0	40	60	60	90	80	30	50					
	(Int.	50	50	40	10	0	0	0	0					
	(2b	20	10	0	0	0	0	0	0					
	(2a	20	0	0	0	0	0	0	0					
	(1	10	0	0	0	0	0	0	0					
Part 3 (AC)	(3a	0	10	20	30	40	50	30	40					
	(Int.	10	30	60	40	50	30	0	10					
	(2b	30	40	20	0	0	0	0	0					
	(2a	60	20	0	0	0	0	0	0					
	(1	0	0	0	0	0	0	0	0					
A + AC	3a + 3b	0	10	20	60	50	70	100	90					
Hermannsburg N = 10 per age														
Part 1 (A)	(3b	0	0	20	0	20	10	0	30		30		40	
	(Int.	0	10	10	50	30	60	70	40		50		50	
	(2b	60	20	30	30	50	20	30	30		10		10	
	(2a	30	70	30	20	0	10	0	0		10		0	
	(1	10	0	10	0	0	0	0	0		0		0	

Cont'd

* Subjects classified at stage 3b were not submitted to parts 2 and 3; thus the percentages on the latter two parts do not necessarily add up to 100.

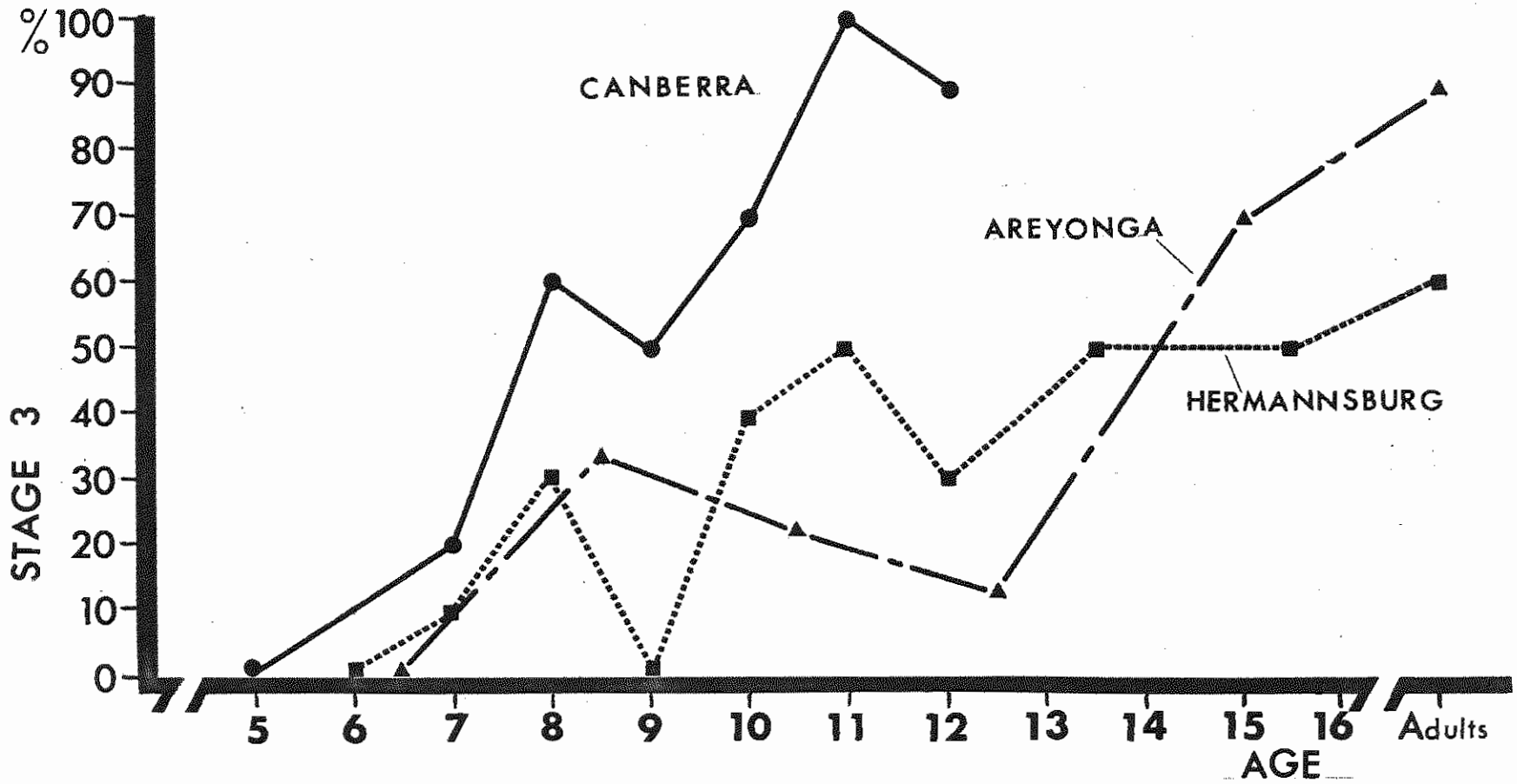
TABLE 16 (Cont'd)

HORIZONTALITY

	Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.
Hermannsburg														
	(3		0	10	20	40	20	50	70	50		70	60	
Part	(Int.		30	70	20	50	60	30	30	20		0	0	
2 (C)	(2b		40	20	40	10	0	0	0	0		0	0	
	(2a		30	0	0	0	0	10	0	0		0	0	
	(1		0	0	0	0	0	0	0	0		0	0	
	(3a		0	10	10	0	20	40	30	20		20	20	
Part	(Int.		30	60	20	70	40	30	70	50		50	40	
3 (AC)	(2b		50	20	40	20	20	10	0	0		0	0	
	(2a		20	10	10	10	0	10	0	0		0	0	
	(1		0	0	0	0	0	0	0	0		0	0	
A + AC	3a + 3b		0	10	30	0	40	50	30	50		50	60	
Areyonga														
	(3b		0		17 (16.6̄)		0		7 (6.6̄)			30	20	
	(													
Part	(Int.		25		25		56		33			30	70	
1 (A)	(2b		0		17		11		40			40	10	
	(2a		75		33		33		20			0	0	
	(1		0		8		0		0			0	0	
	(3		0		25		44		40			60	80	
Part	(Int.		50		58		44		53			10	0	
2 (C)	(2b		0		0		12		0			0	0	
	(2a		50		17		0		7			0	0	
	(1		0		0		0		0			0	0	
	(3a		0		17 (16.6̄)		22		7 (6.6̄)			40	70	
Part	(Int.		50		25		56		60			20	10	
3 (AC)	(2b		0		17		22		20			10	0	
	(2a		50		25		0		7			0	0	
	(1		0		0		0		0			0	0	
A + AC	3a + 3b		0		33		22		13			70	90	
	N		8		12		9		15			10	10	

FIG.18 HORIZONTALITY

Percentage of subjects at stage 3 (a & b)



(Areyonga) performs better than the high-contact one (Hermannsburg). It is an exception, and should certainly be viewed as such, but it suggests that, in future research, learning experiments could yield valuable information. In particular it would be interesting to compare a learning task of spatial operations, such as the present one, with one of the numerous learning experiments which have now been devised (with more or less success) for logico-mathematical operations, and especially for the conservation tasks. (e.g. Wohlwill & Lowe, 1962; Wallach & Sprott, 1964; Beilin, 1965; Gruen, 1965; Almy et al., 1966; Rothenberg & Orost, 1968; Roberts, 1970).

Qualitative analysis

Piaget's description of the stages for this test (see Chapter 3, section C,3) is partly based on the assumption that the different positions of the bottle are hierarchically ordered as to difficulty. The child first succeeds when the jar is inverted (stage 2b), and then when it is lying horizontally on its side (Intermediate stage), and finally when it is tilted (stage 3).

What, however, should be done with those who draw the water horizontal on the more difficult positions but not on the easy ones? And what causes these inversions?

Some of the inconsistencies are certainly due to fluctuations in attention, random answers, and other extraneous factors. They can usually be detected by questioning the child, by asking him to show the level by gestures, or by finding out whether he realizes that the drawing he made on different parts of the test are inconsistent. Due to linguistic difficulties, however, such questioning is not always successful with Aboriginal children and has to remain superficial.

It could also be that Piaget's stages, for this test, correspond to the majority of cases, but that exceptions do sometimes occur. Vinh Bang's standardization (in prep.) gives the figures for each position, and thus avoids the problem. The scoring procedure we have designed (see flow chart, Fig. 5b)overcomes the difficulty in a different way,

namely by taking into account, in some cases, only part of the information. In most cases, the stages determined in this way should correspond well to those of Piaget. Since the few inconsistencies which do occur are by no means restricted to the Aboriginal results, they are not of prime importance.

In fact, the reactions of the subjects in all three samples are almost identical. The only difference is that the older European children are able to generate a law ("It's always level"), and try to explain the phenomenon, whereas Aboriginal children and adults, be it because of verbal or conceptual difficulties, make no such attempt, even with the help of extensive questioning.

C. ORDER OF DIFFICULTY OF TESTS AND 'HORIZONTAL DÉCALAGES'

1. Order of difficulty of tests

Table 17a shows the rank-order of difficulty of the operational tests. There seemed to be no point in performing a Guttman scale analysis to determine whether the given series of tests conforms to an uni-dimensional scale, since there are no theoretical grounds to suppose that this should be so. Only the three tests of conservation of Q, W and V are hypothesized to be of increasing difficulty, and this question will be discussed in detail later in this chapter.

On the other hand it could be interesting to know whether the order of difficulty of the tests is the same for all three samples. The data relating to this question are summarized in Table 17b.

Although, at first glance, the order of difficulty of the tests appears to be quite different for the three groups, the coefficient of concordance is statistically significant. The order of difficulty of the tests is most similar for the two Aboriginal groups, but the correlation coefficient is also statistically significant at the .05 level for the Canberra/Areyonga comparison. This latter result is unexpected, since it indicates a greater similarity between the low contact and European groups than between the high contact and European groups.

TABLE 17a

ORDER OF DIFFICULTY OF OPERATIONAL TESTS

		Canberra		Hermannsburg		Areyonga	
		Proportion Stage 3	Rank-order	Proportion Stage 3	Rank-order	Proportion Stage 3	Rank-order
Tests:	Q	.65	2	.33	5	.20	7
	W	.39	9	.15	9	.10	10
	V	.29	10	.22	8	.18	8
	L_1	.52	4	.43	3	.26	4
	L_2	.44	8	.24	7	.14	9
	L_3	.60	3	.14	10	.21	6
	Ser.	.48	6.5	.44	2	.29	3
	Orders	.76	1	.80	1	.75	1
	Rotation	.48	6.5	.34	4	.22	5
	Horizontality	.50	5	.32	6	.37	2

TABLE 17b

SPEARMAN RANK-ORDER CORRELATIONS (ρ) AND
KENDALL'S COEFFICIENT OF CONCORDANCE (ω)
OPERATIONAL TESTS

Samples	ρ	Significance level
Canberra / Hermannsburg	.455	NS
Canberra / Areyonga	.624	.05
Hermannsburg / Areyonga	.734	.05
	ω	
Canberra / Hermannsburg / Areyonga	.9376	.01

For both Aboriginal groups, the test of seriation is relatively easy, whereas conservation of Q is relatively difficult. In the European group, a higher proportion of subjects achieve the conservation of W than the conservation of V, whereas in both Aboriginal groups, V appears to be somewhat easier than W. This finding will be discussed later in this section.

The test involving topological relations (Orders) was performed most successfully by all samples. The two other spatial tests, involving projective and/or euclidean relations, proved equally difficult.

For both Aboriginal groups, these spatial tests appear easier than the logico-mathematical tests, although this relationship shows up more clearly when the results in scores are compared (chapter 4, section E).

2. The constant order hypothesis and the quantity/weight reversal (de Lemos, 1966, 1969a/b)

As has been mentioned before, this study was in part designed to repeat some of the research carried out by de Lemos (1966, 1969a/b).

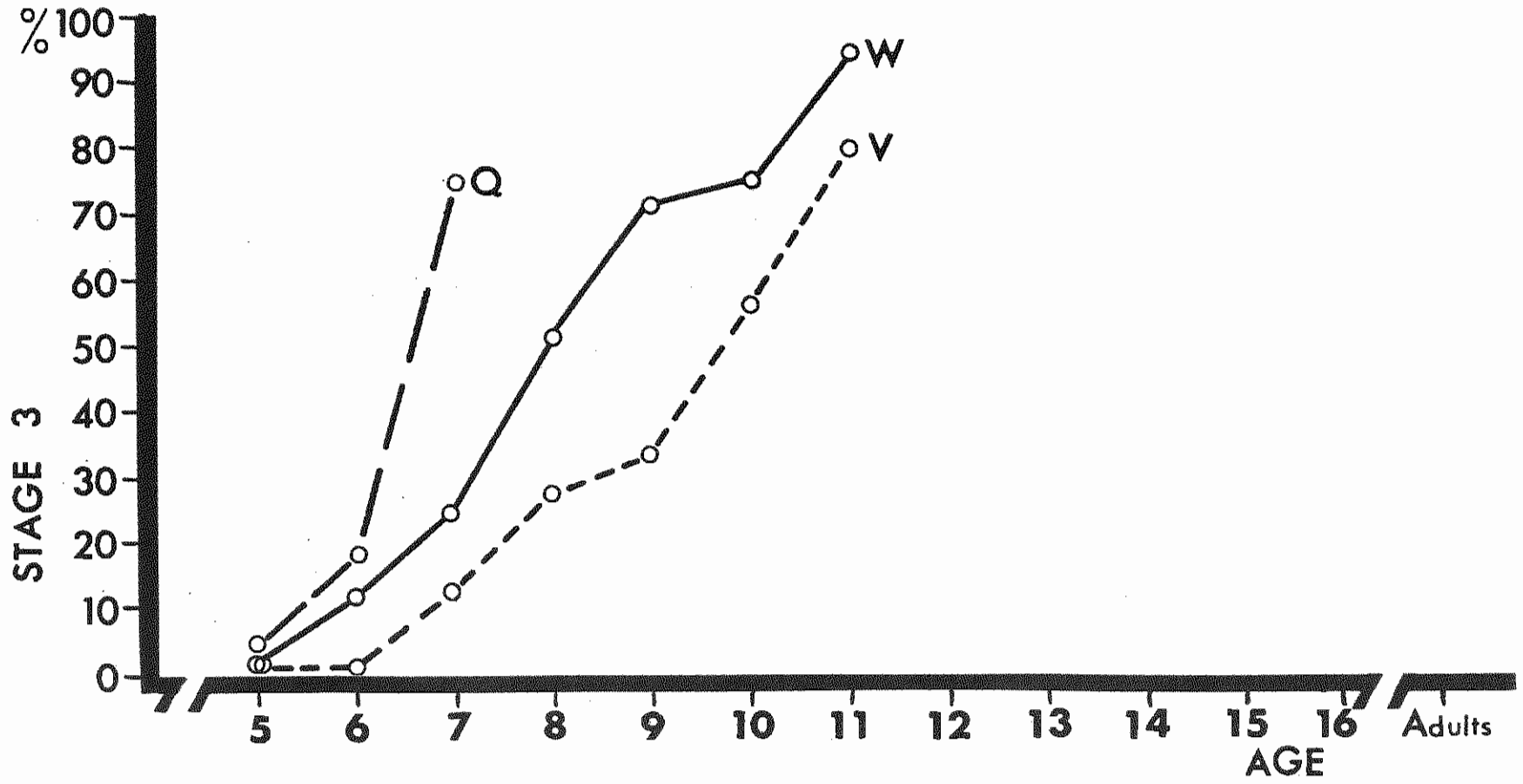
The results reported in section A of Chapter 4 show that the main findings of de Lemos' study are confirmed. In some cases, e.g. the conservations of Q and L, the agreement is almost perfect. For the conservation of W and V, however, the match is not quite as close, and this discrepancy warrants further discussion, since it bears on the reversal de Lemos found in the relative difficulties of the tests of Q and W.

The results obtained with the three conservation tasks, Q, W and V, in Geneva (Piaget and Inhelder, 1963b; Inhelder 1963) on 25 subjects per age, (Fig. 19), show the familiar pattern of Q being relatively easier than W, and both of these being acquired much earlier than V. This particular 'horizontal décalage' has been replicated in various western countries (e.g. Elkind, 1961; Lovell and Ogilvie, 1960, 1961a, 1961b; Uzgiris, 1964) as well as in non-western ones (for a discussion, see pp.17-19).

Of course, neither such a graph, nor the table of figures from which it is drawn, tell us if this order is

FIG. 19 GENEVA (Piaget & Inhelder, 1963 b)

Percentage of subjects conserving Q, W & V



constant for each individual as well as for the mean performance of the group; we shall come back to that point later in this section.

The results which we obtained in Canberra are similarly represented in Fig. 20. In the age-range 5-9 years, the results are similar to those reported from Geneva or elsewhere. At age 10 and 11, a drop in performance occurs for the conservation of W and to some extent V, (for a discussion of this phenomenon, see Appendix 2) but in spite of this, the order of difficulty of the 3 conservation tasks is confirmed.

In contrast, de Lemos found the conservation of W to be acquired earlier than Q and V in her two groups of Aboriginal children. The results of the Hermannsburg group are represented graphically in Fig. 21.

De Lemos (1966) suggested that "the reversal in the order of development of Q and W from the invariant order postulated may be due to the effects of experience on the tests" because conservation of W was always presented after the test of Q. De Lemos had no direct proof of this assumption, but the results of another test she used seemed to confirm the intervention of an order-effect: the conservation of number was one of the most difficult tests in the Hermannsburg group, where it was administered as the first test of the series, but it was one of the easiest tests for the Elcho group, where it was presented last. These findings led de Lemos to propose a series of conditions under which order-effects should be most effective (de Lemos, 1966, pp.292-295).

From Fig. 22 and 23, it can be seen that the reversal between Q and W is not found in the present study. Hypothesis 6 ("The order of difficulty usually found with the tests of conservation of Q and W is reversed in Australian Aborigines: W is found to be easier than Q") has to be rejected.

This failure to confirm de Lemos' findings could be attributed to one of three causes, or possibly to a combination of these.

FIG. 20 CANBERRA

Percentage of subjects conserving Q, W & V

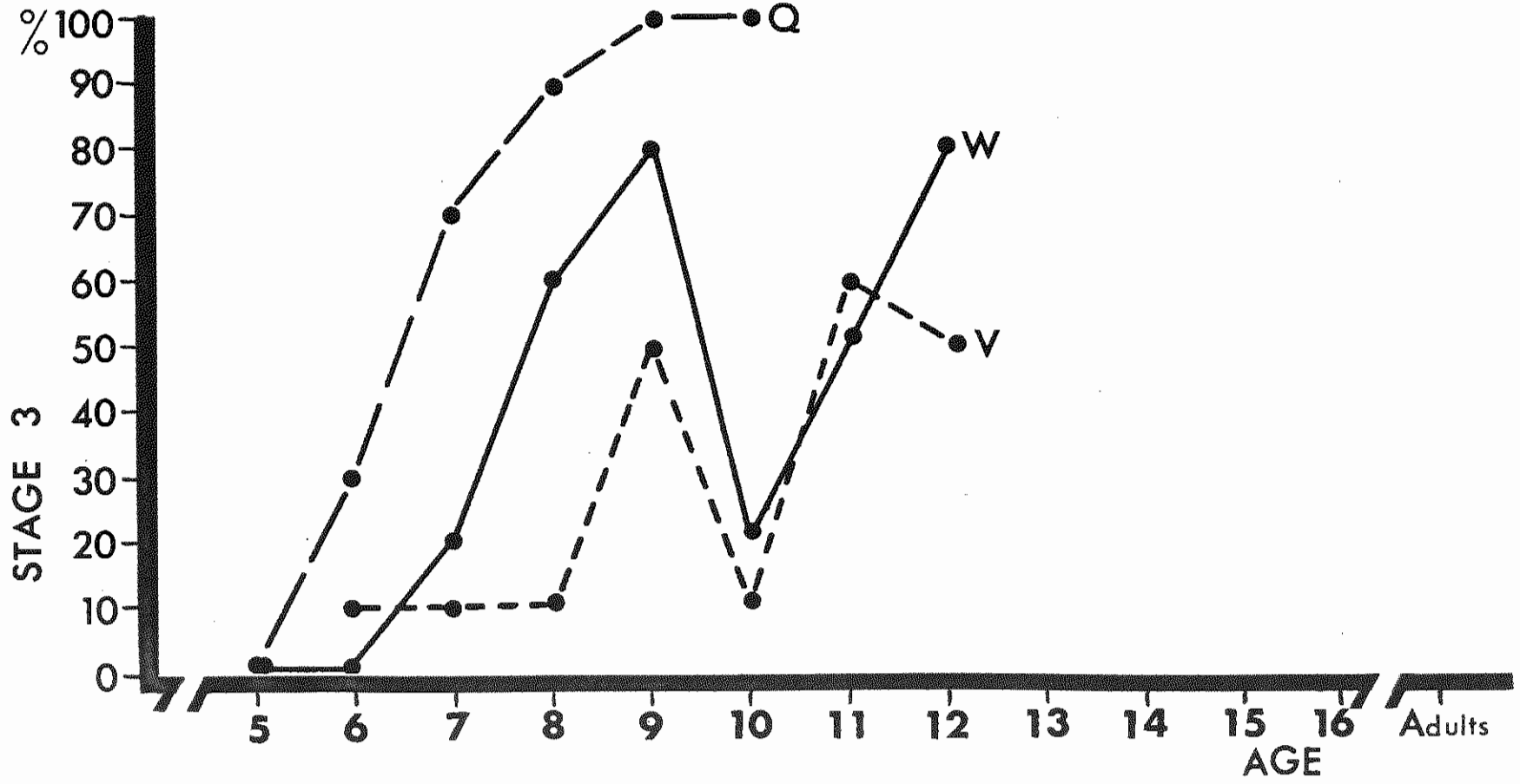


FIG. 21 HERMANNSBURG (de Lemos, 1966)

Percentage of subjects conserving Q, W & V

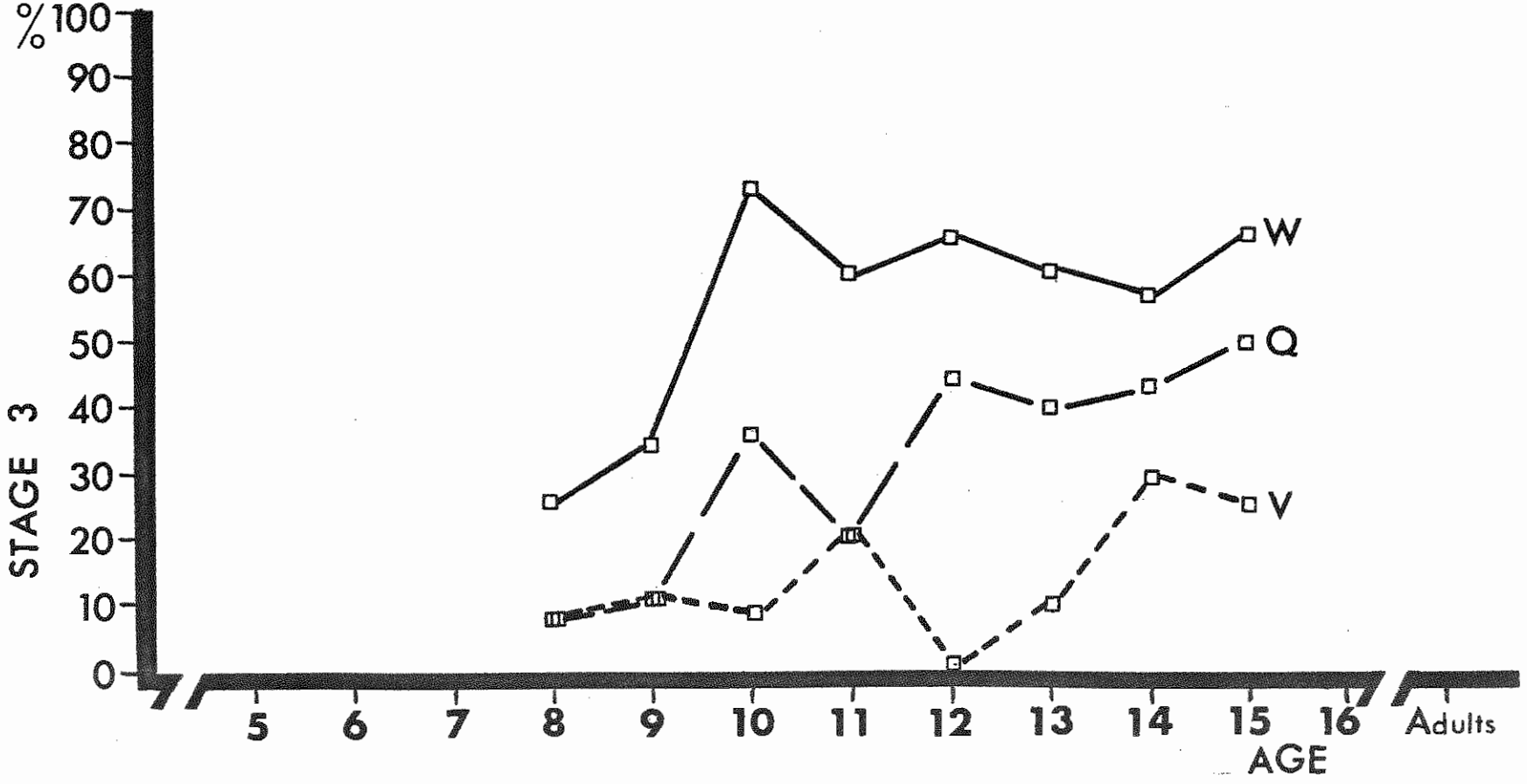


FIG. 22 HERMANNSBURG (Dasen)

Percentage of subjects conserving Q, W & V

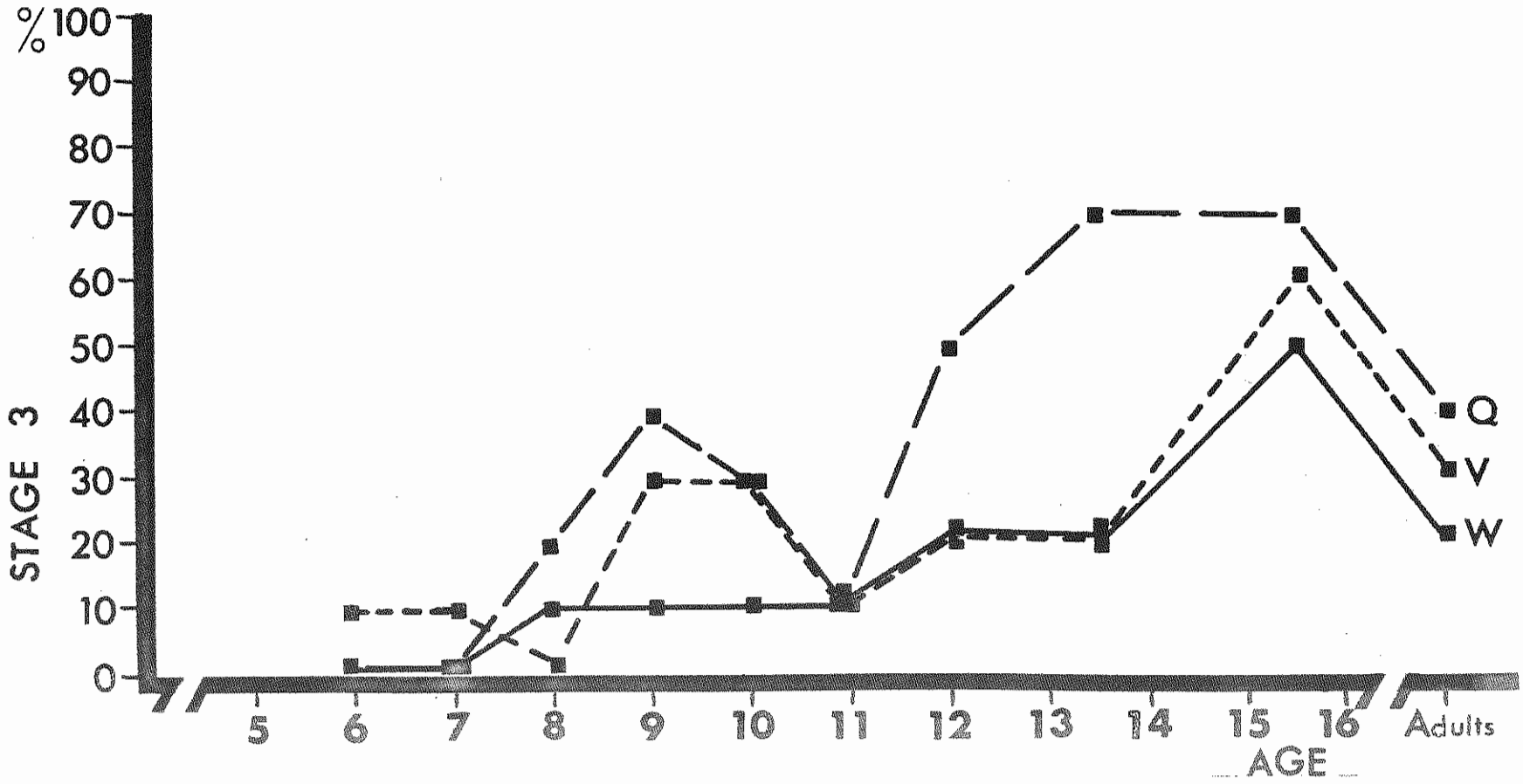
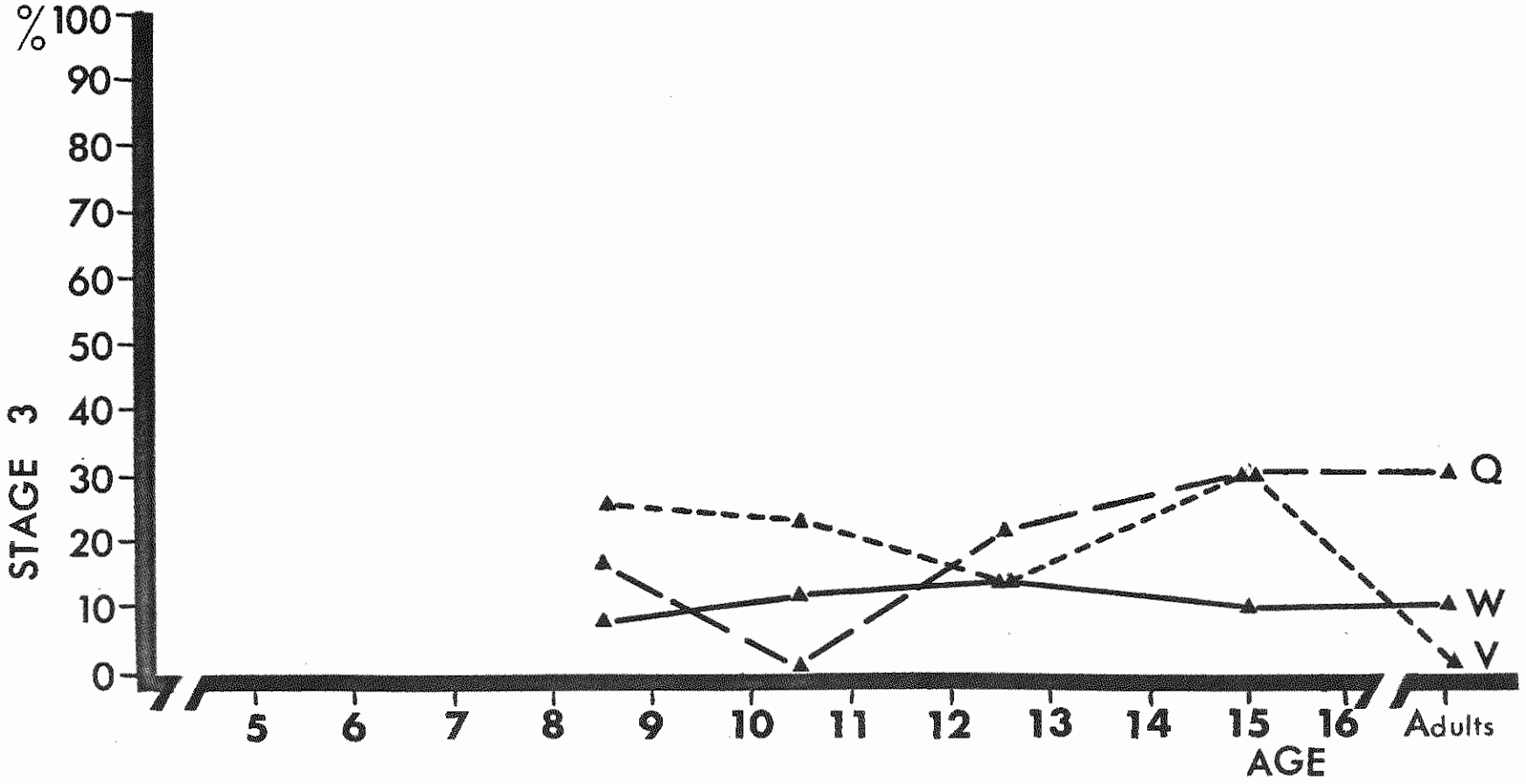


FIG. 23 AREYONGA

Percentage of subjects conserving Q, W & V



(a) Test content: it will be remembered that de Lemos used sugar for the conservation of Q, and tea in plastic bags for the conservation of W, whereas we used the classical materials (liquid and plasticine) in the present study.

(b) The reduction of an effect of separation of the testing sessions.

(c) The elimination of systematic order effects in the present study.

(a) Test content

In regard to test content, de Lemos (1968c) conducted an experiment which was partly intended to investigate this problem. She administered the three tests in a constant order (Q, W, V) to three groups of 13 six year-old European children, matched on intelligence and on a pre-test (de Lemos, 1967). The standard plasticine technique was used with one group. For the two other groups, the same materials as in the study of Aboriginal children were used.

The reversal of Q and W did not occur, but nor did the conservation of Q appear to be much easier than that of W:

> No difference in difficulty between the tests on Q and W was found, and there was no clear difference in the difficulty of these tests according to the materials used, although for the test on W slightly fewer children were successful on the plasticine balls than on the tea leaf, suggesting that these materials may present a more difficult problem. (de Lemos, 1968c, p.3).

(b) Separation of testing sessions

In the same study, (de Lemos, 1968c), the administration of the tests in one or in several sessions did not affect performances on conservation of Q and W, but:

> it was also found that fewer children succeeded on the test of V when all the tests were administered in a single session. This is contrary to what would be expected if there were a tendency for perseveration of responses to occur in this situation, and suggests that experience on the tests may be more effective in inducing conservation when the tests are separated by an interval of some days. (de Lemos, 1968c, p.3).

While this study does not enable us to draw any definite conclusions, it does suggest the following hypotheses:

1. That the difficulty of the tests is determined to some degree by the materials used. This effect seems to be greater for Aborigines than for Europeans.

2. That presenting the tests in sessions separated by a few days induces an improvement in performance on some tests. Again, these effects would be greater for Aboriginal than for European children.[1]

(c) Order-effects

The design of the present study, in which order was counter-balanced, enables us to formulate the following null-hypothesis: the proportion of subjects classified at the particular stages will not be related to the order in which the tests were taken.

Along with de Lemos (1966, p.292-3), we further hypothesize that the effects of experience would be more marked at a medium level of development, and could depend on the particular test involved.

It should be noted, however, that our hypothesis, at this stage, does not distinguish between the effects of the previous experience of the testing situation, and the previous experience on a particular conservation test.

The frequencies of occurrence of each stage were tallied for the three orders of presentation in 4 x 3 contingency tables. These were later collapsed into 2 x 3 contingency tables, by grouping NC and F scores on the one hand, and T and C scores on the other.

Chi square values were computed for two age groups, first separately and then combined, in each sample. The frequencies and chi-square values are presented in Table 18a.

The results in Table 18a provide no reason for a rejection of our null hypothesis for the Canberra sample, the chi-square values being all close to zero.

---

[1] In de Lemos' study, the interval between the administration of the tests in Hermannsburg was 10 to 14 days, whereas in the present study it was only 1 to 5 days. Should improvement be linearly related to the separation between testing sessions, the difference between the two studies might thus be partly explained.

TABLE 18a

ORDER-EFFECTS : CHI-SQUARE TESTS

Total frequencies on Conservation of Quantity, Weight and Volume (see text).

Canberra

Age-groups		5-9		10-12		5-12	
Stages		F+NC	T+C	F+NC	T+C	F+NC	T+C
Order of Presentation	1	20	30	10	20	30	50
	2	21	30	11	19	32	49
	3	22	27			22	27
χ^2 value		0.261		0.060		0.703	
Significance level		NS		NS		NS	

Hermannsburg

Age-groups		6-10		11-16 + Ad.		6-16 + Ad.	
Stages		F+NC	T+C	F+NC	T+C	F+NC	T+C
Order of Presentation	1	32	18	29	21	61	39
	2	35	15	20	30	55	45
	3	34	16	19	31	53	47
χ^2 value		0.421		4.893		1.406	
Significance level		NS		.05		NS	

Areyonga

Age-groups		8-10		11-16 + Ad.		8-16 + Ad.	
Stages		F+NC	T+C	F+NC	T+C	F+NC	T+C
Order of Presentation	1	12	7	21	13	33	20
	2	15	4	23	11	38	15
	3	9	10	22	12	31	22
χ^2 value		2.824*		0.256		2.130	
Significance level		NS		NS		NS	

* Yates correction for continuity applied.

In the Aboriginal samples, the chi-square values are consistently higher, but only one of them is statistically significant at the .05 level. We take this to mean that order-effects are indeed influencing the results of Aboriginal subjects, but only if they have reached a level of development sufficient to enable them to take advantage of it. This seems to be the case with the older children and adults at Hermannsburg.

Further support for an interpretation of de Lemos' results in terms of order effects is provided by the chi-square values reported in Table 18b. Here the calculations have been performed for each test individually. Again, no significant values appear for the Canberra and Areyonga samples. For the older age-group at Hermannsburg, it is the test of W which seems to be most affected by previous experience. (The chi-square value just fails to reach significance at the .05 level.)

How, excactly, are these order-effects likely to work? De Lemos (1966, p.292ff) suggested that it was not experience with the testing situation per se which produced improvement, but experience with a certain type of operational structure involved in the previously presented tests. She hypothesized that improvements would occur if the latter required the same or slightly less advanced operational structures. If the tests presented first involved more advanced or a different set of operational structures, little or no improvement in performance would occur.

Again, our design enables us to test these assumptions, although conclusions will be limited by the small N's involved. Only the results of the older age-group in Hermannsburg will be presented; the same calculations on the other samples or sub-samples have failed to show any significant results.

The results of an analysis of the possible effects exercised by the succession of particular tests are presented in Table 19. The calculations which are reported were made in grouping T and C answers; other comparisons (NC/C and NC+T/C) were also made and led to the same conclusions.

TABLE 18b

ORDER-EFFECTS : CHI-SQUARE TESTS

Based on frequencies for each conservation test (Q = Quantity, W = Weight, V - Volume) separately (see text).

Canberra

Age-groups	5-9			10-12			5-12		
Tests	Q	W	V	Q	W	V	Q	W	V
χ^2 value	0.052	0.233	0.334	-	0.150	0.000	-	0.858	0.653
Significance level	NS	NS	NS		NS	NS		NS	NS

Hermannsburg

Age-groups	6-10			11-16 + Ad.			6-16 + Ad.		
Tests	Q	W	V	Q	W	V	Q	W	V
χ^2 value	2.396*	0.934*	0.116	0.960*	4.137*	0.152*	2.588	3.769	0.263
Significance level	NS	NS	NS	NS	.10	NS	NS	.10	NS

Areyonga

Age-groups	8-10			11-15 + Ad.			8-15 + Ad.		
Tests	Q	W	V	Q	W	V	Q	W	V
χ^2 value	1.182*	1.157*	1.336*	0.295*	1.077*	1.198*	1.610*	2.294*	2.936*
Significance level	NS	NS	NS	NS	NS	NS	NS	NS	NS

* Yates correction for continuity applied.

TABLE 19

ORDER-EFFECTS ON PARTICULAR CONSERVATION TASKS

Chi-square values, calculated on the frequency of subjects classified at stages 2 and 3 (T+C), Hermannsburg, age-group 11-16 + adults (see text)

Comparison		χ^2 (Yates correction for continuity applied each time)	Significance level (one-tailed test)
Quantity first :	after W	0.3536	NS
	after V	0.0000	NS
	after W + V	0.0000	NS
Weight first :	after Q	0.9180	NS
	after V	3.0078	.05
	after Q + V	3.0063	.05
Volume first :	after Q	3.7862	.025
	after W	0.3120	NS
	after Q + W	0.0066	NS

The conservation of Q is not affected by any previous test; performance on conservation of V is improved if the test is presented after Q, but previous experience of W has no effect. Performance is not improved if the task is presented last, after both Q and W, and we are unable to offer an adequate explanation of this finding.[1]

Conservation of W is improved by previous experience on V, but not Q. If presented after both, the improvement is also statistically significant.

These findings, assuming that they are valid, further confirm de Lemos' hypothesis that order-effects vary according to the particular test involved, but they partly contradict other assumptions. We would have expected, for example, that the conservation of W would be improved by the previous experience on the test of Q, which involves a similar, or slightly easier operational structure. Instead, it is experience with the test of V, thought to involve a more advanced, quasi formal operational structure, which seems to lead to improvement.

If this is true, de Lemos' reversal could no longer be explained by order-effects, since in her study, W was always presented after Q but before V. However we have to remember that, with these detailed comparisons, N is very small (N=30) and the interpretation thus rather hazardous.

In summary, our results show that order-effects can occur among conservation tasks; improvement depends on the level of development of the child and on the particular sequence of tests involved. Experience with the testing situation seems to have no effect, even for Aboriginal subjects.

The interpretation of de Lemos' Q/W reversal in terms of order-effects is thus generally supported, although a detailed analysis reveals some inconsistencies. Order-effects could not account completely for the large difference in the results of the two studies, for the performance, in the present one, on the conservation of W tests which seem to

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[1] In fact, it points out, we believe, the precariousness of these results; what would be needed is a study designed specifically to deal with this problem.

have been influenced by order-effects, is still far below the performance evidenced in the previous study.

We therefore tentatively conclude that the reversal effect was due to a combination of test-material and order-effects.

The Weight/Volume reversal

In both Aboriginal samples, the conservation of V is of the same difficulty or is easier than the conservation of W (Fig. 22 and Fig. 23).

If the test of V had always been presented after the two others (Q and W), such a result could have been explained by order-effects. However, this is not the case, and no explanation of this new reversal comes to mind at the present time.

It is left to further investigation to find more definite answers. What the present study and that of de Lemos show, is that the particular horizontal décalages typically found in European children may not apply in the same way to other ethnic groups.

3. The constant-order hypothesis applied to individuals

Another point which seems to have been constantly overlooked is the following: the results for or against the constant-order hypothesis are always reported in broad statistical terms; it is in the total sample that one test appears to be more difficult than another. However, if the concept of hierarchical development is to have any qualitative value, a constant order of development should be found in each individual.

There are 7 combinations of classifications into stages which favour the constant-order hypothesis:

Tests:	Q	W	V
Confirming combinations:	C	NC	NC
	C	T	NC
	C	T	T
	C	C	NC
	C	C	T
	T	NC	NC
	T	T	NC

There are 3 combinations which neither confirm nor disconfirm the hypothesis:

Q	W	V
C	C	C
T	T	T
NC	NC	NC

All other combinations can be considered as non-confirming. There are 17 of these:

NC	NC	C
NC	C	NC
NC	T	C

etc.

Each subject was classified into one of these groups, which we shall call: 1. confirming; 2. neutral; and 3. non-confirming. The figures are presented in Table 20, which also includes the only other data which could be analysed in this way, namely that of Hyde (1959).

To comment on Hyde's findings first, there is some indication that Q (S and Liq.) is easier than W and V, "but the results of individual subjects suggest that the sequence is not invariable ... There was no support for the theory that the concepts of S, W and V are invariably acquired in that order".

But Hyde's cross-cultural data are not really relevant; because of their young age, most subjects had to be classified in the 'neutral' group (NC on all 3 tests). But in the European sample, as much as 35.5% of the subjects were in the non-confirming group.

In our Canberra sample, 16% of the subjects are classified in the non-confirming group, which is higher than what might be expected if the three conservation tasks formed a true hierarchical series.

In the Aboriginal samples, there is a large percentage of 'neutral' cases, and 42% of the subjects in Hermannsburg,

TABLE 20

CONSTANT-ORDER HYPOTHESIS:

Percentage of subjects classified into the confirming, neutral and non-confirming groups. (see text)

Hyde (1959)

	Canberra		Hermanns-burg		Areyonga		European		Arab		Indian		Somali		Total	
	%	(N)	%	(N)	%	(N)	%	(N)	%	(N)	%	(N)	%	(N)	%	(N)
1.Confirming	49	(34)	19	(19)	23	(13)	25	(12)	12.5	(6)	12.5	(3)	4	(1)	15	(22)
2.Neutral	35	(25)	39	(39)	42	(24)	39.5	(19)	77	(37)	83.5	(20)	92	(22)	68	(98)
3.Non-confirming	16	(11)	42	(42)	35	(20)	35.5	(17)	10.5	(5)	4	(1)	4	(1)	17	(24)

and 35% in Areyonga are in the non-confirming category.[1] This, of course, is due to the fact that conservation of V was found to be relatively easier than W.

However, the fact that these inversions occur in the European group as well, suggests that the concept of horizontal décalages is mainly to be regarded as a statistical phenomenon. More data on horizontal décalages in individuals should be obtained, both in European children and cross-culturally. This could be partially achieved by a re-analysis of already existing data.

D. TOTAL SCORES FOR LOGICO-MATHEMATICAL AND SPATIAL TESTS. SEX DIFFERENCES. THE INFLUENCE OF EUROPEAN CONTACT.

The total scores for the logico-mathematical and spatial tests are obtained by adding the scores of the individual tests. The total maximum scores are obtained as follows :

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[1] The high percentage of subjects in the 'non-confirming' group indicates that it is unnecessary to perform a Guttman-scale analysis on the data of the present study; the coefficients of reproducibility would be small. The coefficients of .90 and higher obtained by de Lemos (1966, p.229) could have been produced partly by order-effects, since the constant order between the tests of Q and W in her study works in favour of her scale. Counterbalancing the order, on the other hand, is expected to decrease the coefficient of reproducibility.

Of the 22 subjects tested in both studies (see pp.175-178), 10 performed better on W than on Q when tested by de Lemos (10 found the tests equally difficult, and 2 found Q easier than W). In the present study, 4 of the children still perform better on W than on Q, 8 find the tests equally difficult, and 10 find Q easier than W (of these latter 10 there are 3 children who had previously found W easier than Q). These longitudinal results, although limited by the small number of subjects, confirm the difference in the results of the two studies and further indicate that the reliability of the tests should be examined more closely in future research projects.

Logico-mathematical tests:	Maximum score:	
Conservation of Q	4	
" W	4	
" V	4	
" L	6	
Seriation	6	
	24	Total maximum score

Spatial tests:		
Orders	18	
Rotation	28	
Horizontality	30	
	76	Total maximum score

The mean logico-mathematical scores are presented in Table 21a and Fig. 24, the mean spatial scores in Table 22a and Fig. 25. Figures 26 and 27 show the distribution of the scores; the spatial scores distributions prove to be more negatively skewed then the logico-mathematical ones, and the skewness is especially pronounced for the Canberra group. The results of the parametric tests will have to be viewed with these departures from the normal distribution in mind.

1. Sex differences

Sex is usually considered to be irrelevant to the study of operational development. Most investigators control the sex variable by studying only one sex, or by including the same number of subjects of each sex, but the topic is usually ignored in the analysis of the results.

Among those who have studied this factor (mainly in conservation tests), Almy et al. (1966) and Rothenberg and Orost (1968) report no sex differences in favour of males but most correlations with sex were insignificant; in Goldschmid's (1965) study the sex difference is definitely in favour of males.

TABLE 21a

LOGICO-MATHEMATICAL TESTS : MEAN SCORES IN POINTS (MAX. 24)

	Age	5	6	7	8	9	10	11	12	13	14	15	16	Total Sample
Canberra														
N = 10 per age	$\bar{x}$	2.4[1]	8.8	14.8	18.3	21.1[2]	17.9[2]	21.2[2]	22.2[2]	-	-	-	-	15.8
	S.D.	2.0	4.4	3.9	3.6	3.5	2.8	3.1	1.8					
Hermannsburg														
N = 10 per age	$\bar{x}$		3.1	5.8	7.6	10.3	11.5	9.8	12.9	12.8	14.2	18.8	16.6	10.2
	S.D.		2.7	3.3	3.5	4.8	5.1	3.5	4.7	13.5		17.7		
										3.0		3.9		
Areyonga	$\bar{x}$		2.9[1]		8.8		8.2		8.7			11.4		8.2
	S.D.		1.7		3.6		3.2		4.3			4.1		
	N		8		12		9		15			8		
$\bar{x}$ not grouped			1.0	4.0	8.0	9.5	7.9	9.5	8.7	8.8	8.3	13.0		
	N		3	5	4	8	7	2	6	9	6	2		

[1] Assuming non-conservation on those tests which were not administered at these ages

[2] Assuming conservation on those tests which were not administered at these ages

TABLE 21b

LOGICO-MATHEMATICAL TESTS : T-TESTS BETWEEN MEAN SCORES IN POINTS

Age	6	7	8	9	10	11	12	13	14	15	16	Total Samples
Canberra / Hermannsburg												
Value of t	3.473	5.545	6.780	5.775	3.465*	7.666	5.867**					5.593**
Sign. level	.005	.0005	.0005	.0005	.005	.0005	.0005					.0005
Hermannsburg/ Areyonga												
Value of t	1.661		0.082		1.671		2.635		2.966			2.477*
Sign. level	N.S.(.10) (.05=1.706)		NS		N.S.(.10) (.05=1.703)		.01		.005			.01

*, ** indicates significance of F value; Cox t value used.

FIG. 24 LOGICO-MATHEMATICAL TESTS

Mean total scores

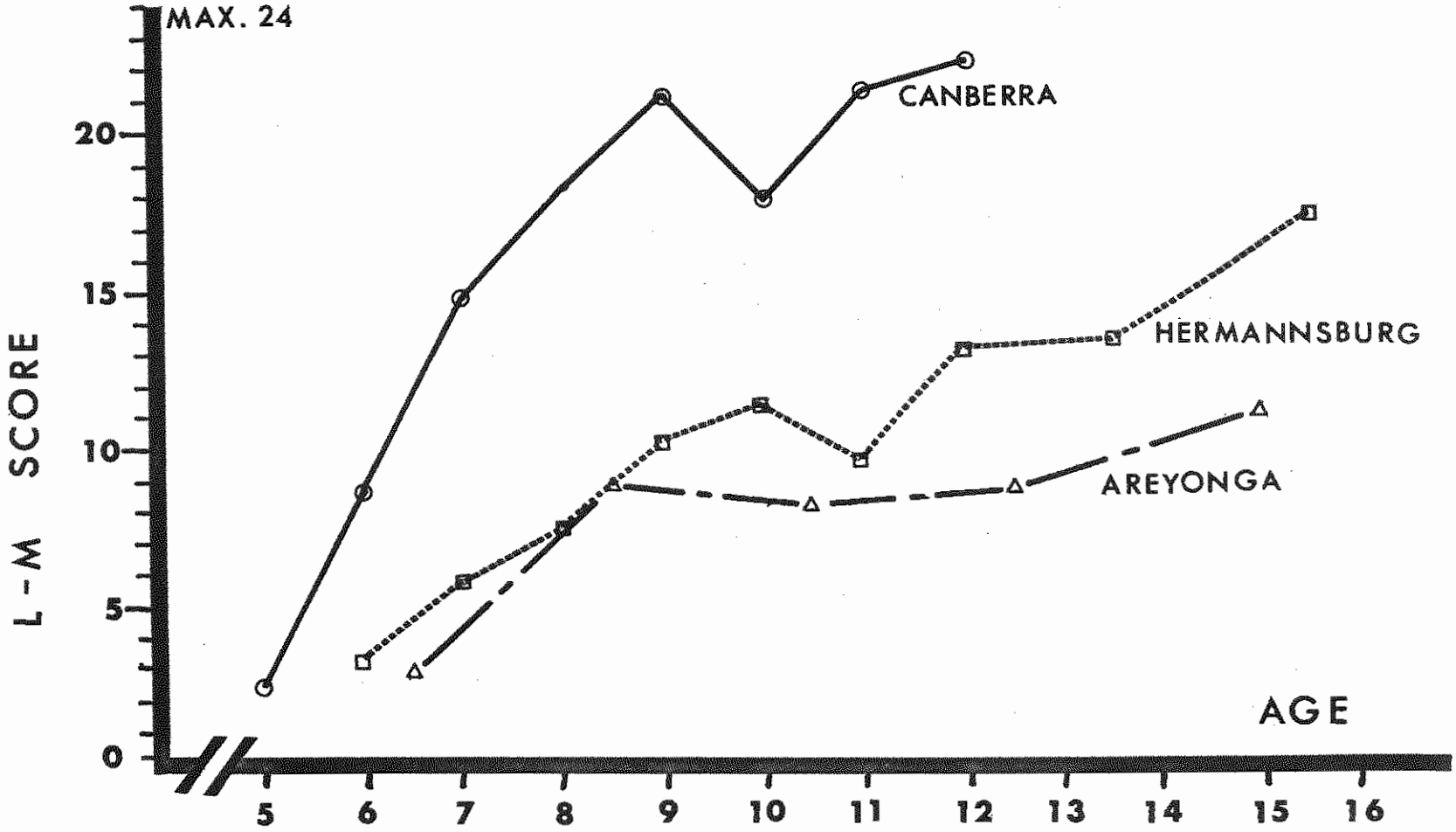


TABLE 22a

SPATIAL TESTS : MEAN SCORES IN POINTS (MAX. 76)

	Age	5	6	7	8	9	10	11	12	13	14	15	16	Total Sample
Canberra														
N = 10 per age	$\bar{x}$	42.8	53.2	56.7	66.2	68.9	71.1	72.9	72.8	-	-	-	-	63.1 (N=80)
	S.D.	5.4	7.0	5.3	4.7	3.8	1.9	2.6	3.3					11.2
Hermannsburg														
N = 10 per age	$\bar{x}$	-	46.8	53.4	55.3	60.4	63.4	64.8	66.0		70.3		70.2	61.2 (N=90)
	S.D.		5.3	8.7	9.9	7.0	7.6	9.3	3.1		2.9		3.8	10.0
Areyonga	$\bar{x}$	-	47.5		59.2		59.4		62.3			65.6		59.2
	S.D.		10.1		9.1		7.5		6.1			6.9		9.4
	N		8		12		8		15			7		50
$\bar{x}$ not grouped			38.7	52.8	52.8	62.4	58.4	66.0	60.8	63.3	67.6	60.5		
	N		3	5	4	8	7	1	6	9	5	2		

TABLE 22b

SPATIAL TESTS : T-TESTS BETWEEN MEAN SCORES IN POINTS

Age	6	7	8	9	10	11	12	13	14	15	16	Total Samples	
Canberra / Hermannsburg												All ages	Ages 6-12
Value to t	2.296	1.025	3.147*	3.398*	3.106**	2.644*	4.738					1.157	4.765
Sign. level	.025	NS	.01	.005	.01	.025	.0005					NS	.0005
Hermannsburg / Areyonga													
Value of t		0.652		0.402		1.454		2.757		1.658**		1.173	
Sign. level		NS		NS		.10		.01		.10		.05	

*, ** Indicates significance level of F test (.05 and .01 respectively). Cox correction applied.

FIG. 25 SPATIAL TESTS

Mean total scores

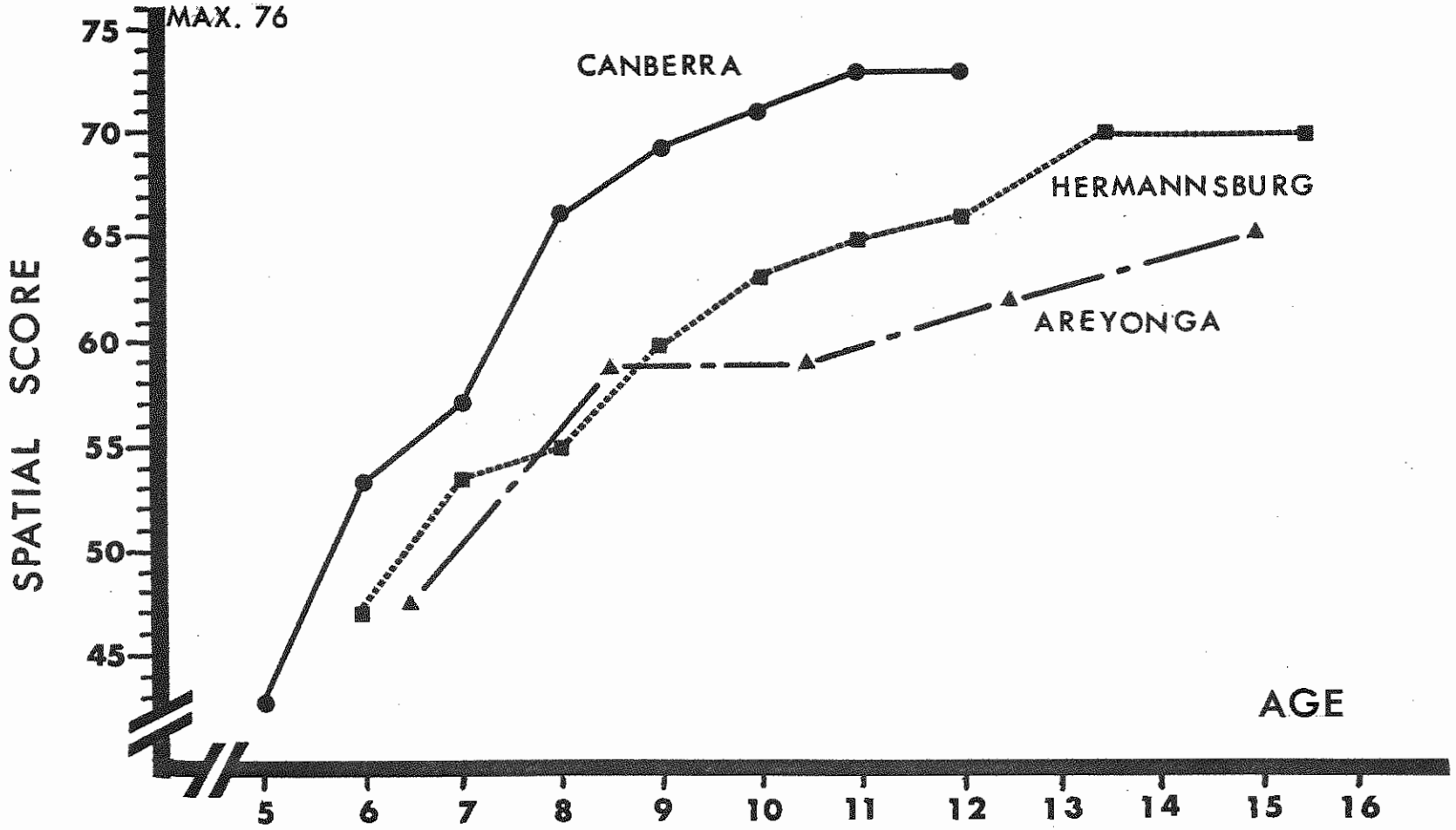


FIG. 26 DISTRIBUTION OF L-M SCORES

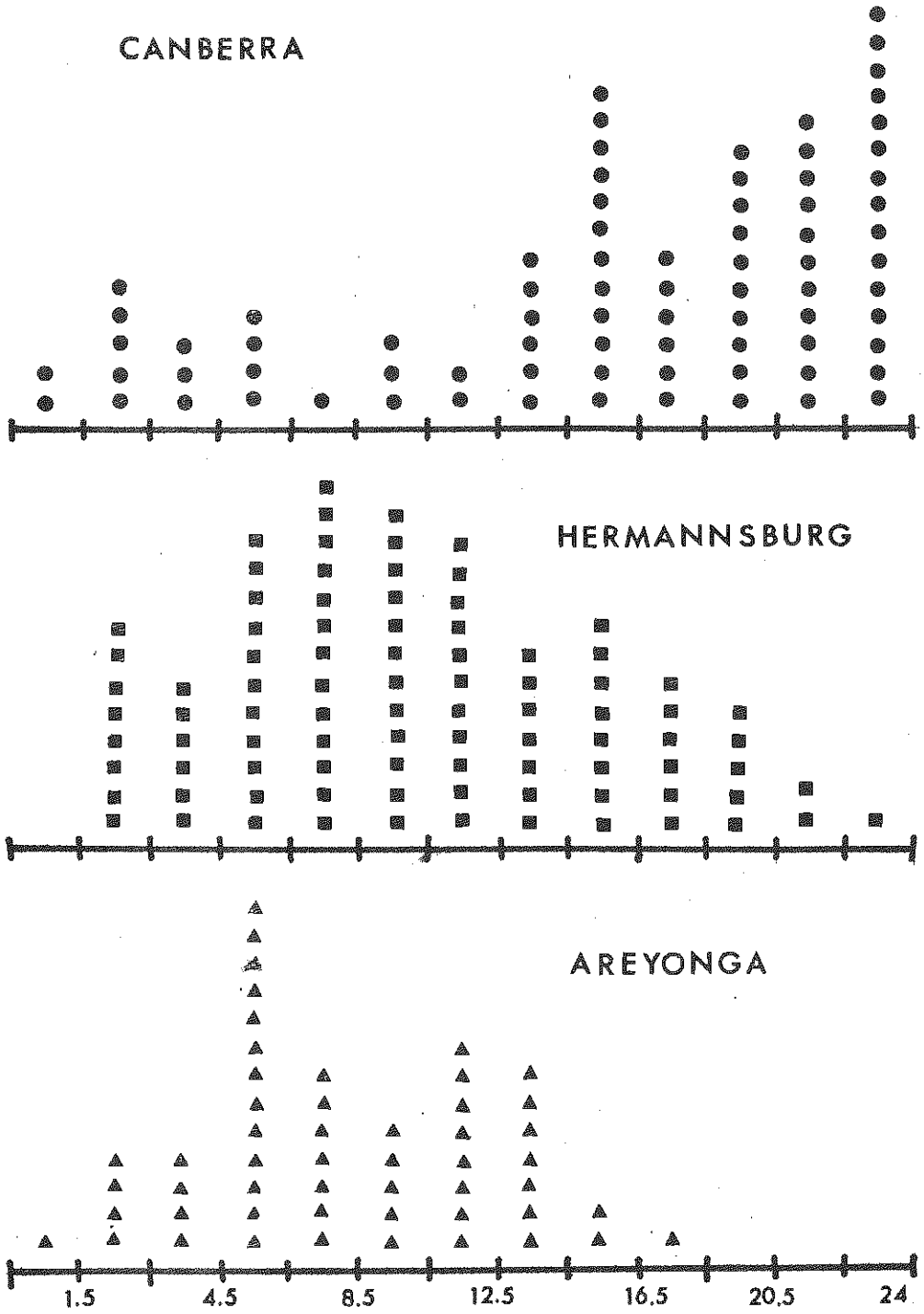
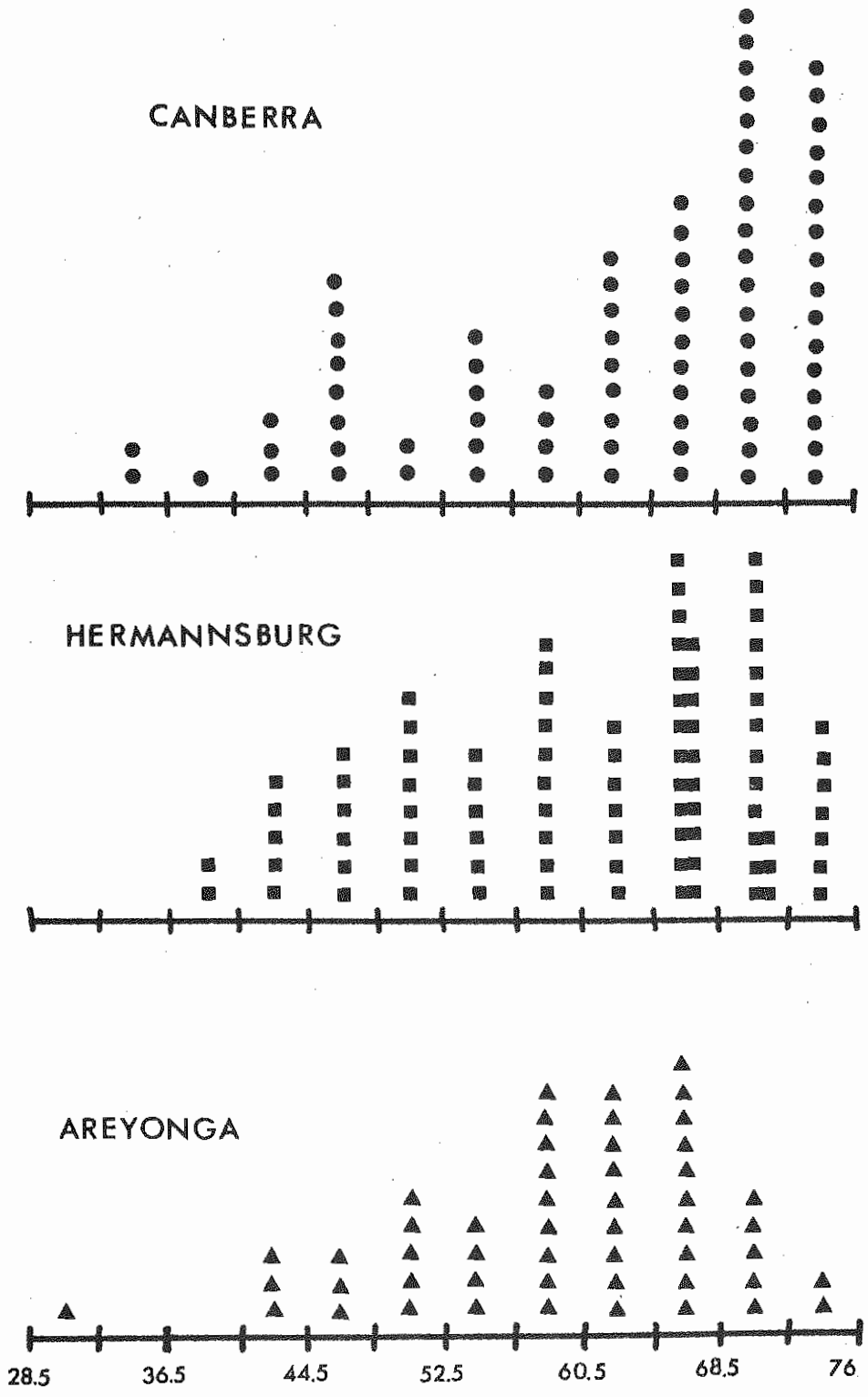


FIG. 27 DISTRIBUTION OF SPATIAL SCORES



In the present study (see Table 23), there were no significant sex differences except for one (Areyonga, spatial scores). The latter can easily be explained in cultural terms, Aboriginal boys, in a traditional setting, being much more likely to acquire spatial skills than are girls.

In view of these results, the sex variable is ignored for all other analyses.

2. The influence of European contact

It is evident in all the data presented in chapter 10, that the development of logico-mathematical concepts is much slower in Aboriginal children than in European children. The differences between the mean scores of the Canberra and the Hermannsburg samples are significant at beyond the .005 level at each age level as well as when the total samples are compared (Table 21b). Significance tests have not been calculated between the Canberra and the Areyonga results, the differences being even larger.

The differences between the average spatial scores of the Canberra and of the Hermannsbrug groups are significant at beyond the .025 level for each age group (6 to 12) except at age 7 (Table 22b). If the means of the total samples are compared, the difference is not significant. If only the common ages are compared (i.e. excluding the 13 to 16 year-olds in Hermannsburg), the means for the two groups are significantly different.

The interesting comparison bearing on our hypothesis 2, concerning the influence of 'European contact' is that between the Hermannsburg and the Areyonga groups. Chi-square tests have been calculated on the number of subjects, in each sample, attaining stage 3 on each test (Table 24).

For the logico-mathematical tests, all chi-square values are statistically significant, or are approaching significance, except for part 3 of the conservation of L. For the spatial tests, on the other hand, only one chi-square value is approaching significance. For all tests combined, the difference between the two groups is significant at the .001 level.

TABLE 23

SEX DIFFERENCES ON LOGICO-MATHEMATICAL AND SPATIAL SCORES

	Canberra			Hermannsburg			Areyonga		
	M	F	t	M	F	t	M	F	t
Logico-mathematical scores									
$\bar{x}$	15.7	16.0	0.1686	9.9	10.6	0.5571	7.8	8.5	0.5125
S.D.	6.9	7.7		5.2	6.0		3.6	4.8	
N	40	40		44	46		19	31	
Spatial scores									
$\bar{x}$	63.8	62.3	0.5950	62.0	60.4	0.7374	63.8	56.6	2.8782**
S.D.	11.7	10.9		10.3	9.8		8.2	9.2	
N	40	40		44	46		18	32	

** Significance at the .01 level

TABLE 24

EUROPEAN CONTACT : CHI-SQUARE TESTS ON TOTAL FREQUENCIES

(Number of subjects attaining stage 3 in the Hermannsburg and Areyonga samples)

	Quantity[2]		Weight[2]		Volume[2]		Seriation[5]	
Tests and stages	3	1+2	3	1+2	3	1+2	3	1+2
Hermannsburg	33	47	15	65	20	50	40	50
Areyonga	11	45	6	51	10	46	15	37
χ^2	7.0176		1.7262[1]		1.9656		3.3654	
Significance level (one tailed test)	.001		.10		.10		.05	

	Length 1[3]		Length 2[3]		Length 3[3]		All tests	
Tests and stages	3	1+2	3	1+2	3	1+2	3	1+2
Hermannsburg	32	38	21	49	12	58	173	357
Areyonga	11	32	6	37	9	34	68	282
χ^2	4.5765		3.7629[1]		0.2486		18.4800	
Significance level (one tailed test)	.025		.05		NS		.001	

TABLE 24 Cont'd

Tests	Orders[6]		Rotation[5]		Horizontality[4]	
Stages	3	<3	3	<3	3	< 3
Hermannsburg	40	10	31	59	32	68
Areyonga	19	7	11	40	24	40
S^2	0.1520[1]		2.5662		0.5084	
Significance level (one tailed test)	NS		.10		NS	

1) Yates correction for continuity applied
2) Age groups 8-16 + adults
3) Age groups 8-16
4) Age groups 6-16 + adults
5) Age groups 6-16
6) Age groups 6-10

The hypothesis that European contact is influential in operational development is thus confirmed, although the effect differs depending on the test used, the differences for the logico-mathematical scores being greater than for the spatial scores.

The above analysis only takes into account the number of subjects classified at stage 3, whereas the lower stages have all been grouped. The scores, however, take these lower stages into account more fully. The mean logico-mathematical scores for the Hermannsburg and Areyonga samples are significant at the .01 level (Table 21a & b). For the spatial scores, the difference is significant at the .05 level (Table 22a & b). Thus, with these statistics, the hypothesis regarding the influence of European contact is confirmed for both types of tests.

The differences, however, are not statistically significant at all levels. For the logico-mathematical scores, the difference is not significant at age 8-9, it approaches significance at age 10-11 and becomes significant at the .01 level after age 12.[1] The trend which is also evident by simple inspection of Fig. 24 is thus for a gradual increase with age of the difference between the two groups.

When comparing the two Aboriginal groups on the spatial scores, the same trends are evident.

This finding confirms de Lacey's (1970a, in press) observation with different Piagetian tests (classification) and different Aboriginal samples. In the latter study, the influence of European contact also became evident on the test results only after about age 10.

This age effect could be due to the fact that the discriminative power of the tests increases with age.

On the other hand, 'European contact' is one of these complex variables - just like 'socio-economic status' or 'environmental deprivation' - which can be hypothesized to have a progressive influence with age. It probably exerts

---

[1] The difference approaches significance in the 6-7 age group; this result has to be considered with caution, since it is based on the assumption that all subjects at Areyonga would have given non-conservation answers, had it been possible to use the tests with these younger subjects.

its influence on operational development through the amount of cognitively relevant stimulation it provides. A deficiency in the latter at one stage may lead to the impossibility of assimilating the next step, and the deficiencies could be cumulative and self-perpetuating.[1]

Thus, various degrees of European contact can be considered to increase the difference between groups as its influence accumulates in this self-perpetuating way.

Secondly, it is probably at about the age of ten, and thereafter, that the motivational aspects of European contact become evident. The child, as his involvement in school and his ability to communicate in English increase, becomes influenced by the values of his European teachers. He probably starts to realize the difference in the amounts of goods and comfort the Europeans enjoy, when compared to his parents. In a high-contact community, his parents are likely to promote European values to some extent, insofar as they have accepted these themselves, or believe that their children will have a better chance if they conform to European values.[2]

On the other hand, in the low-contact group, the influence of the parents and elders becomes increasingly strong in the opposite way: as they feel that the children are gradually moving away from traditional values, they are afraid of losing their authority and try to enforce traditional rules and values. As the youths (especially the boys) approach puberty, they are almost completely subjected

---

[1] Similarly, this is why it could be untrue that schooling will help socio-economically disadvantaged children to 'catch up': when they start school, they are less prepared for the new learning situation than their middle-class peers. They cannot accommodate to the new situation, and cannot assimilate the new material to existing schemes. The usual teaching is designed to match the cognitive level of the already advantaged child, and only the latter will be able to make full use of it.

[2] In the present situation, of course, this motivational aspect is likely to cease, once the youths realize that there is no future for them. P.E. Vernon (pers. commun., in Dasen and Seagrim 1970) even hypothesizes that mental development (i.e. the development of the capacity to reason, measurable by intelligence tests) is likely to cease at that time.

to traditional values, and are motivated by them for the all-important initiation period.

Unfortunately this description cannot be substantiated by any facts and figures, but it corresponds to a close observation of life at Hermannsburg and Areyonga. Further research could well be devoted with profit to these motivational aspects of cognitive development.

In conclusion, hypothesis 2 ("The rate of operational development is faster in the high-contact group (Hermannsburg) than in the low-contact group (Areyonga)") is confirmed.

The importance of European contact for operational development is strongly supported and can probably be generalized to all aspects of operational development. The importance of the factor is further emphasized by the fact that even a relatively small difference in European contact (compared to the differences used in other studies, for example, de Lacey, 1970a, in press) is sufficient to produce statistically significant differences in the results.

E. THE RELATIVE DEVELOPMENT OF LOGICO-MATHEMATICAL AND SPATIAL OPERATIONS

It is expected that "Aborigines, because of their cultural background, will develop spatial concepts more readily than logico-mathematical concepts" (hypothesis 3).

No claim is being made to equate tests in the two domains. Even if a strict structural analogy between tasks of the two areas could be made, a comparison would not be possible because of the occurrence of horizontal décalages. It is this type of difficulty that led Pinard and Laurendeau (1969, p.143) to suggest that experimentation should be limited, at the moment, to the "intraconcept level of generalization".

However, if both sets of tests are reduced to some form of standard score, a comparison of the relative development of each domain becomes possible, even if the scores are not strictly comparable in absolute terms.

The logico-mathematical scores of the three samples were thus pooled, and transformed into z' scores with a mean of 50 and a standard deviation of 10 (Ferguson, 1966, p.225), according to the formula:

$$z' = 50 + 10 \frac{(X - \bar{x})}{(S.D.)}$$

The same computation was performed for the spatial scores.

For our hypothesis to be confirmed, the spatial z' scores in the Aboriginal samples should be relatively higher than the logico-mathematical z' scores, whereas the reverse should be true for the Canberra sample.

The means and standard deviations of the z' scores, at each age, and for the three samples, are set out in Table 25a. The graphical representation of the results (Fig. 28) makes it clear, at a first glance, that our hypothesis is confirmed. In the European sample, the mean scores for the spatial tests are consistently lower than the mean scores for the logico-mathematical tests, whereas in both Aboriginal samples, this is reversed; the mean scores for spatial tests are consistently higher than the mean scores for the logico-mathematical ones.

In other words, the Aborigines in our samples, on the average, acquire the particular set of spatial operations we are testing before they acquire the particular set of logico-mathematical operations, whereas the Europeans in our sample find the logico-mathematical tests relatively easier.

A statistical analysis of these trends is presented in Table 25b. Parametric statistics have been used since the data is in terms of z' scores, although a case could easily be made for the fact that non-parametric statistics, for example a sign test, would be psychologically more appropriate, since we are mainly concerned with relative differences.

The difference between the means of logico-mathematical and spatial z' scores are highly significant in all three samples.

Bravais-Pearson correlation coefficients between spatial and logico-mathematical scores are presented in Table 25b, but their interpretative value is restricted. The correlations are of .5 or higher if the total samples are considered, but these correlations mainly express the influence of age. If the correlation coefficients are calculated

TABLE 25a

LOGICO-MATHEMATICAL AND SPATIAL TESTS : z' SCORES

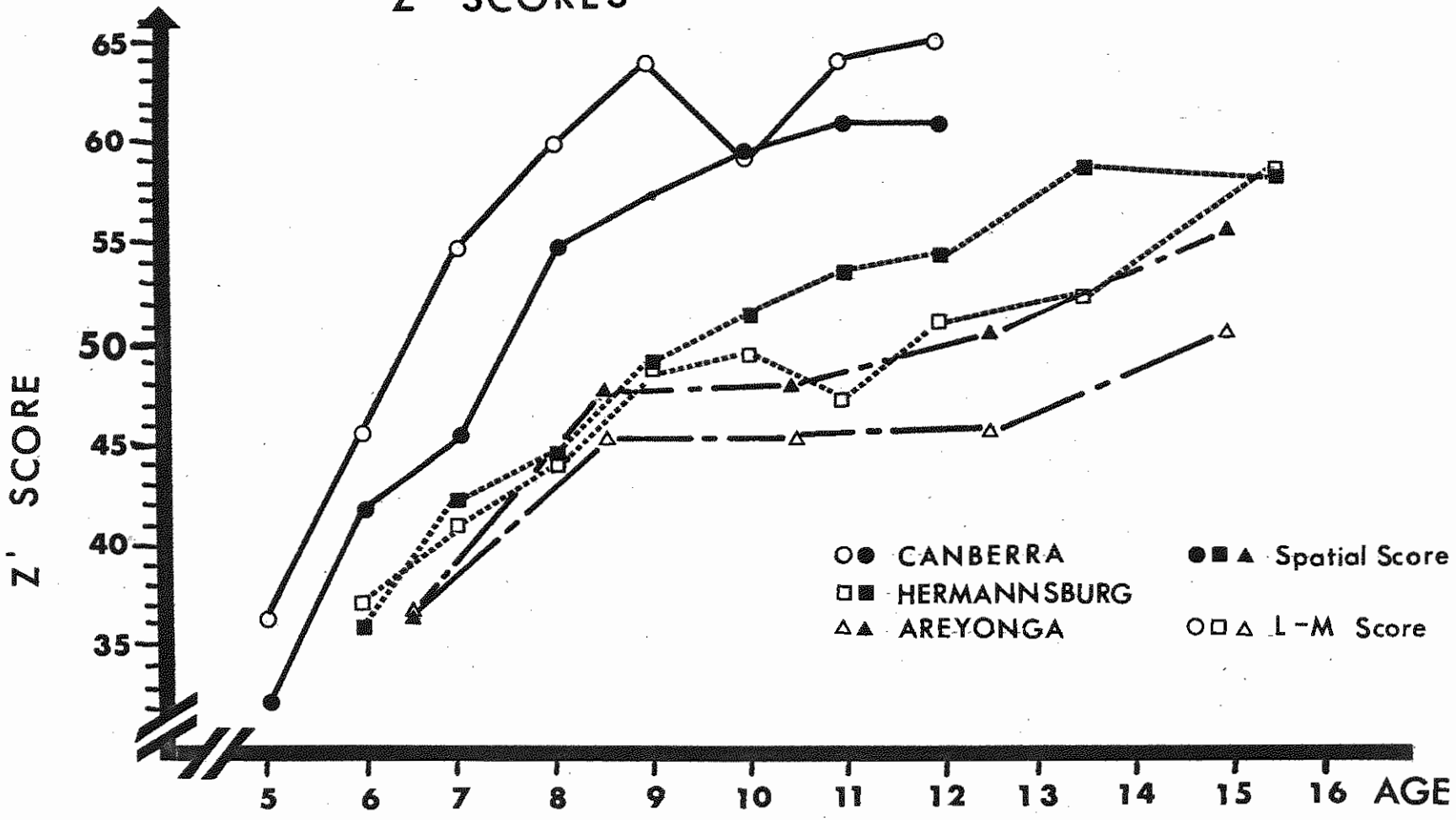
	Age	5	6	7	8	9	10	11	12	13	14	15	16	Total Sample
Canberra														
Logico-mathematical														
	$\bar{x}$	36.1	45.6	54.5	59.7	63.8	59.1	63.9	64.4					56.0
	S.D.	2.8	6.2	5.5	5.0	5.0	4.0	4.4	3.2					10.6
Spatial	$\bar{x}$	32.2	42.1	45.5	54.6	57.2	59.3	61.0	60.9					51.6
	S.D.	4.9	6.4	4.8	4.3	3.4	1.7	2.4	3.0					10.7
Hermannsburg														
Logico-mathematical														
	$\bar{x}$		37.1	41.1	43.8	48.7	49.6	47.1	51.6	52.6		58.8		47.7
	S.D.		3.8	4.6	4.9	8.2	7.2	5.0	6.6	4.2		5.6		8.3
Spatial	$\bar{x}$		36.0	42.3	44.1	49.0	51.9	53.3	54.4	58.5		58.4		49.7
	S.D.		4.8	7.9	9.0	6.3	6.9	8.5	2.8	2.6		3.5		9.9
Areyonga														
Logico-mathematical														
	$\bar{x}$			36.8		45.6		44.9		45.5		50.5		44.7
	S.D.			2.4		5.1		4.9		6.1		5.2		6.4
Spatial	$\bar{x}$			36.6		47.9		48.0		50.9		55.4		47.9
	S.D.			9.1		8.4		6.8		5.7		6.8		9.0

TABLE 25b

LOGICO-MATHEMATICAL AND SPATIAL TESTS : CORRELATIONS AND t-TESTS

	Age	5	6	7	8	9	10	11	12	13	14	15	16	Total sample
Canberra														
	r	.23	.13	.17	-.36	-.00	-.48	.55	.66					.80
	Sign. level	NS	NS	NS	NS	NS	NS	.05	.025					.005
	t	2.422	1.254	4.056	1.981	3.278	0.149	2.377	4.084					5.783
	Sign. level	.05	NS	.006	.05	.005	NS	.025	.005					.0005
Hermannsburg														
	r		-.14	-.17	.82	-.16	.65	.15	-.29	-.15		-.40		.60
	Sign. level		NS	NS	.005	NS	.025	NS	NS	NS		NS		.005
	t		0.524	0.356	0.168	0.083	1.171	2.028	1.048	3.405		0.129		2.272
	Sign. level		NS	NS	NS	NS	NS	.05	NS	.005		NS		.025
Areyonga														
	r			.81		.17		.14		.28		.02		.49
	Sign. level			.005		NS		NS		NS		NS		.005
	t			0.086		0.815		1.060		2.842		1.411		2.693
	Sign. level			NS		NS		NS		.01		NS		.005

FIG. 28 LOGICO-MATHEMATICAL AND SPATIAL TESTS: Z' SCORES



for each age group separately, their validity is restricted by the small N's. Some of these coefficients are very high (and statistically significant), but most of them are rather low or even negative (and statistically not significant). No consistent pattern appears.

F. DIFFERENCES BETWEEN PART-BLOOD AND FULL-BLOOD ABORIGINES

In Hermannsburg the possibility exists of comparing part-blood and full-blood Aboriginal children living in what appears to be identical conditions. A description of the way in which full-blood and part-blood subjects have been selected for the sample has been given (Chapter 2, section C,4). It will be remembered that a reclassification had to be made, upsetting the original design, a reclassification which had the unfortunate effect of decreasing the number of full-blood subjects in the younger age-groups and of part-blood subjects in the older age-groups. Thus, if age were not taken into account, the bias would be in favour of the full-blood group.

To avoid this, equal numbers of full-blood and part-blood subjects were selected in each age-group. Those part-blood subjects who had the greatest proportion of European ancestry were chosen, so as to maximise the possible differences.

Before we present our own results, let us recall those of de Lemos (1966, 1969a/b). As can be seen from Table 26, (which is drawn from de Lemos, 1969b, table 4, p.262 - see also 1966, table 9, p.215) "the part Aboriginal children showed markedly better performance, the differences being significant or approaching significance on all the tests, while the difference in the total number of conservation responses achieved was highly significant".

For comparative purposes we have analysed our data in exactly the same way; chi-square tests for the total population are presented in Table 27a. None of the values

TABLE 26

COMPARISON OF THE NUMBER OF PART ABORIGINAL AND FULL ABORIGINAL CHILDREN (HERMANNSBURG GROUP) SHOWING CONSERVATION

(de Lemos, 1969b, table 4, p.262)

TEST	FULL.ABOR. N = 38	PART.ABOR. N = 34	χ^2	p
Quantity	4	18	15.214	< .001
Weight	16	25	7.227	< .01
Volume	2	8	3.595	.05<p< .10
Length	12	20	5.365	< .05
Area	3	10	4.225	< .05
Number	3	9	3.22	.05<p< .10
Total	40	90	36.141	< .001

TABLE 27a

COMPARISON OF THE NUMBER OF PART-ABORIGINAL AND FULL ABORIGINAL SUBJECTS CLASSIFIED AT STAGE 3 (HERMANNSBURG, PRESENT STUDY)

Total sample (except subjects whose ancestry is uncertain)

Tests	Quantity		Weight		Volume		Length 1	
Stages	3	<3	3	<3	3	<3	3	<3
Full Aboriginal	13	22	5	30	8	27	17	14
Part Aboriginal	17	35	8	44	14	38	17	32
χ^2	0.1827		0.0174[1)]		0.1740		3.1520	
Sign. level	NS		NS		NS		.10 (two-tailed)	

Tests	Length 2		Length 3		Seriation	
Stages	3	<3	3	<3	3	<3
Full Aboriginal	8	23	5	26	17	14
Part Aboriginal	10	39	7	42	19	30
χ^2	0.3120		0.0480[1)]		3.3540	
Sign. level	NS		NS		.10 (two-tailed)	

Cont'd

TABLE 27a Cont'd

Tests	Orders		Rotation		Horizontality		Total all tests	
Stages	3	<3	3	<3	3	<3	3	<3
Full Aboriginal	11	4	8	23	10	25	102	208
Part Aboriginal	27	3	17	32	18	34	154	329
χ^2	1.0350[1)]		0.6960		0.3480		0.0793	
Sign. level	NS		NS		NS		NS	

[1)] Yates correction for continuity applied.

TABLE 27b

TOTAL SAMPLE DIVIDED INTO TWO AGE GROUPS

		Age-group 6-11				Age-group 12-16 + Ad.			
		Fb	Pb	χ^2	Sign. level	Fb	Pb	χ^2	Sign. level
	N	17	36			18	17		
	Q	3	7	$0.2120^{1)}$	NS	10	11	$0.0420^{1)}$	NS
Tests:	W	1	3	$1.1322^{1)}$	NS	4	6	$0.2310^{1)}$	NS
	V	2	6	$0.0000^{1)}$	NS	6	5	$0.0595^{1)}$	NS
	L_1	6	14	$0.0583^{1)}$	NS	11*	4*	$5.1660^{1)}$	.05

* N = 14

1) Yates correction for continuity applied.

prove to be statistically significant;[1] for two tests, length (part 1) and seriation, the chi-square values approach significance in favour of the full-blood group. However this is certainly due to the age-bias mentioned above.

This bias does not interfere when the chi-square values are computed for two age groups separately. This has been done for the 4 conservation tests which are common to both studies (Table 27b). None of the values is statistically significant, except on the test of Length, for the older age group, where the result is significant at the .05 level in favour of the full-blood group.

The chi-square values for the samples matched on age are presented in Table 28a. None of the values achieve statistical significance;[1] for the test of Horizontality, the value approaches significance in favour of the part Aborigines.

Although frequency counts are more appropriate to our kind of data, the comparisons have also been made in terms of the scores, which, although arbitrary, have the advantage of taking the lower stages into account with a corresponding weighting. The results for the two groups, matched on age, are presented in Table 28b.

The means are higher for the part-blood groups for both the logico-mathematical and the spatial scores. The differences are not statistically significant (t tests), although the t-value for the spatial scores approaches significance ($.10 < p < .05$; one-tailed test).

Both types of statistics lead to the conclusion that no racial differences are evident in the acquisition of logico-mathematical operations, even when the chances of finding such a difference are maximized.

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[1] Our hypothesis being directional, namely that more part-Aborigines will be classified at stage 3, a one-tailed test has been used. On the other hand, in those cases where the full-Aboriginal group shows a superior performance, which is against our hypothesis, a two-tailed test has been used. This procedure, although statistically questionable, maximizes the chances of replicating de Lemos' findings. The selection, for matching purposes, of those part-Aborigines with most European ancestry has the same purpose.

TABLE 28a

COMPARISON OF THE NUMBER OF PART ABORIGINAL AND FULL ABORIGINAL SUBJECTS CLASSIFIED AT STAGE 3 (HERMANNSBURG, PRESENT STUDY)

Reduced sample; matched on age

(a) Chi-squared tests

Tests	Quantity		Weight		Volume		Length 1	
Stages	3	<3	3	<3	3	<3	3	<3
Full Aboriginal	11	20	4	27	6	25	14	14
Part Aboriginal	13	18	8	23	7	24	8	20
χ^2	0.2718		0.9238[1)]		0.0000[1)]		2.6880	
Sign. level	NS		NS		NS		NS (two-tailed)	

Tests	Length 2		Length 3		Seriation	
Stages	3	<3	3	<3	3	<3
Full Aboriginal	5	23	4	24	14	14
Part Aboriginal	4	24	3	25	15	13
χ^2	0.0000[1)]		0.0000[1)]		0.0672	
Sign. level	NS		NS		NS	

Cont'd

TABLE 28a cont'd

Tests	Orders		Rotation		Horizontality		Total all tests	
Stages	3	<3	3	<3	3	<3	3	<3
Full Aboriginal	10	5	7	21	8	23	83	195
Part Aboriginal	11	4	11	17	14	17	94	186
χ^2	0.0000[1)]		0.7336[1)]		2.5296		0.8370	
Sign. level	NS		NS		.10 (one tailed)		NS	

1) Yates correction for continuity applied.

TABLE 28b

(b) Mean scores for the two groups and t-tests

	Logico-mathematical scores		Spatial scores	
	Full Ab. (N=28)	Part Ab. (N=28)	Full Ab.	Part Ab.
mean	10.5	10.7	58.5	62.7
S.D.	5.9	5.4	10.7	9.9
t	0.1181		1.5428	
Sign. level	NS		.10 (one tailed)	

Hypothesis 7 ("At Hermannsburg, the performance of part-blood Aborigines is better than that of full-blood Aborigines") is rejected.

With the conservation tests, our findings are in direct conflict with those of de Lemos, and we shall now attempt to discuss some of the factors which could explain the failure to replicate the results reported previously.

1. Sampling

The conflicting results obtained in the two studies could be due to the fact that the overlap of the two samples is only small (22 subjects, or approximately 1/4 of the total sample). Thus, both results might be valid only for the particular samples studied, and generalizations correspondingly hazardous.

However, both samples seem to represent the total school population rather well. De Lemos randomly selected 12 subjects at age 8, and, for the subsequent ages, tested all the subjects who were available during the total time of the investigation, and whose age was known. Her total of 80 subjects represents approximately 50 per cent of the school enrolment (calculated on 1963 figures).

The sampling procedures for the present study, and the age structure of the school population from which our sample was drawn, have been described previously (Chapter 2, Section C,4). Our total sample of 90 children represents 60.8 per cent of the 1969 enrolment. Compared to the previous study, the younger children are relatively over-represented, since we included 6 and 7 year-olds but only 5 subjects at ages 13 to 16.[1]

In spite of slight differences in the representativeness of the two samples, we find it difficult to believe that this factor could account for the marked difference in results.

2. Test-materials and techniques

A more striking difference between the two studies lies in the test-materials used for the conservation tasks. It

[1] On the other hand, our sample has been extended to adults.

will be remembered that de Lemos used sugar for the conservation of Quantity, and tea in plastic bags for Weight, whereas we preferred to use the standard test-materials.

It is difficult to imagine how this change in test-materials could have affected the results of the part-blood/full-blood comparison. We would have to hypothesize that the standardized materials are more favourable to full-blood subjects, and de Lemos' adaptation more favourable to part-blood children; this seems to be unlikely.

Similarly, there were some procedural differences in the conservation tests.

Three of these are conspicuous:

(a) The check-items in the present study seem to have been slightly more extensive.

(b) Whereas both studies used the 'méthode clinique', techniques such as 'counter-suggestions' have been avoided in the present study. The reasons for this departure from standard Genevan methodology were discussed on pp.111-112.

(c) In the present study, as far as possible, the children performed all transformations themselves (pouring, rolling out, etc.). The reasons for this precaution were spelled out on p.108.

Other, more subtle differences, may have occurred, since no two experimenters will conduct a Piagetian test in exactly the same way. However, it may well be claimed that both experimenters were fully qualified and trained in the clinical method, and any differences are likely to have been insignificant.

The three modifications mentioned above, which were introduced to adapt the tests for cross-cultural use, should have made the tests easier for Aborigines. The overall results should therefore have been better in the present study than in that of de Lemos. This is not the case, and it cannot therefore be argued that these procedural differences had any significant effect.

Again, it would have to be argued that the modifications affected the results of the full-blood and part-blood groups selectively, in favour of the full-blood group. If this

were the case, it would mean that the difference de Lemos found was not a true reflection of the level of concept attainment, but was due, for the full-blood group, to a relatively more frequent misunderstanding of the task (modification a), a greater suggestibility when confronted with a European adult (modification b), or to the greater susceptibility to 'action-magic' (modification c).

3. Experimenter bias

In both studies the experimenters were unaware, at the time of testing, which children were full- and which part-blood. Some cues may, however, have been available, as the following experiment shows.

Sixty-eight children were classified, on their general appearance, skin colour, and facial features, into the two groups, and the classification was later compared with the genealogical information. Of the 68 children, 27 were full-bloods; they were all recognized correctly as being full-bloods. Of the remaining 41 part-Aboriginal children, 21 were correctly recognized. Thus, a full-blood was never mistaken for a part-blood, but the reverse was not true, and for the part-bloods the recognition was no better than that which might be expected from chance guessing.

It is thus possible that an experimenter might be influenced by his partial ability to recognize the two groups.

This experimenter-effect could be influential in one or both of the following ways:

(a) The child's response could actually be inadvertently or 'unconsciously' determined by the investigator through the formulation of the questions or through hints as to the right answer.

(b) The response could be incorrectly interpreted by the investigator.

Concerning the first possibility, it could be argued that the freedom the 'méthode clinique' allows the experimenter in formulating the interview could increase considerably the danger of guiding the child's answer into the expected direction.

On the other hand, the advantage of the clinical method is precisely that it can be adapted to each subject, so that the experimenter may discover what the child really thinks. Children whose thought structure is definitely established at one of the stages are less likely to be suggestible than those who are at an intermediate stage.

It is also for children of the intermediate stage that the possibility of a misclassification may arise.

Two safeguards should have been taken to avoid a possible experimenter effect, or at least to be able to assess its influence:

(1) The experimentation should have been carried out by a person who had no knowledge of the hypotheses.

(2) The data should not have been analysed by the experimenter himself, and should have been checked by a second, independent, judge.

Unfortunately, the constraints of the research programme did not allow for either of these precautions to be taken. It is thus possible that some experimenter-effect could have occurred in this study, although it seems unlikely that it could account by itself for the difference between the results of the present study and that of de Lemos. This question, again, is open to discussion, if not easily to experimentation.

(For a more general discussion of experimenter effects in psychology, see Rosenthal, 1966.)

4. Statistical artefact

It is well known that "the value of chi-square is related to the size of the sample. If an actual difference exists between observed and expected values, this difference will tend to increase as sample size increases" (Ferguson, 1966, p.211).

If our sample size had been greatly inferior to that of the previous study, our failure to find significant results might have been explained. However, the size of our reduced, matched sample is 56, compared to 72 in the previous study, and the numbers of subjects classified at stage 3 are also quite comparable: an explanation in these statistical terms is therefore unacceptable.

5. Improvements in the last 5 years

(a) A further possible explanation of the difference in the results between the two studies is that a general improvement in performance has occurred amongst Aboriginal children in the five years separating the two studies, and that this masks the expected differences.

That this is not so is shown by the results presented previously. If the figures of Table 8 are interpreted in terms of 'improvement' over time, we can see that a non-significant improvement (9%) has occurred on the tests of Quantity and Volume, no improvement on Length and a highly significant decline in performance on Weight.

(b) It might be assumed that only the full-blood subjects had improved. Relevant figures are presented in Table 29. The improvement of the full-blood subjects is significant on Q (24%) only, but is also noticeable for V (14%) and L (18%).

The part-blood subjects, on the other hand, show a significant decline (30%) on L, and a non-significant decline on Q (11%) and V (1%). Furthermore, their decline on W is larger (48%) than that of the full-bloods (29%).

In these terms, some event(s) may have occurred during the five years separating the two studies which caused an improvement in the performance of full-blood subjects and a regression in that of the part-blood subjects. What this event, or these events, could be is open to discussion.

6. Family genetics

Another possible explanation for the difference in the results of the two studies has been suggested by de Lemos (personal communication). Operational development could still be influenced by the genetical factor, but this would be one of family genetics rather than of race genetics.

A small Aboriginal community, such as the one at Hermannsburg, tends to be composed of a few families only. Although intermarriage among these is necessarily high, the genetic potential for operational development could be hypothesized to vary significantly between the families. The difference in results could be attributed to a different

TABLE 29

CHANGES IN THE NUMBER AND PROPORTION OF SUBJECTS CLASSIFIED AT STAGE 3 IN 1964 AND 1969

(Full-blood and part-blood Aborigines in Hermannsburg) (see text)

Tests	Quantity		Weight		Volume		Length 1	
Stage 3	N	proportion	N	proportion	N	proportion	N	proportion
Part-blood Aborigines								
1964 (N = 34)	18	.53	25	.74	8	.24	20	.59
1969 (N = 31)	13	.42	8	.26	7	.23	8[2]	.29
χ^2	0.7865		14.7680		0.0065[1]		5.6730	
Significance level	NS		.001		NS		.02	
Full-blood Aborigines								
1964 (N = 38)	4	.11	16	.42	2	.05	12	.32
1969 (N = 31)	11	.35	4	.13	6	.19	14[2]	.50
χ^2	4.8645[1]		5.7201[1]		2.0700[1]		2.2902	
Significance Level	.05		.02		NS		NS	

1) Yates correction for continuity applied.

2) N = 28

contribution of these families to the samples of the two studies.

That this was not the case was established by a comparison of our genealogical information with that of de Lemos. The fit was perfect, and the contribution of different lineages was found to be approximately equal in both samples.

Conclusion

We have envisaged a variety of explanations of the disagreement between the present study and that of de Lemos (1966, 1969a/b) concerning the possible differences in cognitive development between part-blood and full-blood Aborigines living in apparently identical conditions. None could be sufficiently substantiated, and the problem remains open to discussion and to further investigation.

CHAPTER V : RESULTS AND DISCUSSION, PERCEPTUAL TESTS

The results and discussion of the perceptual tests will be presented in the following way:

1. For each illusion separately, a brief review[1] of the literature will summarize the results obtained by other investigators; special attention will be paid to the developmental studies, whereas cross-cultural studies will be only briefly mentioned, since they have been extensively reviewed in Chapter 1, Section B.

For each illusion, the results of the present study will be presented in a table of the means, standard deviations and medians for each sample and for each age. The graphs representing the change in the extent of the illusions with age will be based on median values.[2] Computer-fitted polynomial regression curves on the same data are grouped in Appendix 6. Additional statistics will be included as seems appropriate for each particular illusion.

2. The results of the preceptual tests will be drawn together for a general discussion of the hypotheses set out in Chapter 2, Section A.

A. MULLER-LYER ILLUSION

1. Review of the literature

There is a substantial agreement among the developmental studies of the M-L figure in regard to the decrease of the illusion with age (Binet, 1895; Pinter and Anderson, 1916; Sun, 1964; Piaget, 1961, 1969a; Gaudreau et al., 1963; for a review, see Wohlwill, 1960). But whereas in the above studies the decrease was reported to be continuous, the adult

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[1] This review is kept to a minimum. Excellent reviews of the developmental studies in perception have been provided by Wohlwill (1960), and by Over (1968) of theories attempting to explain perceptual illusions.

[2] The use of medians rather than means is standard practice in cross-cultural studies of perception.

samples yielding the smallest illusion, Walters (1942) and Wapner and Werner, 1957) have reported a rise in the strength of the illusion in later adolescence and early adulthood.

Cross-cultural developmental data are almost non-existent. Segall et al. (1966, pp.197-198) mention that:

> Of 11 possible comparisons between children and adults, 9 showed greater susceptibility among children. The confirmation by non-Western data of the trends found among Western groups indicates the cross-cultural validity of those trends; it appears that the children (at least beyond six years of age) were more susceptible to the Müller-Lyer illusion than the adults in their societies. Further, the results indicated that the relative magnitudes of the illusion among children paralleled the relative magnitudes among adults. That is to say, in societies in which adults were minimally susceptible to the Müller-Lyer illusion, children also showed a relatively small illusion susceptibility. Indeed, only one of the non-Western samples of children had a mean illusion score as high as the score of any Western adult sample.

Unfortunately, Segall et al. do not give any indication of the age characteristics of the samples nor do they report the change in susceptibility over the age-range. But, in any case, these developmental trends cannot be explained by the ecological cue validity theory, a fact Segall et al. have themselves recognized: "This examination of Müller-Lyer age-trend data indicates that the carpentered-world hypothesis in its original form is far from perfectly adequate." (1966, p.199).

The relationship between the M-L illusion and intelligence has received the attention of many investigators. A brief review of these studies is given by Vurpillot (1966). No correlation is usually found between IQ and the extent of the M-L illusion, but no research has previously been conducted into the correlation between the illusion and intelligence as Piaget defines it.

2. Results

The results obtained in the present study are presented in Table 30 and Fig. 29.

The decrease of the illusion with age is verified for each sample. In the Canberra group, the minimum susceptibility occurs at age 10 years, and the illusion increases

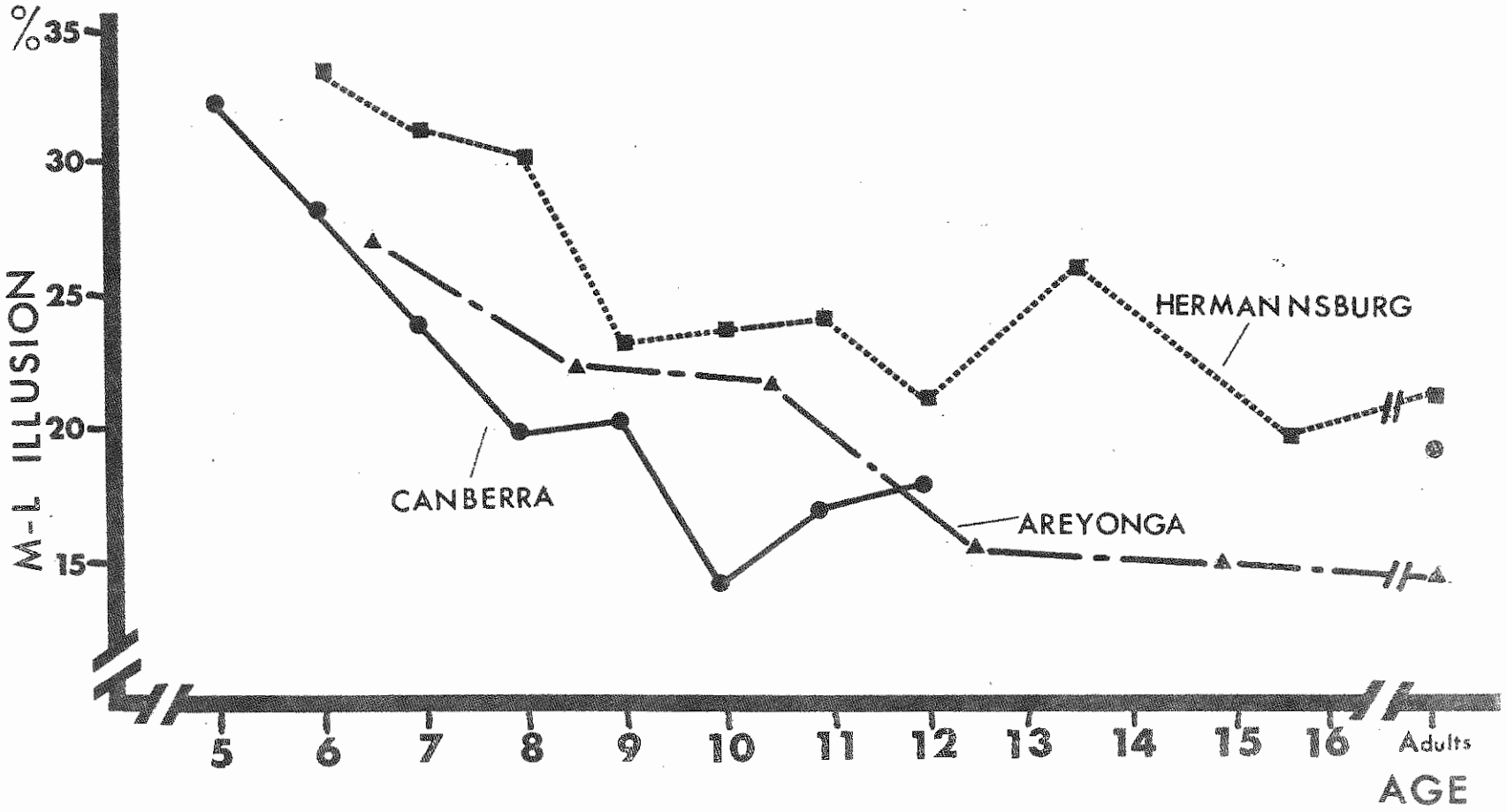
TABLE 30

MÜLLER-LYER ILLUSION:

means, standard deviations and medians for each sample and each age.

Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.	Total sample 6-12 + Ad.	Total sample 6-16 + Ad.
Canberra															
Mean	30.7	29.3	24.6	19.7	21.2	15.0	17.0	17.5					20.4	20.6	
S.D.	5.9	5.3	3.0	4.8	3.3	4.8	4.1	5.6					5.4	6.2	
Median	32.4	28.4	24.0	20.0	20.4	14.4	17.2	18.0					19.6		
N	10	10	10	10	10	10	10	10					20	90	
H'burg															
Mean		32.9	32.0	31.3	23.5	23.6	22.8	19.7	24.2		19.8		18.1	25.5	24.8
S.D.		5.3	6.2	8.9	3.2	7.0	6.4	5.1	6.8		5.6		11.5	8.7	8.4
Median		34.0	31.6	30.8	23.6	24.0	24.4	21.2	26.4		19.6		21.4		
N		10	10	10	10	10	10	10	10		10		10	80	100
Areyonga															
Mean			25.2		22.5		19.3		15.3		15.0		14.8	19.8	18.3
S.D.			5.3		5.7		11.1		6.1		8.2		5.3	8.0	7.9
Median			27.2		22.8		22.0		15.6		14.8		14.8		
N			8		12		9		15		11		9	44	64

FIG. 29 MÜLLER-LYER ILLUSION: MEDIANS



slightly thereafter, thus confirming the results of Walters (1942) and of Wapner and Werner (1957); this is not so for the Aboriginal samples.

The carpentered-world hypothesis receives only qualified support. As predicted, the 'lowly carpentered' Areyonga group has a significantly lower illusion[1] than the 'more highly carpentered' Hermannsburg sample ($p<.001$; $t = 5.000$, d.f. = 162). However, the sample with the most highly carpentered environment, Canberra, does not have the highest illusion, as would be expected from the hypothesis; the mean illusion of the Canberra sample is not statistically different from the mean illusion of the Areyonga sample ($t = 0.5659$, d.f. = 132), and is significantly lower than the mean illusion of the Hermannsburg group ($p<.001$; $t = 4.204$, d.f. = 168).

On the other hand, if the illusion was determined by operational development alone, we would expect the Areyonga sample to have the highest illusion, Hermannsburg an intermediate one, and Canberra the lowest. This hypothesis is supported by the relative illusion for the Hermannsburg and Canberra samples, but not by the low illusion in the Areyonga group.

Following Berry (1968), these partly contradictory findings could be considered to result from a confounding of the ecological and the developmental variables. The non-significant difference between the Canberra and the Areyonga samples could be explained by the fact that the two samples have widely different operational levels (high for Canberra, predicting low susceptibility, and low for Areyonga, predicting high susceptibility) and widely different ecologies (highly carpentered for Canberra, predicting high susceptibility, and minimally carpentered for Areyonga, predicting low susceptibility). Similarly, the higher illusion of the Hermannsburg sample could be explained by the interaction of a relatively low operational level (predicting a high illusion) and a relatively highly carpentered environment

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[1] The term 'illusion' is substituted throughout as a terminological convenience for 'error'. Thus a "lower illusion" means that the error of estimation was less.

(also predicting a high illusion).

Unfortunately, Berry's (1968) matching-of-sub-samples design can only partly be applied in the present study, but other attempts can be made to test the conflicting developmental and ecological hypotheses (to use Berry's terminology).

3. The developmental hypothesis

Three tests of the hypothesis of a direct relationship between susceptibility to the M-L illusion and operational development will be reported (hypothesis 4a). They all have the disadvantage of failing to control for the possibly confounding factor of ecology. It is not possible to match sub-samples on the latter variable, because the physical environment within each sample is considered to be homogeneous.

(a) Partial correlations

According to our hypothesis derived from Piaget's (1961, 1969a) work, it seems reasonable to expect a negative correlation between the extent of the M-L illusion and operational development (hypothesis 4a) even if age is held constant.

The partial correlation coefficients (Table 31a and b) between the M-L illusion and the operational scores (Logico-mathematical and Spatial), with age held constant, are very small (.01 to .27) if calculated for each sample separately. This is possibly due to the fact that the variation in operational level within each age group and each sample is too small. This variation is increased if the three samples are combined, and, in that case, the correlation coefficients are .23 and .26; these are statistically highly significant ($p < .0005$) and thus lend partial support to the hypothesis. But chronological age remains a better single predictor of the extent of the M-L illusion, confirming the findings of Spitz and Blackman (1958) and Gaudreau et al. (1963).

(b) Median-split on operational score

As a further test of the relationship between the extent of the M-L illusion and operational development, treatments x levels analyses of variance (Lindquist, 1953, pp.121-155) were performed for each sample separately and for the 3 samples

TABLE 31

CORRELATION BETWEEN M-L ILLUSION AND COGNITIVE DEVELOPMENT

A. Partial correlation: M-L illusion x Logico-Mathematical score (LM) with Age held constant (see text)

	r_{12} LM x ML	r_{13} LM x Age	r_{23} ML x Age	$r_{12.3}$ LM x ML with Age held constant	t for $r_{12.3}$	N
Canberra	-.576	.796	-.660	-.112	0.994	80
Significance level	.005	.005	.005		NS	
Hermannsburg	-.414	.718	-.530	-.057	0.530	90
Significance level	.005	.005	.005		NS	
Areyonga	-.289	.490	-.392	-.121	0.855	52
Significance level	.025	.005	.01		NS	
Canberra + Hermannsburg + Areyonga	-.376	.423	-.442	-.232	3.548	222
Significance level	.005	.005	.005		.0005	

TABLE 31

B. Partial correlation M-L illusion x Spatial score (Sp.) with Age held constant (see text)

	r_{12} Sp x ML	r_{13} Sp x Age	r_{23} ML x Age	$r_{12.3}$ Sp x ML with Age held constant	t for $r_{12.3}$	N
Canberra	-.672	.866	-.660	-.268	2.447	80
Significance level	.005	.005	.005		.01	
Hermannsburg	-.527	.713	-.530	-.251	2.427	90
Significance level	.005	.005	.005		.01	
Areyonga	-.221	.580	-.392	-.008	0.377	50
Significance level	NS	.005	.005		NS	
Canberra + Hermannsburg + Areyonga	-.465	.644	-.442	-.264	4.024	220
Significance level	.005	.005	.005		.0005	

combined. Above or below median logico-mathematical scores (respectively spatial scores) were considered to be the two treatments, the levels being the age groups. Significant treatment main-effects were predicted, the M-L illusion being expected to be lower for the above-median groups, and higher for the below-median groups.

No significant F values were found. This was also true when the analyses were performed with the top three and bottom three operational scores as the treatment variables.

(c) Practice effects (repeated measures)

First reported by Judd (1902), the decrease of the M-L illusion with practice has received the attention of many psychologists (e.g. Köhler and Fishback, 1950; Rudel and Teuber, 1963) including Piaget (1969a, pp.145-149), who bases his interpretation on developmental data collected by Noelting (1960).

According to Piaget, the decrease is due to the compensatory effect of exploratory perceptual activities which results in an equalisation of the density of encounters and in the completion of couplings. The gradual increase of perceptual activities with age explains why, in Noelting's data, the decrease with practice increases with age. It seems therefore reasonable to regard the decrease of the illusion as indicative of perceptual activities.

Practice effects were examined on the basis of the differences between the first and last (5th) PSE's. Since an average of about 20 stimulus presentations were used for each subject, the situation seems to be closely comparable to that reported by Piaget (1969a, p.146), where the mean of the first five presentations (with a method of adjustment) was compared to the mean of the last five presentations in a series of 20 trials per subject.

According to hypothesis 4b, the mean decrease of the illusion should be largest in the Canberra sample, followed by the Hermannsburg and Areyonga samples, in that order. Furthermore, if the decrease increases with age, the maximum decrease should occur at an earlier age in the Canberra sample than in the Hermannsburg and Areyonga samples, in that order. The results are presented in Table 32a and in Fig. 30.

TABLE 32

MÜLLER-LYER ILLUSION : DECREASE WITH PRACTICE

A. Means and mean differences

	Canberra				Hermannsburg				Areyonga			
	PSE 1	PSE 5	D1-5	N	PSE 1	PSE 5	D1-5	N	PSE 1	PSE 5	D1-5*	N_{D1-5}*
Age: 5	31.2	27.6	3.6	10								
6	31.2	27.2	4.0	10	33.2	31.6	1.6	10	26.5	25.7	0.8	8
7	27.6	24.8	2.8	10	29.2	34.0	-4.8	10				
8	22.8	18.8	4.0	10	30.0	34.4	-4.4	10	26.2	22.6	2.9	11
9	23.6	19.6	4.0	10	23.6	20.8	2.8	10				
10	18.0	13.6	4.4	10	26.2	22.4	3.8	10	20.4	18.0	2.4	9
11	22.0	13.6	8.4	10	24.4	22.2	2.2	10				
12	20.4	17.2	3.2	10	22.4	19.8	2.6	9	17.7	14.6	2.6	13
13					21.6	24.8	-3.2	10				
14												
15					24.4	17.0	7.4	10	19.1	12.8	8.0	10
16												
Adults	21.7	18.6	3.1	20	26.9	23.3	3.6	9	14.9	11.1	3.8	9
$\bar{x}$ 6-12 + Adults			4.1	90			0.9	78			2.7	43

* For the Areyonga sample, the mean differences are not necessarily equal to the differences between means, because 5 subjects have not completed all 5 PSE measurements.

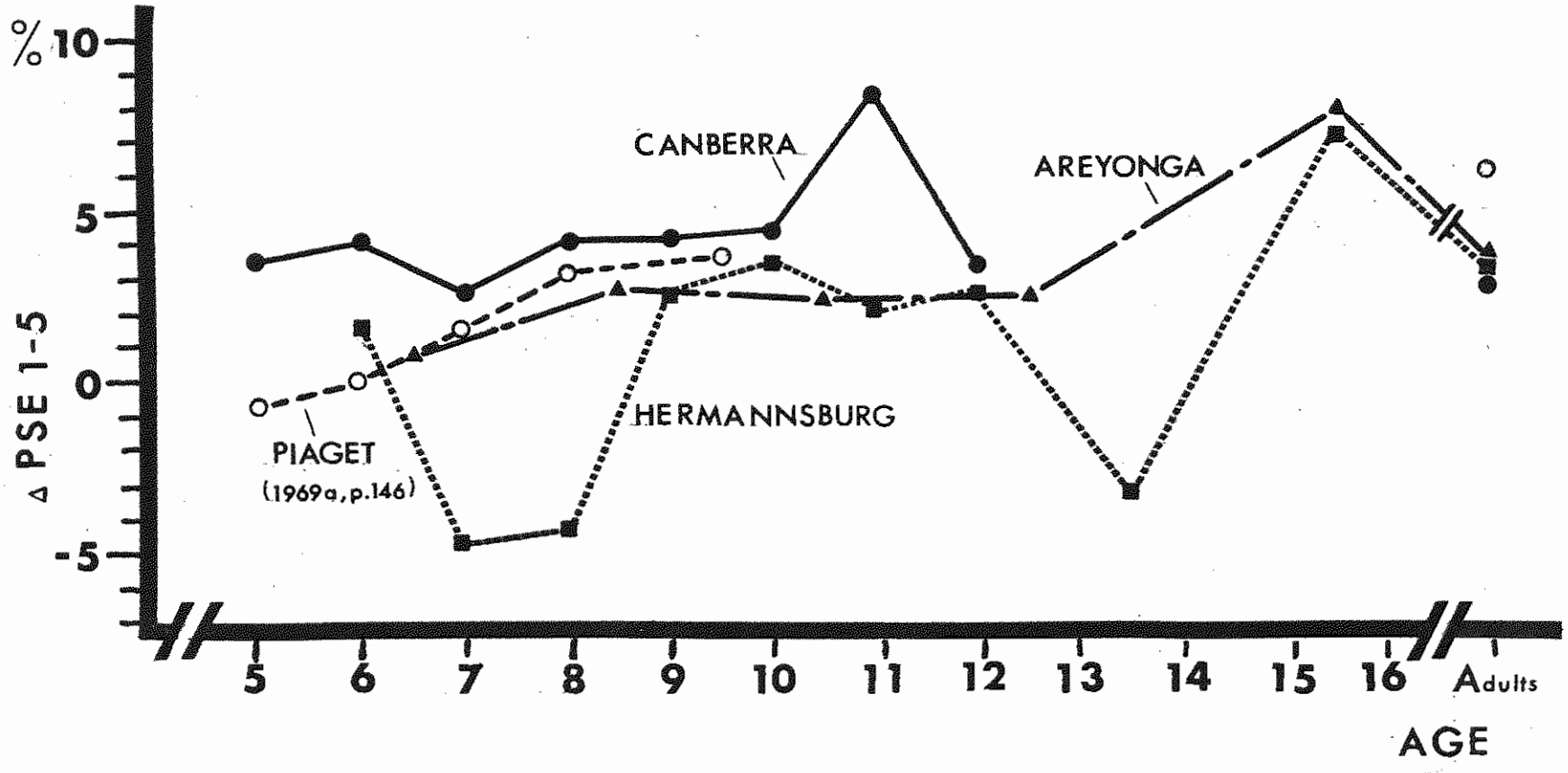
TABLE 32

B. Analyses of variance

	Canberra		Hermannsburg		Areyonga	
	F	p	F	p	F	p
Main effect, age (between, rows)	8.65	< .01	4.66	< .01	4.14	< .01
Main effect, PSE's 1-5 (within, columns)	27.32	NS	0.75	NS	6.31	< .05
Interaction Age x PSE's 1-5 (rows x columns)	0.44	NS	0.90	NS	0.50	NS

FIG. 30 MÜLLER-LYER ILLUSION

Decrease with practice



The hypothesis receives qualified support from the fact that the average decrease in illusion is larger for the Canberra sample than for the Aboriginal sample (over the common age ranges), but the mean decrease is larger in the Areyonga group than in the Hermannsburg group.

The change with age of the practice effect is not as regular as that reported by Piaget; large fluctuations occur especially in the results of the Hermannsburg sample. The largest decrease occurs at age 11 in the Canberra sample, and at about age 15 in the two Aboriginal samples, which further supports the hypothesis.

On the other hand, the three adult samples have about the same mean decrease in illusion (3.0% to 3.8%), whereas their operational levels are clearly different.

An analysis of variance (mixed design, type 1, Lindquist, 1953, pp.269-277) was performed on this data (Table 32b), with negative results. There are, however, serious doubts whether this is a valid procedure, because the requirement that the treatment x subjects interaction effects be normally and independently distributed for each level is almost certainly not satisfied. When individual treatment x subjects designs are applied to each age level, the interaction mean squares show large variations (for example from 16 to 148 in the Areyonga sample).

The individual treatment x subjects analyses of variance give significant F values for the treatment effects (PSE 1 - 5) at ages 9 and 11 in the Canberra sample ($p < .05$), at age 15/16 in the Hermannsburg sample and age 14/16 in the Areyonga sample (both $p < .01$). All other F values do not reach the .05 level of significance.

A further non-confirmation of the hypothesis is provided by the low correlation coefficients of the practice effect with age and with operational scores (Table 33).

4. The ecological hypothesis

To test the ecological cue validity hypothesis (hypothesis 5a) with operational level held constant, sub-samples were

TABLE 33

MÜLLER-LYER ILLUSION : CORRELATIONS BETWEEN THE DECREASE IN ILLUSION AND LOGICO-MATHEMATICAL SCORE, SPATIAL SCORE AND AGE.

	D_{1-5} x LM score			D_{1-5} x Sp score			D_{1-5} x Age		
	r	p	N	r	p	N	r	p	N
Canberra	.07	NS	80	.16	NS	80	0.09	NS	80
Hermanns-burg	.13	NS	89	.19	.05	89	0.22	0.25	89
Areyonga	.06	NS	50	.09	NS	48	0.14	NS	52

matched on age and on logico-mathematical score (respectively spatial score)[1]. The results are presented in Table 34.

The relative extents of the illusion in the three samples are not changed by the matching: the Hermannsburg sample has a stronger illusion than both the Canberra and the Areyonga samples, whereas there is no significant difference between the mean illusions in the latter two samples.

The hypothesis is thus confirmed in relation to the two Aboriginal groups, but is not confirmed when comparisons with the Canberra sample are made. In most previous studies, non-significant differences were obtained with intra-ethnic comparisons and significant results with inter-ethnic comparisons (see review, Chapter 1,B), and the present findings are therefore rather surprising.

B. HORIZONTAL-VERTICAL ILLUSION

1. Review of the literature

According to Künnapas (1955), the so-called H-V illusion is due to the combination of two different factors: (a) the overestimation of the dividing line, called the dichosection effect, and (b) the overestimation of the vertical line as compared with the horizontal line.

This distinction is also made by Piaget (1961, 1969a) who interprets the first factor as a primary mechanism and the second factor as a secondary one (in short, the differential distribution of attention to the top of the vertical and the middle of the horizontal). Accordingly, Piaget prefers to call 'T figures' those in which the lines intersect and the corresponding effect the 'illusion of semi-rectangles'; for these figures, the combination of the two factors mentioned above is sometimes cumulative, and sometimes subtractive, depending on the relative positions of the

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[1] At each age level, those subjects who had the most similar operational score were matched, allowing for a maximum discrepancy of 2 points. If several matching possibilities occurred, one was chosen at random.
Only for the Canberra/Areyonga comparison was the matching on logico-mathematical score not possible, because there was no overlap between scores within each age-group.

TABLE 34

MÜLLER-LYER ILLUSION, THE ECOLOGICAL HYPOTHESIS : SAMPLES MATCHED ON AGE AND ON OPERATIONAL SCORE

Matching:	Age and logico-mathematical score							Age and spatial score						
	$\bar{x}$ LM score	SD LM score	$\bar{x}$ illus.	SD illus.	t	p	N	$\bar{x}$ SP score	SD Sp score	$\bar{x}$ illus.	SD illus.	t	p	N
Canberra))) - Hermannsburg)	12.7	5.8	21.9	6.4	2.277	.05	18	62.9	8.7	21.7	6.2	3.106	.01	34
	12.5	5.9	27.8	8.7				62.8	8.9	27.4	8.6			
Hermannsburg))) - Areyonga)	8.5	4.3	23.8	8.1	2.686	.02	41	60.2	8.8	26.2	6.8	3.174	.01	33
	8.6	4.4	19.8	8.3				60.2	8.7	20.8	7.2			
Canberra))) - Areyonga)	Not feasible							62.4	7.3	21.3	4.5	0.910	NS	16
								62.7	7.3	22.9	5.4			

segments. In the L-type figures ("right-angle figures" in Piaget's terminology) on the other hand, the dichosection effect is absent. (For a discussion of the consequences of this distinction for the ecological cue validity theory, see Deregowski, 1967.)

Wohlwill (1960) remarks that the nature of the change with age in susceptibility to the illusion remains uncertain despite a considerable amount of developmental work on this illusion, but he suggests the following tentative conclusion (p.256):

> If the two lines of the figure intersect (...), the effect decreases with age; if, on the other hand, the subject has to compare noncontiguous segments, ... the illusion increases up to a maximum at about age 10, subsequently declining up to adulthood.

Piaget's interpretation of the illusion as a combination of primary and secondary mechanisms fits this conclusion extremely well, whereas the ecological cue validity theory alone cannot account for a decrease of the illusion with age. (Segall et al. (1966, pp.199-200) mention some developmental data, but these are mainly ambiguous.)

2. Results

The results obtained with the H-V figure are presented in Table 35 and in Fig. 31.

Although large fluctuations occur, it seems reasonable to interpret the developmental trends as an initial increase followed by a decrease in each sample. This confirms the results obtained by other investigators with L-type figures (Wohlwill, 1960; Piaget, 1961, 1969a).

The ecological cue validity hypothesis receives support from the inter-ethnic comparison of the strength of the illusion; the maxima attained by the two Aboriginal samples are higher than the maximum in the Canberra sample. Furthermore, the relative susceptibility to the illusion of the adults in the three samples follows the predictions of the 'open-vista' hypothesis.

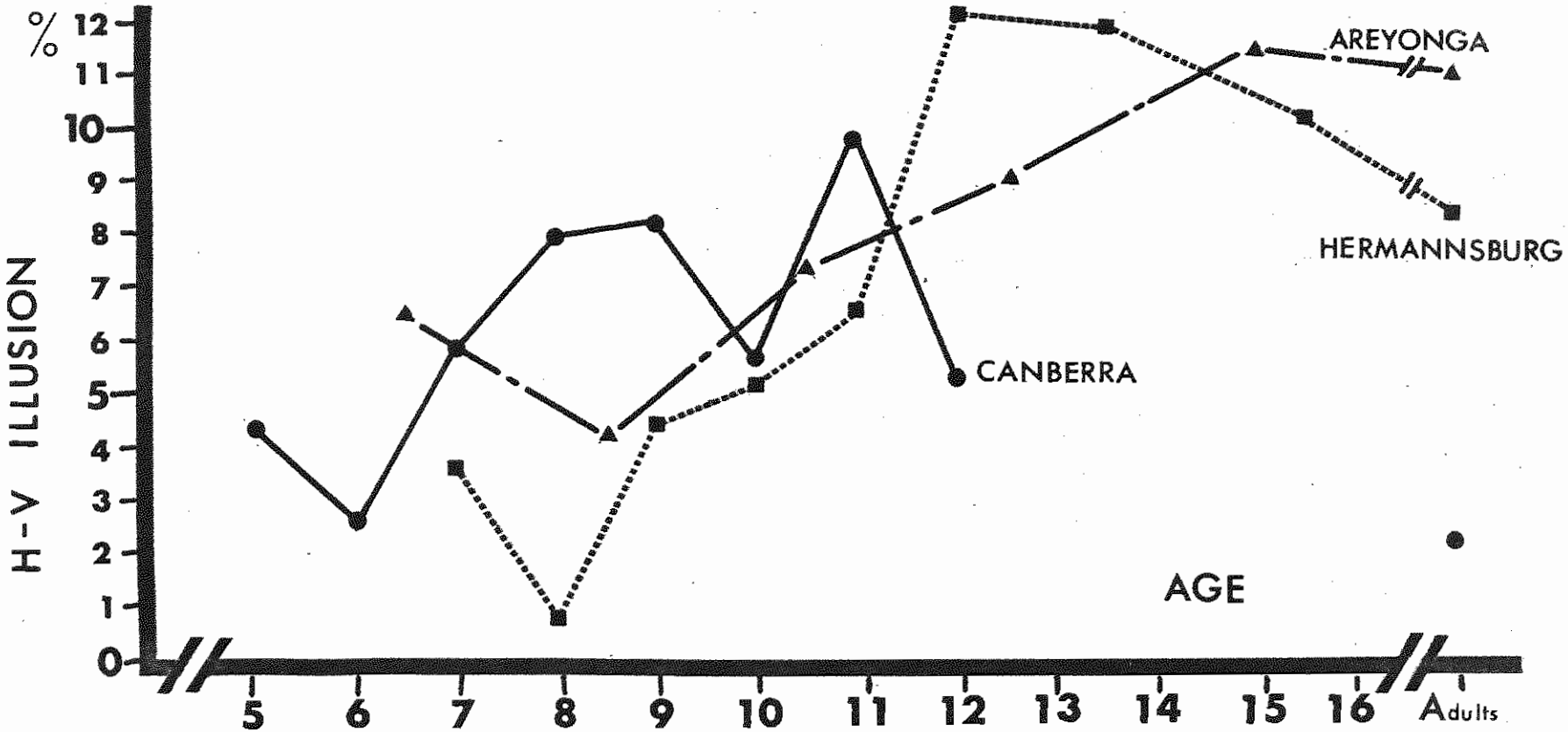
An interpretation in terms of the influence of operational development on perceptual activities (hypothesis 4c) is supported by the inverted-U shaped developmental

TABLE 35

HORIZONTAL-VERTICAL ILLUSION : MEANS, STANDARD DEVIATIONS AND MEDIANS FOR EACH SAMPLE AND EACH AGE

	Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.
Canberra														
	Mean	4.1	2.8	5.5	8.1	8.2	6.8	10.1	4.9					3.0
	S.D.	5.8	4.3	4.9	2.5	4.0	3.4	4.2	2.0					4.1
	Median	4.2	2.6	5.8	7.9	8.1	5.6	9.9	5.2					2.2
	N	10	10	10	10	10	10	10	10					20
Hermannsburg														
	Mean		3.3	3.1	0.9	5.6	5.9	5.3	10.9		10.4		10.9	6.6
	S.D.		6.7	7.7	4.8	5.3	6.0	6.3	7.4		6.1		5.2	7.5
	Median		2.6	3.5	0.6	4.4	5.1	6.6	12.1		11.9		10.1	8.3
	N		10	10	10	10	10	10	10		10		10	10
Areyonga														
	Mean			7.9		3.5		7.2		9.9		11.4		10.6
	S.D.			8.9		3.7		5.8		5.4		5.9		5.8
	Median			6.5		4.1		7.4		9.0		11.6		11.0
	N			8		12		9		15		11		10

FIG. 31 HORIZONTAL-VERTICAL ILLUSION: MEDIANS



curves, as mentioned above, and by the fact that the maximum strength of illusion seems to be attained at different ages in the three samples, and this in the same order as their respective levels of operational development.

Because of the curvilinear relationship of the illusion with age, it is not possible to apply the same statistical techniques as were applied with the M-L illusion. However it is possible to plot the extent of the illusion as a function of logico-mathematical[1] score (Table 36 and Fig. 32).

The resulting curves no longer display a horizontal displacement, as in Fig. 31, but show about the same increase with increasing operational score in the three samples, the relative order in susceptibility to the illusion being as predicted by the ecological hypothesis (hypothesis 5b)[2].

If subsamples are matched on both age and operational score (logico-mathematical and spatial scores), only one of the comparisons (Hermannsburg/Areyonga matched on logico-mathematical score) is statistically significant in the direction predicted by the ecological hypothesis (Table 37).

Practice-effects (PSE 1 - 5) were also examined with this illusion, but there is no consistent decrease nor increase in any of the samples.[3] This confirms the findings of Piaget (1969a, pp.151-152).

C. DELBOEUF ILLUSION

The Delboeuf illusion has received only scant attention in developmental studies (Wohlwill, 1960) and, as far as is known, has never been investigated in a cross-cultural context.

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[1] The same calculations were performed with the spatial scores. There is a general tendency for the illusion to increase with increasing spatial score, but fluctuations are large. To save space, the results are not reported in detail.

[2] The three curves show an initial drop in the illusion; this also happens when the illusion is plotted over age (Fig. 31), although it is less marked. No appropriate explanation of this phenomenon could be found.

[3] This is also the case for the Delb., O-K and S-W illusions.

TABLE 36

HORIZONTAL-VERTICAL ILLUSION AS A FUNCTION OF LOGICO-MATHEMATICAL SCORE

L-M score:	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24
Canberra													
$\bar{x}$ illusion	7.7	0.2	2.3	1	1.6	5.2	4.1	7.0	8.0	6.0	7.9	6.9	7.3
S.D.	6.3	6.2	3.9		4.2	4.0	5.0	2.2	5.1	3.2	2.9	0.9	4.8
N	4	3	6	1	3	2	3	6	15	5	12	5	15
Hermannsburg													
$\bar{x}$ illusion	5.6	1.4	3.0	5.0	4.5	6.6	8.0	6.6	9.9	10.8	12.6	10.4	8.2
S.D.	8.3	8.2	5.7	7.6	5.5	6.7	6.6	7.4	6.1	8.1	4.6		
N	4	8	7	10	17	10	7	6	11	5	3	1	1
Areyonga													
$\bar{x}$ illusion	10.0	1.4	7.6	6.9	6.2	8.3	8.3	12.1	9.4				
S.D.	4.2	6.5	10.0	4.8	6.6	7.3	4.9	3.7	13.0				
N	5	2	7	11	7	7	6	5	2				

FIG. 32 HORIZONTAL-VERTICAL ILLUSION
as a function of L-M score

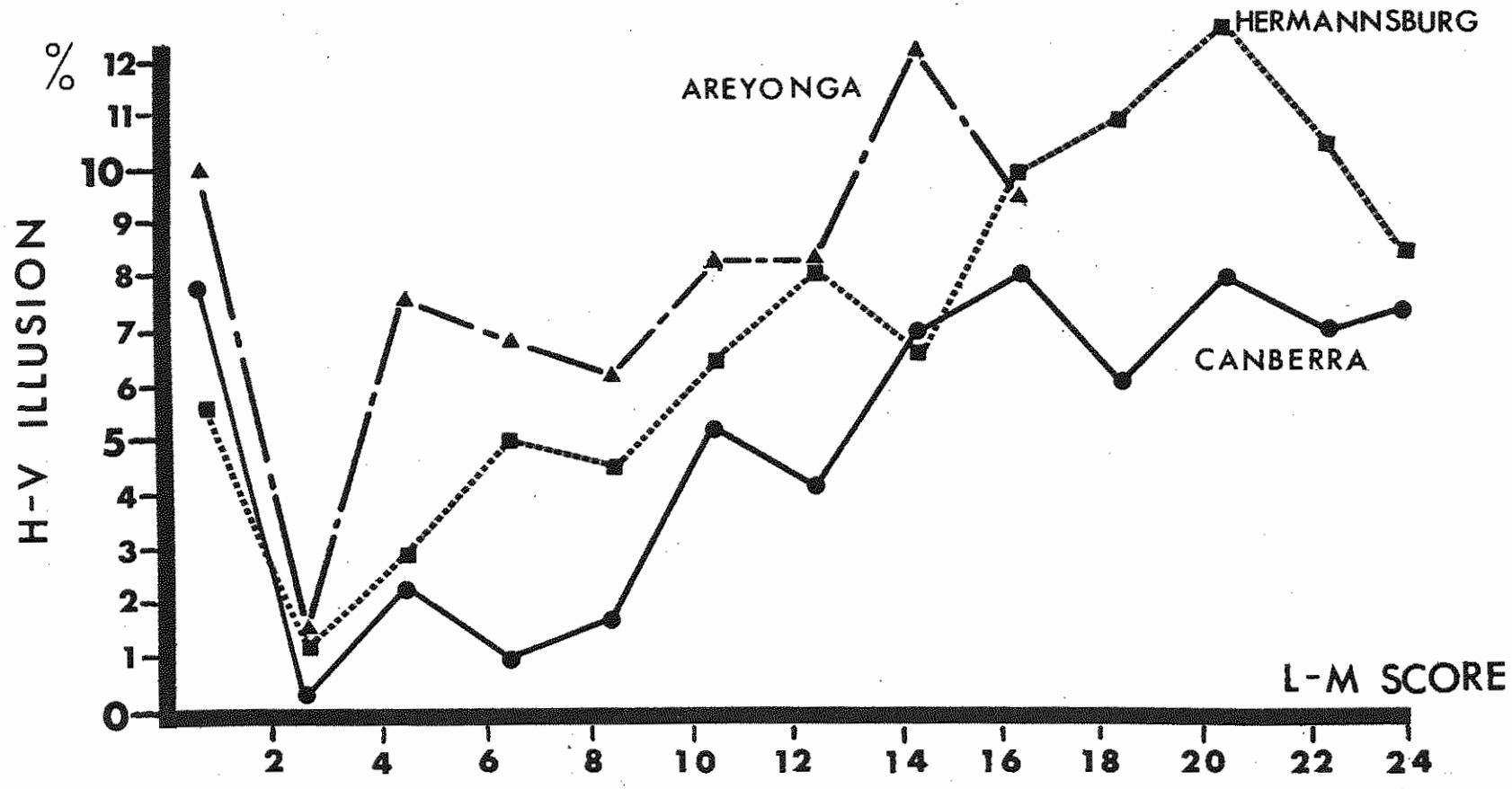


TABLE 37

HORIZONTAL-VERTICAL ILLUSION, THE ECOLOGICAL HYPOTHESIS : SAMPLES MATCHED ON AGE AND ON OPERATIONAL SCORE*

Matching:	Age and logico-mathematical score				Age and spatial score			
	$\bar{x}$ illus.	t	p	N	$\bar{x}$ illus.	t	p	N
Canberra	4.6				6.5			
		0.311	NS	18		1.943	NS	34
Hermannsburg	5.1				4.0			
Hermannsburg	5.2				6.1			
		2.012	.05	41		0.153	NS	33
Areyonga	7.6				6.3			
Canberra					7.4			
		Not	feasible			0.012	NS	16
Areyonga					7.4			

* as in table 34 for the M-L illusion.

It was included in this study because, according to Piaget (1961, 1969a), it obeys the same (primary) mechanisms as the M-L illusion, whereas it is not relevant to the ecological cue validity theory.

The results are presented in Tables 38 and 39, and Figs. 33 and 34.

The illusion clearly follows the pattern of a secondary illusion: after an initial increase with age, it reaches a maximum and then decreases slightly. The developmental curves of the two Aboriginal samples overlap almost exactly; the curve for the Canberra sample has the same aspect, but the maximum illusion occurs three years before it is reached in the Aboriginal samples. Europeans are, generally speaking, more susceptible to the illusion than Aborigines.

When the illusion is plotted as a function of logico-mathematical score (Table 39 and Fig. 34), the hypothesis of a relationship between operational development and the extent of the illusion is demonstrated in the same way as for the H-V illusion.

Thus, instead of showing a primary illusion pattern, the results of the Delboeuf illusion resemble those of the (secondary) H-V illusion.

Possible causes for this reversal of prediction need to be considered. One possible cause would be the spatial separation of the stimulus figures: the figures were large, and the centres of the circles to be compared were separated by 24.2 cm (cf. p.146-8). From casual observation of the subjects' behaviour, it was obvious that most subjects did not attend to both parts of the figure in a single fixation, but made the comparisons by alternatively fixating the standard and the variable.

If this is so, perceptual activities of "transport" (Piaget, 1969a, pp.176-182) are involved, and it seems reasonable that the illusion should become a secondary one. This possibility was overlooked when the stimulus material was designed, but, a posteriori, seems quite logical in view of Piaget's work.

Other, similar, reports in the literature comprise a transformation of the M-L illusion into a secondary illusion

TABLE 38

DELBOEUF ILLUSION : MEANS, STANDARD DEVIATIONS AND MEDIANS FOR EACH SAMPLE AND EACH AGE

Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.
Canberra *													
Mean	2.8	6.9	8.9	7.4	7.6	7.8	6.6	7.0					7.0
S.D.	5.0	2.9	2.1	2.9	3.3	3.4	2.4	2.9					2.0
Median	3.0	7.8	9.3	8.3	8.1	8.3	6.9	7.8					7.2
Hermannsburg													
Mean		0.6	-2.4	-2.5	5.2	4.8	1.3	4.9		3.6		1.4	
S.D.		5.4	8.3	6.0	6.2	5.0	9.5	3.0		3.9		9.0	
Median		-1.2	-0.9	-3.3	3.5	5.9	2.4	4.2		3.3		4.2	
N		7	10	10	10	10	10	10		10		10	
Areyonga													
Mean			-1.3		2.2		5.1		3.8		4.0		
S.D.			7.8		7.1		5.0		5.2		2.0		
Median			-4.1		1.9		5.7		3.9		4.5		
N			8		12		7		15		8		

Canberra * N = 10 at each age, except at age 5 (N=9) and Adults (N=20).

FIG.33 DELBOEUF ILLUSION : MEDIANS

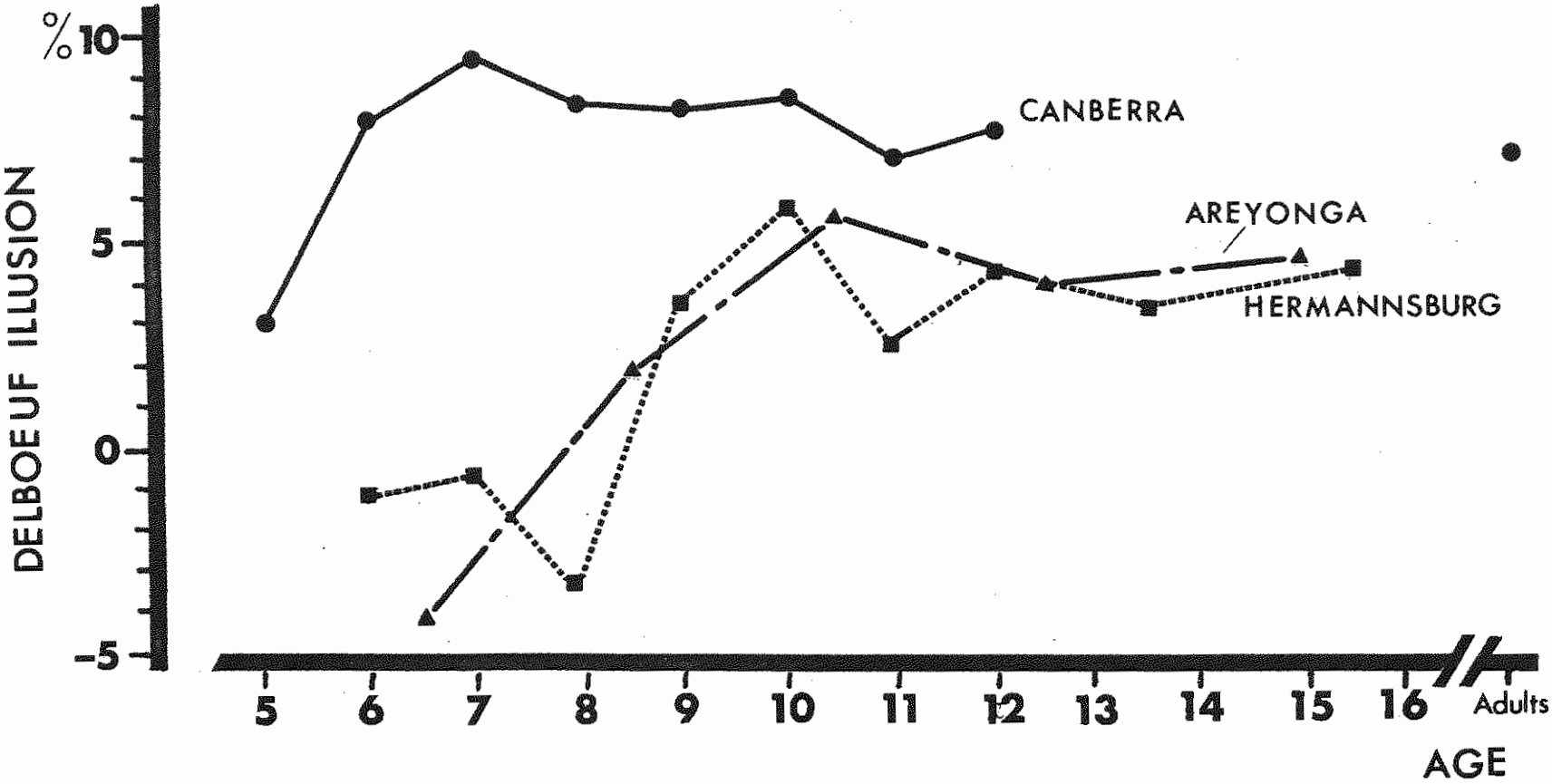
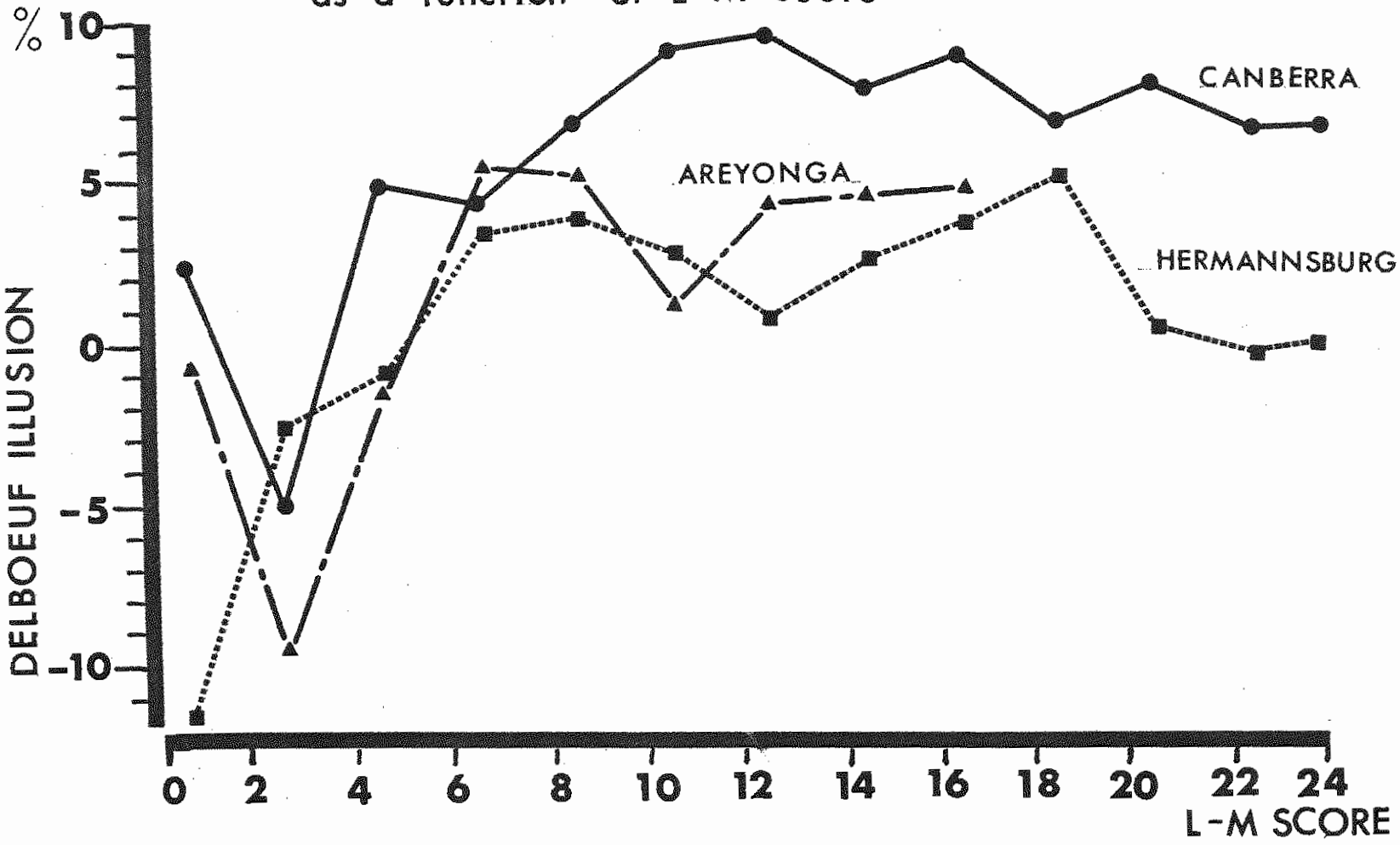


TABLE 39

DELBOEUF ILLUSION AS A FUNCTION OF LOGICO-MATHEMATICAL SCORE

L-M score:	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24
Canberra													
$\bar{x}$ illusion	2.3	-5.0	4.8	4.2	6.5	9.0	9.6	7.7	8.7	6.8	7.9	6.4	6.5
S.D.	6.9	10.7	3.2	-	1.8	0.6	2.1	1.9	2.9	3.8	2.6	2.2	2.9
N	4	3	6	1	3	2	3	6	15	5	12	5	15
Hermannsburg													
$\bar{x}$ illusion	-11.6	-2.5	-0.9	3.5	3.9	2.6	0.9	2.5	3.6	5.0	0.4	-0.3	0
S.D.	5.0	5.6	5.0	7.6	7.4	5.5	3.5	7.0	7.1	3.3	8.7	-	-
N	2	9	7	10	16	10	6	6	11	5	3	1	1
Areyonga													
$\bar{x}$ illusion	-0.8	-9.6	-1.7	5.4	5.1	1.1	4.1	4.3	4.5	-	-	-	-
S.D.	7.0	3.6	5.5	4.1	5.3	6.6	3.2	2.3	0.9				
N	5	2	6	11	6	7	6	5	2				

FIG. 34 DELBOEUF ILLUSION
as a function of L-M score



by increasing the temporal interval between the successive presentation of the line and the arrows (Pollack, 1964). The Delboeuf illusion is reversed if the circles are presented with a temporal interval of 300 ms (Usnadze effect: Piaget, 1969, pp.186-188; Vurpillot, 1966). Vurpillot (1966) uses these experiments, among others, to argue against a distinction between primary and secondary illusions.

It would be interesting to conduct a developmental study of the effect of increasing the spatial separation between the standard and the variable Delboeuf circles, to establish whether the present post-hoc interpretation is correct.

If this interpretation were correct, the results of the Delboeuf illusion could be seen as confirming hypothesis 4c, since the maximum susceptibility to the illusion is attained earlier in the Canberra sample than in the two Aboriginal samples. There is, however, no clear difference between the ages at which the maximum is attained in the Aboriginal samples.[1]

D. OPPEL-KUNDT ILLUSION

The developmental aspects of this illusion have been studied by Vurpillot (in Piaget, 1961, 1969a). The O-K illusion folows the typical shape of secondary illusions, with a maximum at 12 years for boys and at 9 years for girls. A positive correlation with IQ was found by Gaudreau et al. (1963).

The results of the present study are presented in Tables 40 and 41, and in Figs. 35 and 36.

The illusion is generally much weaker than that reported by Piaget, and no definite age trends are evident, although one might imaginatively interpret the graphs (Fig. 35) as examples of the expected secondary illusion curves.

When studied as a function of logico-mathematical score, (Table 41, Fig. 36), the illusion shows a tendency to increase

[1] The Delboeuf illusion was also measured by a much simpler technique, in which the subjects had to select, among a series of 8 cutout circles, the one which would fit the standard exactly. The results obtained with this technique were chaotic.

TABLE 40

OPPEL-KUNDT ILLUSION : MEANS, STANDARD DEVIATIONS AND MEDIANS FOR EACH SAMPLE AND EACH AGE GROUP

Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.
Canberra													
Mean	2.4	6.3	2.5	7.9	4.9	4.0	6.4	4.1					4.3
S.D.	5.4	4.9	3.7	5.5	5.0	3.6	4.9	5.3					4.3
Median	1.7	6.7	2.3	7.3	4.0	3.7	5.7	3.8					3.4
N	10	10	10	10	10	10	10	10					20
Hermannsburg													
Mean		5.5	1.1	1.2	9.6	6.4	5.7	2.8		3.8		2.7	
S.D.		4.8	6.5	6.1	7.8	8.8	8.4	6.2		3.8		8.2	
Median		5.7	2.8	1.9	8.4	8.2	6.6	2.7		4.1		4.4	
N		8	9	10	10	10	10	10		10		10	
Areyonga													
Mean			2.6		2.7		5.9		3.1		4.6		
S.D.			5.9		6.3		8.5		4.8		5.8		
Median			2.8		3.1		6.8		3.2		1.1		
N			7		12		8		15		8		

FIG.35 OPPEL-KUNDT ILLUSION: MEDIANS

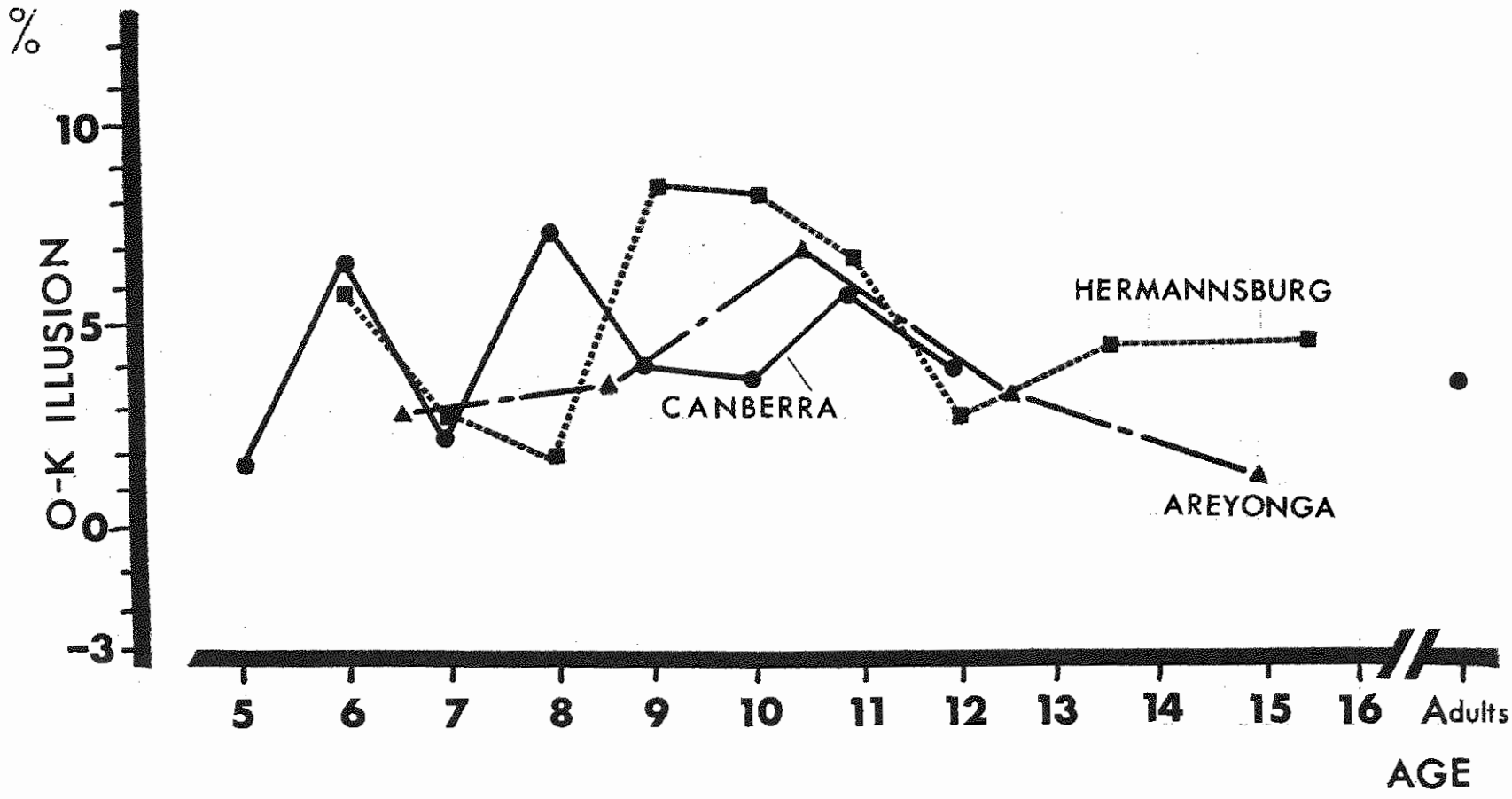


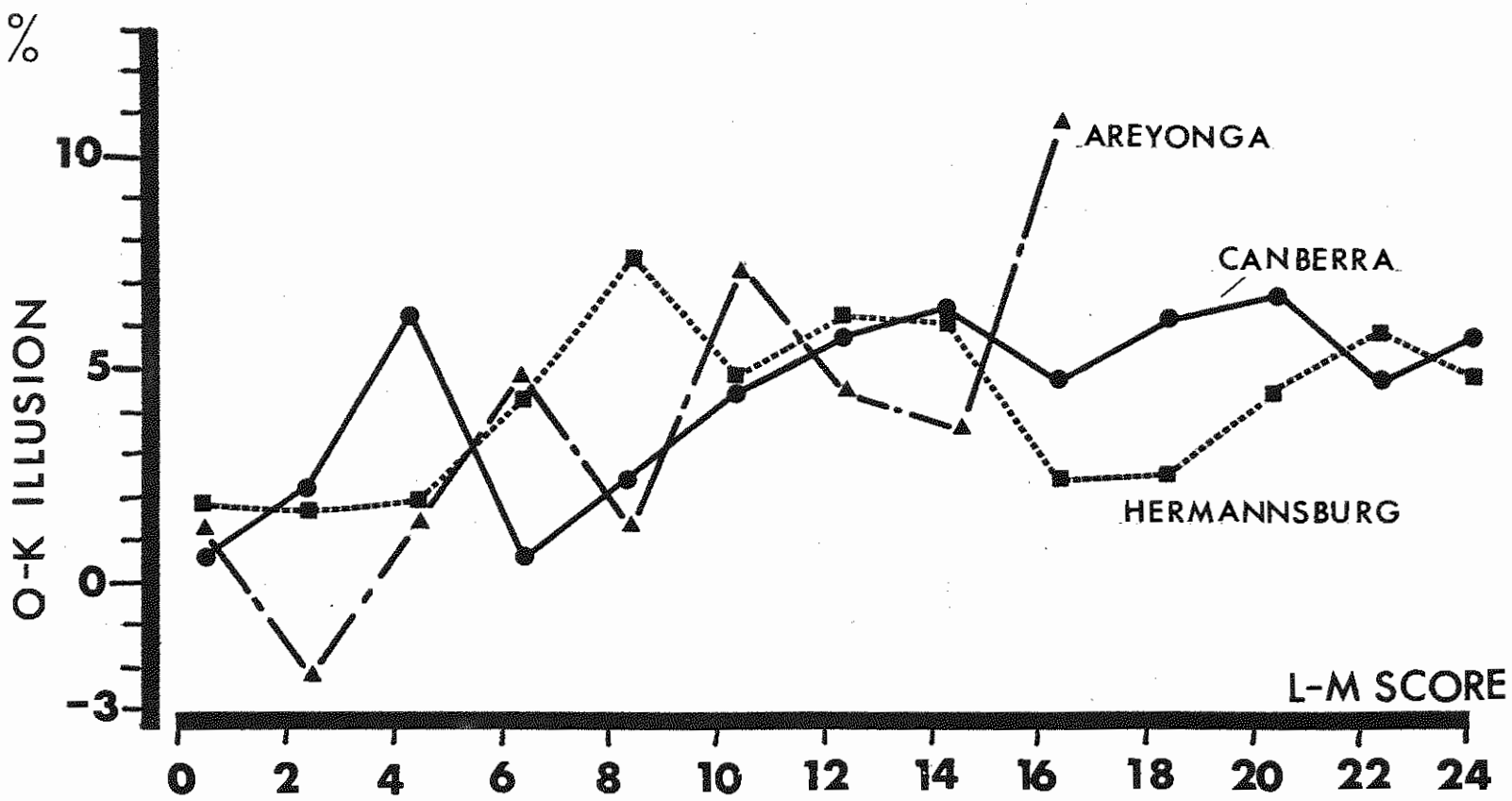
TABLE 41

OPPEL-KUNDT ILLUSION AS A FUNCTION OF LOGICO-MATHEMATICAL SCORE

L-M score:	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24
Canberra													
$\bar{x}$ illusion	0.6	2.1	6.2	0.6	2.1	4.3	5.4	6.2	4.4	5.7	6.2	4.1	5.5
S.D.	3.6	3.7	5.9	-	2.6	5.3	3.2	7.2	3.2	2.0	4.6	6.7	5.4
N	4	3	6	1	3	2	3	6	15	5	12	5	15
Hermannsburg													
$\bar{x}$ illusion	2.0	2.0	2.0	4.4	7.4	4.4	5.7	6.2	2.1	2.2	4.3	6	4.8
S.D.	10.3	5.4	3.9	6.9	6.9	6.7	4.6	10.2	8.6	4.5	0.3	-	-
N	2	8	6	10	17	10	7	6	12	5	2	1	1
Areyonga													
$\bar{x}$ illusion	1.5	-2.2	1.3	4.6	1.1	7.2	4.0	3.4	10.7	-	-	-	-
S.D.	6.0	4.0	6.6	6.6	4.2	4.3	4.6	3.5	3.5				
N	4	2	7	11	6	7	6	5	2				

FIG.36 OPPEL-KUNDT ILLUSION

as a function of L-M score



with increasing operational score, but the fluctuations are very large.

E. SIZE-WEIGHT ILLUSION

1. Review of the literature

This illusion has received considerable attention since Charpentier (1891) first described it. In Geneva, Flournoy and Claparède (for a review, see Claparède, 1937) devoted some time to it, and Rey (1930) provided one of the first developmental studies. The illusion was reported to increase to the age of 9 years and then to decrease again.[1]

It is on this early data that Piaget (1961, 1969a) has based his interpretation of the S-W illusion as a secondary one: Among the many variables affecting this illusion, the anticipation of a proportion between weight and volume, followed by a contrast-effect if this anticipation is not confirmed, is a necessary condition and provides the link with the anticipatory activities found in visual perception. The correlation of the illusion with intelligence (mentally retarded children are usually reported not to be subject to the illusion (Rey, 1930; Claparède, 1937; Vurpillot, 1966)), provides another indication in favour of Piaget's interpretation.

Other investigations, however, provide conflicting results. Ciampi (in Wohlwill, 1960) and Ohwaki (1953) both found an increase with age in the percentage of subjects showing the illusion, and so did Philippe and Clavière (in Robinson, 1964). Oostlander (1967) found that the development "followed the general form" (increase followed by decrease), but that the decrement of the illusion took place much earlier than supposed, suggesting that the illusion was more like a primary than like a secondary illusion.

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[1] If Rey's (1930) data are recalculated and expressed as extent of illusion over age, we find, in fact, that the illusion increases sharply from age 5 and 6 years to a maximum at age 7 years, then decreases until age 11, increases to a new maximum at age 14 years and declines again for the adult sample.

Robinson (1964) claims that most reported results were not valid because of the verbal instructions which were used: younger children (and mentally defectives) might not understand what is meant by 'heavier'. This sounds rather unconvincing, at least as far as normal children aged 5 or more are concerned. In Rey's (1930) investigation, a pretest was taken to control for the subjects' understanding and only four (retarded) children had to be eliminated.

In Robinson's study, the children were previously trained always to select the heavier of two cylinders of the same size; when they had reached the criterion of 19 correct out of 20 trials in two successive sessions, 5 illusion trials were introduced: objects differing in size but identical in weight. Subjects aged 2 years exhibited the illusion on 91% of the trials.

Other experiments by Robinson (1964) showed that the size of the illusion decreased with age from 2 to 10 years, and this as a function of training in weight discrimination.

All in all, studies of the S-W illusion still present considerable inconsistencies, both in experimental results and in their interpretations. It may, however, be possible to integrate most results in the following hypothetical construct:

The illusion depends on an 'expectation' (without implying consciousness) that the larger object will be heavier; this 'anticipation' (as Piaget calls it) may be effective as soon as visual and tactilo-kinaesthetic cues can be coordinated and sufficient experience that larger objects are heavier has been accumulated. It is not impossible that this happens during the sensori-motor period and that therefore the illusion can be demonstrated very early in life; in fact, it would be surprising if it were not so.

Thereafter:

1. The gradual building up of this expectation with experience causes the illusion to increase.

2. As weight discrimination becomes more accurate, the illusion decreases; this decrease can be obtained at an early age by special training (Robinson, 1964) or will become effective by normal development at a later age.

3. As with other secondary illusions, susceptibility will also decrease as the expectation becomes more flexible. This factor will play a role only as the child gets older, unless we train him, as in Robinson's study, to overcome the 'set' in presenting repeatedly situations in which the anticipation is deceived (as is the case with two objects of same volume and different weights.)[1]

This speculative interpretation of the interaction of these three influences could account for both Piaget's and Robinson's findings, if we accept that 2 and 3 are speeded up by the conditioning situation.

2. Results

The results of the present study are presented in Tables 42 and 43, and in Figs. 37 and 38.

In the Canberra sample, the illusion does follow the pattern of a secondary illusion: it increases until age 9, and then decreases slightly; when plotted against operational score, the tendency is for an increase in the illusion with increasing score. In both graphs, rather large fluctuations occur. These are even more marked for the Hermannsburg sample, and no clear pattern emerges. In the Areyonga sample, the illusion decreases, both with age and as a function of operational score, but the illusion is generally higher than in the two other samples.

Thus, the results of the Canberra sample confirm Piaget's interpretation, whereas the results of the two Aboriginal samples are more difficult to interpret in theoretical terms.

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[1] It should be noticed that such an experiment was suggested by Claparede (1902, p.92): "It would be interesting to see if these visuo-motor associations ... could be destroyed or modified by new practice: we should confine ourselves for a few days or weeks to lift only small and heavy objects and large and light ones, objects prepared in advance which we would dispose around us to have them at hand." (Present writer's translation).

TABLE 42

SIZE-WEIGHT ILLUSION : MEANS, STANDARD DEVIATIONS AND MEDIANS FOR EACH SAMPLE AND EACH AGE

Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.
Canberra													
Mean	28.8	37.9	39.1	42.6	46.0	38.7	43.0	41.0					38.2
S.D.	10.7	9.5	10.1	7.2	8.5	5.3	6.4	6.4					7.1
Median	30.0	37.5	36.3	41.3	45.0	39.3	43.8	40.0					38.8
N	10	10	10	10	10	10	10	10					20
Hermannsburg													
Mean		31.6	46.8	41.0	45.25	39.4	45.6	40.6		34.3		40.5	42.8
S.D.		8.9	8.1	8.8	7.8	7.1	8.8	9.2		11.6		7.4	2.4
Median		35.0	47.5	38.8	42.5	39.5	50.0	41.3		36.3		42.5	43.1
N		10	9	10	10	10	10	10		10		10	10
Areyonga													
Mean			49.3		48.0		45.8		47.7		43.2		44.3
S.D.			12.7		6.8		6.8		6.6		7.3		6.7
Median			50.4		49.4		47.5		47.5		41.3		42.5
N			6		12		8		15		11		10

FIG. 37 SIZE-WEIGHT ILLUSION : MEDIANS

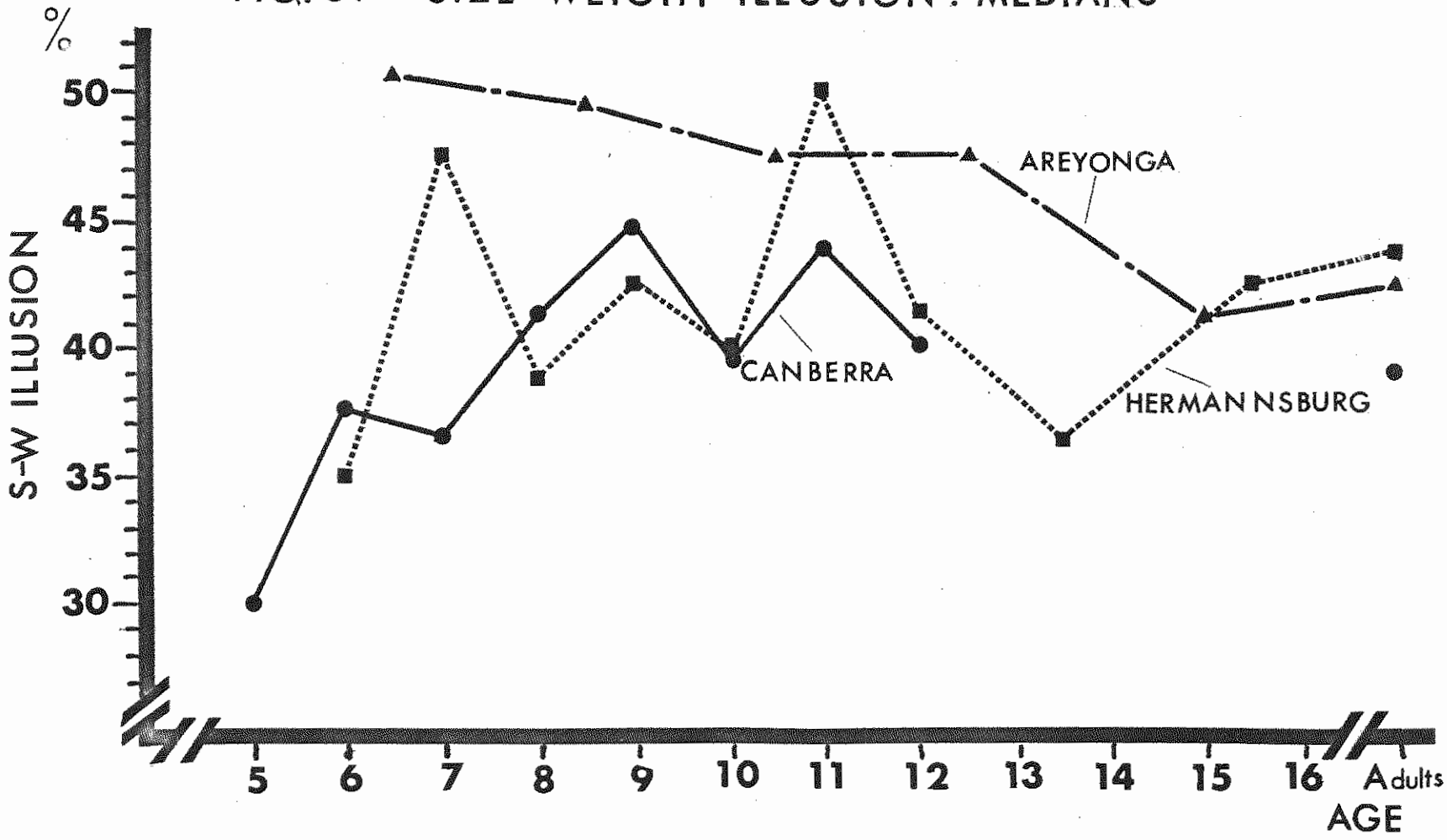


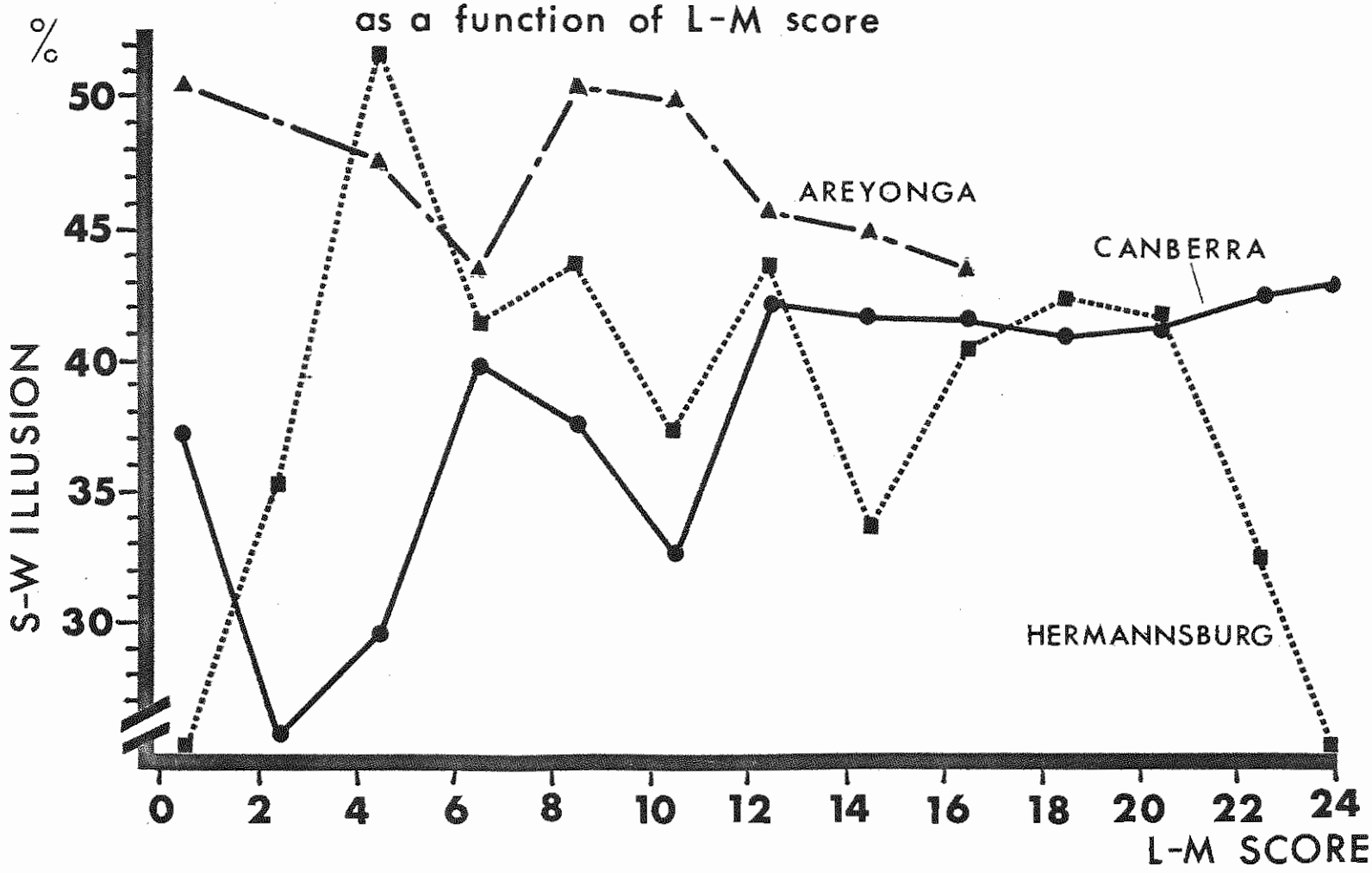
TABLE 43

SIZE-WEIGHT ILLUSION AS A FUNCTION OF LOGICO-MATHEMATICAL SCORE

L-M score:	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24
Canberra													
$\bar{x}$ illusion	37.1	25.7	29.6	40.0	37.5	32.5	42.1	41.5	41.3	41.0	41.2	42.5	43.0
S.D.	2.6	9.2	11.7	-	5.4	2.5	12.3	8.4	7.9	4.4	9.1	7.4	5.9
N	3	3	6	1	3	2	3	6	15	5	12	5	15
Hermannsburg													
$\bar{x}$ illusion	25.2	35.3	51.6	41.9	43.6	37.3	43.6	33.3	40.6	42.3	41.9	32.5	25.0
S.D.	8.0	9.1	6.2	3.9	7.8	6.6	2.6	8.9	8.5	15.1	7.3	-	-
N	3	8	7	10	17	10	7	6	11	5	3	1	1
Areyonga													
$\bar{x}$ illusion	50.3		47.6	43.6	50.2	50.0	45.9	45.0	43.8	-	-	-	-
S.D.	8.0		10.5	3.2	8.0	3.1	7.8	9.4	6.3				
N	5		6	11	7	7	6	5	2				

FIG. 38 SIZE-WEIGHT ILLUSION

as a function of L-M score



F. SUMMARY AND DISCUSSION

1. The developmental hypothesis

The hypothesis of a direct relationship between operational development and perceptual activities (hypothesis 4, cf. p. 59) receives only qualified support from the data. In summary, the hypothesis is confirmed by the following findings:

(1) Statistically significant, although low, partial correlation coefficients between the extent of the M-L illusion and operational level, with age held constant (hypothesis 4a).

(2) The general decrease of the M-L illusion with age in all three samples, and the relative extent of the illusion in the Hermannsburg and Canberra samples (hypothesis 4a).

(3) The results of the H-V illusion (and of the Delb. illusion, if the latter is viewed, in this particular case, as a secondary illusion), as a function of both age and logico-mathematical score (hypothesis 4c).

The following findings disprove the hypothesis:

(1) The absence of a difference in the extent of the M-L illusion between the Canberra and Areyonga samples (hypothesis 4a).

(2) The absence of a difference in the extent of the M-L illusion between the subjects scoring above the median on operational scores and those scoring below the median (hypothesis 4a).

The results of practice effects (hypothesis 4b) and those obtained with the O-K and S-W illusions (hypothesis 4c) are ambiguous.

2. The ecological cue validity hypothesis

The hypothesis based on Segall et al.'s (1966) ecological cue validity theory (hypothesis 5, cf. p. 60) receives partial support from:

(1) The relative extent of the M-L illusion in the Hermannsburg and Areyonga samples, even when matched on

age and operational score (hypothesis 5a).

(2) The relatively higher susceptibility of the two Aboriginal samples to the H-V illusion (hypothesis 5b).

(3) The relative extent of the H-V illusion in the adult samples, and when the illusion is analysed as a function of logico-mathematical score (hypothesis 5b).

However, the ecological cue validity theory cannot account for or is in contradiction with :

(1) The decrease of the M-L illusion in all three samples (hypothesis 5a).

(2) The absence of a difference in the extent of the M-L illusion between the Canberra and Areyonga samples (hypothesis 5a).

(3) The higher susceptibility to the M-L illusion of the Hermannsburg sample, when compared to the Canberra sample even when matched on age and operational score (hypothesis 5a).

(4) The decrease in the H-V illusion after a maximum has been reached (hypothesis 5b).

(5) The absence of a difference in the H-V illusion between the Canberra and Hermannsburg samples and between the Canberra and Areyonga samples, when they are matched on age and operational score (hypothesis 5b).

3. The confounding of the developmental and the ecological hypotheses

As was suggested by Berry (1968), the failure to find unequivocal support for the ecological cue validity hypothesis could be due to the confounding of ecological and developmental determinants.

In Berry's study, when sub-samples were matched on perceptual development (defined as field-independence, and measured by Kohs Blocks scores), the confounding effect was removed, and the ecological cue validity hypothesis was supported by statistically significant results (see review, pp.44-45).

In the present study, sub-samples were also matched on a developmental measure (operational score) which, according to our hypothesis 4, is related to perceptual development. The carpentered world hypothesis (concerning the M-L illusion) was supported by statistically significant results when the two Aboriginal samples were compared, but the hypothesis was disconfirmed when comparisons with the Canberra sample were made.

The open-vista hypothesis (concerning the H-V illusion) was confirmed by one comparison only (Hermannsburg and Areyonga sub-samples, matched on logico-mathematical score), all other differences being statistically non-significant.

In Berry's (1968) study, sub-samples could also be matched on ecology. This was not possible in the present investigation, and the second aspect of Berry's hypothesis could therefore not be tested.

4. The hypothesis of ecological determinants of perceptual activities

An alternative ecological hypothesis, concerning perceptual activities (as defined by Piaget, 1961, 1969a), was formulated during the planning stage of this study. It was then discarded, because it was felt to be too vague and, at least in its present form and with the given situation, untestable. Some mention may however be made of it at this stage. It happens to fit the data as well, if not better, than the ecological cue validity theory.

According to this hypothesis, perceptual activities develop under the influence of the ecological need for an active, accurate and flexible perception. The hunting and gathering economies of the Eskimos (Berry, 1966a/b) and of the Australian Aborigines, for example, are seen as providing this ecological need. Furthermore, the latter may be stronger in people (such as those of the Areyonga sample) who continuously exercise their perceptual skills. Similarly, different professional groups may have different levels of perceptual exercise (Fraisse, in Piaget, 1969a; p.200; Jahoda and Stacey, 1970).

Exactly what is meant by perceptual skills, perceptual exercise and ecological need, and how these are related to or

could foster perceptual activities remains to be defined and studied more carefully.[1] Intuitively, however, it seems reasonable to expect that exploratory activities, spatial transports and activities of referral (frames of reference and perceptual co-ordinates) are enhanced if a need for them exists. In the terms of Berry's ecological functionalism, of which the present hypothesis is an application to Piaget's concept of perceptual activities: "The perceptual skills and characteristics possessed by a people form a pattern which effectively contributes to the adjustment of that people to its particular environment - people develop and maintain those skills and characteristics which they have to". (Berry, 1966a, p.157).

Contrary to the ecological cue validity theory, the present hypothesis could handle the decrease of the M-L illusion and the increase of the H-V illusion with age, since the ecological need for perceptual activities would become stronger as the children grew older and were introduced to the adult skills.

The ecological functional hypothesis is not necessarily in contradiction with Piaget's theory, but would require an extension of the basic diagram (see Fig. 2a, p. 57) to include the ecological factor (Fig. 2b, p. 57).

5. Conclusions

The results of the perceptual part of this study have failed to support or to disprove unequivocally either of the hypotheses set out in Chapter 2. On the other hand, some of the data are interesting, and could be stimulating further research.

The ambiguity of the results could be due to
(a) the complexity of the factors involved, or to
(b) the possible lack of reliability of the measures.

(a) The complexity of the factors involved

Our review of the literature has shown (Chapter 1, section B) that many different factors could be associated

[1] This applies also to the relationship between perceptual activities and field-independence.

with cross-cultural differences in susceptibility to visual illusions: for example, the ability to interpret two-dimensional drawings, field-dependence, sensotypes, child-rearing practices and macular pigmentation. Most of these factors could not be controlled for in the present study, and may have produced the ambiguous results.

In this respect, it would have been an advantage to be able to conduct a series of smaller experiments,[1] attempting to assess the relative influence of each of the above mentioned factors. The research could also have been centred on the study of perception in Aborigines per se, instead of using the cross-cultural situation to test hypotheses stemming from Western psychological theories.

(b) The possible lack of reliability of the measures

Whereas every possible precaution was taken to ensure that reliable results were likely to be obtained, it was not possible to obtain test-retest reliability measures.

Lack of reliability may have produced some of the inconsistencies in the results. This is indicated by the generally larger standard deviations in the Aboriginal samples compared to the Canberra sample. On the other hand, the consistent patterns obtained with the M-L, H-V and Delb. illusions suggest that the results are not likely to be unreliable.

Segall et al. (1966, pp.116-121) have overcome the problem of inconsistent data by discarding from their calculations all 'biased' protocols (arbitrarily defined as those presenting more than one Guttman error). They do, however, report the results both ways (with, and without the inconsistent data); in other studies the precaution was not taken, in spite of the fact that more than 30 per cent (e.g. in Gregor and McPherson, 1965) of the subjects were omitted from the calculations.

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[1] The best possibility for conducting such a series of experiments would be a situation where the University is located "in the field". Experiments could then be conducted in the laboratory, or by successive but short field trips. Such an ideal situation has been described by Heron (1968, 1969c).

Because of the special technique of the concentric clinical method, it is unfortunately not known how many subjects would have produced inconsistent protocols in the present study. It would be interesting to investigate this problem more closely.

We do not suggest that all cross-cultural data on illusions, or, indeed, the results of the present study, are necessarily unreliable. We are only proposing that future research should attempt to assess problems of reliability more closely.

Neither do we suggest that cross-cultural studies do not provide a useful ground for testing the theories elaborated in western laboratories. Just as any general theory of perception should be able to explain the situations where veridical perception fails, any theory of illusions should be able to deal with cross-cultural differences. Neither Piaget's theory, nor the ecological cue validity theory, nor any other current theory (Over, 1968) seem able to account for all of these.

However, it would be wrong to conclude from the present results that Piaget's theory is not at least as predictive as others. Firstly, we have based the study on the assumption of a direct and measurable relationship between operational level and perceptual activities (hypothesis 4). This hypothesis should undergo further investigation with different methods and samples, for it is neither confirmed nor disproved by the present study.

Secondly, we have only been concerned with the quantitative aspects of these illusions, or, expressed differently, with the differential susceptibility of various samples to the illusions. Piaget, on the other hand, was mainly concerned with the qualitative aspects of illusions. The fact that these could be universal remains an untested possibility.

CHAPTER VI : GENERAL DISCUSSION, CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH

A. THE DEVELOPMENT OF CONCRETE OPERATIONS IN ABORIGINAL CHILDREN AND THE INFLUENCE OF EUROPEAN CONTACT

1. Hypothesis 1.

The results of this research confirm those of most previous cross-cultural studies in genetic psychology: the qualitative aspects of the development of concrete operations are found to be identical in all children. Both in Europeans of Canberra and in Aborigines of Central Australia, the stages described by Piaget are found to occur in the same order, and the reactions to the tests as well as the answers and explanations given by the children correspond to those reported by Piaget.

This means that the operational structures under study correspond at least partially to basic, and possibly universal, mechanisms of human thinking.

The regularities found in the qualitative aspects of cognitive development lend support to Piaget's interpretation of cognitive development in terms of three basic kinds of factors:

(1) "biological factors depending on the 'epigenetic' system"
(2) equilibration or autoregulation factors, which "correspond to the sequential forms in general coordination of the actions of individuals as interacting with their physical environment", and
(3) "general socialization factors, which are identical for all societies" (Piaget, 1966, p.3).

On the other hand, the quantitative aspects of the results, namely the rate at which operational development occurs in Australian Aborigines, indicate the strong influence of Piaget's fourth factor, that of "educational and cultural transmission".

The rate at which the concepts under study develop in Aboriginal children is typical of what we have labelled 'curve d' (cf. Fig. 1): the development is very slow and is asymptotic at the higher ages. This means that a more

or less large proportion (depending on the particular concept and sample) of Aborigines do not develop these concrete operational concepts at all, even as adults.

In fact, the incidence of operational thinking is found to be less in adults than in the older school children. Since, theoretically, it is not possible to 'lose' a concept once it has been acquired, we may suppose that these adults had not reached the concrete operational stage at the time when they were about to leave school. The superior performance of the older school children can be interpreted as either being due to improved education or to the fact that the generally larger amount of European contact is more influential in children than in adults. Possibly, education and/or European contact are only effective during a "critical period" in childhood, and we may assume that European contact is greater for the children of today than it was for their parents.

In conclusion, hypothesis 1 ("The qualitative aspects of operational development are identical in Australian Aborigines and in Europeans, but the rate of development is slower in Aborigines") is fully confirmed.

2. Hypothesis 2

Another indication of the importance of environmental factors is the significant difference in operational development, after the age of 9 or 10, between the two Aboriginal samples, a difference which we can attribute to the influence of European contact.

The mechanisms by which European contact affects cognitive development are still unclear, and the present study unfortunately can shed no light on that question. Several avenues are open to discussion and investigation:

(1) The concepts under study could be culturally specific to the Western world, and the mechanism of the influence of European contact could be to render the concepts relevant to the acculturated group.

In this respect, it would have been interesting to study an ethnic group which had not had any contact with European culture. This is no longer possible with Australian

Aborigines.[1]

(2) European contact could be influential in providing a physical and social environment favourable to the development of operational thinking.

(3) European contact could be influential in providing a second language, in this case, English, which, in its content and structure, is more relevant to the concepts under study than the vernaculars.

(4) European contact could be influential in providing the cognitively relevant attitude and motivations.

Most likely, these four factors are all influential to some extent, and future research will have to assess their relative contribution and their interaction.

In conclusion, hypothesis 2 ("The rate of operational development is faster in the high-contact group than in the low-contact group") is supported.

B. THE ECOLOGICAL AND CULTURAL RELEVANCE OF THE CONCRETE OPERATIONAL CONCEPTS (HYPOTHESIS 3)

Possibly one of the most interesting findings of this study is the indication that spatial concepts are more readily developed in Aboriginal children than are logico-mathematical concepts, whereas in European children the contrary is true.

The hypothesis, in this respect, was that spatial concepts would be more relevant to the ecological and cultural background of Aborigines, than are concepts related to number and measurement. Hypothesis 3 is supported, confirming the importance of the factor of specific cultural influences.

However, from the fact that the spatial skills needed by people of a nomadic hunting and gathering economy are nowadays (and, in fact, traditionally) more relevant to the Pitjantjara people of Areyonga than to the more acculturated Aranda of Hermannsburg, one might have expected the operational development of the Areyonga sample, in regard to spatial

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[1] We are awaiting with interest the results of two ongoing research projects, one on isolated tribes in the upper Sepik region of New Guinea (Kelly, personal commun.), and one on previously uncontacted indians in the Amazone region of Colombia (Jaccopin, personal commun.).

tasks, to be superior to that of the Hermannsburg sample. This was not the case, and the conclusion is indicated that the factor of European contact is predominant.

Similar results were obtained by Berry (1966a/b): the more acculturated Eskimos scored higher on spatial (performance) tests than did traditional Eskimos.

This is possibly due to the fact that the spatial concepts (or spatial skills, in Berry's study) we are studying are only partly equivalent to those needed for survival by Aborigines (respectively, Eskimos), whereas they are the spatial concepts typically relevant to the European culture. It would be interesting to follow up this line of reasoning, trying to analyse, in less general terms than we have done here, the spatial skills and concepts actually required by nomadic Aborigines.[1]

C. THE DEVELOPMENT OF SUSCEPTIBILITY TO VISUAL ILLUSIONS (HYPOTHESES 4 and 5)

The findings relating to the perceptual tests have been summarised and discussed in Chapter 5, section F, and will not be repeated here.

In short, hypotheses 4 and 5 received only qualified support.

D. REPLICATION OF DE LEMOS' (1966, 1969a/b) STUDY (HYPOTHESES 6 and 7)

The results of de Lemos' research are confirmed, both in their qualitative and in their quantitative aspects, except for the two points which gave rise to hypotheses 6 and 7. These read as follows:

> Hypothesis 6: The order of difficulty usually found with the tests of conservation of Q and W is reversed in Australian Aborigines: W is found to be easier than Q.
>
> Hypothesis 7: At Hermannsburg, the performance of part-blood Aborigines is better than that of full-blood Aborigines.

Both hypotheses were rejected. These results cannot,

[1] This has apparently been done for the navigational skills of Micronesians (Gladwin, 1970).

of course, be taken to be conclusive until their contradiction with those obtained by de Lemos has been resolved. We have been unable to do this.

Considering their non-confirmation, de Lemos' results should not be used as an argument for genetic differences, as has been done in the recent 'Jensen controversy' (Jensen, 1969; de Lemos, 1970). While the results of this study do not eliminate the possibility of there being genetic differences in mental functioning between Aborigines and Europeans, they do suggest that genetic differences, should they exist, are not important.

E. PROBLEMS OF RELIABILITY

Unfortunately, no direct measure of reliability has been obtained in the present study. However, there are several points which can be raised to argue against the possibility that the results may be unreliable. For example, concerning the operational tests:

(1) The general pattern of the results is very consistent, be it for the type of answers the children give, the general aspect of the developmental ogives for each test, the difference between spatial and logico-mathematical tests and the influence of European contact.

(2) Except for the two points mentioned above, the results of de Lemos' research are confirmed.

(3) The re-testing of a few subjects after 5 years (see p.175) shows that most children either stayed at the same level or moved towards a higher stage.

Similarly, for the perceptual tests, there are inconsistencies which lead one to think that the results may be unreliable. On the other hand, other aspects of the findings are very consistent, such as the decline with age of susceptibility to the M-L illusion, and the developmental aspects of the H-V and Delb. illusions. It is difficult to believe that these would have been obtained had the data been generally unreliable.

In respect of these problems, it is suggested that future research should attempt to measure reliability directly, for example during a pilot study. As for the present study,

a follow-up would provide the necessary information.

F. SUGGESTIONS FOR FUTURE RESEARCH

1. Longitudinal follow-up study[1]

As has been mentioned above, the reliability of the results of this study remains unchecked, and it would be valuable to re-test a part or all of the children (including more adults) on at least some of the tests.

Having established a reliable 'base-line', a longitudinal study could then assess any changes occurring in cognitive development under the influence of improved or modified conditions. The latter could consist of, for example, improved health and material conditions, social change and motivation, pre-schooling and improved teaching methods, and the introduction of television.

Possibly some changes, particularly in relation to schooling and pre-schooling, could be introduced by a research team under controlled conditions.

2. Further research on the ecological and cultural relevance of operational concepts

The results of the present study indicate that certain concepts may develop more readily than others if they are culturally and ecologically relevant. This finding suggests the possibility of relating different aspects of operational development to the cultural and ecological characteristics of many other ethnic groups, until a clear picture of the relationships between the development of operational concepts and their cultural background can be obtained.

This type of research could follow the same pattern as the present study. For example, as one possible step towards the above mentioned goal, it would be interesting to replicate the relevant part of the present study with Canadian Eskimos. Spatial concepts should develop earlier than logico-mathematical concepts in Eskimos for the same cultural

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[1] This study is presently being organised at Hermannsburg. The first re-testing has already taken place, but the data has yet to be processed.

and ecological reasons as in Australian Aborigines. These findings could be linked with those of Berry (1966a/b) and Vernon (1966).

Another, completely new approach, would be to adopt Piaget's framework and methodology in studying the cognitive development of a particular cultural group from within that culture (or, in other words, taking an emic rather than etic point of view.)[1] Such an approach would automatically point to those aspects of cognitive development which are ecologically and culturally relevant.

3. Further research on the influence of European contact

Another finding of the present study concerns the influence of European contact on operational development. Although the importance of this factor seems to be fairly well established (see review, Chapter 2), it is necessary to extend the research to other samples.[2]

Furthermore, it seems important to clarify the notion of European contact, and, in particular, to break it down into its components, in order to assess their relative influence.

The present research has dealt with one extreme of the scale of European contact by including 'low-contact' and 'medium-contact' groups. De Lacey's study (1970a, in press) has provided another point on the scale by including a 'high-contact' group. It would be interesting to extend the research to the upper extreme of the scale, studying non-Western children who have lived all or most of their lives in a completely European environment. This would be the case of children who have been fostered or adopted by European families since early infancy.[3]

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[1] See Introduction, p. 3. In this respect, an interesting study of the concept of "Lakkal" (more or less equivalent to 'intelligence') has been made by Bisilliat et al. (1967), without, however, using a Piagetian methodology.

[2] This is presently being done by de Lacey (personal commun.) with various samples of Australian Aborigines; de Lacey's (1970a, in press) findings seem to be confirmed.

[3] Such a study has been carried out by the writer in Adelaide, S.A. The data have yet to be processed.

4. Investigation into linguistic factors

Cross-cultural research could provide valuable information on the relationship between language and thought.

In particular, the following two points should be investigated:

(a) the cognitive relevance of the vernaculars

(b) the influence of the introduction of a Western language.

In this respect, it could also be interesting to investigate the influence of the language in which the tests are administered on the performance of the subjects.

These points could be investigated, in particular, in the Australian situation.

(a) A further analysis of the Aboriginal languages by a psycho-linguist would be interesting if it could be brought to bear specifically on cognitively relevant contents and structures. This analysis could include Aboriginal pidgin and Aboriginal English as well as the vernaculars.

(b) The influence of learning the English language should be studied, particularly in view of the educational application the findings might have. It is still open to question whether teaching should be conducted in the vernacular, with English being introduced gradually as a second language, or whether the child should be immersed completely in an English speaking environment as early as possible.[1]

(c) The tests should be administered in the vernacular by an experimenter competent in both the language and the testing techniques, or with a very reliable interpreter. As a check on the present findings, one possible design for such an investigation would be to match two groups on age and performance on the tests of the present study, and to re-test one group in English and the other group in the vernacular.

This experiment would answer the objection that failure

[1] This question has been discussed briefly in relation to Greenfield and Bruner's (1966) study by Jahoda (1968).

on the tests could be due to the fact that the children are tested in English.[1] On the other hand, the strong separation between the world of school and the world of 'camp' could tend to produce a separation between the reasoning applied in each situation. We could therefore expect the children to reason according to European norms and values in English but not in the vernacular. In this case, they could be expected to display the concepts under study in English but not in the vernacular.

Our hypothesis, however, is that the language in which the testing is conducted should have no influence on the results, as long as adequate communication can be established and the true thought processes assessed, which we believe we have been able to do.

5. Sensori-motor development and child rearing practices

Attention has been drawn more and more to the importance of the early development of the child, but very little research has been carried out, cross-culturally, on the sensori-motor stage, or on the child from 2 to 6 years of age.

This seems to be a very important lacuna. Since we have now established that the concrete operational development in some non-Western cultures is slow and asymptotic, future research should attempt to establish at what age the deficit starts to occur, and, if possible, what the causative factors are. To study the sensori-motor development, the scales developed by Uzgiris and Hunt (1966) might be used.

Attention should also be paid to the possible influence on cognitive development of early (mal)nutrition, of child rearing practices, and of motivational aspects.

6. Investigation of the practical importance of operational development

It is generally believed that concrete operational thinking is a pre-requisite of successful primary schooling,

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[1] Kelly (personal commun.) tested a few Greek immigrant children in Sydney. They failed to conserve Q when tested in English, subsequently conserved when tested in Greek, and were non-conservers again when re-tested in English!

and formal thinking of successful secondary education. This notion, however, has recently been questioned by Heron (1969b), who found no correlation between conservation of W and school achievement in Zambian children.

If the findings of cross-cultural research in genetic psychology are to be applied to education (see Appendix 1), it is most important and urgent that the practical importance of reaching Piaget's stages be investigated more fully.

Cross-cultural research on cognitive development could be carried out most effectively by a full-time research team, having a permanent base in the field, and regular access to University facilities. This should be an inter-disciplinary team, for many aspects are involved which are not specifically psychological. The problems to be solved could be a focal point for bringing together experts in cognitive and social psychology, medicine, education, ethnology, sociology and linguistics.

APPENDIX 1 : THE APPLICATION OF COMPARATIVE GENETIC PSYCHOLOGY TO EDUCATION

The development of concrete operations is seen as a pre-requisite for the adequate understanding and handling of number, measurement, time, space, speed, causality, and other 'scientific' concepts. Furthermore, it is theoretically only after concrete operations have been fully coordinated into a common, equilibrated structure, that the possibility of a further development, namely into formal thinking, exists.

Put into broad and simplified educational terms, concrete operations can be seen as indispensable for primary education and formal operations for tertiary education (although this hypothesis has recently been countered by some negative evidence, e.g. by Smedslund, 1963; Heron, 1969b, etc.). No wonder, then, that Piaget's theory has received increasing and world-wide attention in the educational sphere, in spite of its relatively esoteric nature.[1]

It is under Piaget's influence, among others, that increasing attention is being paid to early childhood development and pre-schooling and that activity methods are being devised for mathematics and science. On the other hand, Piaget has continuously stressed the child's 'natural' or 'spontaneous' development and the necessity of the child's 'readiness' for learning: "This is the essential conclusion, as far as education is concerned: learning cannot explain development, but the stage of development can in part explain learning" (Piaget's foreword to Almy et al., 1966). In this respect, Piaget has warned time and again against excessive enthusiasm in attempts to accelerate learning.

It is unfortunately a chronic tendency of educational systems to be conservative and traditionally oriented, and age-old, outdated methods, such as rote-learning, will not die out without great convulsions. Developing countries, needing an increased number of adults capable of dealing with European concepts in industry, administration and science, are faced with the double problem of reforming the outdated schooling inherited from colonial times, and of devising

[1] For Piaget's own point of view, see for example Piaget, 1969.

especially powerful methods, capable of helping the children to overcome their handicaps.

The main contribution of cross-cultural cognitive psychology, so far, has been to point out what these handicaps could be, and a great deal of research is still needed in this respect.

Implications for Aboriginal education

The problems of Aboriginal education have been receiving increasing attention (e.g. Elkin, 1936, 1958; Watts, 1963; Watts and Gallacher, 1964; Rassmussen, 1964; Lindstrom, 1965; Dunn and Tatz, 1969); they are extremely complex and cannot be reviewed here.

Very little research has been done, however, on the development in Aboriginal children of concepts which are basic to a European type of education. The middle-class European child has already acquired these concepts when he enters school, or he will acquire them more or less spontaneously without the school's help, and no attention is usually paid to their teaching.

The findings of cross-cultural genetic psychology are obviously relevant to this point, and de Lemos (1969a) has provided a discussion of the implications for education of the results of her study. The present comments are seen as complementary to her paper.[1]

Aboriginal children are often said to have a good 'picture memory' and a very good rote memory:

> They can quickly memorize whole lines and verses of songs and hymns in any or in several languages, and sing them without having or desiring any clue to their meaning. They learn songs and chants in this way in tribal life and are not expected to learn the meaning until, maybe, years later.
>
> The problem is, do they also learn, e.g. our arithmetic tables with this same facility and lack of meaning? Some teachers incline to this opinion. Further, while the children learn to multiply or add and even "take away" certain sums and to give correct answers, they do not grasp the principle involved and can only guess in the case of fresh or untaught, unrecited questions and answers. (Elkin, 1958, p.608).

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[1] See also the discussion of research problems in African education by Jahoda (1968), and the study of Gay and Cole (1967).

Thus, because of their good memory, Aboriginal children can learn the skills of adding, subtracting and multiplying (but usually not of dividing) without having a full grasp of the number system, without having, in fact, the concept of number.

Some teachers seem to be mainly concerned with an adequate performance on skills such as arithmetic and reading, and little or no time is spent on attempting to foster a true understanding of the underlying concepts.[1] Most of the teaching involves memory drills, and even new methods, such as the Cuisenaire or Dienes, are modified (and, in our view, rendered useless) by stressing memory rather than understanding. Thus, the "adaptation" the schools have sometimes undergone in order to teach Aboriginal children has been towards stressing traditional, outdated, methods of teaching, and even new methods are assimilated to the old ones.

Thus, the Aboriginal child seems to be caught in a vicious circle: he lacks certain basic concepts when he enters school; this renders teaching more difficult, and produces a drift of the teaching methods towards memory-drills which, in turn, will not induce concept development. As the years go by, schooling builds up a facade of skills which cover up the fundamental gaps in the cognitive structures.

If this analysis of the present teaching situation in schools for Aboriginal children is correct, two implications follow:

1. Teachers should be trained to assess the child's understanding of a concept, rather than to rely on the assessment of skills. Teaching should then be geared at the level the pupil has effectively reached, even if this means that the official curriculum has to be modified. Furthermore, the teaching should follow the natural development of the child, and should not advance beyond what the child can

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[1] A short time-sampling of the daily activities in a few classes showed that, on the average, only about half an hour was spent each day on activities involving active 'thinking' (as opposed to memory, verbal skills, etc.) Rarely were the children asked questions (7 to 18 questions per day for the whole class), and the questions were mainly of the form "what is" (on a picture), and "how" but not "why".

assimilate at any one time.

The example of measurement will clarify what is meant by the last point:

With the present method, the child is taught immediately about feet and inches; he is taught how to transform feet into inches, and vice-versa; he is also taught to measure off different lengths with a ruler.

However, as the present study shows, many Aboriginal children, even the older ones, do not have the concept of length; length changes with spatial displacement. Another experiment would certainly show that these children do not have the concept of a unit and of the iteration of the unit, which is the basis of measurement.[1]

The alternative method, based on Piaget's analysis of the development of the concept of measurement, would be to start teaching the concept of comparison as such (terms like 'same length','longer','shorter'), and then the possibility of comparing the length of two objects by using one's own body as a measuring device. This can then be replaced by another object serving as intermediary, for example, a stick which is of the same size or longer than the objects to be compared. Once this has been firmly grasped, (including the fact that the length does not change during transport), the concept of a unit can be introduced; the object can be measured by a smaller stick, which is moved along the object a number of times. Only once this notion has been firmly established should the concepts of arbitrary, socially defined units, and the use of a ruler, be taught.

Such a sequence could be established for all the important concepts. It implies, of course, that teaching is adapted to the cognitive level (or stage) of each individual child, and cannot be suitable for the whole class (unless the whole class has reached the same stage, which is unlikely).

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[1] This fact could explain some of the difficulties manual training teachers have with their pupils; for example some pupils can handle feet and inches in class, but not in the practical situation, because their knowledge relies purely on memory.

2. Probably the best way to produce a change in the present pattern is through early intervention programmes (Hechinger, 1966; Hellmuth, 1967, 1969) which are designed to offer the disadvantaged child those aspects of the physical, social and intellectual environment the middle-class European child has at home. Priority should be given to compensatory pre-school programmes, and the best approach seems to be one which does not stress socialization (which Aboriginal children do not need), but comprises a curriculum specifically designed to foster cognitive and linguistic development. Traditional pre-school programmes would not be adequate to meet the needs of disadvantaged children (Bereiter and Engelman, 1966; de Lemos, 1968a).

Furthermore, since it is not yet know which sort of programme would be most effective, this pre-school would necessarily have to be an experimental one, its methods being continuously assessed by independent observers.[1]

In other words, "in the immediate future, action research may need to take precedence over pure research" (Dunn, 1969, p.350).

The present study shows that, in today's situation, a large proportion of Aboriginal children do not reach the concrete operational stage. This implies that they will not be able to handle efficiently the major part of the primary school curriculum. Furthermore, it means that these children will not be able to reach the stage of formal operations, which is thought to be indispensable for secondary education.

The findings of this study and their educational implications are specific to Central Australia, but it is likely that they would be applicable to the majority of Aboriginal children in other parts of Australia, including the eastern states, as recent research projects have shown (Bruce, 1970; Nurcombe, 1970; de Lacey, personal commun.).

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[1] Such a programme is currently being conducted at Bourke, N.S.W., under the direction of Dr B. Burcome (Nurcome, 1970).

APPENDIX 2 : A REGRESSION PHENOMENON IN THE CONSERVATION OF WEIGHT[1]

Studies of the conservation of W covering the whole primary school age-range are few and usually restricted in sample size. Thus, fluctuations are easily interpreted as statistical variations. However, in a series of experiments, a drop in performance was noticed at ages 10 and 11 with such a regularity, that it is difficult to believe that it could be an artefact.

Experiment 1

Experiment 1 concerns the conservation of W, as reported in the present study for the Canberra sample.

The percentage of subjects classified at each stage is shown in Table 1. (excerpted from Table 5 in the main study).

The increase of conservation responses and the corresponding decrease in non-conservation responses is very gradual up to the age of 9. But at age 10, a sudden drop occurs; at age 11 performance is still surprisingly poor and only at age 12 are all subjects at the conservation or at least at the transitional stage.

It should be noted that the performance of this 10 year-old group on the other tests (Conservation of Q, seriation, spatial and perceptual tests) did not show any such 'regression'. Only the conservation of V seemed to be affected at the same time (only one out of ten subjects conserved V), although it is difficult to speak of a 'drop', since this test is generally more difficult.

Why do the 10 year-olds perform at the same level as the 7 year-olds for the conservation of W? The first reaction was to dismiss the problem as 'statistical fluctuation'. In view of the importance of the drop, however, it was thought that some further investigation could be of interest.

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[1] A modified version of this appendix will be submitted as a Research Note to the British Journal of Educational Psychology by the present writer and R. Christie.

TABLE 1

EXPERIMENTS 1 - 3 : PERCENTAGE OF SUBJECTS CLASSIFIED AT EACH STAGE

	Experiment 1.								Exp. 2	Exp. 3
Age:	5	6	7	8	9	10	11	12	10	10
(N = 10 per age)										
Stages:										
C	0	0	20	60	80	20	50	80	50	30
T	0	30	40	30	0	20	20	20	10	20
NC	100	70	40	10	20	60	30	0	40	50

Experiment 2

In order to rule out the possible factor of 'rapport', experimenter-bias, or general lack of reproducability, the same 10 year-old subjects were re-tested a few weeks later by another experimenter, who was unconnected with this research project, but well familiar with the test and the clinical method.[1]

Results:

The results of this re-test are given in Table 1. Either because of the difference in experimenter or because some learning had occurred in the meantime, the performance of the group is somewhat better than in experiment 1: half of the subjects are conserving W. This result is, however, still much lower than what could be expected after the 60% and 80% obtained at ages 8 and 9, and leads to the conclusion that the absence of conservation noticed in the first experiment was genuine and relatively reliable.

Experiment 3

Of course, the re-testing did not exclude the possibility of a sampling fluctuation, although nothing indicated that the children selected at ages 10 or 11 were in any way peculiar or retarded.

Thus another group of 10 children aged about 10 (mean age 10;1; age range 9;9 - 10;2) was randomly selected from another class of the same school and re-tested with the complete battery of tests in exactly the same way as in experiment 1.

Results:

The results for the conservation of W are reported in Table 1. Only three out of the ten children displayed a complete conservation of W, which is very similar to the results of experiment 1.

Again, the performance of this group on all other tests was not peculiar in any way, except for a relatively low

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[1]We gratefully acknowledge the help of Mrs Susan Page,M.A.

result on conservation of V.

Experiment 4

An independent study by R. Christie, comparing the performance of deaf and hearing subjects on conservation of W and the use of sumbols, indicated similar results. For our purpose, it is the control (hearing) group's performance on the conservation of W which is of interest. Non-verbal methods were used for all tests so as not to prejudice the deaf children's performance. The test for conservation of W was modeled on Furth's (1966) non-verbal method, whereby a child is taught to discriminate between objects of differing weight and respond accordingly. Full details of the precise nature of the items and procedures are given elsewhere.[1] Children were classified as conservers, non-conservers or in an uncertain category, on the basis of a criterion of correct responses.

The control group (to be considered here) consisted of 36 hearing children of normal intelligence (measured by Raven's Coloured and Progressive Matrices) between the ages of 7;6 and 13;3 drawn at random from two Catholic schools in Canberra. These were divided into six groups of six children according to age. The percentages of conservers in each age group are given in Table 2. As in the previous experiments, the percentage rose to 100% at age 9 years, dropped off to 33% at 10-11 years, before rising again to 100% at age 12 years.

Discussion

The experiments reported so far are suspect because of the small N's. However, the drop of performance at ages 10-11 recurs so regularly across samples, experimenters and techniques, that it seems difficult to escape the conclusion that something is happening at that age. But exactly what? And could it be some peculiarity of Australian children?

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[1] R. Christie, M.A. thesis in preparation.

TABLE 2

EXPERIMENT 4: PERCENTAGE OF SUBJECTS CLASSIFIED AS CONSERVERS, NON-CONSERVERS AND UNCERTAIN, AT EACH AGE GROUP

Mean age	7 ; 8	8 ; 7	9 ; 5	10 ; 2	10 ; 11	12 ; 0
Stages:						
C	33	67	100	67	33	100
Uncertain	17	17	0	17	50	0
NC	50	17	0	17	17	0

The literature contains few studies which report conservation performance up to, and beyond, the 11-12 year age group. We were surprised to find a number of studies reporting a flattening off in the increase in percentage of conservers about this age, while one recent study in Canada (Pinard et al., 1969) shows a drop similar to that being reported here. Cross-cultural studies, dealing with non-Europeans, have been excluded to eliminate possible extraneous effects, although the regression found in Goodnow's (1962) Hong Kong groups cannot go unmentioned.

The available data have been plotted on three separate graphs: those showing an actual drop in performance (Fig. 1) those showing a flattening only (Fig. 2), and those showing no (or little) such effect (Fig. 3). There is, of course, no clear distinction between the three groups, and some studies could perhaps be re-classified.

Taken as a whole, the only conclusion that may be drawn with any conviction is that some factor may be present a little before the onset of formal operations (10-11 years) which tends to depress performance on conservation of W. It may also be that such a factor depends in part upon the relevant schooling or social situation.

Pinard et al. (1969) hypothesize that "the Montreal children aged 11 have already acquired the conservation of weight; their performance is lower than that of the 9 year-olds because they start to be preoccupied by problems of the formal stage, which leads them to complicate the problem unnecessarily" (p.12, present writer's translation).

Without being able to spell out exactly what sort of formal structures are acquired from about age 10 which would interfere more or less electively with conservation of W and maybe V, we have made some observations of our own.

If we look at the explanations given by the children of their conservation responses for experiments 1 and 3 (no explanations were requested in experiment 4), we find that over the whole age range, children generally use identity, and, to a much lesser degree, compensation and reversibility. From about age 10-11, however, many children

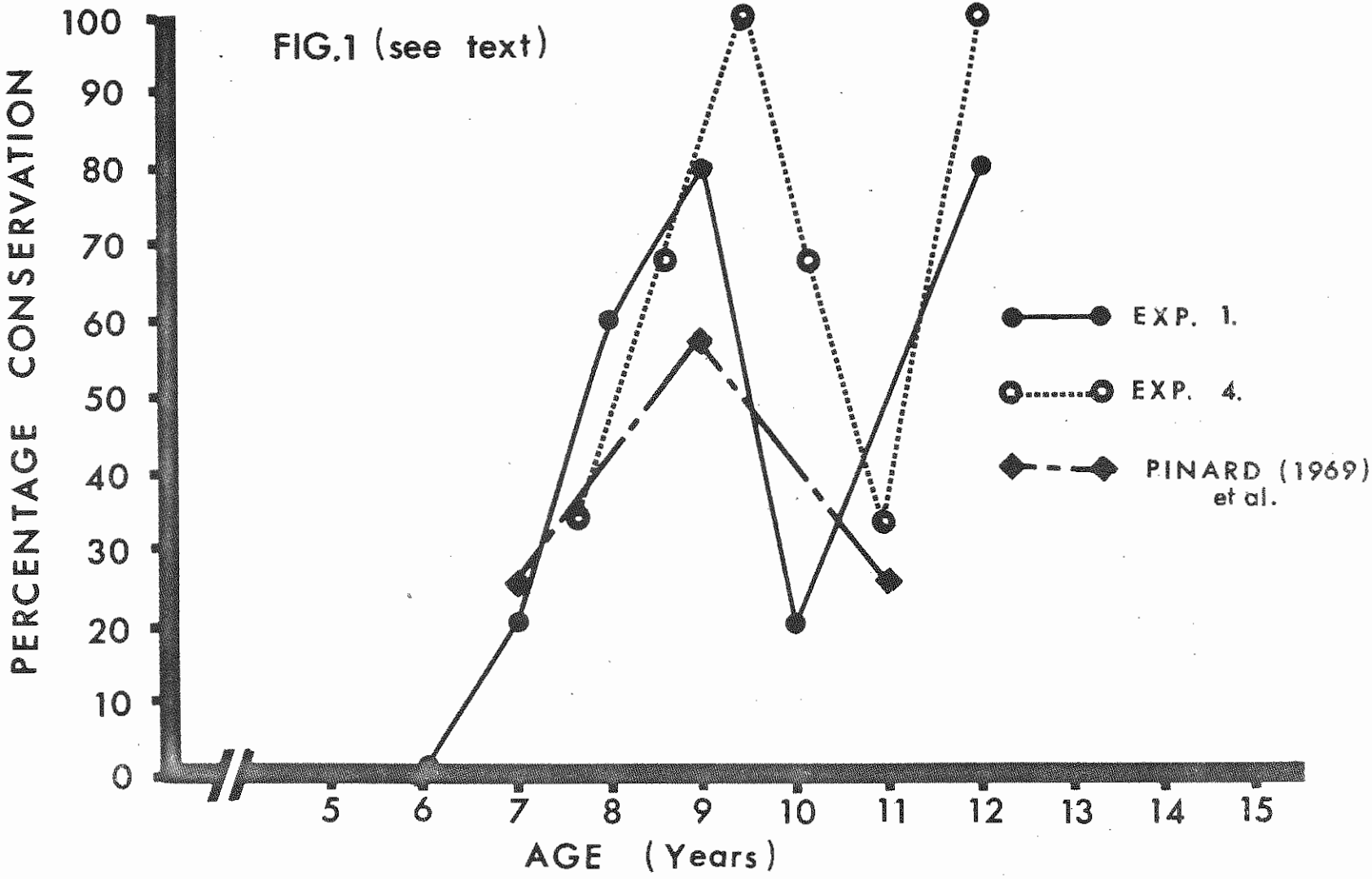


FIG.1 (see text)
PERCENTAGE CONSERVATION
100
90
80
70
60
50
40
30
20
10
0
5
6
7
8
9
10
11
12
13
14
15
AGE (Years)
EXP. 1.
EXP. 4.
PINARD (1969) et al.

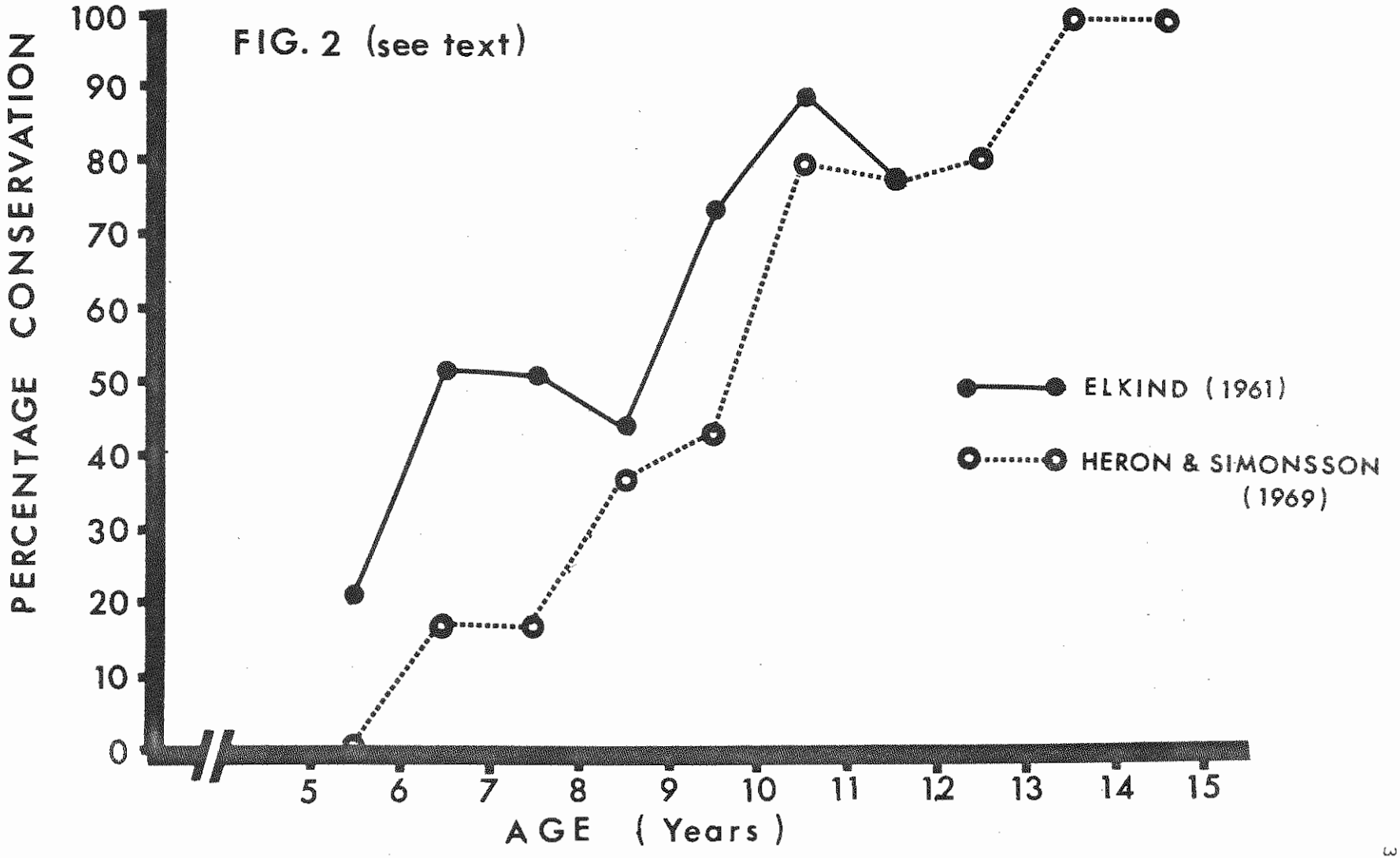
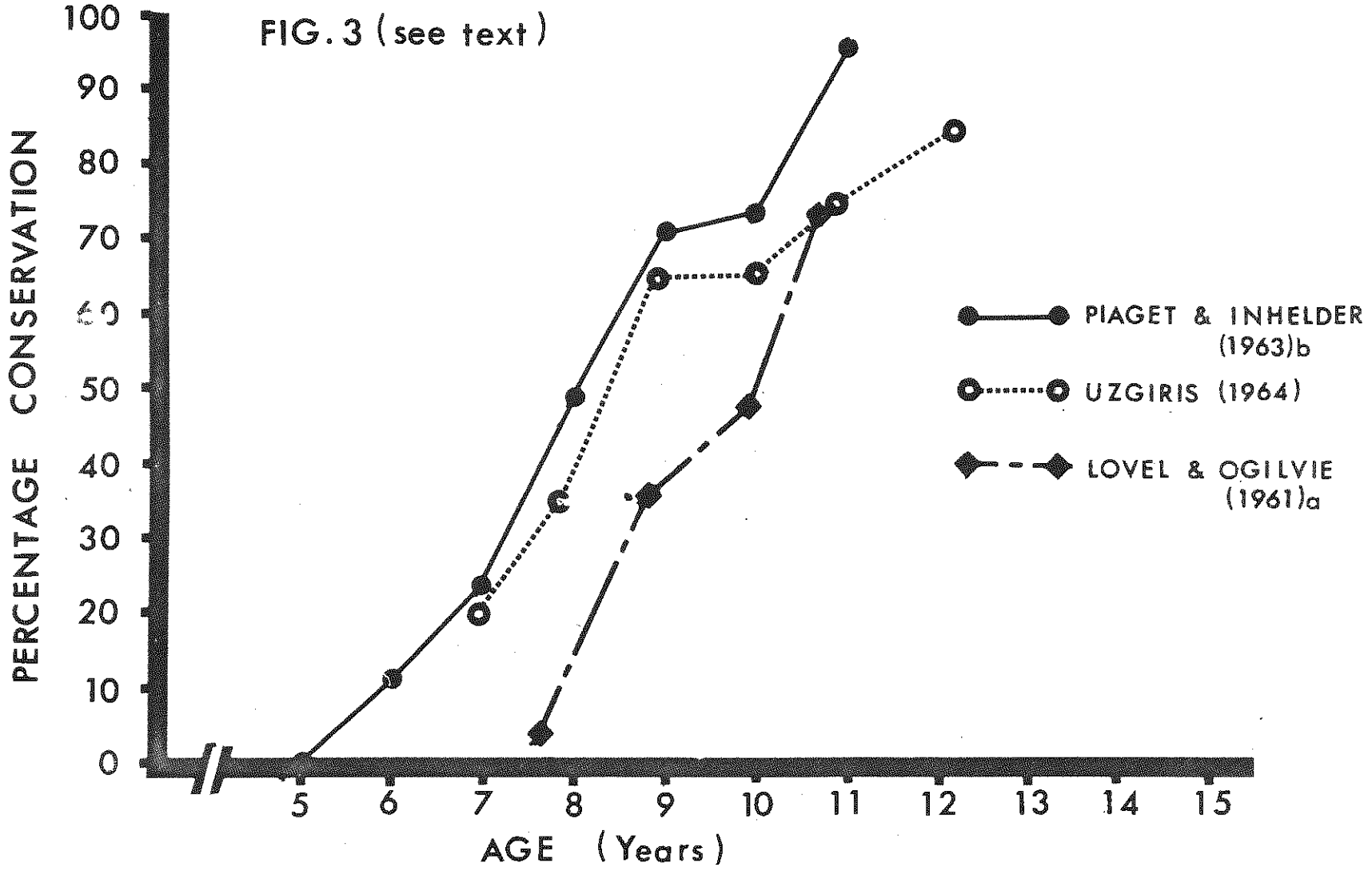


FIG. 2 (see text)
PERCENTAGE CONSERVATION
100
90
80
70
60
50
40
30
20
10
0
5
6
7
8
9
10
11
12
13
14
15
AGE (Years)
ELKIND (1961)
HERON & SIMONSSON (1969)

FIG. 3 (see text)



also fomulate their reasoning in a general law, which seems to indicate a beginning of formal thinking. For example, they will say: "If you change the shape, the weight doesn't change" or "Whatever you do to it, it's always the same weight, unless you take something off". One 12 year-old said: "It doesn't matter how you shape them, it's just the same whatever" and he was quite positive in adding: "It always works!".

To explain non-conservation, the most frequent answer at all ages is the classical reliance on one dimension of the shape or size of the plasticine. However, at age 10, a new type of explanation appears rather frequently, whereas it never occurred at earlier ages in our experiments. This explanation seems to link weight with some idea of density. Children will say things like: "The ball is more compact, in the flat one the weight is spread more evenly", or "This one (ball) is compressed, it's more solid, it's got all its weight together; this one (rolled out) is stretched out for weight". Other phrases like "It's tight, it's all together, it's squashed up" and their inverses often occur.

Some children also use concepts like pressure or gravity "It's gravity that pulls it down", "it's the centre of gravity that matters" and they link this idea of a pulling force with density. In their conception, pressure or gravity act differently on compact or spaced out objects (a fact which had already been documented in unpublished research by Vinh Bang) and leads to the non-conservation of W.

A very similar finding is also reported by Goodnow (1962, p.9):

> It is the 11- and 12-year-olds especially who are bringing down the group's performance by saying 'unequal' for reasons like these: 'because there's no centre of gravity in this one; because gravity centers in the middle; because here the weight is all concentrated in one place, but here the weight is all spread out evenly; because all the air has been pushed out of the round one; because more air presses down on this one'.

These children thus use formal concepts which they do not yet fully comprehend, and which seem to interfere with

the previously established concrete operational concept of W.

We have now clearly moved into the realm of speculation, but the purpose of this research note is to present a problem, not hurried conclusions. In particular, we would like to suggest that, if the interference which we have pointed out can be replicated on other, and larger samples, its relation to science teaching should be investigated.

APPENDIX 3 : THE PILOT-STUDY

The pilot-study was carried out at Amoonguna Settlement, 10 miles S-E of Alice-Springs, in July-August, 1968.

The tests which were used will be described briefly under the following headings:

(a) those which were retained for the main study without modification;
(b) those which were retained for the main study with modification;
(c) those which were excluded from the main study.

A. TESTS RETAINED WITHOUT MODIFICATION

The following tests were administered with exactly the same test-materials and procedures as in the main study. They proved to be satisfactory and were retained without modification.

1. Conservation of L
2. Conservation of V
3. M-L illusion (method of constant stimuli)
4. Delboeuf illusion (method of constant stimuli)

B. TESTS RETAINED WITH MODIFICATION

1. Conservation of Q and W

These tests were administered, at first, with the test-materials (sugar for Q, and tea in plastic bags for W) used by de Lemos (1966). These proved to be impractical and did not seem to interest the children. After some time, the standard test-materials were used as an alternative, and these proved to be more satisfactory.

For the conservation of Q, two black dolls were used at first; the children were told that the dolls would get sugar to eat, or cordial to drink. But the dolls were discarded when it was found that they did not seem to interest the children.

2. Seriation

Parts 1 and 2 of the test were administered to 33 children. The test proved to be satisfactory, except that,

on part 1, 12 children did not understand the instructions if they were not shown the model of the seriation. This is why, in the main study, the model was shown to all subjects.

The instructions for part 3, the "seriation behind a screen", were not understood by most of the subjects, and this part of the test was excluded after a few trials.

3. Orders

The test of Orders was administered to 27 children, using coloured beads strung on wire. The test proved to be satisfactory, but it was found that, contrary to Piaget's expectation, part 3 of the test (circular order) proved to be, on the average, more difficult than part 2 (inverse order). This reversal could have been due to the differential difficulty of the test materials, Piaget having mainly used miniature clothes. The latter test material was tried out, and since it proved to be satisfactory, it was decided to use it for the main study.

4. Horizontality

This test was administered to 29 subjects in its complete form, using both a round and a square bottle. The test was satisfactory, but seemed to be too long to maintain sufficient attention. The test was therefore shortened to the form used in the main study.

5. S-W illusion

For the S-W illusion, cubic tin boxes (respectively 16 cm and 8 cm high) were used, the weight being altered by changing the number of 50 gr. and 20 gr. weights piled up in the boxes.

This test material proved to be impractical because the boxes were too heavy for small children (200 gr. to 450 gr.), and because it was difficult to keep the subjects from turning the boxes to look inside.

The test materials were therefore changed to those described for the main study.

C. TESTS EXCLUDED FROM THE MAIN STUDY

The following tests were tried out in the pilot study, but were excluded from the main study, mostly because the test-materials or the instructions were unsuitable. These tests could certainly have been used in some modified form, but it was decided that the number of tests in the main study would be too large if they were retained.

1. M-L and O-K illusions, method of adjustments

In the pilot study, the M-L illusion was measured by two different methods:

(a) the method of constant stimuli, using stimulus figures drawn on cards, as in Segall et al. (1966)

(b) the method of adjustments, using a slide apparatus similar to that used by Rivers (1901).

The results obtained with the two methods were found to be equivalent. The mean M-L illusion for 18 Aboriginal children was 24.6% (S.D. = 9.6%) with method (a) and 23.0% (S.D. = 5.5%) with method (b).[1] The difference between the means was statistically not significant (t-test for matched samples: $t = 0.028$).

The O-K illusion was measured with the method of adjustments only.

The method of adjustments was not used in the main study for the following reasons:

(1) The instructions require the subject to adjust the lines until they are equal ("the same"), which is more difficult to understand than the instructions for the method of constant stimuli, where the subject has to point to the longer ("big") line.

(2) The attention and motivation of the children is not maintained beyond about 5 trials, because the subjects are asked to repeat the same task several times. With the method of constant stimuli, Aboriginal children reacted as if they were faced with a new problem each time.

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[1] The subjects were also asked to match two lines of 50 mm. The average error was -3% (S.D. = 9.4%). When asked to match two circles (Ø = 75 mm), the average error was 1.4%.

2. Horizontality adjustment

An apparatus similar to the Rod-and-Frame-Test was tried out; the subjects were asked to adjust a rotating rod to the horizontal position (the children were asked to adjust the rod so that a bead, placed in a groove on the rod, would not roll down). Frames of various sizes and orientations could be used.

The error in the apparatus, however, was very large (about 5 degrees), and the test was discarded.

3. Size-constancy

The subjects were asked to adjust the size of a variable triangle to the size of a standard triangle placed 5 meters away; the apparatus was similar to that devised by Mundy Castle and Nelson (1962). Alternatively, the subjects were asked to select, among a series of cut-out triangles, the one which would fit a standard triangle placed 5 meters away.

A number of children failed to understand the procedure, especially for the adjustment technique.

Furthermore, the two techniques produced contradictory results. With the adjustment method, Aboriginal children showed a 15.8% under-constancy, and with the choice method a 12.7% over-constancy. This was probably due to the "error of the standard", which would be expected to influence the results in opposite directions for the two techniques.

The test was discarded.

4. Hudson's 3-D test

Hudson's 3-D test (Hudson, 1960) was adapted for use with Australian Aborigines by replacing the elephant and the antelope, on the drawings, by kangaroos.

It was found, however, that the instructions were not understood by some of the Aboriginal children. They would understand the first two questions ((a) "What do you see?" and (b) "What is the man doing?"), but not the third one ("Which kangaroo is nearer to the man?"). No suitable alternative word for "nearer" could be found. Since it is the third question which is taken as indicative of the

type of dimensional pictorial perception possessed by the subject, the test was excluded.

The responses of all subjects who understood the instructions were classified as three-dimensional.

5. Cube construction test

A construction test similar to that devised by Deregowski (1968a) was used to study pictorial depth perception. A "Tinkertoy" wooden construction set was used, but this material proved to be inadequate, young children finding it too difficult to fit the sticks into the holes. The test also proved to be very time consuming, and it was excluded.

6. The Embedded Figures Test (EFT)

Witkin's EFT was tried out with a few subjects. The complete test (24 items with a 5 minute time limit per item) would have been too long, and too difficult for Aboriginal children. Even when a small series of easy items was selected (items C4, A4, F1, G1, E4, E5), it was necessary to leave both cards visible, and many subjects had to be helped in order to maintain their interest.

The errors the children made seemed worthy of being more closely analysed. For example, some children pointed to the correct shape, but with the wrong size; others recognized different parts of the figure, but failed to coordinate them into a single outline; others changed the figures' orientation.

The test was excluded in spite of its obvious interest.

APPENDIX 4 : CONSERVATION TESTS : RESULTS OF THE COMPLETE INTERVIEWS FOR THE CANBERRA SAMPLE

In the main study, the results of the conservation tests are based on the first two items, and, although each child underwent extensive questioning, no 'counter-suggestions' (c.s.) or 'counter-experiments' (c.e.) were used.

For the Canberra sample, the results can also be analysed by taking into account the complete interviews (three items, and extensive questioning, including c.s.and c.e.). The results of this analysis are presented in the table below (in percentage of subjects classified at each stage).

If these results are compared to those presented in Tables 4, 5 and 6 of the main study, it will be noticed that only small divergences occur. The effect of using the complete interview for the classification into stages is to increase the number of subjects classified at the transitional (T) stage but the general aspect of the results remains unchanged.

	Age:	5	6	7	8	9	10	11	12
Tests:	Stages:								
	C	0	20	50	80	90	100	-	-
Quantity	T	50	50	50	20	10	0		
	NC	50	30	0	0	0	0		
	C	0	0	0	60	60	10	50	-
Weight	T	0	70	90	40	30	30	40	
	NC	100	30	10	0	10	60	10	
	C	-	10	10	10	50	0	50	-
Volume	T		30	50	50	40	30	30	
	NC		60	40	40	10	70	20	

APPENDIX 5

AVERAGE SCORES IN POINTS FOR EACH OPERATIONAL TEST

TABLE 1

CONSERVATION OF QUANTITY : AVERAGE SCORES IN POINTS (Max. 4)

Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.
Canberra	.2	1.4	2.9	3.7	4.0	4.0	4.0[1)]	4.0[1)]					
Hermannsburg	-	0	0.3	1.5	1.7	1.2	1.0	2.2	3.0		3.3		2.0
Areyonga	-	-	-	0.75		0		1.2			1.4		1.5

1) assumed score

TABLE 2

CONSERVATION OF WEIGHT : AVERAGE SCORES IN POINTS (Max. 4)

Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.
Canberra	0	.4	2.0	3.1	3.1	1.0	2.3	3.5					
Hermannsburg	-	.1	.4	.4	.8	.4	.8	.9	1.7		2.8		0.8
Areyonga	-	-	-	.8		1.0		.93			1.0		0.5

TABLE 3

CONSERVATION OF VOLUME : AVERAGE SCORES IN POINTS (Max. 4)

Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.
Canberra	0[1)]	.9	1.4	1.0	2.3	.7	2.6	2.8					
Hermannsburg		.6	.8	.7	1.7	2.3	.8	1.4	1.5		3.0		1.1
Areyonga	-	-	-	1.75		1.8		.7			1.7		0

1) assumed score

TABLE 4

CONSERVATION OF LENGTH : AVERAGE SCORES IN POINTS (Max. 6)

Age	5	6	7	8	9	10	11	12	13	14	15	16
Canberra	.4	1.7	3.7	5.1	5.6	5.8	6.0[1)]	6.0[1)]				
Hermannsburg	-	.5	1.5	1.4	1.5	2.6	2.0	2.6	1.3		2.6	
Areyonga	-	-	-	1.5		1.0		1.5		2.5		

1) assumed score

TABLE 5

SERIATION : AVERAGE SCORES IN POINTS (Max. 6)

Age	5	6	7	8	9	10	11	12	13	14	15	16
Canberra	1.8	4.4	5.1	6								
Hermannsburg		1.7	2.8	3.6	4.6	4.9	5.2	5.8	6		6	
Areyonga			2.9		3.9		4.3		4.6		5.8	

TABLE 6

ORDERS : AVERAGE SCORES IN POINTS (Max. 18)

Age	5	6	7	8	9	10	11
Canberra	12.8	17.0	16.6	18	18	-	-
Hermannsburg		14.8	17.0	17.4	18	18	-
Areyonga		11.3	16.0	18	17.5	18	18
ages grouped		14.2		17.7		18	

TABLE 7

ROTATION : AVERAGE SCORES IN POINTS (Max. 28)

Age	5	6	7	8	9	10	11	12	13	14	15	16
Canberra	15.8	20.0	18.7	22.5	25.0	26.3	25.5	26.7	-	-	-	-
Hermannsburg		16.2	17.9	19.0	21.9	20.7	22.1	23.2	25.5			25.0
Areyonga			18.1		21.2		19.4		21.8		22.9	

TABLE 8

HORIZONTALITY : AVERAGE SCORES IN POINTS (Max. 30)

Age	5	6	7	8	9	10	11	12	13	14	15	16	Ad.
Canberra	14.3	16.2	21.4	25.7	25.9	26.8	29.4	28.1	-	-	-	-	-
Hermannsburg		15.8	17.8	20.1	21.1	24.7	23.7	24.9	26.9		27.2		27.4
Areyonga			14.6		20.0		22.0		22.6		25.6		27.5

APPENDIX 6

VISUAL ILLUSIONS : POLYNOMIAL REGRESSIONS

Extent of illusion (in per cent of the standard) as a function of age[1)]

1) We gratefully acknowledge the help of Mrs. R. Landau and of the A.N.U. Computer Center.

TABLE 1 M - L ILLUSION: CANBERRA

Polynomial Regression of Degree 4

$$Y = -0.9037613.10^{1} + 0.2608095.10^{2}\ x - 0.5270532.10^{1}\ x^{2} + 0.3882036.10^{0}\ x^{3} - 0.9573456.10^{-2}\ x^{4}$$

Degree	F Value	Improvement in terms of sum of squares
1	18.74	742.56
2	43.43	1443.05
3	28.80	5.77
4	26.01	226.64
5	-	None

X Value (Age)	Y Estimate (Illusion in %)
5.0	32.1
6.0	29.2
7.0	25.4
8.0	21.8
9.0	19.0
10.0	17.2
11.0	16.6
12.0	17.3
Adults	18.8

TABLE 2 M - L ILLUSION: HERMANNSBURG

Polynomial Regression of Degree 4

$$Y = 0.9256499.10^{3} - 0.3430022.10^{3}x + 0.4754352.10^{2}x^{2} - 0.2831668.10^{1}x^{3} + 0.6096685.10^{-1}x^{4}$$

Degree	F value	Improvement in terms of sum of squares
1	39.45	2005.53
2	22.63	217.54
3	15.37	44.65
4	23.66	1219.53
5	-	None

X value (Age)	Y Estimate (Illusion in %)
6.0	46.6
7.0	29.4
8.0	24.3
9.0	25.4
10.0	28.0
11.0	29.1
12.0	27.0
13.5	18.0
15.5	5.7
Adults	14.7

TABLE 3 M - L ILLUSION: AREYONGA

Polynomial Regression of Degree 3

$$Y = 0.3844406.10^{2} - 0.1906023.10^{1}x - 0.3519128.10^{-1}x^{2} + 0.3737433.10^{-2}x^{3}$$

Degree	F value	Improvement in terms of sum of squares
1	16.80	834.36
2	9.13	66.59
3	6.00	1.95
4	-	None

X value (Age)	Y Estimate (Illusion in %)
6.5	25.6
8.5	22.0
10.5	18.9
12.5	16.4
15.0	14.5
Adults	14.2

TABLE 4 H - V ILLUSION: CANBERRA

Polynomial Regression of Degree 3

$$Y = -0.2198955.10^{2} + 0.6249495.10^{0}x - 0.4117016.10^{-2}x^{2} + 0.8107181.10^{-5}x^{3}$$

Degree	F value	Improvement in terms of sum of squares
1	1.32	28.47
2	10.52	353.29
3	7.39	19.91
4	-	None

X value (Age)	Y Estimate (Illusion in %)
5.0	2.4
6.0	4.7
7.0	6.3
8.0	7.2
9.0	7.7
10.0	7.7
11.0	7.4
12.0	6.8
Adults	3.0

TABLE 5 H - V ILLUSION: HERMANNSBURG

Polynomial Regression of Degree 4

$$Y = 0.5083878.10^{1} + 0.8348722.10^{-2}x - 0.2710431.10^{-2}x^{2} + 0.3477345.10^{-4}x^{3} - 0.1047428.10^{-6}x^{4}$$

Degree	F value	Improvement in terms of sum of squares
1	14.60	597.47
2	9.24	140.14
3	7.63	149.88
4	6.42	93.26
5	-	None

X value (Age)	Y Estimate (Illusion in %)
6.0	1.8
7.0	2.1
8.0	2.8
9.0	3.9
10.0	5.4
11.0	7.1
12.0	8.7
13.5	10.9
15.5	11.1
Adults	7.8

TABLE 6 H - V ILLUSION: AREYONGA

Polynomial Regression of Degree 3

$$Y = 0.9985777.10^{2} - 0.2247483.10^{1}x + 0.1681465.10^{-1}x^{2} - 0.3895872.10^{-4}x^{3}$$

Degree	F value	Improvement in terms of sum of squares
1	7.23	258.83
2	3.80	15.50
3	5.97	296.47
4	-	None

X value (Age)	Y Estimate (Illusion in %)
6.0	10.7
7.0	6.6
8.0	4.6
9.0	4.2
10.0	5.0
11.0	6.6
12.0	8.5
13.0	10.5
14.0	12.1
15.0	12.9
Adults	10.4

TABLE 7 DELBOEUF ILLUSION: CANBERRA

Polynomial Regression of Degree 3

$$Y = -0.9316472.10^{2} + 0.3438953.10^{2}x - 0.3783369.10^{1}x^{2} + 0.1345653.10^{0}x^{3}$$

Degree	F value	Improvement in terms of sum of squares
1	4.72	97,73
2	8.37	208.06
3	8.05	107.08
4	-	None

X value (Age)	Y Estimate (Illusion in %)
5.0	1.0
6.0	6.0
7.0	8.3
8.0	8.7
9.0	8.0
10.0	6.9
11.0	6.4
12.0	7.2

TABLE 8 DELBOEUF ILLUSION: HERMANNSBURG

Polynomial Regression of Degree 3

$$Y = 0.8774096.10^{1} - 0.5017634.10^{1}x + 0.7158290.10^{0}x^{2} - 0.2735405.10^{-1}x^{3}$$

Degree	F value	Improvement in terms of sum of squares
1	2.81	131.72
2	3.35	171.99
3	2.42	26.67
4	-	None

X value (Age)	Y Estimate (Illusion in %)
6.0	-1.5
7.0	-0.7
8.0	0.4
9.0	1.7
10.0	2.8
11.0	3.8
12.0	4.4
13.5	4.2
15.5	1.1

TABLE 9 DELBOEUF ILLUSION: AREYONGA

Polynomial Regression of Degree 5

$$Y = 0.3980905.10^{2} - 0.1878812.10^{2}x + 0.2325262.10^{1}x^{2} - 0.7884223.10^{-2}x^{3} - 0.1192215.10^{-1}x^{4} + 0.4665782.10^{-3}x^{5}$$

Degree	F value	Improvement in terms of sum of squares	X value (Age)	Y estimate (Illusion in %)
1	3.58	119.83	6.5	-2.1
2	2.74	60.33	8.5	1.7
3	1.88	8.36	10.5	4.4
4	1.42	5.53	12.5	4.2
5	1.40	43.58	15.0	5.3
6	-	None		

TABLE 10 O - K ILLUSION: CANBERRA

Polynomial Regression of Degree 3

$$Y = -0.1843147.10^{2} + 0.5905590.10^{0}x - 0.4583023.10^{-2}x^{2} + 0.1095303.10^{-4}x^{3}$$

Degree	F value	Improvements in terms of sum of squares
1	0.01	0.19
2	0.56	26.86
3	0.87	36.08
4	-	None

X value (Age)	Y Estimate (Illusion in %)
5.0	2.9
6.0	4.4
7.0	5.3
8.0	5.7
9.0	5.7
10.0	5.4
11.0	4.9
12.0	4.4
Adults	4.3

TABLE 11 O - K ILLUSION: HERMANNSBURG

Polynomial Regression of Degree 6

$$Y = 0.2325401.10^{3} - 0.9566913.10^{1}x - 0.1471874.10^{0}x^{2} - 0.9820361.10^{-3}x^{3} + 0.2103838.10^{-5}x^{4} + 0.4986799.10^{-8}x^{5} - 0.2058433.10^{-10}x^{6}$$

Degree	F value	Improvement in terms of sum of squares
1	0.19	9.72
2	1.03	95.37
3	0.70	4.01
4	0.63	21.58
5	0.80	75.78
6	0.79	39.48
7	-	None

X value (Age)	Y Estimate (Illusion in %)
6.0	3.5
7.0	3.8
8.0	5.0
9.0	5.9
10.0	5.9
11.0	5.3
12.0	4.6
13.0	3.9
14.0	3.5
15.0	2.7
16.0	0.2

TABLE 12 O - K ILLUSION: AREYONGA

Polynomial Regression of Degree 3

$$Y = 0.2166547.10^{2} - 0.5885864.10^{0}x + 0.5787715.10^{-2}x^{2} - 0.1749945.10^{-4}x^{3}$$

Degree	F value	Improvement in terms of sum of squares
1	0.02	0.73
2	0.31	22.65
3	0.29	9.80
4	-	None

X value (Age)	Y Estimate (Illusion in %)
6.0	2.8
7.0	2.7
8.0	3.0
9.0	3.6
10.0	4.1
11.0	4.6
12.0	4.7
13.0	4.1
14.0	2.7

TABLE 13 S - W ILLUSION: CANBERRA

Polynomial Regression of Degree 3

$$Y = -0.4138060.10^{2} + 0.1882462.10^{1}x - 0.1342827.10^{-1}x^{2} + 0.2997174.10^{-4}x^{3}$$

Degree	F value	Improvement in terms of sum of squares
1	1.05	79.71
2	8.17	1006.88
3	7.00	216.11
4	-	None

X Value (Age)	Y Estimate (Illusion in %)
5.0	29.7
6.0	35.7
7.0	39.8
8.0	42.1
9.0	43.1
10.0	42.9
11.0	42.1
12.0	40.7
Adults	38.3

TABLE 14 S - W ILLUSION: HERMANNSBURG

Polynomial Regression of Degree 3

$$Y = -0.1095410.10^{3} + 0.3616640.10^{1}x - 0.2725461.10^{-1}x^{2} + 0.6478080.10^{-4}x^{3}$$

Degree	F value	Improvement in terms of sum of squares
1	0.04	3.44
2	0.41	66.70
3	5.41	1133.29
4	-	None

X value (Age)	Y estimate (Illusion in %)
6.0	33.7
7.0	40.3
8.0	43.8
9.0	44.8
10.0	43.9
11.0	42.0
12.0	39.7
13.0	37.3
14.0	36.0
15.0	36.3
16.0	38.3
Adults	44.0

TABLE 15 S - W ILLUSION: AREYONGA

Polynomial Regression of Degree 1

$Y = 0.5300446.10^{2} - 0.4631684.10^{-1}x$

Degree	F value	Improvement in terms of sum of squares
1	3.99	215.29
2	-	None

X value (Age)	Y Estimate (Illusion in %)
6.0	49.7
7.0	49.1
8.0	48.6
9.0	48.0
10.0	47.4
11.0	46.9
12.0	46.3
13.0	45.8
14.0	45.3
15.0	44.7
Adults	43.6

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