

LANGUAGE AND LOGICAL THINKING  
STRUCTURES IN THE NORMALLY  
HEARING AND DEAF

A Thesis

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Master of Arts

by

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LANGUAGE AND LOGICAL THINKING STRUCTURES IN  
THE NORMALLY HEARING AND DEAF

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The performance of twelve deaf subjects with an extremely poor comprehension of language and control over language structure, was compared with that of a normally hearing control group on four tasks of formal thinking. Six deaf subjects performed at the formal operational level on at least one task, supporting the hypothesis that formal thinking can develop to its primary formation in the severely linguistically deprived. The implications of the findings for certain cognitive theories and for educational practice are presented.

Introduction

Piaget clearly delineates symbolic functioning and operative thinking, placing himself in opposition to any view that considers language as a central, constitutive component of operative thinking (Furth, 1969). The origins of logico-mathematical structures are identified in the co-ordination of actions at the preverbal sensory-motor stage. Bruner (1966) considers internalized language to be a prerequisite for logical thinking, relating the child's organization of experience to specific linguistic transformational rules.

## Method

### Hypotheses:

1. The deaf experimental group, by virtue of language deprivation, will be significantly inferior to a hearing control in language comprehension and control over language structure, failing to achieve by adolescence the average linguistic competence of a mature speaker of a language.
2. On Piaget-type tasks, adapted for non-verbal presentation, the performance of the deaf experimental group will not be significantly inferior to that of the normally hearing control.
3. The acquisition of formal operational structures does not need as a prerequisite the average linguistic competence of a mature speaker of a language as measured by performance on two specified language tests.

### Subjects:

The experimental group comprised twelve deaf subjects fulfilling the following criteria: (a) loss of hearing before CA 18 months; (b) hearing loss greater than 77 db. in the better ear; (c) age on first admission to school between 2:6 and 7:4; (d) no secondary physical defect nor any accompanying behavioural problems; (e) etiology of hearing loss was considered. Fourteen subjects with normal auditory acuity comprised the control group. The mean age of both groups was 13:10. The mean IQs of the deaf and hearing groups were 108.4 and 107.4 respectively.

### Tests Administered:

The Snijders Oomen Non-verbal Intelligence Scale  
 Paragraph Meaning Test - Junior Form A  
 Woodward's Nonsense Test of Structural Meaning

Four Piaget-type tasks were adapted in order to exclude or minimize the use of language in instruction and as a criterion of success. Instructions were given mainly by pictorial representation. The tasks involved:

Judgement of displaced volume  
Probability concepts and probabilistic responses  
Judgement and measurement of equivalent three dimensional  
space  
Combinations of chemicals.

Analysis of Results:

The inferiority of the deaf group on both language tests was statistically significant at the .001 level (Mann-Whitney U test). The application of the  $X^2$  and Fisher exact probability tests supported the hypothesis that the inferiority of the deaf on the Piaget-type tasks was not statistically significant. Six deaf subjects performed at the formal operational level on at least one task.

Discussion

The efficacy of evaluating cognitive level on Piaget's tasks by means of manual responses alone needs further experimental investigation. Level of achievement on the Piaget-type tasks was largely independent of performance on either of the language tests, lending support to Piaget's theoretical position. The role of language as a determinant of cognitive development must be distinguished from the role of language as facilitating cognitive skills. The performance of six deaf subjects at the formal operational level suggests that language does not play a truly constitutive role in the development of logical structures, while it is conceded that language may play a supportive role in the elaboration of logical structures.

Implications for Education

The findings of the present study suggest the need to provide the language-handicapped child with the opportunity to use operational thinking structures by presenting problems non-verbally and with manipulable materials in order to encourage learning through action in a situation in which the child is not penalized for linguistic incompetence.

Main References

- Bruner, J. On cognitive growth: I & II. In J. Bruner, R. Olver & P. Greenfield (Eds.), Studies in cognitive growth. New York: Wiley, 1966.
- Furth, H. Piaget and knowledge: theoretical foundations. New Jersey: Prentice Hall, 1969.

## PART I

### BACKGROUND TO THE PRESENT STUDY

#### A. PIAGET'S CONCEPTION OF THINKING AND SYMBOL FORMATION.

Critical aspects of Piaget's position on logical thinking in relation to symbolic functioning have recently stimulated comment (Sutton-Smith, 1966; Ausubel, 1965; Inhelder et al, 1966; Furth, 1967).

Berlyne (1957, 1965) has postulated an affinity between Piagetian and neobehaviouristic theory on conceptions of thought and mediational hypotheses about the nature of meaning. Ausubel (op. cit.) analyzes Piaget's views on the nature and development of symbolic functioning to assess the extent to which this claimed parallelism is warranted. He focuses on what he describes as a "currently unresolved contradiction in Piaget's theory" (ibid., p. 1031). Piaget is said to postulate a qualitative continuity between the motor- or action-basis of early and later manifestations of thought, while denying such continuity between the motor and verbal stages of symbolic representation. Ausubel concedes that internalized actions may serve as signifiers during the preoperational stage when symbolization may be dependent on deferred imitation, but claims that there is no empirical evidence to support the assumption that such actions continue to serve a signifying function once verbal symbolization becomes consolidated. Ausubel contends that there is no

Piaget (1966) has clarified the place of representation in his model, in response to current misinterpretations of his position (Sutton-Smith, op. cit.). He relates representation to the semiotic or symbolic function of intelligence, placing it midway between operational activities and motoric output. Imaginal symbols and linguistic signs, the products of representation, are not constituent elements of operative knowing. Knowing, in Piaget's theory, is never reduced to representation.

Piaget (1951, p. 69) states that the primary purpose of the representational process is one of differentiation between a signifier and that which the signifier represents, namely the significate. The symbolic function is characterised by the capacity to evoke, by means of differentiated signifiers, significates that are not present. A symbol, as something that signifies and represents has a descriptive or figurative component, which refers to some sensory or motoric event. Piaget suggests that it derives developmentally by internalization from external motoric imitation. A preoperational scheme is accommodated to the figurative-descriptive aspect of a state of reality. He classifies symbolic instruments as derived from accommodative imitations of two sources: gestural or imaginal, for example, the observable movements of play; and linguistic, the conventional audible and motoric linguistic utterance.

The operative aspect of a symbol, as distinct from the figurative aspect, refers to meaning, that is, to its significate. It therefore embodies the basic act of differentiation between the signifier and the significate. A second characteristic of the operative aspect is the symbol's assimilation to operative schemes, that is, action schemes in the form of pre-operational schemes or logical operations. The operative component takes account of transformations and builds upon sensory-motor actions, interiorized actions and thought operations. The symbolic instrument, that is, the figurative aspect of the symbol, must therefore not be confused with symbolic thought, which is symbolic behaviour in its totality, including the figurative and the operative component.

"The figural aspects of cognitive functions are never sufficient to explain representative or conceptual knowledge" (Piaget, 1966, p. 111). The figurative components' role is useful only to the degree to which they are subordinate to the operative component. This distinction between the plane of operativity and the plane of representation inherent in the figurative aspect of a symbol, allows for a specification of the relation between the symbol and the real event. Representation is not passively inherent in the symbol. It functions only through the operation which has produced or comprehended the figurative aspect as a symbol initially.

Piaget (ibid.) bases his conception of intellectual operations on the premise that to know or to understand means transforming reality and assimilating it to schemes of transformation. Thinking is an action that transforms one reality state into another and in this process leads to knowledge of the state. This active, transformational aspect of thinking constitutes the unifying link between preoperational action schemes and formal operations.

Any symbolic event, be it linguistic or imaginal, constitutes a figurative and an operative component. It is however the operative component which is instrumental in determining the level at which reality is comprehended. The figurative aspects therefore cannot explain intellectual functioning, since they are totally dependent on the level of operative thinking.

## B. THE ROLE OF LANGUAGE IN COGNITIVE DEVELOPMENT.

### B.1. Piaget's Views.

In his early writings Piaget (1926) did not directly concern himself with the problem of the relation of language and intellectual operations, though these works suggest a belief in close relations between language and thinking since the emphasis is on verbal thought. Later works show a clearer insight into the action-derived structure of operational thinking and consequently find no logic for incorporating language as an explanatory principle. Today Piaget stands the lone exponent of logical intelligence who does not include language as an intrinsically necessary element of operational thinking.

The origin of the current theoretical status of the language-thought relationship in Piaget's work has been related by him (1963) to his observations regarding the nature of sensory-motor intelligence before the acquisition of language. Analysing the proposition that language is ipso facto a sufficient condition for the formation of intellectual operations, after identifying the philosophical roots of such a proposition in the position taken by logical positivism, Piaget (ibid.) poses an important problem. Are the origins of intellectual operations to be looked for in verbal behaviour or do they precede language?

At the preverbal sensory-motor period a system of schemes is elaborated that prefigures certain features of the structure of relations and classes. The baby will reach a distant object by pulling the blanket on which it rests and will generalize this action-scheme by utilizing other supports to bring objects to him in many situations. In the presence of a new object, the baby will assimilate it by applying to it successively all the schemes he has available. The coordination of sensory-motor action schemes results further in prefigurations of elementary forms of conservation and operative reversibility. Between 6 and 18 months the scheme of the permanent object develops. This scheme constitutes the first "invariant of a group". The search for an object that is hidden is a function of its localizations. These localizations depend on the constitution of a "group" of displacements in which are coordinated detours and returns, which correspond respectively to associativity and reversibility.

The coordination and decentrations of the sensory-motor period can be found in a different form playing a role in the constitution of operational intelligence, which is thus rooted in action. By the end of the sensory-motor period the baby will have overcome his early perceptual and motor egocentrism through a series of decentrations and coordinations, before the appearance of language.

The formation of representational thought is contemporaneous with the acquisition of language, however both are linked to the more general process which is the symbolic function. Language is but a part of a large complex of processes that occur during the second year of life and as such partakes of the entire cognitive development of this vital period. The development of the symbolic function is linked to the development of intelligent behaviour in its totality. It follows therefore, that the acquisition of language is not sufficient for providing thinking with ready-made structures. There can be no external imposition of ready-made structures through the medium of linguistic constructs, since a verbal transmission of information relative to operational structures will be assimilated only at levels where these structures have already been elaborated as interiorized actions (ibid. p. 127). Piaget clearly opposes any view that considers a particular symbolic product, such as language, to be a central, constitutive component of operative thinking.

The question arises within the Piagetian framework, as to whether language, though not a sufficient condition, may be a necessary condition for the formation of operations. Piaget does not consider language even a necessary condition for the constitution of concrete operations. As regards the level of formal or hypothetico-deductive operations, he stresses the need for research to provide a decisive answer. Formal operations no longer bear upon objects themselves and upon the

immediately present, but on propositions and hypotheses. Hypothetico-deductive and propositional operations are manifestly more closely linked to language. Piaget remarks however, that " ... just as operations take root before language in the coordinations of actions, they go beyond language in the sense that the operational propositional structures constitute rather complex systems that are not inscribed as systems in the language ..." (*ibid.* p. 127). These systems are the lattice of possible combinations, that replaces the simple hierarchical ordering of concrete operations, and the group of four transformations that coordinate the two forms of reversibility, namely, inversions and reciprocals, that at the concrete operational level were separated as groupings of classification and seriation. Neither can be formulated in ordinary language. They are expressed in logico-mathematical models by Piaget. The extent of the supportive role of language in the actual elaboration of these logical structures is left an open question by Piaget. The origins of logico-mathematical structures are however explicitly identified by Piaget as being anterior to language:

" ... the roots of the logico-mathematical structures must go far deeper than language and must extend to the general coordination of actions found at the elementary behaviour levels, and even to sensory-motor intelligence: sensory-motor schemes already include order of movements, embedding of a sub-scheme into a total scheme and establishing correspondences". (Piaget and Inhelder, 1969).

## B.2. Bruner's Views.

The position taken by the Harvard Center for Cognitive Studies on the relation of thinking and language is perhaps most concisely outlined in Bruner's paper "The course of cognitive growth" (1964). He distinguishes three systems of processing information that the child acquires to represent recurrent features in his environment; enactive, iconic and symbolic representation. The enactive mode refers to the representation of events through motoric response patterns, iconic relates to perceptual imagery and symbolic to internalized language as a vehicle for organising experience. Research has focussed on the transition from iconic to symbolic representation, "For it is in the development of symbolic representation that one finds, perhaps, the greatest thicket of psychological problems" (ibid. p.3.). Addressing himself to the language-thought relationship, Bruner describes the role of language as twofold. Language provides a means for representing and ordering experience, but also transforms it according to the transformational rules of grammar. Language becomes internalized as a cognitive instrument making possible an extremely flexible and powerful representation and systematic transformation of experience. He refers to Vygotsky's (1962) book on language and thought, seeming to take a stand along with Soviet psychology on the internalized linguistic system. Bruner speaks of internalized speech as a prerequisite for logical thinking. To succeed in Piaget's conservation tasks, the child must, according to Bruner, employ some internalized verbal formula that shields

him from the overpowering appearance of the perceptual display.

Referring to experiments (Olver, 1966; Rigney, 1966; Nair, 1963; Mosher, 1962; Bruner and Kenney, 1966) said to show how language shapes the child's modes of processing information, Bruner states that the models the growing child constructs to go beyond present information seem to be governed by syntactical rather than associative rules. The language the child brings to bear on a task will enable him to make remote reference to states and constraints that are not given by the immediate situation, while the structural and semantic complexity will enable him to cumulate information into a structure that can be operated on by specific linguistic transformational rules.

To go beyond the immediately perceptual, to a more extended model of the environment, the child requires a system that allows him to deal with the non-present. Dealing with things that are remote from the present situation has been acknowledged as the crucial feature of language. Between the ages 4 and 12 language becomes increasingly influential as an implement of knowing. The translation of experience into symbolic form, with the resulting ability to achieve remote reference, transformation and combination, "opens up realms of intellectual possibility" that Bruner claims could never be attained even by a powerful image forming system. The domination of perceptual representation hinders the development of the processing of information by consecutive inferential

steps that take one beyond what is present. Once the child uses language as a medium for translating experience, there is a progressive release from immediacy. By representing what lies beyond the immediate cues, he can integrate long sequences of events and consider a range of possibilities in a problem solving situation. .

Quoting the conclusion of Miller and Chomsky (1963, p. 488) that " .... sentences have a compelling power to control both thought and action", Bruner (1966) considers how sentences might have this power. Describing some of the properties of language, namely hierarchy, categoriality, predication, causation and modification, he expresses the belief that " .... in order for the child to use language as an instrument of thought, he must bring the world of experience under the control of principles of organization that are in some degree isomorphic with the structural principles of syntax" (ibid. p. 47). This discussion has a direct bearing on Piaget's unconditional assertion that language is in no way sufficient to assure the transmission of operational structures ready-made (See Section B. 1.). In support of this, Piaget points out that it is only at the level of concrete operations that a child masters the use of inclusive definitions in spite of the classificatory hierarchy found in language. Verbal expressions referring to inclusion of a subclass within a class are not fully comprehended until the concrete operational level when inclusion becomes established as a result of the interplay of additive and multiplicative operations of classes.

Bruner and his associates, frequently using such phrases as "reorganizing experience and action to conform to the requirements of language", do not sufficiently take cognizance of and critically appraise Piaget's account of the sources of operations being anterior to language and the argument that verbal information will only be effectively assimilated to structures if these structures have been elaborated on the plane of actions or operations.

Bruner's views did not pass unchallenged by the Genevan research team. The reply of Inhelder et al (1966) serves " ... to clarify certain basic differences in theory and methodology between the Harvard and Genevan cognitive growth projects ..." (p. 160). Discussion centred on experimental data and will therefore be included in the Section C.

C. REVIEW OF SELECTED EXPERIMENTAL APPROACHES PERTAINING TO THE RELATIONSHIP BETWEEN LANGUAGE AND THOUGHT.

C.1. The effects of learning verbal formulations on operations.

The aims of this approach, exemplified in the work of Inhelder et al (op. cit.) and Sinclair-de-Zwart (1969), are firstly, to determine whether the profound modification occurring in the child's thinking with the constitution of the first concrete operations is paralleled by a linguistic development and secondly, to ascertain whether a child who has not yet spontaneously acquired a certain operation will show operatory progress after having undergone verbal training. Such training would focus on systematic teaching of expressions typically used by children already in possession of the operation in question.

A conservation of liquids and seriation task ~~were~~ chosen, since they require an understanding and use of quantitative and dimensional terms and comparatives. The child was required to describe simple situations, unrelated to conservation and seriation tasks, which had been devised to explore his language of description in this domain. In addition, the child's comprehension of the examiner's verbal instructions, couched in certain relevant expressions, was determined. Subsequently all children were tested to determine whether they had the concept of conservation on the Piagetian tasks. Results concurred with Bruner (1964, p. 5.) in that the use and structure of language patterns closely paralleled the operational behaviour structure of the child. The use of comparatives, differentiated

terms and co-ordinated description of a difference in two dimensions occurred with greater frequency among children with conservation. It was noted however that these terms were sometimes available to children, yet not spontaneously used in certain situations. The operational structure therefore appears to be a prior acquisition to that of coding the event sequences into comparatives and co-ordinated terms. The difficulties the child experiences in the use of these expressions appear to be the same as those he is confronted with in the development of the operations themselves, namely lack of decentration and incapacity to co-ordinate.

"The possession of certain expressions does not structure operations nor does their absence impede their formation; the expressions are acquired and their use becomes functional according to a process similar to the mode of structuring of the operations themselves, namely through an interplay of decentrations and co-ordinations" (Sinclair-de-Zwart, 1967, quoted by Furth, 1968, p. 130).

Subjects without conservation were given verbal training in the use of operational terms, and post-training tests of conservation were administered. Conservation was not achieved even by those children who managed to acquire the terms in which to express it. Conclusions were that language learning might serve to direct the subjects' attention to important aspects of the problem, but it does not ipso facto bring about the integration and co-ordination of information necessary to achieve conservation.

This conclusion has a direct bearing on Bruner's interpretation of the origin of the child's difficulties in applying ordering principles to the re-organization of a double classification matrix (Bruner and Kenney, 1966). He suggests that the language that children at the iconic level bring to bear on the task is insufficient as a tool of ordering and proposes that improvement in language would aid this type of problem solving.

Agreement between the Harvard and Genevan projects regarding the link between the precise use of syntactical structures and the advent of the first operational structures has been reached, but completely different conclusions have been drawn regarding the source of this parallelism. Piaget's associates take the theoretical standpoint, arising from research on verbal learning of conservation, that correct linguistic behaviour depends on operational structures and not vice versa:

"Language learning does not provide, in our opinion, a ready-made "lattice" or lens which organizes the child's perceptual world. Rather, the lattice is constructed in the process of the development of intelligence, i.e., through the actions of the child on the environment and the interiorization of these actions to form operational structures". (Inhelder et al, op. cit. p. 163).

It is acknowledged however, that language plays a role in the refinements of the "lattice" and there is a possibility of the feedback of language on operational structures, particularly at the formal stage.

The efficacy of verbal training procedures remains a contentious issue. Ervin (1960), Wohlwill (1960) and Beilin (1965) demonstrate the limitations of verbal training and question the role of verbal mediation in logical thought, although the approach of Braine and Shanks (1965) aimed at enhancing the child's differentiation between appearance and reality at a linguistic level on conservation tasks gives expression to the opposite view. Morf (1959, reported by Pinard and Laurendeau, 1969), working with children at an intermediate level between concrete and formal operations, administered problems of implication and disjunction. He analysed the spontaneous solutions of the subjects and then furnished them with verbal information by repeating questions with supplementary details. Only those subjects who had spontaneously succeeded in solving one or other question by hypothetico-deductive methods were able to assimilate the meaning of the supplementary information and apply it to the solution of problems they had failed earlier.

Sigel et al (1966) reflect with some scepticism on reported experiments of verbal training. Until such experiments are presented in more detail and utilize stringent methodological procedures they will remain open to alternative interpretations, since it is not always indisputable that verbalization per se is the operative factor.

C.2(a) The effects of language-deprivation on the intellectual development of the deaf.

Conflicting opinions concerning the language-thought relationship give rise to a query of the level to which intellectual development may proceed independently of the normal acquisition of language. Does a difference in cognitive structure exist between the hearing child and the child who, though normally equipped to develop symbolic behaviour, has grown up without being steeped in the verbal language of his society? Using a natural "deprivation" experiment, it becomes possible to investigate whether or not language deficiency leads to a serious and general deficiency in cognitive development.

At present, the published reports on the cognitive status of deaf children present a large body of contradictory data. The great diversity in methods and questions underlying the many reports makes direct comparison between various studies difficult.

The deaf child has been subjected to considerable psychological scrutiny over the past sixty years, though investigations have been largely aimed at making global comparisons with hearing children (Ewing, 1957; Myklebust, 1966; Pintner et al, 1941). In contrast, a growing volume of research is emerging, devoted to the effects of deafness on specific psychological processes. The most notable leaders of this work are Oléron in France and Furth in America.

In the area of concept attainment Oléron (1962, reported in Furth, 1966b) recorded no significant differences between deaf and hearing children between the ages 4 and 7 on learning tasks utilizing concepts of sameness and difference. Furth (1961a) studied the discovery of the principles of sameness, symmetry and opposition, noting that on the first two concepts no appreciable difference was evident, while on opposition principles hearing children were superior at all age levels, 7 through 12. Furth argued that the constant use of opposites in verbal language gave hearing children an advantage over the deaf. Vincent (1957, reported in Furth, 1966b) presented the task of discovering three different principles of sorting to deaf children aged 6 to 8 years and measured the transfer of these principles. Results showed the deaf children to be one year behind on the attainment and transfer of the concepts. Youniss and Furth (1967) assessed logical thinking by devising a series of symbol cards containing logical symbols for affirmation, negation,

conjunction and exclusive disjunction. The deaf succeeded on symbol use, but showed marked retardation on symbol discovery in which subjects were required to take the initiative in discovering the meaning of logical symbols.

Furth (1966a) has reported a series of studies investigating the role of language in the development of thinking in which deaf subjects are presented with various problem solving tasks to assess the effects of the absence of long-term linguistic stimulation on the development of cognitive structures. With the progression of this series, increasing use of Piaget's developmental system has been made, particularly in assessing the implications of the findings for cognitive theories. Arguing from the standpoint of Piaget's delineation of symbol functioning and operative thinking, Furth (1964, 1966a) administered conservation of weight and liquid tasks to profoundly deaf children to determine whether operative thinking would be present without contemporaneous linguistic support. The main conclusion of a quantitative analysis of the data was that deaf subjects were on an average 18 months behind the hearing control. Furth stated however, that a qualitative investigation of failures revealed that the deaf were closer to the correct solution than a mere summary of successes and failures would indicate. Darbyshire and Reeves (1969) reported that the performance of hearing-impaired children on conservation of number experiments was not significantly inferior. Bradshaw (1964, reported in Ives, 1970) carried out a study of inferential reasoning of size

relations, demonstrating that 8 year old deaf children were two years retarded on sequential tasks, but were equal to hearing children on the simultaneous operational task.

The findings of these explorations into the performance of deaf children on Piaget's concrete operational tasks are more striking if it is considered that blind children are able to solve these tasks on the average four years later than a normal control (Hatwell, 1960, reported in Sinclair-de-Zwart, op. cit.). The visual deficit of the blind retards the constitution and coordination of sensory-motor schemes. Hatwell (ibid.) reports that verbal acquisitions cannot compensate for such a retardation, and postulates the necessity for "action-learning" before blind children are able to reach an operational level comparable to that of the normal and deaf.

The levels achieved by deaf subjects in the experiments reviewed are consistently higher than those reported by other workers. Oléron and Herren (1961, reported in Furth, 1966b) reported a six year retardation of deaf children in comparison with a hearing group on conservation of weight and liquid tasks. Oléron concluded that Piaget's theory does not sufficiently emphasize the role of language in the emergence of operative thinking, particularly in the subordination of the perceptual realm to symbolic or conceptual conditions.

Reviews of cognitive research with the deaf (Ives 1967; Furth 1966b) reveal the focus of experimentation to be at the level of concrete reasoning. A recent development in research concerning the language-cognition relation, has been the experimental investigation of thinking in deaf adolescents. A pioneering step in this field has been taken by Furth (1969, personal communication). Seven deaf adolescent boys were observed on a series of tasks on which clear success would be considered symptomatic of formal operational thinking. The results presented a mixed picture, since no subject clearly succeeded on all tasks nor failed completely on all tasks. Considerable difficulty was experienced in determining by non-verbal methods whether formal operations had been reached. The tentative conclusion was that propositional thinking can develop at least to its primary formation without the support of linguistic competence. Darbyshire and Reeves (op. cit.) administered two Piaget-type logical thinking tasks to deaf and hearing adolescents. While reporting no significant inferiority of deaf children on the tests, the authors note a significant correlation between poor performance on one of these tasks and severity of hearing loss.

C.2(b) Limitations of previous research with the deaf.

Studies of the cognitive development of the deaf do not present a unified picture. The methodological deficiencies so prevalent in this area of research may be responsible for conflicting results. Problems related to the control and exclusion of language from the experimental situation are frequently not sufficiently taken into account by experimenters. Even if a task does not require a verbal response, high performance may depend on understanding complicated instructions and the ability to ask questions. Only recently have isolated researchers (Furth, 1964, Oléron and Herren, op. cit.), begun to take cognizance of the need to exclude language from the testing procedure and creatively adapt materials for non-verbal presentation. There is a marked lack of clear explanation in the literature as to the nature of the presentation of tasks. Frequently no details are given beyond the remark that test instructions were presented by "pantomimed, manual and verbal methods". The extent to which verbal communication is relied upon is not explicit.

It is possible that discrepancies between the results of Furth (op. cit.) and Oléron and Herren (op. cit.) on conservation attainment of deaf children may in part be due to differing techniques of task presentation. It should be further cautioned that Oléron's results were obtained on samples where no check was made to assure that the subjects were congenitally

or prelinguistically deaf. His results therefore need to be replicated with a carefully diagnosed population.

Blank (1965) notes that in none of Furth's studies has he controlled for or reported the age at which the children first entered school. She questions whether the deaf can a priori be considered an adequate linguistically deficient control group, citing modern teaching practices for the deaf that emphasize early language training. The different learning histories within a deaf group and between deaf and hearing children, due to the deaf child's complete lack or general impoverishment of auditory input, should be acknowledged. Age of onset of deafness and severity of hearing loss are often omitted from research reports. Considerable difference in language proficiency may thus exist in any random sample of deaf children.

Ervin and Miller (1963) have cautioned that a great proportion of children with neurological disorders or emotional disturbances in a deaf sample may affect results. Myklebust (op. cit.) and Lenneberg (1967) report many more children with psychiatric problems among the deaf than among the hearing. Ives (1967) states that the majority of studies pay insufficient attention to the etiology of the hearing loss and disregard the possibility that a purely random sample of deaf children would probably contain a number with psycho-neurological learning disorders.

The above critique indicates that, in order that studies analysing the intellectual development of deaf persons may make a significant contribution to the theoretical status of the influence of language on cognitive development, improvements over previous research in experimental design must be made.

D. LANGUAGE ACQUISITION BY THE DEAF CHILD.

D.1. Contributions of contemporary psycholinguistics.

The "new wave" in psycholinguistics (Chomsky, 1957, 1965; Katz, 1966; McNeill, 1966) offers a transformational or generative grammar which is an explicit description of a finite set of rules which can, in principle, generate an infinite number of grammatical sentences in its native language. This description of rules, as they must be mastered by an idealized speaker-listener, is referred to as linguistic competence. A difference exists between linguistic competence and linguistic performance, which takes the form of distinguishing what a person knows about a language and his expression of this knowledge in talking and listening which operates under constraints such as memory limitations. A syntactical, phonological and semantic component are contained in the system of rules of a generative grammar. The syntactical component, which accounts for the creative aspect of language, consists of a base, which generates deep structures according to certain rules. In addition to the recursive properties of the base, the syntactical component contains rules of transformation.

Katz (op. cit.), using Chomsky's model of a language acquisition device that has internalized linguistic rules as its output and speech as its input, demonstrates conclusively that the input is far too impoverished to account in full for the child's construction of the complex grammar of

his native language in a surprisingly short period of time. "Grammatical speech does not begin before 1.5 years of age; yet, as far as we can tell, acquisition is virtually complete by 3.5 or 4 years" (McNeill, op. cit., p. 22).

In a later paper, McNeill (1968, p. 407) gives a more accurate version of the "rapid-acquisition" assertion: "In approximately 30 months, therefore, language is acquired, at least that part of it having to do with syntax". The accumulating evidence that children have a general capacity to acquire syntax, developing a complex grammar, in spite of the fact that only "scanty and unsystematic data are provided by parental speech" (McNeill, 1966), has led to postulations of a language acquisition device containing innate structures. Chomsky (1965, p. 58) emphasizes the important problem of developing a hypothesis about the "initial structure" that the child brings to language learning. Such a predisposition to acquire syntax, as described by current linguists, should be of vital interest to those concerned with the development of language in deaf children. Since this capacity is something that the child brings with him to the task of language acquisition, it can be assumed to be possessed also by deaf children. An examination of children's capacity to acquire language and a more detailed specification of the initial assumptions concerning the nature of language that the child brings to language learning, may elucidate ways in which to structure information available to the deaf child in order to take advantage of his predispositions to develop language.

The minor revolution in the field of language development, resulting in an exposé of the inadequacy of associationistic psychology in accounting for the structural complexity of the young child's language and the rapidity with which it is acquired, has left in its wake the need for a great deal of theory construction. This is reflected in the fact that theoretical writings have greatly outnumbered research reports in this first phase of renewed interest in language development (Smith and Miller, 1966). Modern psycholinguistic theory, striving for "explanatory adequacy" (Chomsky, op. cit., p. 27), seems to find no alternative but to introduce innate linguistic structures to account for the beginnings of language acquisition. Psycholinguists working within the Piagetian framework (e.g., Sinclair-de-Zwart, op. cit.) acknowledge the need for postulating a structural richness within the acquisition device, but attempt to account for this by considering acquisitions during the preverbal sensory-motor period. Piaget and Inhelder (1969) have tentatively formulated a hypothesis concerning the existence of parallel mechanisms and parallel constructive processes in cognitive development and in the acquisition of syntactic structures. They postulate similarities between Chomsky's descriptions of deep structure (Chomsky, op. cit.) and Piaget's account of sensory-motor structure (Piaget, 1950):

"At the age of 18 months, before the infant can talk, he can order, temporally and spatially; he can classify in action, that is to say he can use a category of objects for the same action, or apply different action-patterns to one object; and he can relate objects to objects and actions to actions. The linguistic equivalents of these capacities are concatenation, categorization and function, where categorization means the major categories (noun phrase, verb phrase, etc.) and function the grammatical relation (subject-of, object-of, etc.). These are the main operations at the base of the syntactic component which characterizes a highly restricted set of elementary structures from which actual sentences are constructed by transformational rules".

(Piaget and Inhelder, op. cit. p. 148)

Inhelder, in discussion with McNeill at the conclusion of the paper (ibid.), emphasizing her point that language acquisition is based on cognitive developmental mechanisms and not the contrary, states that it is "no accident" that language acquisition should occur after sensory-motor intelligence has reached its final stage. Piagetian and Chomskian psycholinguists agree that the child brings with him to the task of language acquisition a capacity to acquire syntax, but differ regarding the degree of innateness of this capacity.

Addressing himself to the problem of defining the initial assumptions concerning the nature of language that the child brings to language learning, McNeill (op. cit.) suggests that one aspect of the innate capacity to acquire language is an expectation of hierarchical structure, which the child looks for in parental speech. The child expects that in order for the meaning of two words to interact, they must belong to the same sentence constituent. The model of language acquisition postulated is analogous to scientific hypothesis testing.

The child is thus credited with a general expectation of the basic grammatical relations, namely subject and predicate, verb and object, modifier and head, that he makes use of in formulating hypotheses about hierarchical structures. The child tests his hypotheses against his parents' speech. Frequently adults repeat the speech of small children, and in so doing, change the child's sentences into the nearest well-formed equivalent. This phenomenon has been termed "expansion" by Brown (1965). A situation close to controlled experimentation is thus created, in which the child is able to test hypotheses against parental speech. It seems reasonable to expect that the deaf child will possess a source of hypotheses comparable to those of the hearing child, since for both, hypotheses result from a capacity for language acquisition rather than from language per se. It is the ability to test hypotheses against parental speech that the deaf child is deprived of. The problem in educating the deaf child therefore rests in getting the relevant information to him. Current psycholinguistic theory indicates that the role played by such information is the opposite to what has been customarily assumed, since parental speech has been shown to be necessary for the testing of hypotheses rather than for the formulation of them. A model for educating the deaf can be found in the expansion situation, that is, a situation in which the child is given new information in a form that differs minimally from what he already knows and in which there is a maximal chance that such information is relevant to what the child wants to know. In order to secure the effectiveness of expansion-like instruction, the deaf child

should be introduced initially to "child language" as described by Brown and Fraser (1963):

" ... a deaf child's acquisition of linguistic competence would be faster if his first exposure to English took the form of nouns, verbs, and undifferentiated pivot classes, presented in sentences that are generated by simple hierarchical rules free of transformations" (McNeill, op.cit., p.31).

The presentation of child language to the deaf would vastly simplify their testing of hypotheses. Children begin language acquisition with hypotheses derived from a general capacity to acquire language, therefore their early speech is likely to consist of little other than these universally derived hypotheses.

The study of the syntax of sign language remains a task for some interested linguist, however it is possible that sign language is also dominated by the same universally derived hypotheses. The main objection, among educators of the deaf, to signing has been that it does not adhere to normal grammatical structure, being "systematic neither in its structure nor its meanings" (Lewis Report, 1968). Signs do not follow normal word sequence, symbols are lacking for certain parts of speech, and verbs are used less frequently than in spoken or written English and in uninflected form. The educational potential of the new Paget systematic sign language (Paget, 1968), which follows English syntactical constructions, is being assessed. +++

The possibility of a critical period for language acquisition (McNeill, 1966; Brown, 1965) reaching a peak at age two to four and declining steadily thereafter, makes it imperative that attempts to take advantage of the deaf child's capacity for language acquisition should be directed at this age level.

The recent trends in developmental psycholinguistics discussed above, highlight the shortcomings of traditional methods of teaching language to the deaf which attempt to impose an adult grammar on the child in the initial stages of his education. Testimony to the failure of such methods can be found in the data of investigations of the language comprehension of deaf children, adding impetus to Furth's (1966a) remark that " ... under our present educational system the vast majority of persons, born deaf, do not acquire functional language competence, even after undergoing years of intensive training" (p. 13, Furth's emphasis).

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+++ A pilot study in progress at the Glasgow School for the Deaf since 1967, is comparing the progress of a small group of children exposed to the new Paget sign language with that of a group taught by purely oral methods. (Reported in the Lewis Report, op. cit.).

D.2. Review of Studies of Deaf Children's Language.

The grammars written by modern psycholinguists have been presented "as pictures of competence, as models of the ability to grasp the structural patterns of sentences" (McNeill, op. cit., p. 22). These models have led to new research objectives, for example, the study of successive stages or "pregrammars" in the child's discovery of the specific rules that define linguistic competence in his native language. Within the new theoretical "paradigm" (Kuhn, 1969), mastery of the sequential ordering and syntactical modifications of words are recognized as more important aspects of linguistic knowledge than such variables as vocabulary size and sentence length.

Investigations of deaf children's language have been dominated by quantifications of indices of performance, such as sentence length, and hence give little insight into the linguistic proficiency of the deaf. Heider and Heider (1940) compared the compositions of 1,118 deaf and hearing children 8 to 17. The immaturity of the deaf subjects' performance was said to be most strikingly revealed by a measure of sentence length. Characteristic of the style of the deaf was the use of relatively rigid, unrelated language units. These results have been supported in subsequent studies by Myklebust (1966) and Simmons (1962).

Furth (1969, personal communication) considers that there is no ready test available which would quantify linguistic competence and suggests the comprehension of Grade IV reading material as a measure of implicit comprehension of linguistic structure. Wrightstone, Aronow and Moskowitz (1963) gathered data on the silent reading achievement of over 5,000 deaf pupils. Comprehension of Grade IV reading material is considered to require mastery of the basic structure of English (Furth, 1966a). Less than 10% of the total sample tested by Wrightstone et al reached such a level. A further comparison of these data with hearing norms indicated that between the ages of 10 and 16 the mean reading score of the deaf rose less than one year. Myklebust (op. cit.), with a sample of 564 deaf, reports essentially the same results.

The theoretical models and methods of a growing number of researchers (Brown, 1965; Braine, 1963; Miller and Ervin, 1964; Menyuk, 1963), attempting to construct grammars to describe linguistic competence, are providing techniques for the measurement of the development of control over language structure. The experimental applications of these techniques can be found in the work of Porter (1959), Brown and Berko (1960) and Woodward (1968). The test of control over language structure devised by Woodward (ibid) +++ represents one of the first endeavours to measure responses of the normally hearing and deaf to syntactic structure.

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+++ Woodward's Test formed part of the battery administered in the present study and will be discussed fully in Section A.1.

PART IITHE PRESENT STUDY

## A. INTRODUCTION.

The broad aim of the present study is to empirically evaluate thinking in a linguistically deprived sample and present some theoretical implications which have a direct bearing on the role of language and its relation to thinking behaviour.

A further aim is to examine the implications that can be derived from the findings for educational practices with deaf and hearing children.

The possibility of separating the linguistic from the nonlinguistic component in Piaget's tasks was explored. Modifications made in the administration procedure of four Piaget-type tasks represent a contribution toward adapting cognitive tasks for non-verbal presentation, thereby improving their diagnostic validity with linguistically deprived groups.

Deaf children participating in the study were selected according to a number of specific criteria which defined and classified deafness. Within the framework of the present study, the "deaf child" refers to the profoundly deaf, who have lost their hearing before the age of eighteen months, some of whom underwent specialized language training for the first time after they had passed the critical phase for language acquisition. A more detailed specification of the selection criteria is presented in Section A.1.

The three main hypotheses to be tested can be framed as follows:-

1. The deaf experimental group, by virtue of language deprivation, will be significantly inferior to a hearing control group in all aspects of language comprehension and control over language structure, failing to achieve by adolescence the average linguistic competence of a mature speaker of a language.
2. On Piaget-type tasks, adapted for non-verbal presentation, the performance of the deaf experimental group will not be significantly inferior to that of the normally hearing control group.
3. The acquisition of formal operational structures does not need as a prerequisite the average linguistic competence of a mature speaker of a language as measured by performance on two specified language tests.

A minor hypothesis to be tested may be stated as follows:

There will be a positive and significant correlation for each group between the score for the Paragraph Meaning Test and the total score of the Woodward Nonsense Test of Structural Meaning.

## A.1. METHOD.

Subjects.

The sample for the study consisted of twenty-six children, twelve constituting the deaf group and fourteen the hearing group. The deaf group comprised eleven boys and one girl, the hearing control group thirteen boys and one girl. The ratio of boys to girls was determined by the availability of deaf subjects (Ss) meeting the criteria of selection. Ten of the deaf children were enrolled at St. Vincent's School for the Deaf in Johannesburg and two were pupils at the Dominican-Grimley School for the Deaf in Cape Town. The control group of children with normal auditory acuity was drawn from a co-educational secondary school in Cape Town.

A pilot study was conducted in order to ascertain whether the non-verbal method of task presentation was fully comprehensible and adequate to cope with response situations that might arise during the administration procedure. Seven hearing Ss, four boys and three girls between the ages 14:0 to 15:3 and one deaf boy aged 14:0 participated. The IQ range of the pilot sample was 100 to 126. Following the pilot study minor modifications in task administration procedure were made and will be discussed under the relevant tasks. The high percentage of task solutions at the formal operational level suggested that the age range should be lowered to between 13 years 0 months and 14 years 10 months.

It was hoped that this would allow for a more even distribution of solutions over the concrete and formal operational sub-stages.

The hearing and deaf groups in the present study were matched on age and IQ by group means. The IQs were obtained on the Snijders-Oomen Non-verbal Intelligence Scale which was administered by the experimenter (E) during the first testing session. Age and IQ data for the sample are provided in Table 1.

Table 1

AGE AND IQ DATA FOR DEAF AND HEARING GROUPS

Group	Mean Age	Age Range	Mean IQ	S.D.	IQ Range
Deaf	13:10	13:0 - 14:10	108.4	5.7	101 - 117
Hearing	13:10	13:0 - 14:9	107.4	6.1	100 - 119

All hearing Ss were scholastically at the Std. 6 level. The deaf Ss were not such a unified group regarding educational achievement, one being in Std. 3, nine in Std. 5, one in Std. 6 and one in Std. 7. The fact that deaf children do not enter school at a uniform age and further that their curriculum must needs place special emphasis on language training prior to the fostering of more general skills, accounts for their lag in scholastic attainment.

Socio-economic data, collected in the form of father's occupational level, revealed no appreciable difference in socio-economic status between the experimental and control group.

A global term such as "the deaf child" is most unsatisfactory without some frame of reference. The present study sought to define and classify deafness, fulfilling a number of important selection criteria in order to ensure that the sample represented an adequate language deprived population. Five basic factors were considered.

(i) Degree of deafness. Severity of deafness was such as to preclude the normal development of language embracing auditory decoding and vocal encoding psycholinguistic skills. One half of the group had a 100 db. loss in both ears, the hearing loss of the remaining being greater than 77 db. in the better ear. The hearing losses were obtained from audiograms in the pupils' files kept by the schools. The hearing threshold level in decibels was calculated and the audiogram plotted according to the 1964 ISO reference thresholds for all Ss except R.P. and J.O. for whom audiograms provided by the school did not state the basis on which the db. loss was calculated. In all cases the hearing loss was obtained from the pupil's most recent audiogram. Since hearing tests are regularly administered, all audiograms were dated post 1966.

(ii) Age of onset. Information obtained from the school files of Ss stated that deafness was presumed congenital in the case of ten of the Ss selected. The remaining two became deaf before the age of eighteen months, that is, prior to the onset of language acquisition, specifically that part of it having to do with syntactic development (McNeill, 1966, 1968). Children with progressive deafness were excluded from the sample.

(iii) Etiology of hearing loss. The cause of deafness appeared to be hereditary in the case of four Ss; deafness followed otitis media in one, and resulted from rhesus incompatibility in another. The cause of deafness was unknown for the remaining half of the sample. Ives (1967) states that deaf children presenting psychoneurological learning disorders in which a minimal disorder of the brain markedly affects a specific type of learning (Eisenson, 1966) often have histories of anoxia, rhesus incompatibility, encephalitis, meningitis or maternal rubella. Ives (op cit.) brands as "unsophisticated" studies that do not take into account etiological factors, however the high percentage of cases in schools for the deaf in which cause of deafness is stated as "unknown" (Backer, 1964; Myklebust, 1966) makes this requirement, from a practical viewpoint, difficult to fulfil. In cases where minimal brain dysfunction was suspected by the class teacher, children were excluded from the sample.

(iv) Age on first admission to school. The age at which Ss first received specialised language training ranged from 2 years 6 months to 7 years 4 months. In the case of two Ss the age at which they were first admitted to a school was unknown, however both had been enrolled at a school for the physically handicapped, which had no specialised teaching facilities for the deaf, until three years prior to the present study when they were transferred to a school for the deaf. Four of the ten Ss for whom age data concerning first nursery enrolment were available, had passed the critical period for language acquisition (Brown, 1965; McNeill, 1966). Speaking of the transitory nature of the capacity to acquire language, McNeill (*ibid.*) cautions that efforts to train the deaf child linguistically, that are instigated after the age of four years, may meet with little success.

(v) No secondary physical defect or abnormality nor any obvious accompanying behavioural or emotional problems were present in children constituting the sample. Teachers at the school for the deaf from which ten Ss were drawn made use of a behavioural check list of personality traits, adjustment problems and deviate habits. In the remaining cases the principal's judgement was relied upon concerning this matter.

Data on which the selection was based are tabled below.

Table 2

SOME SELECTION DATA OF DEAF GROUP

Subject	Age of onset	Etiology of Deafness	Db. Loss	Age on first School Admis.
S.V.	Congen.	Familial	100,100,100	3:1
D.H.	Congen.	Unknown	100,100,100	3:5
A.J.	Congen.	Unknown	100,100,100	3:3
S.W.	Congen.	Familial	100,100,100	2:6
J.U.	Congen.	Unknown	100,97,97	3:0
A.E.	Congen.	Familial	97,99,98	4:8
A.B.	Congen.	Familial	100,100,100	4:3
A.M.	Congen.	Unknown	100,100,100	7:4
K.W.	Congen.	Unknown	100,99,99	-
L.P.	6 months	Otitis Media	84,100,87	-
R.P.	18 months	Unknown	88,78,83	5:0
J.O.	Congen.	RH Factor	87,77,82	2:6

### General Procedure

Each S participated in three testing sessions of varying length. The same E tested all Ss. Tests were administered in a fixed order and by standard non-verbal methods to the deaf and hearing group. Testing took place in individual sessions with the exception of the language tests, which were administered to Ss in pairs.

At the first session hearing Ss were introduced to the non-verbal testing method, being cautioned to carefully observe the introductory materials presented with each task, since they served as preparation for the final problems. The deaf responded naturally and spontaneously to instructions presented non-verbally.

In order to establish rapport with the deaf, E asked some questions assumed to be familiar to S, such as, "How old are you?", "Who is your teacher?". The speech of almost all deaf Ss was extremely difficult to comprehend and their ability to lipread varied, however, the answers to these questions had already been made available to E in the preliminary information collected for sample selection purposes. This introductory "conversation" made Ss feel able to communicate with E, noticeably relaxing them.

First session

## THE SNIJDERS-OOMEN NON-VERBAL INTELLIGENCE SCALE

The P-Scale of the S.O.N. Scale was administered to the deaf and hearing Ss participating in the present study as a screening procedure, in compliance with the selection criterion requiring that Ss fall within the intelligence quotient range of 100 to 120. The Scale was administered in individual sessions lasting approximately one hour.

The S.O.N. Scale was standardised in Holland in the early 1950s by J. Th. Sniijders and N. Sniijders-Oomen on 1,400 hearing and 1,054 deaf-mute Ss between the ages of 3 and 16 years. Further investigations in Belgium and Germany (Formesyn and Mammitzsch, et al, reported in Sniijders, 1968) suggested that the materials and method of administration were as equally adaptable to Belgian and German Ss as to the Dutch. No significant differences in results were found in the three countries. A preliminary examination of the use of the Dutch Scale in England and Scotland (Gaskill et al, 1970) has provided similar promising results. The Dutch Form of the S.O.N. Scale has been standardised in South Africa on 470 children between the ages of 5 to 17 years in 4 White schools for the Deaf (Backer, 1964). The sample comprised an impressive 68% of the total deaf population in that age range in White schools for the deaf. The S.O.N. Scale is the only intelligence scale for deaf children that has been standardised in South Africa and was therefore considered a more reliable

and valid measure of intelligence than many of the tests traditionally used in studies of the deaf child's intelligence; for example, Raven's Progressive Matrices (1960), Arthur Point Scale of Performance Tests (1947), Hiskey-Nebraska Test of Learning Aptitude (1966). The Performance Scale of the Wechsler Intelligence Scale for Children (1949) is considered by Ives (1970) to be the most frequently used non-verbal test in research with deaf children (Murphy, 1957; Myklebust, 1966; Evans, 1966; Pickles, 1966), however standardised pantomimed instructions are not available.

#### Materials, Procedure and Scoring

The S.O.N. Scale is entirely non-verbal and can be administered and performed without the use of spoken or written language. In addition to the non-verbal instructions, a set of verbal instructions that may be used with hearing children is presented in the Snijders-Oomen Manual (1968). The present study employed only non-verbal instructions with both deaf and hearing Ss. It was hoped that adherence to a non-verbal procedure would familiarise the hearing group with pantomimed instructions, since this technique was to be employed throughout the three testing sessions.

The S.O.N. Scale consists of eight sub-tests paired to form four test groups assessing Form, Combination, Abstraction and Memory. There are two parallel scales of four sub-tests, entitled P and Q, either scale being sufficient

for an IQ assessment. The P-Scale should preferably be used with children aged 12 years and older, since this Scale has the "higher reliability" (Snijders-Oomen, 1968; Backer, 1964) of the two Scales as far as the higher age groups are concerned. The P-Scale is most favoured in research for this reason (Gaskill, op. cit.) and was used in the present study. A brief description of the sub-tests comprising the P-Scale will illustrate the rationale underlying their construction.

FORM: Block Design. On each of the six sides of the blocks is a different configuration of red and white. Patterns are constructed from these blocks, reproducing an illustrated pattern. The analysis and synthesis of form is tested. Speed is a criterion of performance has been excluded from all except this sub-test.

COMBINATION: Picture Series. Eighteen groups of cards are required to be sorted and laid in logical sequence. This is a test of the understanding of relations which are neither purely spatial nor completely abstract, but have a concrete meaning. Later items require comprehension of relations between participants in intricate situations.

ABSTRACTION: Figure Analogies. A principle of arrangement must be abstracted from material presented and then applied to new materials. Abstract figures are used.

MEMORY: Picture Memory. Pictures of objects and geometric shapes are exposed for a few seconds, after which they must be identified on a large card containing a greater number of pictures.

The sub-tests of the S.O.N. Scale are attractively designed and proved interesting to the testees. The deaf child is a careful observer of gesture and facial expression. E therefore had to guard against suggesting answers through facial expressions and hand movements. Deaf children are apt to be very dependent and needed much encouragement and accentuated approval in the test situation. All deaf Ss had been tested on the S.O.N. Scale at least 3 to 4 years prior to the present study.

Raw scores were converted into scaled scores and subsequently into IQs according to the tables in the annexure of the Manual (Backer, op. cit.) for deaf Ss and tables provided by Snijders-Oomen (op. cit.) for hearing Ss.

Second Session

## PARAGRAPH MEANING TEST

The Paragraph Meaning Test of the Silent Reading Tests (Revised Edition, 1963), Junior-Form A, distributed by the National Bureau of Educational and Social Research, was administered. During the same testing session, after a 10 minute interval, Woodward's Nonsense Test of Structural Meaning (1963, 1968) was administered. The total duration of the session was approximately one and a half hours. Both these tests are intended to be administered as group tests, however, in the present study Ss were tested in pairs. This procedure was introduced in view of a qualitative assessment of the behaviour of the deaf child participating in the pilot study. It is an established fact that deaf children are very dependent (Myklebust, 1966; Snijders, 1968), needing sustained attention and reassurance. Certain modifications in the administration procedure of the Paragraph Meaning Test also made it imperative that Ss should be seen in pairs.

Research into the cognitive abilities of deaf persons, which aims to contribute to the theoretical status of the relationship of language and thought, has traditionally used silent reading achievement tests where an attempt has been made to quantify the retardation in language development of the deaf (Furth, 1966 a). In the present study the additional use of the more contemporary approach of Woodward (1968), using the psycholinguistic method, must be considered a pilot application in the area of language-thought research.

The Paragraph Meaning Test administered in the present study, is primarily concerned with measuring Ss' comprehension of the theme of a paragraph; ability to determine the meanings of words from their context; comprehension of figures of speech, the writer's aim and viewpoint and the emotional tone of the paragraph. Ability to answer questions on details specifically mentioned in the paragraph as well as ability to draw conclusions about what is implied rather than stated, are tested (Manual, 1963).

#### Materials, Procedure and Scoring

The paragraphs are graded in order of difficulty and include a variety of subject matter. The test consists of 29 five choice items, the first 4 being practice examples. A separate answer sheet on which the testee is required to make a mark opposite the right number in the relevant section, accompanies the Revised Edition of the Silent Reading Tests. This answer sheet was not used with deaf or hearing Ss because of the obvious difficulties involved in imparting the instructions for its use to the deaf. The administration procedure was modified to allow Ss to circle the correct answer directly in the test booklet. Instructions were presented on a chart, which provided a brief explanation of the purpose of the test and emphasised that Ss should not spend too much time on questions they could not do. E sat between the two Ss in order to work through the practice examples with them, ensuring that they understood how the questions should be answered. The prescribed testing time of

24 minutes was adhered to. Raw scores were obtained and reading ages determined from the table of norms provided in the Manual (op.cit.).

#### WOODWARD'S NONSENSE TEST OF STRUCTURAL MEANING

Woodward (1963, 1968) has devised a test of the structural component of linguistic meaning divorced from the lexical component, employing structural signals described by Fries (1952). Using a paper and pencil technique to measure response to language structure, the test was initially administered by Woodward to groups of normally hearing and deaf children 13 to 15 years. The test uses a nonsense-word technique to eliminate lexical clues to meaning. The profoundly deaf child, markedly retarded in vocabulary development (Gaskill, 1957, reported in Ives 1970) is thus not penalised over his hearing counterpart in this respect. The Nonsense Test consists of nonsense words used in sentences and short sentence sequences wherever words belonging to the form-classes described by Fries (op. cit.) would ordinarily occur. Fries has summarised the devices by which the more important structural meanings are conveyed to the average mature speaker of English, namely those that signal sentence kinds, direction of reference in sentence sequences, part-of-speech membership, meanings carried by subjects and objects and meanings carried by modifiers. Ss are required to respond in a variety of ways designed to test their absorption of the meaning conveyed by these structural signals. Meanings carried by word arrangement and by function words are thoroughly explored.

The Nonsense Test was originally designed to explore relations between response to structural clues to meaning and reading ability in normally hearing and deaf children. Woodward (1963) proposes that the Nonsense Test be used as a diagnostic tool to probe weaknesses in comprehension of sentence structure, considered the most important aspect of linguistic competence by modern developmental psycholinguists (see p.33). In view of the inferiority of the deaf as compared with the normally hearing in comprehending meaning conveyed by syntactic structure, Woodward (ibid.) recommends that language instruction of the deaf should emphasise meaning carried by sentence structure. The vocabulary lag of the deaf is so conspicuous that it overshadows the equally crippling deficiencies in ability to interpret complex sentence structure (ibid., p. 32). Teaching of lexical meaning to the deaf has thus traditionally been engaged in to the neglect of meaning carried by structure.

#### Materials, Procedure and Scoring

The Nonsense Test was administered in a standard way to both deaf and hearing Ss. Introductory information explaining the nature of the test was presented in written form on a large chart. This procedure differed from that used by Woodward (ibid.), who introduced the tasks verbally. Woodward does not report the degree of hearing loss of her deaf Ss. All Ss participating in the present study were profoundly deaf (See Table 2) and since difficulty in lipreading is associated with severity of hearing loss (Moores, 1969), it was decided to adhere strictly to written rather than spoken language. The

introductory chart contained the following information:

This is a new kind of reading test.  
 Most of the words in it are not real  
 words, but make-believe or nonsense  
 words. I want to see how well you can  
 understand sentences when the words are  
 make-believe.

Let us try to understand a sentence  
 of make-believe words.

Woggles ugged.

Who ugged? \_\_\_\_\_

What did Woggles do? \_\_\_\_\_

Since the pilot study had revealed that the deaf needed a great deal of reassurance that the words presented were indeed make-believe or nonsense words, E went over the contents of the chart thoroughly, running a pointer under the lines, to ensure that Ss grasped the idea that they could indeed read and understand the sentence, even though they did not know what Woggles or ugged meant.

The test consists of six sections. Directions for each section and the sample item used in explaining the task are given below. These directions were displayed on large charts, the relevant chart being displayed and worked through before commencing each new section.

Part I - Sentence Recognition\*

Use capital letters, periods, and question marks in the following, to show where the sentences begin and end.

Example:

a munchment sapled lan did he borgle it.

Part II - Sequence Signals

The sentences in the following groups can be arranged to make a story. Put a number after each sentence to show the order in which it should come to make a story.

Example:

The hort sunged. \_\_\_\_\_

Pog abbed a gork. \_\_\_\_\_

Then the surbles bonched grosply. \_\_\_\_\_

Part III - Sentence Kinds\*

Tell whether each of the following sentences is a question, statement, or command.

Example:

Is the fresner storp \_\_\_\_\_

Hoble the frisp gantly \_\_\_\_\_

Rarely had the barg norged \_\_\_\_\_

---

\*In the sections marked with an asterisk, supplementary information had to be provided, since the pilot study indicated that some of the terms used were not familiar to the deaf child, even though the concept was known. The advice of a teacher of the deaf was taken in this respect. Woodward's sample were apparently able to comprehend the instructions without additional assistance.

Part IV - Parts of Speech

Read the following sentences. What do the underlined words mean? Draw a circle around the meaning you think is right.

Example:

The garble sonned frumptiously.

(lonely, angrily, frightened)

Part V - Subjects and Objects

Read each sentence or group of sentences. Then read the questions about it. Draw lines under the right answers.

Example:

The rog was franted by the purnip.

- (a) Who franted something?  
(the rog, the purnip, yes)
- (b) Did the rog do anything in this sentence?  
(Yes, No, We don't know)
- (c) What does "franted" mean?  
(pushed, fussy, frowned)
- (d) What does this sentence tell us?  
What happened to the purnip  
What happened to the rog  
What the rog found

Part VI - Modifiers

Read the sentence and write short answers to the questions about it.

Example:

A burbling fangle gobbled randly into the forstant.

- (a) What kind of fangle did something? \_\_\_\_\_
- (b) How did the fangle gob? \_\_\_\_\_
- (c) What is the verb in this sentence? \_\_\_\_\_
- (d) What was the fangle doing when it went into the forstant? \_\_\_\_\_

E indicated the correct answers to the sample items with a pointer and wrote them on a blackboard. Ss were encouraged by gesture to indicate the correct answer on the chart displayed. The chart containing the sample item and solutions of a particular test section was displayed within S's view while he was completing that section. This enabled S to refer freely to the sample items while the test was in progress. The test was not timed. The scoring criteria of Woodward (ibid.) were adhered to.

Third Session

Tasks devised by Piaget and his associates, which elicit responses distinguishing Ss performing at the concrete operational level from those at the formal operational level, were considered with the view to eliminating or minimising transmission of instructions by language. Although verbal instructions and verbal responses are an integral part of Piaget's "clinical method", recent experimental procedures devised by Furth (1964) and Oléron and Herren (1961, reported in Furth 1966a) indicate that the essential requirements of certain tasks are non-verbal. The four tasks selected for the present study were amenable to modification for non-verbal presentation. Instructions were presented mainly by pictorial representation, occasionally being combined with written words. Responses in the form of actions were required of Ss, thus verbal communication was eliminated from the administration procedure and from the response situation.

The Piaget-type tasks were presented in the following order to all Ss; judgement of displaced volume, probability concepts, combinations of chemical bodies and judgement and measure of equivalent three dimensional space. The length of the session varied according to Ss ability, the average duration being one and a half hours.

## PROBABILITY CONCEPTS AND PROBABILISTIC RESPONSES

The relevance of problems of chance to the study of formal thought has been emphasised by Inhelder and Piaget (1958, p. 224). The vital general property of formal operational thought concerns the real versus the possible. The probability that an event will occur is contained in the relationship between the possible instances of an event and those which actually occur. The estimation of probability laws presupposes the existence of certain formal-operational schemata for the calculation of correlations or associations.

Tracing the development of probability concepts from many experiments in this area, Piaget and Inhelder (1951) argue that cognitive processes must be sufficiently developed for ordering and organising the intrinsically certain, lawful and predictable by means of rational operations before things which are intrinsically uncertain, unlawful and unpredictable can be apprehended. The preoperational child manifests a generalised inability to differentiate between chance and nonchance. He is forever midstream between the deductively certain and the genuinely fortuitous.

The advent of concrete operations marks the development of a distinction between the possible and the certain. The child recognises that in one domain he may know, yet in another he can only guess. He has to move beyond separating chance from nonchance; he must rationally apply the so-called laws of probability to extract from the field of chance events what minimal certainty there is to be found there.

The concrete operational child makes limited progress toward establishing probabilities in lieu of certainties. It requires the fundamental reorientation toward cognitive problems which the period of formal operations brings, especially the advent of combinatorial and proportionality schemata, to systematically solve quantification-of-probability problems. For this reason, experiments involving the calculation of probabilities "yield developmental changes which extend well into adolescence" (Flavell, 1966, p. 342).

The method used in the present study was adapted from the experimental design of Ross (1966). Ss were required to make predictions on a 2-choice probability concept task. This is a simplified version of Piaget and Inhelder's (1951) experiment in which children were required to draw out pairs of counters from a bag containing unequal numbers of different coloured counters, (e.g., 15 yellow, 10 green, 6 brown, 3 blue). The child was required to predict the colour composition of the two counters before each successive withdrawal. Simplification of this procedure allows for a detailed analysis of the effects of performing predictions sequentially, that is not practicable with 3- or 4-choice problems.

Materials and Procedure

S was seated at a table directly opposite a wooden box painted flat black,  $9\frac{1}{4}$ " wide,  $9\frac{3}{4}$ " long and  $7\frac{3}{4}$ " deep. A jointed flap 3" x 3" was cut in the box on the long side. One blue and one red ball 2" in diameter were glued to a board placed slightly to the right of S. The requirements of the problem were that each child should observe a predetermined number of balls of two different colours being placed in the opaque box. S then indicated his prediction of the colour of the single ball he would draw from the box by pointing at one of the coloured balls on the board before him. He continued predicting and drawing out balls until the box was empty. The flap on the side of the box enabled S to insert his hand and take out one ball without being able to see inside the box.

E placed the number of balls specified for a particular problem in front of S where he could see them. Ensuring that S's attention was focused on the problem, E next placed the balls in the box one at a time, putting in all of one colour before putting in those of the other colour. The order of colour placement was randomised from problem to problem. E then shook the box. It was indicated to S by gesture that a ball was to be drawn from the box and his attention was then directed to the two alternatives, represented by the blue ball and red ball mounted on the board, that might be drawn. At this point, a card devised by E,

pictorially representing the alternative responses and their appropriateness was presented. (See Appendix p.118). The card communicates by means of a picture sequence that it is desirable for one's colour prediction to be confirmed by the withdrawal and undesirable if one's prediction and withdrawal do not correspond. Ross (op. cit.) conveyed this idea while the experiment was already in progress by nodding his head, affirmatively to indicate that S had been successful whenever the drawn ball agreed with S's predictions. At the initial explanatory stage however, Ross relied to a great extent on verbal instruction. Reinforcement of S was not given on the basis of whether S made a prediction that was scored as objectively correct, since E nodded affirmatively when S's withdrawal confirmed his prediction. The prediction procedure continued until all balls were drawn out. Drawn balls were placed within the view of S. Subsequent problems were administered in the same manner with S predicting before each withdrawal.

The situation demanded neither the use nor understanding of probabilistic terminology. The confounding of probability capacities and associated verbal abilities in the procedures used by Piaget and Inhelder (op. cit.) in studying the development of chance concepts has been criticised by Yost, Siegel and McMichael (1961) and Braine (1968).

The order of the 10 problems administered to each S, in terms of the number of balls placed in the box at the beginning of a problem was as follows, with R = Red balls and B = Blue balls.

- |    |       |    |       |    |       |    |       |     |       |
|----|-------|----|-------|----|-------|----|-------|-----|-------|
| 1. | 3R-3B | 2. | 2R-4B | 3. | 4R-4B | 4. | 6R-3B | 5.  | 1R-1B |
| 6. | 3R-4B | 7. | 2R-2B | 8. | 3R-2B | 9. | 6R-4B | 10. | 1R-3B |

### Scoring Criteria

Three different types of choice situations were encountered by Ss on the wide range of probability values administered. Firstly "uneven odds" choices occurred whenever S was faced with an uneven number of balls of different colours. Predictions with uneven odds are probabilistic, since the more probable and hence the correct prediction is always the majority colour. Developmental studies of probability concepts have concluded that Ss are more sensitive to small departures from even odds with increasing age and show a growing mastery of probability principles along the general lines indicated by Piaget's research (Pire 1958, reported in Flavell, op.cit; Ross op.cit; Stevenson and Zigler, 1958). Secondly, "sure thing" choices occurred on the last trial or trials of a problem when ball(s) of only one colour remained. If S failed consistently on "sure thing" predictions, this would indicate that he had not mastered the skill of keeping track of events in sequence. Thirdly, "even odds" choices occurred when there were an equal number of balls of each colour.

At the concrete-operational stage S begins to try to quantify probabilities, but fails to do so in a systematic manner. He is able to make objectively correct predictions when faced with uneven odds choices, however he tends to forget that each drawing changes the frequency of the balls remaining in the box and so fails to keep his probabilistic estimates up to date as he goes along (Piaget and Inhelder, op.cit.). These Ss can therefore be expected to sometimes make errors in the terminally occurring "sure thing" predictions. Ss with between 60% and 79% of their predictions in favour of greater odds were classified in the initial sub-stage of concrete operations. Between 80% and 89% predictions according to greater odds indicated performance at the equilibrium sub-stage of concrete operations.

In accordance with the rating criteria of Furth (1969, personal communication), Ss were considered to have reached the initial sub-stage of formal operations if over 90% of their predictions were according to greater odds.

The technique used in the present study to elicit probabilistic responses did not lend itself to a detailed analysis of reasoning in terms of proportions and possible combinations. The present task of responding appropriately to the changing odds of balls of two colours and predicting probabilistic events accordingly does not allow for as clear a theoretical distinction between concrete and formal level responses as does Piaget's (op.cit.) problem of drawing pairs

or trios of elements from collections containing several varieties of objects according to a specified numerical distribution. In Piaget's procedure, however, the probabilistic terminology the child is required to comprehend is formidable.

#### THE CONSERVATION OF VOLUME

The major finding of Piaget and Inhelder's (1941) systematic study of the child's grasp of quantity notions has been that discoveries of conservation follow a regular order that is related to age. Conservation of matter is commonly discovered at 8 to 10 years of age, of weight at 10 to 12 years, and of volume only at 12 years and after. Piaget's theoretical interpretation of this finding is complex and detailed. The first concrete operational schema contributing to the acquisition of matter conservation is embodied in the general capacity to multiply relations. The conservation of matter will be achieved by the child who, when considering a ball of clay transformed into a sausage, notices both length and thickness changes and comprehends that what the clay has gained in length it has lost in thickness, the total quantity thus remaining invariant. Atomism, the second schema, involves a conception of the clay as a whole composed of units which change their location vis-à-vis one another when the whole undergoes a transformation of shape. An understanding that the total sum of these parts remains constant, whatever their spatial distribution, is expressed in the conservation of

matter (Flavell, op. cit.). The possession of these schemata does not immediately result in an extension of invariance of matter to that of weight and volume. An obstacle to the conservation of weight may be posed by S's belief that though the total number of units of clay remain the same, the weight of each unit varies with its location in the whole.

Experimental data dealing with the development of conceptions of density and compression - decompression have illuminated the problems responsible for the late achievement of conservation of volume (Piaget and Inhelder, op. cit.).

Piaget states that non-conservation of volume, where conservation of matter and weight have been attained, results from an implicit belief that each unit of clay varies in the amount of space it occupies, compresses and decompresses and alters in its density as a function of its position in space following transformation of the whole (ibid. pp. 65 - 66, reported in Flavell, op. cit.). Establishment of the concept of volume and of its relation to weight requires the development of a schema of substance density and related concepts concerning the compression and decompression of matter.

"Neither the conservation of volume nor, consequently, of density, is worked out in a systematic fashion before sub-stage III - A (the initial stage of formal operations); however the conservation of weight and certain schemata preparatory to the concept of density are acquired at substage II - B (the upper level of concrete operations)" (Inhelder and

Piaget, 1958, p. 20). The problem of volume is for this reason appropriate for an analysis of the transition from concrete to formal thinking. The conservation of volume throughout changes of shape presupposes the ability to handle proportions expressed in multiplicative compensations.

Two tasks investigating the concept of volume were included in the present study. The experimental method of the first was adapted from the classic "conservation of volume" study by Piaget and Inhelder (1941), while the second, dealing with the judgement and measurement of equivalent three dimensional space followed a design similar to that of Piaget, Inhelder and Szeminska (1960). Important modifications in the administration procedure were devised in order to ensure that sufficient steps were taken to communicate all aspects of the problems by non-verbal methods.

#### VOLUME I: THE JUDGEMENT OF DISPLACED VOLUME

##### Materials and Procedure

In order to make instructions comprehensible to the deaf, E devised a series of cards pictorially representing the test materials in each step in the experimental procedure as well as the possible responses from which S could choose. These cards, reduced in scale, appear in their correct order of presentation in the Appendix pp. 119 - 125). S was presented with two clay balls 2" in diameter, one blue, the other red. He was encouraged to hold the balls against one another to compare their size. It

was imparted by pantomime that he could pinch off or add clay to the balls to equalize them. Since the balls had been made to exact measurements, it rarely occurred that Ss actually altered the amount of clay composing a ball. The two balls were then placed on a scale balance to establish equivalence of weight. The attention of S was drawn to 2 beakers, the water in each being at precisely the same height. The equality of water level was pointed out. Occasional Ss in the deaf and hearing groups poured water back and forth between the beakers before they were satisfied that the level was equal.

The blue ball was retained as a standard of comparison while the red ball was transformed. The various transformations that took place during the experiment involved changing the ball into four balls, a snake and a cylindrical shape. After each transformation, the standard blue ball was immersed in one of the beakers and the resultant rise in water level was pointed out. Pictorially represented alongside the beaker containing the standard ball was the transformed piece of clay immersed in a beaker, the water level of which was being queried by a number of question marks. The transformed clay is of course never actually immersed in the beaker of water. The pictures of the altered piece of clay under water represent an imagined immersion. Three cards representing the "possible" responses were placed in a row before S. These pictures were intended as equivalent symbols of "same level", "lower" or "higher". The original water level before the actual and imagined immersion was marked on the cards by a dotted line. The three cards representing the three

response choices that followed each transformation were placed in a random order to ensure that the correct response, that is, the representation of the "same level", did not always appear in the same position in relation to the other alternatives. As well as indicating his choice on the cards before him S was invited by gesture to point out the level to which he anticipated the water would rise on the beaker. This repetition of choice was introduced to allow Ss giving hesitant responses an opportunity to reconsider their choice. The fact that some Ss in the pilot study returned to problems and corrected their responses seemed to indicate that a second assertion of S's response was advisable.

A brass ball 2" in diameter was then introduced and displayed next to the blue ball. S was again encouraged to compare the size of the two balls and make addition or subtraction adjustments to the clay ball should he consider that the balls were not the same size. The brass and clay balls were then placed in S's hands. The difference in weight was obvious and the comparative heaviness of the brass ball was immediately apparent to all Ss. The balls were also placed on the scale, the heavy brass ball causing the scale to tip sharply. No alternation of shape was made and the blue ball was immersed. Prior to this immersion the attention of S had been drawn to the equality of water level in the two beakers. The height to which the water level would rise should the brass ball be placed in the remaining beaker was then queried by a picture card, followed by pictures of the three alternative responses. The final transformation

took the form of altering the blue ball to a snake-like form and immersing the brass ball, S being expected to predict the water level on the other beaker should the snake be immersed.

### Scoring Criteria

At the initial sub-stage of concrete operations conservation of occupied or displaced volume is not systematically achieved. Modification of form entails variation in surface area and since at this sub-stage S has not yet established the correct relations between the space which is contained and the areas which bound it, he will not conserve volume in a situation of maximal perceptual pull. S therefore would not systematically anticipate equality of water level if the standard ball of clay and transformed clay were to be immersed. A number of hearing Ss at this sub-stage while making their response choice from the cards, spontaneously offered explanations to the effect that the weight of the clay and its density altered as a consequence of the transformation.

Response to the introduction of the heavy ball further indicates that S attributes the displacement of water to the weight of the immersed body rather than to its volume.

The equilibrium sub-stage of concrete operations is marked by the systematic conservation of displaced volume in all cases with the exception of the heavy ball. When confronted with the transformations into 4 balls, a snake and a cylinder, S

is able to shield himself from the "bias of perceptual immediacy" (Bruner et al, 1966). Though the surface areas are variable, S understands that displaced volume remains constant in such transformations. He remains in a transition stage however, since he too lacks a schema of substance density, failing to grasp the concept of volume and its relation to weight. At this point, weight and volume are not yet separable rational concepts and are thus not seen as distinct properties which can vary independently. The weight of the heavy ball is considered responsible for "pushing the water up", a notion which a few of the hearing and deaf Ss spontaneously verbalized.

The major accomplishment of the initial sub-stage of formal operations with respect to the problem of judging displaced volume is a recognition of the logical independence of volume and weight resulting from a genuine quantification of both. Displaced volume is conserved through all transformations in the series including those steps in which the heavy brass ball is introduced. A concept of density, for which formal operational schematization is needed (Inhelder and Piaget, 1958, p. 36), is achieved. The transitivity principle as it applies to equal and unequal weights and volumes would be recognized by Ss at this sub-stage.

VOLUME 2: THE JUDGEMENT AND MEASUREMENT OF EQUIVALENT  
THREE DIMENSIONAL SPACE

Materials and Procedure

S, seated at a table next to E, was shown a solid brass block measuring 4 cm. in height against a square base 3 cm. x 3 cm., its volume being 36 cm.<sup>3</sup> One hundred brass cubes, each measuring 1 cm. were scattered around the solid block. In a quick movement, E placed 3 cubes along the base of the solid block and piled four cubes on top of one another against the solid. These blocks were immediately removed from their position against the solid and placed again among the scattered cubes. The procedure of briefly placing the cubes against the solid was introduced in order to indicate non-verbally to S that it was permissible to manipulate the blocks freely and measure them against the solid block should he wish. A pilot application of this test had revealed that the hearing child at an advanced level commonly asked whether he was permitted to measure the surfaces of the solid block with the 1 cm. cubes, while the deaf child experienced difficulty in formulating this question and consequently could not ascertain that this was permitted. The deaf S could thus have been placed at a considerable disadvantage to the hearing S.

A series of explanatory cards, devised by E (See Appendix, pp. 126 - 130) was presented to S to indicate the problem, namely reproducing the volume of the solid block with the little cubes while altering its form to comply with the base given. These cards utilise pictures and words to clarify the problem. It should be appreciated that the scale has been greatly reduced to accommodate the cards in the Appendix. A description of the presentation of these cards and the supplementary actions accompanying this presentation will illuminate the extent to which reliance on written instructions was minimised.

The first card displays two islands, one being double the area of the other. One is labelled "their island" the other "our island". Card 2 shows that both islands have been built upon, yet in spite of the differences in size, both buildings have "the same amount of space inside". The picture clearly indicates that the house on the larger base is made of two blocks alongside one another, while the house on the smaller base is constructed from the same number of blocks of equal size, one being placed on top of the other to compensate for the smaller area of the island. Two bases, one measuring 1 cm. by 2 cm., the other being 1 cm. square, painted on a background of sea are depicted on Card 3. E placed two cubes one adjoining the other on the 1 x 2 cm. base and two cubes one on top of the other on the 1 x 1 cm. base, pointing respectively to the words "They build a house"

and "ours has the same amount of space inside" on Card 2. Card 3, on which the cubes had been placed, was left on display, while Card 4 was produced. The building on the larger base is depicted in Card 4 as having doubled in size and is accompanied by the words "They make theirs bigger". The building on the 1 x 2 cm. base on Card 3 is correspondingly enlarged. The building on the smaller base is depicted as extending upwards. An incomplete storey on which have been placed question marks indicates that the extent to which the building must rise in order to have the "same amount of space inside" as its neighbour is being queried. S was then invited by gesture to complete the building on the 1 x 1 cm. base on Card 3 while his attention was being drawn to the words "same amount of space inside" on Card 4. All Ss were able to complete the building by placing two blocks one above the other, making the building a total of 4 blocks in height. The building on the 1 x 1 base therefore compensated in height for what it lacked in breadth. E then emphasised the numerical correspondence in the blocks composing the two buildings, the 1 x 2 cm. base having 4 blocks, two covering the base and two forming a second storey; and the 1 x 1 cm. base having 4 blocks placed one on top of the other. Ss attention was again drawn to the words "same amount of space inside". The designs were then broken up and Card 5, displaying "their new island" and "our new island", was presented. The areas of the two islands were again different. Card 6 displaying on the left a base 3 x 3 cm. and on the right a base 2 x 3 cm. surrounded by sea, was

placed next to Card 5. Card 7 was introduced showing that the bases of each "new island" as they appeared in Card 5 had been built upon. The building on the larger base on the left of the card, a solid block, is accompanied by the words "They build a hotel". Ss attention was then drawn to the 3 x 3 cm. base on Card 6 on which was placed the solid 3 x 3 x 4 cm. brass block. Referring again to Card 7, E pointed to the incomplete building on the smaller base on the right, the question marks on the top of this building and the words "same amount of space inside". Turning to Card 6, E pointed to the 2 x 3 cm. base and gestured that S should begin building, pointing as a reminder to the words "same amount of space inside". It should be noted that though the same technique of demonstration as in the earlier cards was used, the buildings in Card 7 were not sub-divided into blocks. Such a division would emphasise arithmetical correspondence. S was then presented with a succession of cards each displaying the 3 x 3 cm. base on the left, on which the solid brass block was placed each time, and other bases or "islands" differing from the 3 x 3 cm. base in size or shape or in both. Their measurements are 3 x 4 cm.; 2 x 2 cm.; 1 x 4 cm. and 2 x 6 cm.

A participant in the pilot study tried so hard to keep the shape of the house the same as the solid block, that he had to be cautioned that the house could not be built over the sea, but must be built on the island. A card displaying this cautionary remark was produced in order to cope with rare Ss

who disregarded the boundaries of the base.

The construction made on the 1 x 4 cm. base was left standing until S had completed the final 2 x 6 cm. construction. This allowed for a comparison of these constructions with one another and with the solid block while S's attention was drawn to the written words "same amount of space". Here, as in previous constructions, S is exposed to what Bruner et al. (1966) have termed "perceptual seduction". The difference in appearance of the three structures is considerable. S must distinguish between the appearance of the variation and its real identity (Elkind, 1969), a distinction that those Ss focusing on a single perceptual feature of the displays, usually the height of the constructions, will not achieve.

The present method dealt with internal volume, or the conservation of the 36 cubes. Results were checked by adapting the procedure of immersing a solid object in water to the present experimental situation. Two beakers containing equal quantities of water were produced. The solid 3 x 3 x 4 cm. brass block was immersed. The method of enquiry used in the previously described conservation of displaced volume task was applied. Card pictorially representing the immersion of the solid block and imagined immersion of the 2 x 6 x 3 cm. construction of cubes, followed by the three alternatives of water level in relation to the level in the beaker containing the solid block, were offered (See Appendix, pp. 129 - 130). Volume as "occupied" space, being the amount of space taken up

by the 36 cubes in the water, was being measured as well as the complementary volume, that is, the volume of the water. These last two volumes are measured by the level of the water. Recognition of their conservation is shown by anticipation that the water levels in two beakers will rise equally with the immersion of the model and transformation.

### Scoring Criteria

While S constructed his "houses", detailed recordings of his responses were made, " ... since the method he adopts is no less revealing than the answer he obtains" (Piaget et al, 1960, p. 357). An analysis of these protocols revealed that no performance could be classified as preoperational, a level at which all reconstructions or comparisons of volume are made entirely in terms of one dimension only. Although differences in volume may be apparent to the preoperational child, he refuses to build higher than the model to allow for a decrease in the size of the base or "island". Ss at an operational stage may occasionally experience difficulty in dissociating height from volume, however this is overcome when attention is drawn to the preceding explanatory cards and procedure, which were designed to convey by pictorial and written means that the house should have as much room in it, but can be different in shape.

The initial sub-stage of concrete operations is marked by the ability to dissociate the three notions of height, shape and volume. S recognises that a building constructed on a narrower base must be higher if it is to retain the same volume. Progress is made in working out the relations between the three dimensions of the block, although S cannot cope with more than two simultaneously and the third is progressively adjusted to these two (Piaget et al, op. cit.). Attempting to build a "house" on a small "island", S now builds a taller house, but he remains unable to consistently determine precisely how much taller it should be. Similarly, on a larger base, he is unsure as to how much shorter than the model his construction should be. He cannot yet make the differences compensatory by using metrical decomposition and recomposition. S may measure a dimension of the solid model with unit cubes, however his constructions are clearly based on logical multiplication, that is, he does not make exact compensations based on a unit system. S will place the model against his construction while the building is in progress and observe for instance that the base of the model may be broader by one layer. He then uses qualitative methods of compensation, that is, he transfers cubes from one dimension which is reduced to another which is increased, hence an increase in height compensates for a decrease in breadth or depth. Attempts to establish relations between the relevant dimensions give rise to compensations which for some reconstructions may be correct, while for others they are no better than approximations, with no equalisation of the

differences. The difference may even be exaggerated, for example, building 7 storeys on the base  $2 \times 3 (=42)$ , the model being  $3 \times 3 \times 4 (=36)$ . Compensations that are determined with accuracy are done by means of reconstruction. S may duplicate the model ( $3 \times 3 \times 4$  cm.) on a base  $1 \times 4$  first reconstructing the model and then transferring it to the  $1 \times 4$  base, thereby transforming it.

S recognises conservation, since he makes transformations in his arrangements of cubes, though these are not based on exact compensations. The conservation of interior volume, of the amount of matter contained within an object, occurs through "qualitative coordination of subdivisions and changes of position ... without a true metrical operation" (Piaget et al, ibid.). Conservation does not yet extend to the spatial relations between the object and its surroundings. When the model is immersed in water and S is required to anticipate the water level should a transformed block of unit cubes be immersed, the fact that interior volume may be conserved does not ensure conservation of the volume of water which is complementary. The volume which the cubes occupy in the water is not conceived of as identical to their interior volume. Why the resolution of this contradiction is a formal operational achievement will become apparent when responses at the formal level are discussed.

The equilibrium sub-stage of concrete operations is characterised by the appearance of metrical relations. Whereas in the previous sub-stage relations between the three dimensions were handled by logical multiplication, relations are now coordinated by metrical means. S begins to measure accurately using the brass cubes as units of measurement by which to gauge the lengths of all three dimensions. He is thus using numbers of metrical relations to substantiate his successive estimates. He may however revert to qualitative methods of compensation on occasions. Measurement at this sub-stage amounts to a "synthesis of subdivision and changes of position" (Piaget et al, ibid. p. 380). S does not carry out mathematical multiplication, and therefore cannot establish numerical relations between area and volume. In an attempt to calculate the volume of the solid model, S can be observed enveloping the surfaces and counting the cubes used to construct them.

This approach to the problem indicates that S has found a compromise between logical multiplication of the relations between dimensions and attempts at using mathematical calculations, by considering volume as if it were the result of the addition of areas. At this sub-stage S is dominated by topological notions of volume. Measurement of the three dimensions with the unit cubes is made, but S does not understand that by multiplying these measurements he will arrive at the sum of units that would be needed to make an exact copy of the solid model. The conservation of volume is limited to interior volume. The volume occupied by

an object in relation to its surrounding spatial medium is not comprehended as invariant. S is distracted by the fact that a volume which is transformed changes in surface area thus seeming to occupy more or less space in relation to its surroundings.

The initial sub-stage of formal operations is characterised by the ability to make mathematical multiplications of three-dimensional measurements. S thus discovers that two volumes are equal if the products of their dimensions are the same. He will measure the three dimensions of the solid model with the unit cubes and will consistently succeed in reproducing the volume of the model, building with unit cubes on the various bases supplied. A second decisive achievement is the discovery of "volume occupied" in relation to the surrounding space. Modification of form in three dimensions implies variation in both length and area while the volume remains constant. The recognition that volume is invariant, in the sense that it occupies a fixed amount of space in relation to its surroundings, is achieved when S establishes the correct relations between the space which is contained and the areas which bound it. This involves not merely logical but mathematical multiplication expressed in S's constructions as  $3 \times 3 \times 4 = 2 \times 3 \times 6 = 2 \times 2 \times 9 = 1 \times 4 \times 9 = 2 \times 6 \times 3 = 36$ . Interior volume can be measured and calculated without fault and its invariance extends to the surrounding space. This is a formal operational achievement since it implies the concept of metrical continuity, the infinite sub-division of continuous space.

## COMBINATORIAL OPERATIONS

Formal thinking is essentially hypothetico-deductive. Unlike the concrete operational child whose deductions refer directly to perceived realities, the adolescent's deductions refer to propositions which are formulations of hypotheses and which postulate facts or events independently of whether or not they really occur. Within Piaget's theory, formal thought is conceived of as a generalised orientation towards problem solving (Inhelder and Piaget, 1958) rather than as a specific behaviour. It implies an orientation toward organising data, isolating and controlling variables as in a combinatorial analysis and towards logical justification of hypotheses.

Inhelder and Piaget (ibid. p. 107) have stated that " .... the formation of propositional logic, which itself marks the appearance of formal thought, depends on the establishment of a combinatorial system". Formal operations are characteristically operations performed on the results of prior (concrete) operations, thus being termed "second-degree operations" (Piaget, 1950). The combinatorial system is manifested in Ss ability to link a set of base elements or associations between elements with one another in all possible ways, extracting the relationships of implication, disjunction, exclusion and so forth. Confronted with an induction problem those Ss who have reached the formal operational stage will determine all the possible relations inherent in the problem and will systematically isolate all the individual variables including all possible

combinations of these variables. Such an approach guarantees that the possibilities will be exhaustively dealt with.

A modified version of the well known experiment of combining chemical bodies, devised by Inhelder and Piaget (op. cit.), was applied in the present study. This experiment poses a problem that involves combinations directly, that is, it involves chemicals whose combination is indispensable if variable results are to be obtained.

#### Materials and Procedure

Placed on a table before S were four similar bottles containing colourless, odourless liquids which were perceptually identical. Each bottle was labelled with a number. The names of the liquids were unknown to S. They were : 1. diluted sulphuric acid; 2. water; 3. oxygenated water; and 4. thiosulphate. The fifth bottle, a smaller one, containing potassium iodide, was labelled g. Each bottle contained a dropper.

Oxygenated water oxidises potassium iodide in an acid medium. Mixture (1 + 3 + g) will thus produce yellow. The water (2) is neutral, so that if it is added, the colour will not change. The thiosulphate (4) will bleach the mixture ( 1 + 3 + g).

Before S entered the room, E prepared two beakers, one containing 1 + 3, the other containing 2. These beakers were placed before S, and while he was watching, E poured several drops from bottle g into each beaker. The liquid in the beaker containing 1 + 3 turned yellow, while the liquid in the beaker containing 2 did not change in appearance. Since S did not know what liquids had been placed in the two beakers prior to his entrance, he knew only that g added to one liquid produced yellow, while g added to another liquid did not yield yellow. A series of cards was devised showing the larger bottles numbered 1 to 4 and the smaller bottle g and recording the pouring of liquid g into the two beakers, each containing liquid, and the consequent appearance of colour in one. These cards recorded step by step the action of E that took place in front of S. They were left on display throughout the experiment enabling S to refer back to the initial procedure. These cards were devised to meet a need that arose in the pilot application of the test, namely the request of the occasional hearing S that E revise the procedure. The cards, pictorially representing the addition of drops from bottle g to the two beakers containing "unknown" liquids, served this purpose. The two beakers that had been used in this demonstration were then washed out and a beaker was placed before S. A card was presented which showed the four bottles plus bottle g and in the foreground an empty beaker under which was written "Make yellow". It was demonstrated by pantomime that S could wash out the beaker in a basin. This

was readily grasped since all Ss repeatedly rinsed out their beakers before starting a fresh combination.

Particularly among the deaf group, Ss were easily discouraged when they failed to produce yellow after a few attempts. This necessitated the introduction of a card stating, "You can make yellow from these bottles". Piaget's "clinical method" involves the asking of leading questions and offering of suggestions, after it has become apparent that S is satisfied that he has tried all combinations. Scoring is however based on the spontaneous responses of S, while those responses elicited by prompting serve only to further illustrate his limitations. Two "prompt cards" were nevertheless devised. The first, stating "Try mixing two bottles with g" was presented to Ss limited to 1 x 1 associations. A card encouraging S to "Try to find another way to make yellow" was shown to those Ss who had produced yellow and were satisfied with a single solution.

There were 15 possible combinations in which the droppers could be squeezed, excluding permutations. Ss were allowed an unlimited number of exploratory trials.

### Scoring Criteria

Scoring was based on the criteria provided by Inhelder and Piaget (ibid.) and the scale for rating manual responses (Wynns, 1967) which was theoretically and empirically derived following an extensive replication study of Piaget's combinatorial task on American children.

At the initial sub-stage of concrete operations, S spontaneously and systematically associates the bottles 1 to 4 with the element g, and /or combines the liquids of all the bottles at the same time. Even when faced with failure, he does not spontaneously use two-by-two combinations. Prompting may elicit a few two-by-two or three-by-three combinations, but S is unable to use these systematically. He possesses logical multiplication operations, but of one-by-one correspondence only. The above behaviours are considered a sine qua non for classification in this sub-stage.

Additional features are sometimes present. S may have a purely quantitative hypothesis, thus distributing the quantity of drops from the bottles differently. His hypothesis may, on the other hand, be related to serial ordering. He will thus begin to try some of the possible permutations rather than combinations. His protocol will convey the general impression that "no true combinatorial operation has appeared as yet, but only correspondences and serial ordering - i.e., first degree combinations based on fixed class inclusions" (Inhelder and Piaget, op. cit., p. 113).

The equilibrium sub-stage of concrete operations

is characterized by the appearance of "multiplicative operations with the empirical introduction of n-by-n combinations" (Inhelder and Piaget, ibid., p. 114). As in the preceding sub-stage, S begins by multiplying each element by g, or he may mix them all together at once. There is however, a visible progression beyond the previous sub-stage in that S spontaneously tries two-by-two or three-by-three combinations, each time with g. The fact that S can impose no system on what remain "tentative empirical efforts", defines the upper limit of his sub-stage. He will not attain all the possible two-by-two (x g) combinations since he is unable to approach the problem systematically. He is clearly not enslaved to the "actual" as the pre-operational child would be, because he can and does deal with the "potential", though his conception of possibilities is limited. Any discoveries that S may make about the elements are fortuitous, since he has no systematic method of proof.

The most outstanding achievement of the initial sub-stage of formal operations is the appearance of a systematic n-by-n combinatorial system. The presence of a systematic method indicates that S is disposed to thinking in terms of all the possible combinations of the elements. A further innovation which appears at this sub-stage is S's dissatisfaction with a single solution and determination to look for others, since he feels the necessity to test the full range of possibilities.

The hypothetico-deductive approach of S is best illustrated by the way he deals with elements 2 and 4. By systematically testing the presence or absence of 2 with the colour, he is able to deduce that 2 is ineffective. The following formula derived by Inhelder and Piaget (ibid., p. 119), illustrates that S can see the possibilities:

$$(p \cdot q) \vee (p \cdot \bar{q}) \vee (\bar{p} \cdot q) \vee (\bar{p} \cdot \bar{q}) = (p^*q)$$

In this formula  $p$  = presence of colour,  $q$  = presence of element 2,  $\bar{p}$  and  $\bar{q}$  are the negations of  $p$  and  $q$ ,  $\vee$  = "or", and  $*$  = a "tautology" or "complete affirmation", i.e., water (2) has no effect.

S also realises that element 4 and the colour are incompatible. He understands that:

$$(p \cdot \bar{q}) \vee (\bar{p} \cdot q) = (p \vee\vee q)$$

Now  $q$  designates the presence of 4 and  $\vee\vee$  = reciprocal exclusion. A protocol at this level should give the overall impression that S is formulating and systematically testing hypotheses, isolating and controlling variables, providing logical justification for his findings.

## A.2. ANALYSIS OF RESULTS

All the scores obtained should be interpreted as being on an ordinal scale rather than an interval scale, therefore non-parametric procedures based as far as possible on rankings were applied.

In order to establish hypothesis 1 it is necessary to determine that the inferiority of the deaf group on the language tests is statistically significant. An appropriate non-parametric test is the Mann-Whitney U test (Siegel, 1956). For the Paragraph Meaning Test each hearing S was ranked ahead of every deaf S (Appendix, Table 3) giving  $U = 0$ , which is significant at the .001 level. For the 6 sub-tests of the Woodward Nonsense Test the respective values of U were  $U = 15.5$ ,  $U = 41$ ,  $U = 9$ ,  $U = 5$ ,  $U = 2$  and  $U = 0$  (Appendix, Table 4). These values are all significant at the .001 level, with the exception of the value  $U = 41$ , which is significant at the .025 level.

The extent of the deaf sample's linguistic retardation is most evident in the reading ages obtained from the scores on the Paragraph Meaning Test (Appendix, Table 5). The chronological ages of the deaf group ranged from 13:1 to 14:10, however four Ss had reading ages between 10:1 and 10:4, while the remaining scores were so low that they could not be converted, since the tables do not assign reading ages below 10 years. In contrast, the reading ages for the hearing group ranged from 11:7 to beyond 15:6.

For the deaf group the product-moment correlation co-efficient between the score for the Paragraph Meaning Test and the total score of the Woodward Nonsense Test was calculated as  $r = .604$ . The correlation coefficient of the hearing group was  $r = .590$ . The correlation for each group is significant at the .05 level.

In order that results on the Piaget-type tasks might be displayed in tabular form, the number 1 was used to denote the initial sub-stage of concrete operations, 2 to denote the equilibrium sub-stage of concrete operations and 3 to denote the initial sub-stage of formal operations. The results are presented in Table 6 below.

To determine the reliability of these ratings, a judge, with no knowledge of whether the protocols were from the experimental or control group, rated one third of the protocols drawn at random from the data. From these ratings a product-moment correlation coefficient of inter-judge reliability of .935 was obtained. For this calculation it was necessary to treat the scores 1, 2 and 3 as numerical values.

TABLE 6  
 RATINGS ON PIAGET-TYPE TASKS FOR  
 THE DEAF AND HEARING

Group	Prob.	Volume	Space	Comb.
DEAF				
S.V.	2	1	1	2
D.H.	3	2	2	2
A.J.	2	3	3	2
S.W.	3	1	1	1
J.U.	2	1	2	1
A.E.	2	1	1	1
A.B.	2	3	2	1
A.M.	3	1	2	2
K.W.	1	2	1	1
L.P.	2	2	2	2
R.P.	2	2	1	1
J.O.	1	3	2	2
HEARING				
M.G.	2	3	2	2
B.F.	1	3	3	2
A.N.	3	1	3	3
A.H.	2	2	2	1
G.M.	2	2	1	1
B.C.	1	2	2	1
T.A.	2	3	2	2
J.B.	1	3	2	2
S.L.	1	2	2	2
A.C.	2	3	2	2
K.G.	2	1	1	2
G.L.	3	2	2	2
S.K.	3	2	3	1
J.C.	2	3	2	2

The results in Table 6 are summarized in the following four tables. In these tables LCO = lower (initial) concrete operations, UCO = upper (equilibrium) concrete operations, and LFO = lower (initial) formal operations.

TABLE 7  
PROBABILITY CONCEPTS: NUMBER OF SUBJECTS  
AT EACH OPERATIONAL SUB-STAGE

	LCO	UCO	LFO	
Hearing	4	7	3	(n = 14)
Deaf	2	7	3	(n = 12)

TABLE 8  
DISPLACED VOLUME: NUMBER OF SUBJECTS  
AT EACH OPERATIONAL SUB-STAGE

	LCO	UCO	LFO
Hearing	2	6	6
Deaf	5	4	3

TABLE 9  
EQUIVALENT THREE-DIMENSIONAL SPACE: NUMBER OF  
SUBJECTS AT EACH OPERATIONAL SUB-STAGE

	LCO	UCO	LFO
Hearing	2	9	3
Deaf	5	6	1

TABLE 10  
 COMBINATIONS: NUMBER OF SUBJECTS  
 AT EACH OPERATIONAL SUB-STAGE

	LCO	UCO	-LFO
Hearing	4	9	1
Deaf	6	6	-

The hypothesis to be tested states that the inferiority of the deaf group on the Piaget-type tasks will not be statistically significant. On the probability task (Table 7) the deaf Ss performed slightly better than the hearing Ss, thus no statistical testing of this table is necessary. On the remaining three tasks the performance of the hearing group was superior. Various statistical tests were applied but none indicated that the superiority of the hearing group was statistically significant.

The  $X^2$  test was applied to Table 8 and 9. The expected values in the cells are rather small, but the discussions in Cochran (1952, 1954) indicate that the  $X^2$  test is applicable. In cases where expected values are about two or more in all cells and five or more in some cells, the  $X^2$  test can be used provided that the value obtained for  $X^2$  is well above or below the critical value. On Table 8 the value of  $X^2$  is 2.66, while on Table 9 the value of  $X^2$  is 2.73. With  $df = 2$  the critical value of  $X^2$ , at the .05 significance level, is 5.99 (Siegel, op. cit.). Since the observed values

of  $X^2$  are so far below the critical value, it can be safely concluded that these values are not statistically significant.

Table 10 contains only one S at the lower formal operational sub-stage, therefore Ss in the upper concrete and lower formal sub-stages were combined and the Fisher exact probability test (Siegel, op. cit.) was applied. The resulting table is:

	LCO	UCO & LFO
Hearing	4	10
Deaf	6	6

This is a table of the form  $\begin{matrix} A & B \\ C & D \end{matrix}$  with  $A + B = 14$  and  $C + D = 12$ . Since  $B = 10$ , a table of this form is significant if the value of  $D$  is at most 3 (ibid., Table 1, p. 265). The observed value of  $D = 6$  is thus not significant.

Graphs in which the results on the Piaget-type tasks are plotted against the scores on the language tests are shown in the Appendix (Figures 4 and 5). The first graph uses scores on the Paragraph Meaning Test, the second uses percentage scores calculated from the total score for each S on the Woodward Nonsense Test. It can be seen from these graphs that success on the Piaget-type tasks was largely independent of performance on either of the language tests.

A major finding of the study is the confirmation of hypothesis 3 by the fact that six deaf Ss performed at the formal operational level on some tasks.

## B. DISCUSSION

Research into the modification of Piaget's tasks to allow for the exclusion or minimal use of language in instruction, performance and as a criterion of success has the potential of extending the application of the tasks to linguistically deprived children. The criticism has been raised that certain of Piaget's tasks demand of the subject an understanding of terminology that is more advanced than the conceptual understanding which the task purports to measure (Braine, 1968). The problem of evaluating the authenticity of level of functioning by means of the subject's manual responses alone must be acknowledged. Sigel (1968) considers that studies applying Piaget-type tasks that do not require a verbal explanation from the child cannot sufficiently separate conceptual and perceptual elements of the task. In contrast, the efficacy of an approach using the child's verbal explanations to help estimate his cognitive level has been questioned by Elkind (1968). Expressing reservations about Piaget's use of verbal explanations in assessing the presence or absence of conservation concepts, Elkind states that: "Verbal explanations are really post hoc rationalizations rather than veridical reflections of the processes leading to conservation" (ibid. p. 464). Only those tasks having solid criteria for evaluating manual responses were used in the present study.

Language was effectively eliminated from the probability and displaced volume tasks, where the space and combinatorial tasks were less successfully adapted, since some written instructions had to be combined with pantomimed and pictorial instructions. Possible improvements in the administration procedure of these tasks became apparent during their experimental application and may be usefully incorporated in future research. In the conservation of displaced volume task the introduction of a few "control steps" in which pairs of unequal volume are presented would ensure that the "same" response would not always be correct. The task requiring the judgement and measurement of equivalent three dimensional space could perhaps have been simplified by the substitution of proper nouns for pronouns in the written instructions. The deaf experience difficulty in learning the correct use of pronouns (Myklebust, 1966).

The severity of the retardation of the deaf group in comparison to the hearing control on measures of linguistic knowledge, clearly emerges from a qualitative and quantitative analysis of performance on the Paragraph Meaning Test and the Woodward Nonsense Test of Structural Meaning, thus confirming the first major hypothesis of the study. The inferiority of the deaf group in ability to comprehend paragraphs and on all sections of the Woodward Nonsense Test reached statistical significance.

The hypothesis that a positive and significant correlation would exist for each group between the two language tests administered was also confirmed. This indicates the importance of the role of structural cues to meaning in the comprehension of sentences. The correlations obtained should be considered in the knowledge that the lexical component of linguistic meaning played a part in the Paragraph Meaning Test, while it was excluded from the Woodward Test.

Paragraph meaning tests are traditionally used to quantify the linguistic knowledge of the deaf, being good indicators of overall linguistic ability. The Woodward Nonsense Test measures control over specific items of linguistic structure, namely ability to group words into meaningful units (sentence recognition); ability to interpret markers of sequence (sequence signals); to recognize implicitly form classes (part of speech membership); ability to interpret meanings carried by subject and object structures (subjects and objects); and ability to interpret sentences containing modifiers (modifiers). In addition to measuring specific linguistic skills, the Woodward Nonsense Test is a "... valid indicator of general language development" (Woodward, 1963, p. 54). The pattern of performance across the six sub-tests allows for an analysis of the subject's knowledge of the properties of linguistic structure considered in certain theoretical models (Bruner, 1966; Vygotsky, 1962) to operate as a "set of rules" for organizing information and greatly increasing the range of problem solving. The inferior

performance of the deaf on all sections of the Nonsense Test indicates a lack of mastery of the basic structure of language, namely predication, causation, modification, categoriality and hierarchy. These properties of language are considered by Bruner (op. cit.) to provide the child with principles of organization by which to bring the world of experience under control, organizing events in a form " ... isomorphic with the structural principles of syntax" (ibid. p. 47).

Developmental trends in control over language structure are the subject matter of some empirical studies (Miller and Ervin, 1964), however the establishment of norms for tracing patterns in normal and abnormal language development with the Nonsense Test is as yet a research goal (Woodward, 1968). The retardation of the deaf group cannot therefore be expressed in specific developmental terms, however indications were that among the deaf group scoring tended to be confined to the earlier items of the sections which were graded for difficulty.

The results of the hearing and deaf group on the four Piaget-type tasks present a mixed picture. Nobody was restricted on all problems to solutions consistent with classification in the initial sub-stage of concrete operations nor did any subject succeed consistently at the formal operational level. On the volume, space and combinatorial tasks the performance of the deaf as a group was inferior to that of the hearing, however, this inferiority was not

statistically significant, thus confirming hypothesis 2.

On the probability concept task the performance of the deaf was actually slightly superior to that of the hearing.

The difference in educational achievement between the deaf and hearing group gives rise to the problem of the effects of schooling on performance on Piaget's tasks.

Although most of the deaf subjects had not reached an equivalent standard placement to the hearing, they had attended school for at least as many years as the hearing subjects. Studies of the effects of schooling on Piaget's tasks have tended to focus on comparisons of schooled and unschooled children (Goodnow and Bethon, 1966; Greenfield et al, 1966). It is possible that children learn more quickly about physical volume, for example, as a result of being exposed in school to learning situations where the effectiveness of the relevant and non-effectiveness of the irrelevant variables may be made evident in the same experiment (Lovell and Ogilvie, 1968). Such information would however be more successfully assimilated by the child in whom the appropriate schemata had already evolved.

The series of investigations into the cognitive development of the deaf by Furth (1966a) have indicated a striking similarity between the deaf and hearing in ability to comprehend and use logical symbols. The deaf however lagged behind when a discovery principle was introduced suggesting

"... a lack of initiative in reasoning" (ibid., p. 147). Furth relates this rigidity in thinking to the influence of long-term "experiential deprivation" among the deaf and cautions that cognizance should be taken of the "... fairly important discovery component in Piaget's tasks" (ibid., p. 158) which may be a possible contributing factor where differences between deaf and hearing are found. Experimental validation of Furth's "experiential deficiency" hypothesis is being undertaken (Youniss and Furth, 1967).

There was no evidence of any definite relationship between level of achievement on the Piaget-type tasks and performance on either of the language tests (see Figures 4 and 5). This lends support to the theoretical position that language is not a central, constitutive component of operative thinking (Piaget, 1963).

The absence of a consistent task-inter-task relationship among the results of both groups is a familiar feature of performance across a variety of Piaget's tasks. Décalages occur "... as a result of the differences in content to which the conceptual structures must be applied and, also, of the differences according to the type of activity in which the structure must function" (Szeminska, 1965).

Hypothesis 3 is tested by the presence or absence of task solutions at the formal operational level in the deaf sample. Five of the twelve deaf subjects responded at a formal operational level on one task, and a sixth used formal reasoning on two tasks. On the probability task three deaf subjects were able to respond appropriately to the changing proportions of the coloured balls and predicted the probabilistic events accordingly. Three other boys conserved displaced volume including the items presenting two balls of markedly different weight but of equal size. In addition to successfully solving the latter problem, one of the deaf boys was able to approach the task of equivalent space using a method indicative of the presence of formal operational structures. No subject in the deaf group was completely successful regarding testing all possibilities in the combinatorial task. Furth (1969) states that "... success on any one task is a more valid indication of the presence of the prerequisite intellectual capacity than failure is indicative of the absence of this capacity". A consideration of the responses of the deaf in comparison with the hearing control indicates that manifestations of logical thinking were present without any important deficiencies in the operatory structures that the present tasks purport to measure.

Cognitive theories have generally accepted that severely linguistically deprived deaf children can achieve concrete operational thinking, however theories in which language is given an explanatory or indispensable role in

intellectual development (Bernstein, 1961, Bruner, 1966) have long held that the severely linguistically deprived are restricted to the concrete operational stage and never develop formal operational thinking structures.

The role of language as a determinant of cognitive development must be distinguished from the role of language as facilitating cognitive skills. This distinction is reflected in Piaget's (1963) discussion following his analysis of the proposition that language is a sufficient condition in the formation of intellectual operations. He concludes that language does not play a truly constitutive role in the development of logical thinking structures while conceding that language may play an indirect or supportive role in the elaboration of these structures.

Piaget considers that observations of the partial isomorphism between the principal operational structures and the syntactic properties of language have led to the more extreme theories that reduce intellectual operations to language. Bruner and his associates have concentrated their empirical efforts on providing evidence that "... the syntactic properties of language ... relate to the logical structures of thought" (Greenfield et al, 1966, p. 299). Piaget and Inhelder (1969) acknowledge "... the existence of parallel mechanisms, of parallel constructive processes in cognitive development and in the acquisition of syntactic structures" (ibid., p. 151).

Piaget's descriptions and observations of sensory-motor structures suggest however that language does not structure thought, but rather, " ... the infant has to acquire co-ordinations of sensory-motor schemes, which will develop into operational structures ... before he can begin to understand and produce syntactic structures" (*ibid.*, p. 152). Language acquisition is considered to be based on cognitive developmental mechanisms, the progressive and systematic co-ordinations of sensory-motor schemes playing an important part in the formation of language. Observations of similarities between Piaget's descriptions of sensory-motor structures and Chomsky's descriptions of the deep structure in language (see section D.1., pp. 28 - 29), together with the fact that sensory-motor intelligence reaches its final stage of development prior to language acquisition, have prompted Piagetian psycholinguists to conclude that " ... language is not the source of logic, but is on the contrary structured by logic" (Sinclair-de-Zwart, 1969, p. 325).

Within Piaget's theory, language is recognized as only one of the ways in which the semiotic function manifests itself. Symbolic play, gestural expression, deferred imitation and so forth also play a part. In considering the transition from sensory-motor to representational and operative intelligence, the importance of the semiotic function as a whole is invoked within the theory.

The major finding of the present study is that linguistic skill or deficiency was largely independent of the level attained on the cognitive tasks administered, suggesting that language did not influence the development of intellectual structures of the subjects in any direct or decisive way. The implications of this finding for educational practice are discussed below.

### C. IMPLICATIONS FOR EDUCATION

The recent vigorous movement to effect a closer liaison between cognitive research and educational practice has focused on curriculum planning within the context of Piaget's developmental findings (Sigel, 1969, Lunzer, 1960). Research into the selection of teaching materials and methods aims at activating the development of thought, facilitating rather than "accelerating" the passage from a lower to a higher cognitive stage. A meticulous analysis of the contents of curricula and teaching methods by Szeminska (1965) has revealed a predominance of teaching strategies that impart information through the static verbal description of data without active experimentation. Bruner (1966) says of the school situation, "Verbal understanding, the ability to say it and to enumerate instances becomes the criterion of learning in such a context ..." (Bruner's emphasis, pp. 62 - 63). Since teaching in the lower standards is based on the "intuitive method" (Szeminska, op. cit.) in which descriptions of perceived events or the representation of past experiences

is the rule, the child is orientated toward reproducing what he has learned through memory rather than by reasoning. Teaching at the secondary level " ... becomes increasingly analytic and relies on the progressive exploitation of what Piaget calls 'formal operations' ..." (Bernstein, 1961, p. 307). The pupil is obliged to use formal operations without having had, in the preceding period, the opportunity to develop concrete operational structures. This results in the transmission of knowledge before pupils possess the intellectual structures to assimilate it successfully. The need exists for a serious revision of school curricula to adapt them to the intellectual possibilities of the student, while reforming methods of teaching to uncover a means to facilitate the transition from concrete to formal operations. The curriculum sequence should be designed in harmony with the child's changing cognitive status. This would require an accurate assessment of the pupil's cognitive structure at a given point in development. At present Piagetian tasks do not constitute a reliable standardized test series. Substantial progress in the replication studies (e.g. Lovell, 1961; Lunzer, 1965) suggests that Piagetian tasks may conceivably be used as diagnostic tools for educational assessment.

A direct application of conclusions derived from the present experimental study is the need to question the emphasis on verbal skills in current educational methods for deaf and hearing. In the education of the deaf the traditional emphasis on oral media of communication together with the prohibition of

signing, has necessitated the devotion of a large part of the curriculum to the teaching of lipreading and articulation skills. While the importance of teaching language to the profoundly deaf child is not being underestimated, (see Section D.1., pp. 30 - 31) this constant exposure to formal linguistic training results in other spheres of cognitive growth, for example, motor and perceptual development, being placed secondary to linguistic achievement (Furth, 1969). The efficacy of traditional language programs with the congenitally deaf who have a severe hearing loss is a hotly debated issue (Moore, 1969).

Furth (1966a) notes that some of the verbal rigour in educational disciplines has been relaxed with an increase in the use of audio-visual and other concrete aids to learning. Piaget (1964) takes a stand along with Montessori, in stressing "self discovery" in the classroom as the crucial element in facilitating cognitive reorganization. "The subject must be active, must transform things, and find the structure of his own actions on the objects" (*ibid.*, p. 4). The child at the concrete operational stage, for instance, must be given the opportunity to actually manipulate objects or task materials in question. A teaching strategy being devised by Lavatelli (1967) utilizing the concept of "action learning" for developing hypothetico-deductive reasoning skills, places emphasis entirely on the enactive level, to use Bruner's terminology, and " ... no attempt is made to hurry emergence of the symbolic stage" (*ibid.*, p. 9). The child is given the

opportunity to solve problems at the concrete operational level, performing actions represented by the logical groupings, for example, associativity, reversibility, or the higher order multiplicative relationships and classifications. Lavatelli (1967) suggests that models which have a strong visual component may be useful, for example, a two-pan balance scale could be introduced, actually showing the child that doing the same thing to both sides of the balance changes nothing as far as equilibrium is concerned. Lavatelli's hypothesis is that providing Ss in the intermediate grades with enough concrete experiences, engaging them in activities involving the combinatorial method and proportionality over a long-term training program, will facilitate the emergence of formal thought in adolescence.

The advantages of such a thinking orientated rather than verbal orientated approach during the early school years, though originally devised to meet the needs of hearing children, holds considerable potential with regard to the education of the deaf. Flavell (1966, p. 369 - 370) has stated that the application of Piaget's views on educational method involves an analysis of the content to be mastered in terms of the operations implicit upon it and arranging the learning materials in a manner allowing the pupil to actually carry out the operations himself. "Once the fundamental action patterns are mastered, the training program could gradually draw the child away from explicit concrete material settings to .....

internalized operations at ever-increasing distances from the immediate perceptual context" (Hooper, 1969, p. 430). The need for encouraging children to discover principles of thinking through activity is becoming widely recognized (Furth, op. cit.).

The techniques used in the present study to present Piaget-type problems non-verbally suggest that advanced problems inviting solutions at a concrete or formal operational level may be posed through pictorial representation in the classroom leading to experimentation via a wide range of concrete media. Science curricula are potentially the most adaptable to such revision. The restrictive environment of the profoundly deaf, a consequence of lack of auditory input, could be improved to a large extent if non-verbal methods of instruction and communication were encouraged in the home and school environment in the early years. The findings of Stuckless and Birch (1966) and Brill (1970) suggest that a manual communication system at a very early age has a beneficial influence on the development of both thinking processes and language skills in the deaf.

Furth (1966a) describes a demonstration of a non-verbal teaching technique to encourage logical thinking at a level which marks the beginning of formal operations. Deaf children aged 9, 13 and 16 years were presented with a series of cards containing symbols for affirmation, negation, conjunction and exclusive disjunction. After four days of teaching even

some of the younger deaf children showed that they could manipulate the symbols in a logical manner being presented with a situation in which they were not penalized for their linguistic incompetence.

The educational implications derived from the findings of the present study pertain also to a great variety of children who are substantially handicapped in linguistic skills, for example, the socially deprived child (Bernstein, op.cit.); the aphasic, and those children with specific deficiencies in speech and reading.

## BIBLIOGRAPHY

Primary Sources

- Arthur, G.A. A Point Scale of Performance Tests, Revised Form II. New York: Psychological Corporation, 1947.
- Ausubel, D.P. Neobehaviorism and Piaget's views on thought and symbolic functioning. Child Development, 1965, 36, 1029-1032.
- Backer, W. The South African standardization of the Snijders-Oomen Non-verbal Intelligence Scale for hearing-defective children. National Bureau of Educational and Social Research, Pretoria, 1964.
- Beilin, H. Learning and operational convergence in logical thought development. Journal of Experimental Child Psychology, 1965, 2, 317-339.
- Berlyne, D.E. Recent developments in Piaget's work. British Journal of Educational Psychology, 1957, 27, 1-12.
- Berlyne, D.E. Structure and direction in thinking. New York: Wiley, 1965.
- Bernstein, B. Social class and linguistic development: a theory of social learning. In A.H. Halsey, J. Floud & C. Anderson (Eds.), Education, economy and society. New York: Free Press, 1961.
- Blank, M. Use of deaf in language studies: a reply to Furth. Psychological Bulletin, 1965, 63, 442-444.
- Braine, M.D.S. On learning the grammatical order of words. Psychological Review, 1963, 70, 323-348.
- Braine, M.D.S. The ontogeny of certain logical operations: Piaget's formulation examined by nonverbal methods. In I.E. Sigel & F.H. Hooper (Eds.), Logical thinking in children; research based on Piaget's theory. New York: Holt, Rinehart & Winston, 1968.
- Braine, M.D.S. & Shanks, B. The development of conservation of size. Journal of Verbal Learning and Verbal Behavior, 1965, 4, 227-242.
- Brill, R.G. The superior IQs of deaf children of deaf parents. Maryland Bulletin, 1970, 90, 97-111.
- Brown, R. Language: the system and its acquisition. Parts I and II. In R. Brown (Ed.) Social Psychology. New York: Free Press, 1965.

- Brown, R. & Berko, J. Word association and the acquisition of grammar. Child Development, 1960, 31, 1-14.
- Brown, R. & Fraser, C. The acquisition of syntax. In C. Cofer & B. Musgrave (Eds.), Verbal Behaviour and Learning. New York: McGraw-Hill, 1963.
- Bruner, J. The course of cognitive growth. American Psychologist, 1964, 19, 1-15.
- Bruner, J. On cognitive growth: I & II. In J. Bruner, R. Olver & P. Greenfield (Eds.), Studies in cognitive growth. New York: Wiley, 1966.
- Bruner, J. & Kenney, H. The development of the concepts of order and proportion in children. In J. Bruner et al (Eds.), Studies in cognitive growth. New York: Wiley, 1966.
- Chomsky, N. Syntactic structures. The Hague: Mouton, 1957.
- Chomsky, N. Aspects of the theory of syntax. Cambridge, Mass.: M.I.T. Press, 1965.
- Cochran, W.G. The  $X^2$  test of goodness of fit. Annals of mathematical statistics, 1952, 23, 315-345.
- Cochran, W.G. Some methods for strengthening the common  $X^2$  tests. Biometrics, 1954, 10, 417-451.
- Cooper, R. & Rosenstein, J. Language acquisition of deaf children. The Volta Review, 1966, 68, 58-67.
- Darbyshire, J. & Reeves, V. The use of adaptations of some of Piaget's tests with groups of children with normal and impaired hearing. British Journal of Disorders of Communication, 1969, 2, 197-202.
- Davies, C.M. Development of the probability concept in children. Child Development, 1965, 36, 779-788.
- Eisenson, J. Perceptual disturbances in children with central nervous system dysfunctions and implications for language development. British Journal of Disorders of Communication, 1966, 1.
- Elkind, D. Piaget's conservation problems. In I.E. Sigel & F.H. Hooper (Eds.), Logical thinking in children: research based on Piaget's theory. New York: Holt, Rinehart & Winston, 1968.
- Elkind, D. Conservation and concept formation. In D. Elkind & J.H. Flavell (Eds.), Studies in cognitive development: essays in honor of Jean Piaget. New York: Oxford Press, 1969.

- Ervin, S.M. Training and a logical operation by children. Child Development, 1960, 31, 555-563.
- Ervin, S. & Miller, W. Language development. Yearbook of the National Society for Studies in Education, 1963, 62, 108-143.
- Evans, L. A comparative study of the Wechsler Intelligence Scale for Children (Performance) and Raven's Progressive Matrices with deaf children. Teacher of the Deaf, 1966, 64, 78-82.
- Ewing, A.W.G. (Ed.) Educational guidance and the deaf child. Manchester University Press, 1957.
- Flavell, J.H. The developmental psychology of Jean Piaget. Princeton: Van Nostrand, 1966.
- Flavell, J.H. & Wohlwill, J.F. Formal and functional aspects of cognitive development. In D. Elkind & J.H. Flavell (Eds.), Studies in cognitive development: essays in honor of Jean Piaget. New York: Oxford Press, 1969.
- Furth, H. Visual paired-associates task with deaf and hearing children. Journal of Speech and Hearing Research, 1961 a, 4, 172-177.
- Furth, H. Influence of language on the development of concept formation in deaf children. Journal of Abnormal and Social Psychology, 1961 b, 63, 386-389.
- Furth, H. Thinking without language: the psychological implications of deafness. New York: Free Press, 1966 a.
- Furth, H. Research with the deaf: implications for language and cognition. The Volta Review, 1966 b, 68, 34-56.
- Furth, H. Concerning Piaget's view on thinking and symbol formation. Child Development, 1967, 38, 819-826.
- Furth, H. Piaget's theory of knowledge: the nature of representation and interiorization. Psychological Review, 1968, 75, 143-154.
- Furth, H. Thinking in deaf adolescents: language and formal operations. Paper submitted for publication in Journal of Communication Disorders. Personal communication, 1969.
- Furth, H. Piaget and knowledge: theoretical foundations. New Jersey: Prentice Hall, 1969.

- Gaskill, P., Longworth, A. & Neilson, J.R. The administration of Snijders-Oomen non-verbal tests to deaf children. Teacher of the Deaf, 1970, 68, 137-142.
- Goetzinger, C.P., Wills, R.C. & Dekker, L.C. Non-language IQ tests used with deaf pupils. The Volta Review, 1967, 69, 500-506.
- Goodnow, J.J. & Bethon, G. Piaget's tasks: the effects of schooling and intelligence. Child Development, 1966, 37, 573-582.
- Greenfield, P.M., Reich, L.C. & Olver, R.R. On culture and equivalence: II. In J.S. Bruner et al, Studies in cognitive growth. New York: Wiley, 1966.
- Heider, F. & Heider, G. A comparison of sentence structure of deaf and hearing children. Psychological Monograph, 1940, 52, 42-103.
- Hiskey, M.S. Manual: Hiskey-Nebraska Test of Learning Aptitude. Lincoln: Union College Press, 1966.
- Hooper, F.H. Piagetian research and education. In I.E. Sigel & F.H. Hooper (Eds.), Logical thinking in children. New York: Holt, Rinehart & Winston, 1968.
- Inhelder, B. Operational thought and symbolic imagery. In P.H. Mussen (Ed.), European research in cognitive development, Monograph of the Society for Research in Child Development, 1965, 30, 4-18.
- Inhelder, B., Bovet, M., Sinclair, H. & Smock, C.D. On cognitive development. American Psychologist, 1966, 21, 160-164.
- Inhelder, B. & Piaget, J. The growth of logical thinking from childhood to adolescence. New York: Basic Books, 1958.
- Ives, L.A. Deafness and the development of intelligence. British Journal of Disorders of Communication, 1967, 2, 96-111.
- Ives, L.A. Verbal language development and concept formation. Teacher of the Deaf, 1970, 68, 111-127.
- Katz, J.J. The philosophy of language. New York: Harper & Row, 1966.
- Kohl, H.R. Language and education of the deaf. National Association of the Deaf, Maryland, 1968.
- Kuhn, T.S. The structure of scientific revolutions. Chicago: Phoenix Press, 1964.

- Lavatelli, C.B. The transition from concrete operational to formal thinking. Presented at the meeting of the Society for Research in Child Development, New York, 1967.
- Lenneberg, E.H. Biological foundations of language. New York: Wiley, 1967.
- Lewis Report: The education of deaf children: the possible place of finger spelling and signing. London: Her Majesty's Stationary Office, 1968.
- Lunzer, E.A. Recent studies in Britain based on the work of Jean Piaget. London: National Foundation for Educational Research, England: Wales, 1960.
- Lunzer, E.A. Problems of formal reasoning in test situations. In P.H. Mussen (Ed.), European research in cognitive development, Monograph of the Society for Research in Child Development, 1965, 30, 19-46.
- Luria, A.R. The role of speech in the regulation of normal and abnormal behaviour. New York: Pergamon Press, 1961.
- Lovell, K. A follow-up study of Inhelder and Piaget's The growth of logical thinking. British Journal of Psychology, 1961, 52, 143-153.
- Lovell, K. & Ogilvie, E. The growth of the concept of volume in junior school children. In I.E. Sigel & F.H. Hooper (Eds.), Logical thinking in children: research based on Piaget's theory. New York: Holt, Rinehart & Winston, 1968.
- McNeill, D. The capacity for language acquisition. The Volta Review, 1966, 68, 17-33.
- McNeill, D. On theories of language acquisition. In T.R. Dixon & D.L. Horton (Eds.), Verbal behavior and general behavior theory. Englewood Cliffs: Prentice Hall, 1968.
- Menyuk, P. A preliminary evaluation of grammatical capacity in children. Journal of Verbal Learning and Verbal Behavior, 1963, 2, 429-439.
- Miller, G.A. & Chomsky, N. Finitary models of language users. In D. Luce, R. Bush & E. Galanter (Eds.), Handbook of mathematical psychology. New York: Wiley, 1963.
- Miller, W. & Ervin, S. The development of grammar in child language. In U. Bellugi & R. Brown (Eds.), The acquisition of language. Monograph of the Society for Research in Child Development, 1964, 29, 9-34.

- Moore, D.F. Communication, psycholinguistics and deafness. In Proceedings of the Teacher Institute, Maryland School for the Deaf, 1969.
- Murphy, L.J. Tests of abilities and attainments. In A.W.G. Ewing (Ed.), Educational guidance of the deaf child. Manchester University Press, 1957.
- Myklebust, H.R. Auditory disorders in children. New York: Grune and Stratton, 1954.
- Myklebust, H.R. The psychology of deafness: sensory deprivation, learning and adjustment. New York: Grune & Stratton, 1966.
- Nair, P. An experiment in conservation. In Center for Cognitive Studies, Annual Report. Cambridge, Mass., 1963.
- Oléron, P. Conceptual thinking of the deaf. American Annals of the Deaf, 1953, 98, 304-310.
- Paget, Lady. On systematic sign language. In Lewis Report: The education of deaf children: the possible place of finger spelling and signing. London: Her Majesty's Stationary Office, 1968.
- Piaget, J. The language and thought of the child. New York: Harcourt, Brace, 1926.
- Piaget, J. The psychology of intelligence. New York: Harcourt, Brace, 1950.
- Piaget, J. Play, dreams and imitation in childhood. New York: Norton, 1951.
- Piaget, J. Comments on Vygotsky. Cambridge, Mass.: M.I.T. Press, 1962.
- Piaget, J. Language and intellectual operations. 1963. Translated in H. Furth, Piaget and knowledge: theoretical foundations. New Jersey: Prentice-Hall, 1969.
- Piaget, J. Three lectures. In R.E. Ripple & V.N. Rockcastle (Eds.), Piaget rediscovered. New York: Cornell Press, 1964.
- Piaget, J. Response to Brian Sutton-Smith. Psychological Review, 1966, 73, 111-112.
- Piaget, J. & Inhelder, B. Le développement des quantités chez l'enfant. Neuchâtel: Delachaux et Niestlé, 1941.

- Piaget, J., & Inhelder, B. La genèse de l'idée de hasard chez l'enfant. Paris: University Press, 1951.
- Piaget, J., Inhelder, B., & Szeminska, A. The child's conception of geometry. London: Routledge & Kegan Paul, 1960.
- Piaget, J., & Inhelder, B. The gaps in empiricism. In A. Koestler & J.R. Smythies (Eds.), Beyond reductionism. London: Hutchinson, 1969.
- Pickles, D.G. The Wechsler Performance Scale and its relationship to speech and educational response in deaf slow-learning children. Teacher of the Deaf, 1966, 64, 382-392.
- Pinard, A., & Laurendeau, M. "Stage" in Piaget's cognitive-developmental theory: exegesis of a concept. In D. Elkind & J.H. Flavell (Eds.), Studies in cognitive development: essays in honor of Jean Piaget. New York: Oxford Press, 1969.
- Pintner, R., Eisenson, J., & Stanton, M. The psychology of the physically handicapped. New York: Crofts, 1941.
- Porter, D. Non-semantic identifiers of a grammatical category. American Psychologist, 1959, 14, 363.
- Raven, J.C. Guide to the Standard Progressive Matrices. London: Lewis, 1960.
- Ross, B.M. Probability concepts in deaf and hearing children. Child Development, 1966, 37, 917-927.
- Siegel, S. Nonparametric statistics for the behavioral sciences. New York: McGraw-Hill, 1956.
- Sigel, I.E. Reflections. In I.E. Sigel & F.H. Hooper (Eds.), Logical thinking in children: research based on Piaget's theory. New York: Holt, Rinehart & Winston, 1968.
- Sigel, I.E. The Piagetian system and the world of education. In D. Elkind & J.H. Flavell (Eds.), Studies in cognitive development: essays in honor of Jean Piaget. New York: Oxford Press, 1969.
- Sigel, I.E., Roeper, A., & Hooper, F.H. A training procedure for acquisition of Piaget's conservation of quantity: a pilot study and its replication. British Journal of Educational Psychology, 1966, 36, 301-311.

- Simmons, A.A. A comparison of the type-token ratio of spoken and written language of deaf and hearing children. The Volta Review, 1962, 64, 417-421.
- Sinclair-de-Zwart, H. Developmental psycholinguistics. In D. Elkind & J.H. Flavell (Eds.), Studies in cognitive development: essays in honor of Jean Piaget. New York: Oxford Press, 1969.
- Smith, F. & Miller, G.A. The genesis of language. Cambridge, Mass.: M.I.T. Press, 1966.
- Snijders, J. Th. & Snijders-Oomen, N. Non-verbal intelligence tests for deaf and hearing subjects. Groningen: Wolters-Noordhoff, 1968.
- Stevenson, H.W., & Zigler, E.F. Probability learning in children. Journal of Experimental Psychology, 1958, 1956, 185-192.
- Stuckless, E.R., & Birch, J.W. The influence of early manual communication on the linguistic development of deaf children. American Annals of the Deaf, 1966, 111, 499-503.
- Sutton-Smith, B. Piaget on play: a critique. Psychological Review, 1966, 73, 104-110.
- Szeminska, A. The evolution of thought. In P.H. Mussen (Ed.), European research in cognitive development, Monograph of the Society for Research in Child Development, 1965, 30, 47-57.
- Vygotsky, L.S. Thought and language. Cambridge, Mass.: M.I.T. Press, 1962.
- Wechsler, D. Wechsler Intelligence Scale for Children. New York: Psychological Corporation, 1946.
- Werner, H., & Kaplan, B. Symbol formation. New York: Wiley, 1963.
- Whetnall, E., & Fry, D.B. The deaf child. New York: Heinemann, 1963.
- Wohlwill, J.F. Absolute versus relational discrimination on the dimension of number. Journal of Genetical Psychology, 1960, 96, 353-363.

- Woodward, H. The structural component of linguistic meaning and the reading of normally hearing and deaf children. Unpublished Master's dissertation, University of Washington, 1963.
- Woodward, H. A nonsense test of structural meaning. Journal of Verbal Learning and Verbal Behavior, 1968, 7, 31-32.
- Wrightstone, J.W., Aronow, M.S. & Moskowitz, S. Developing reading test norms for deaf children. American Annals of the Deaf, 1963, 108, 311-316.
- Wynns, F.C. A developmental study of problem solving requiring use of a combinatorial system: Piaget replication. Presented at the meeting of the Society for Research in Child Development, New York, 1967.
- Yost, P.A., Sigel, A.E. & McMichael, J.E. Non-verbal probability judgments by young children. Pennsylvania State University, Research Bulletin, 1961, 16.
- Youniss, J. & Furth, H. The role of language and experience on the use of logical symbols. British Journal of Psychology, 1967, 58, 435-443.

#### Secondary Sources.

- Bradshaw, D.H. A study of inferred size relations using non-verbal methods. Unpublished doctoral dissertation, Catholic University of America.
- Gaskill, P. Tests of abilities and attainments. In A.W.E. Ewing (Ed.), Educational guidance and the deaf child. Manchester: University Press, 1957.
- Hatwell, Y. Privation sensorielle et intelligence. Paris: Presses University France, 1960.
- Morf, A. Apprentissage d'une structure logique concrète (inclusion): effets et limites. In A. Morf, J. Smedslund, V. Bang & J.F. Wohlwill (Eds.), Etudes d'epistémologie génétique. Volume IX. Paris: Presses University France, 1959.
- Oléron, P. La développement des réponses a le relation identité-dissemblance: ses rapports avec le langage. Psychologie Française, 1962, 7, 4-16.

Oléron, P. & Herren, H. L'acquisition des conservations et le langage: étude comparative sur des enfants sourds et entendants. Enfance, 1961, 14, 203-219.

Pire, G. Notion du hasard et développement intellectuel. Enfance, 1958, 131-143.

Vincent, M. Sur le rôle du langage à un niveau élémentaire de pensée abstraite. Enfance, 1957, 10, 443-464.

APPENDIX

Figure 1  
Card Presented for Probability  
Concept Task

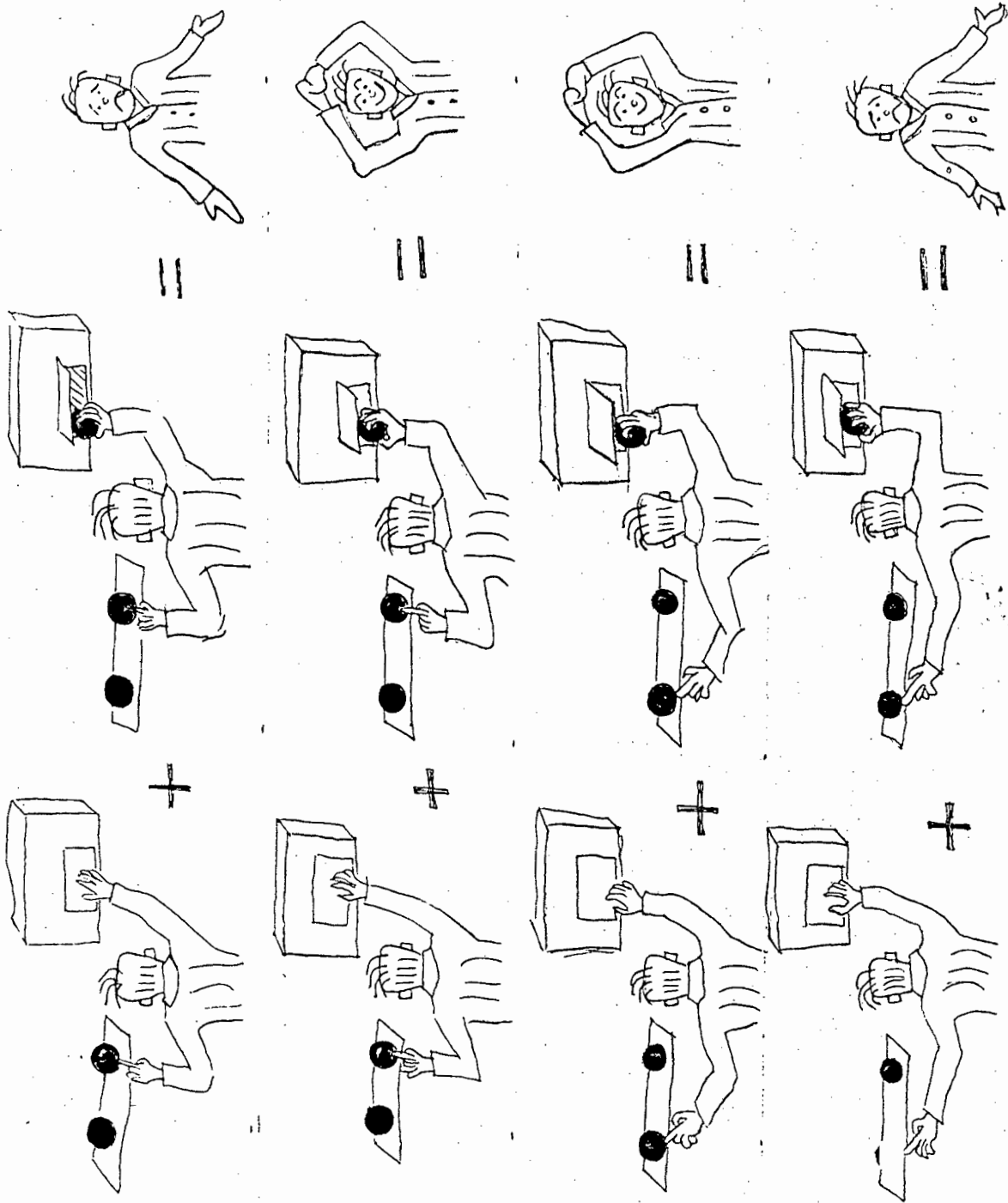
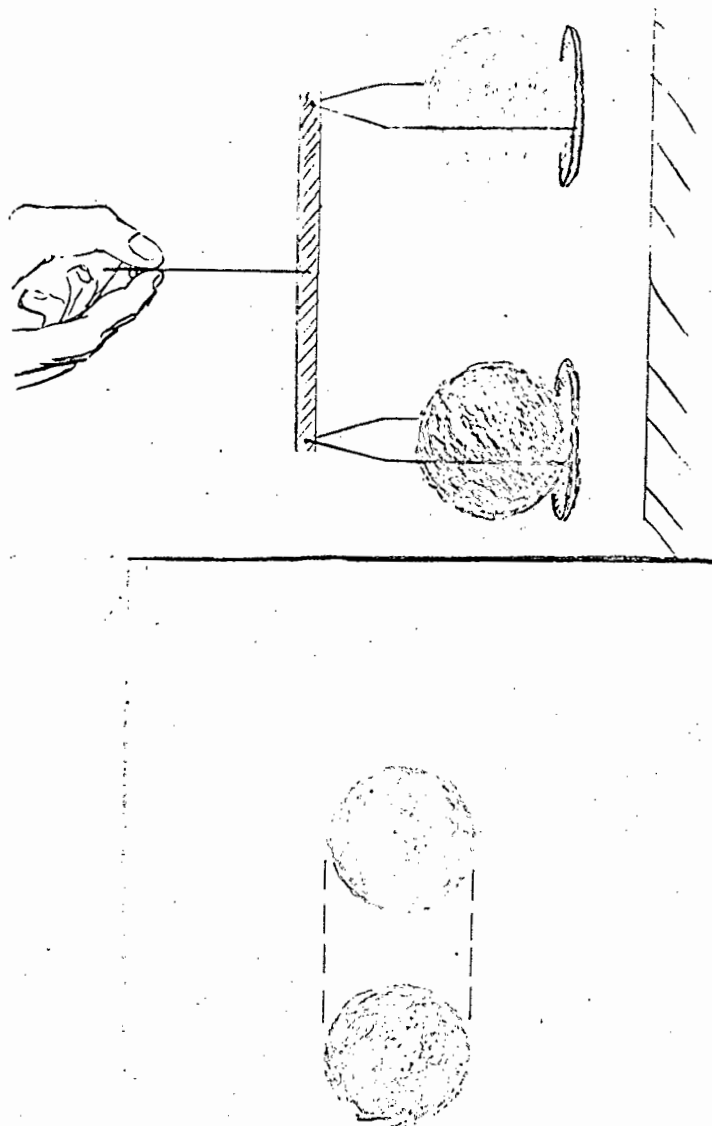
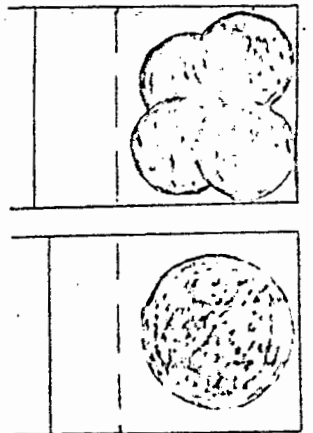
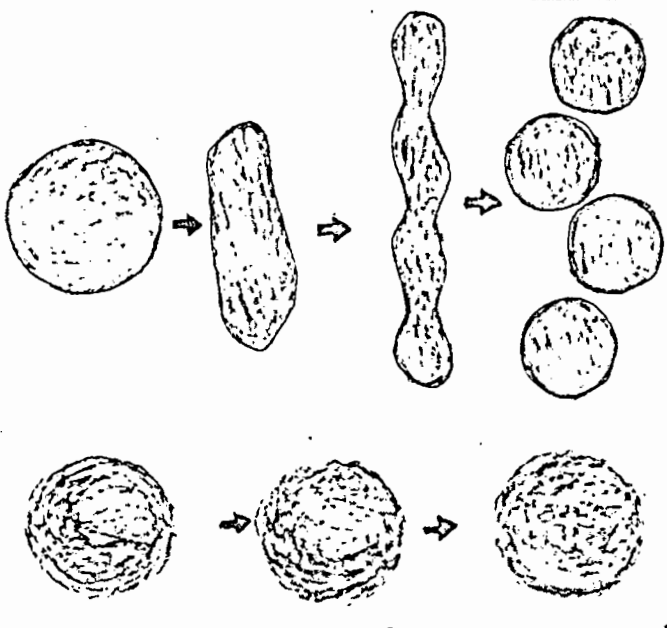
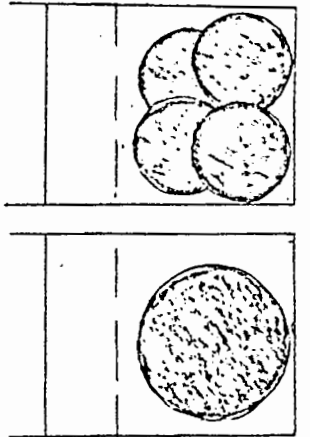
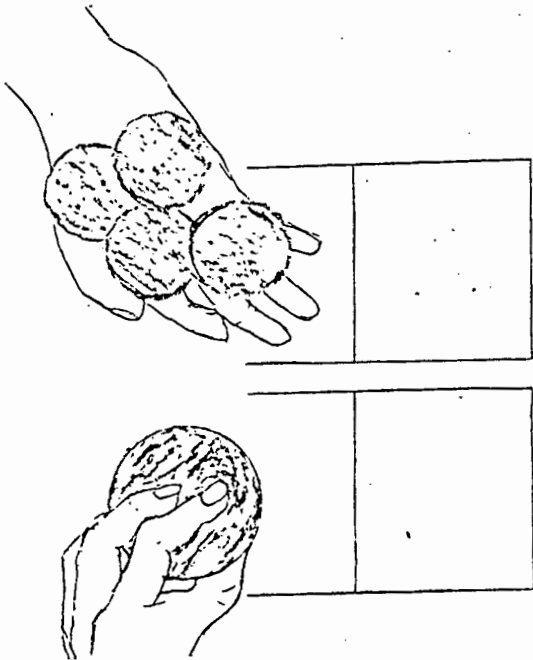
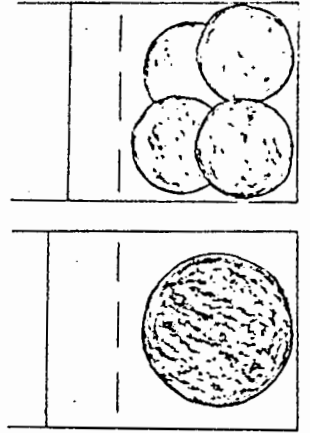
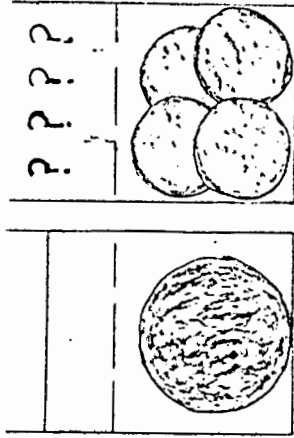
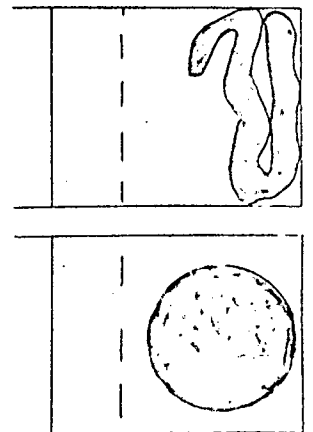
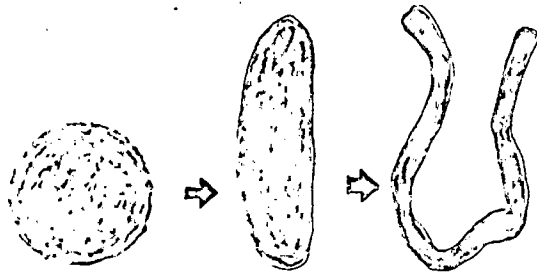
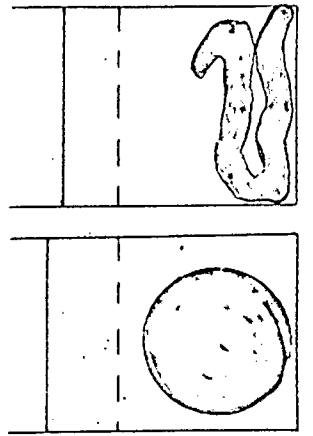
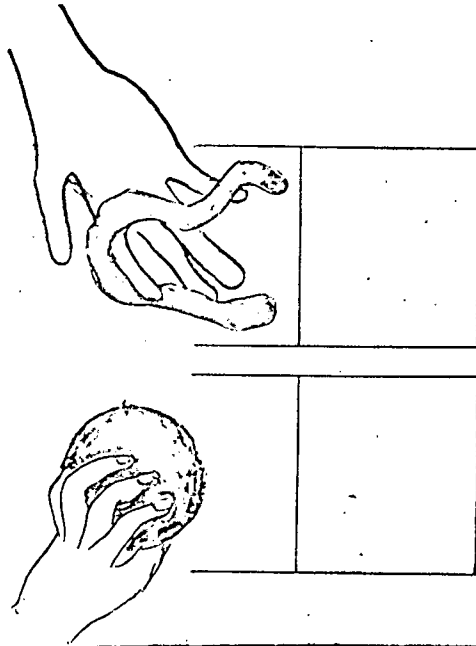
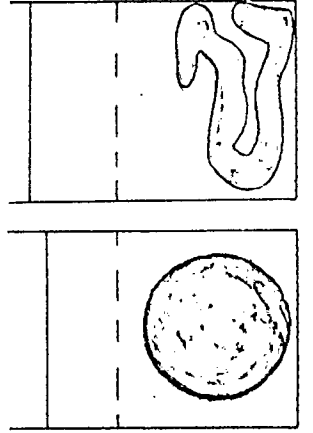
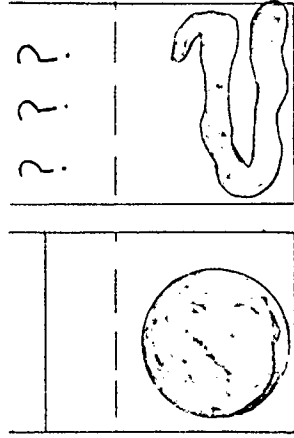


Figure 2  
Cards Presented For  
Displaced Volume Task







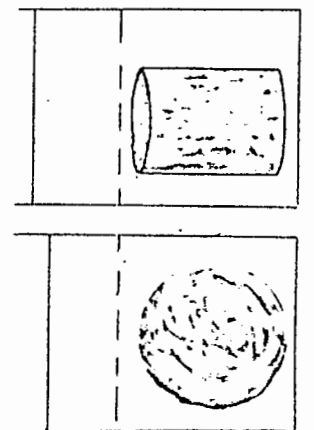
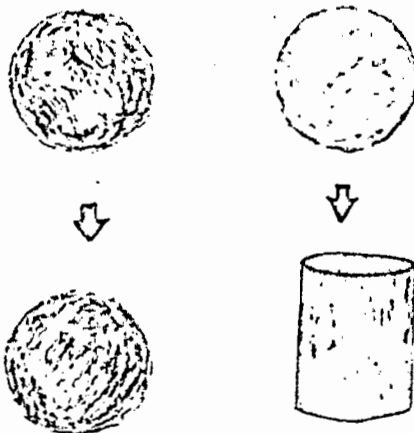
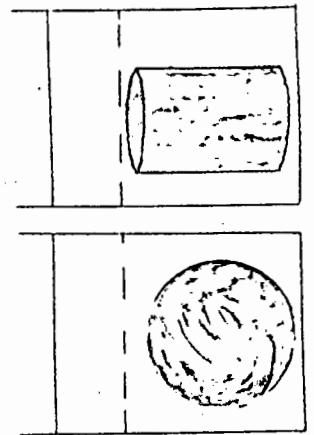
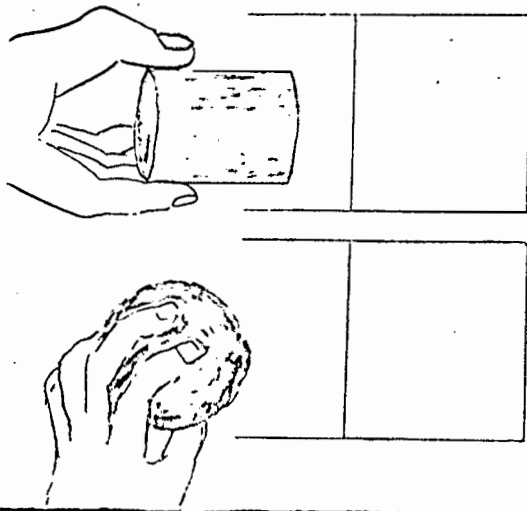
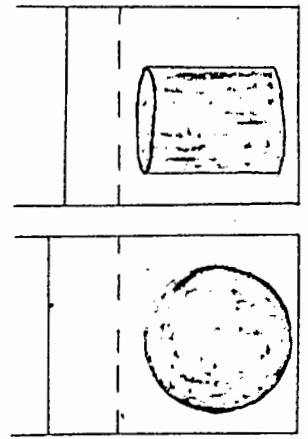
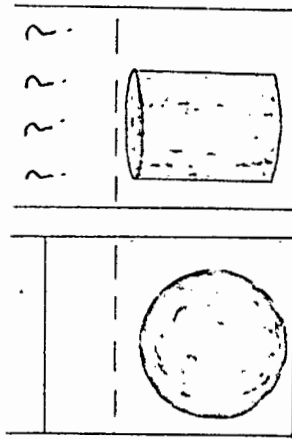


Figure 2 Continued

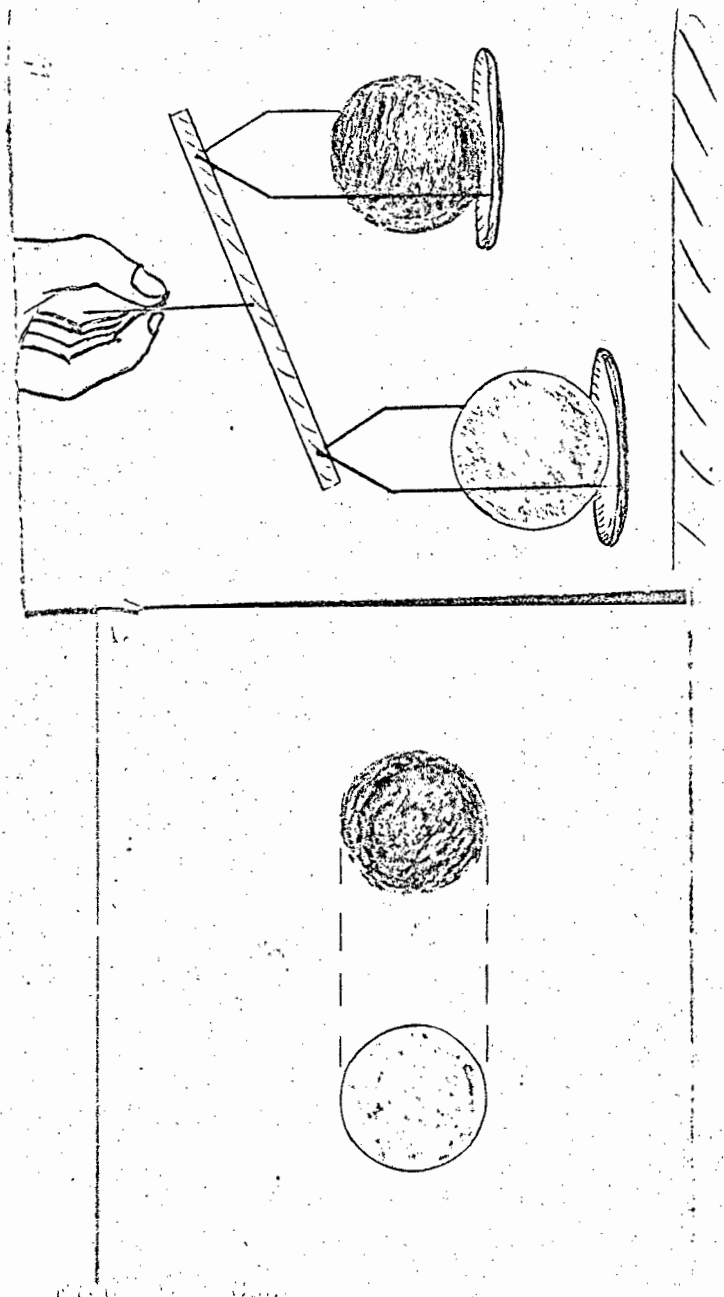
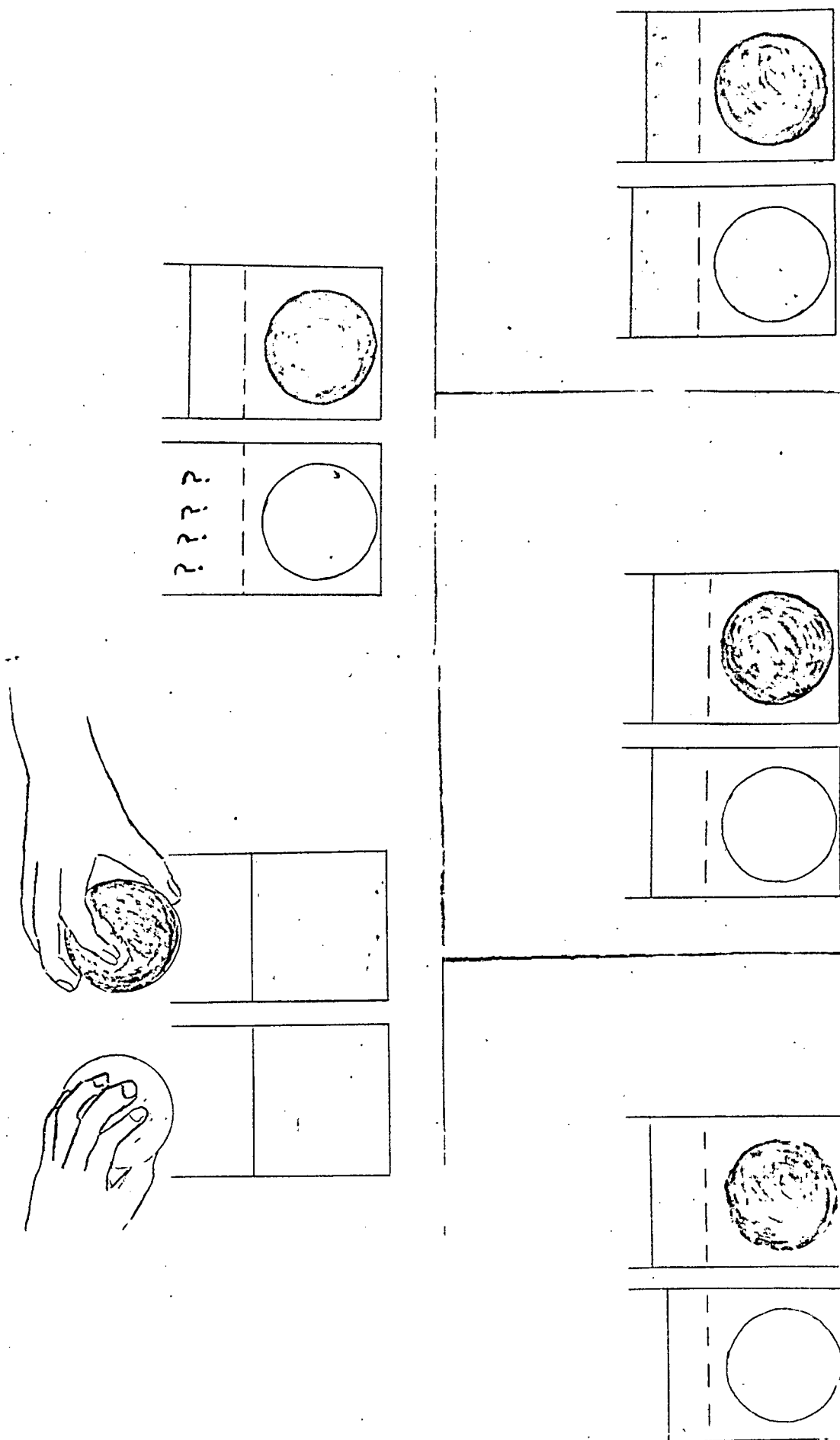
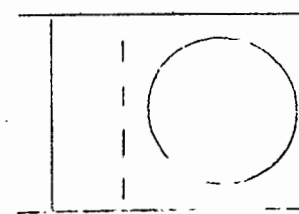
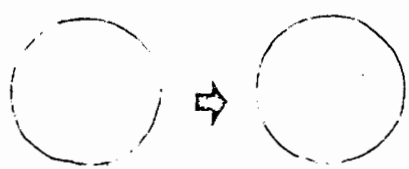
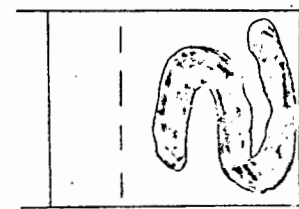
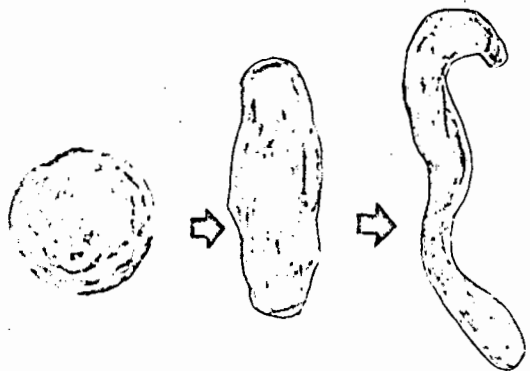
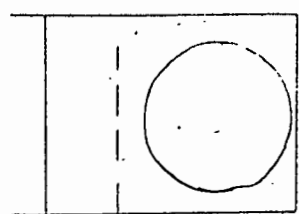
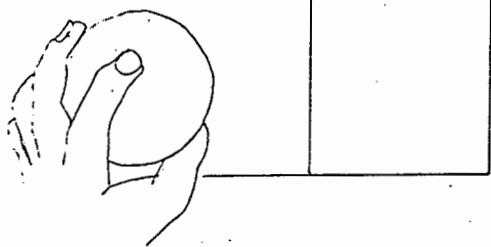
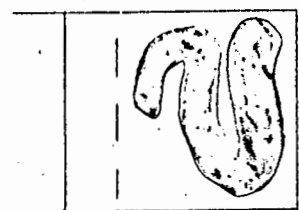
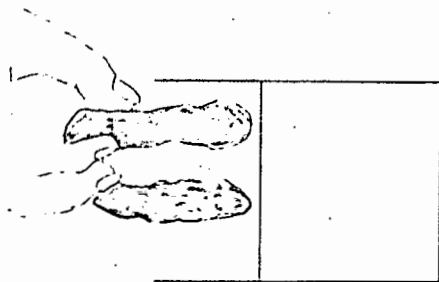
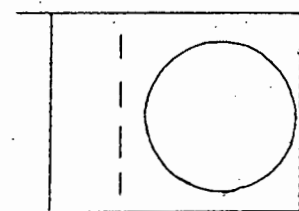
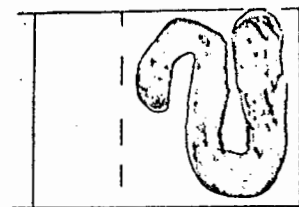
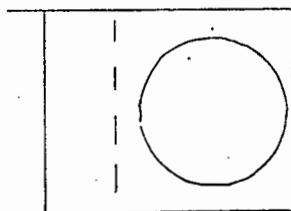
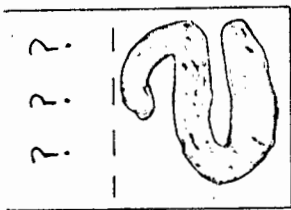


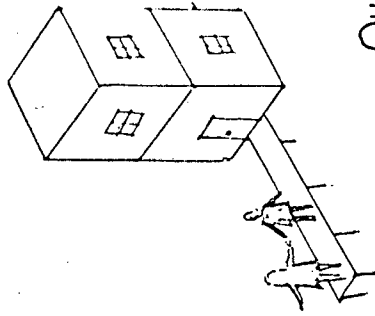
Figure 2 Continued



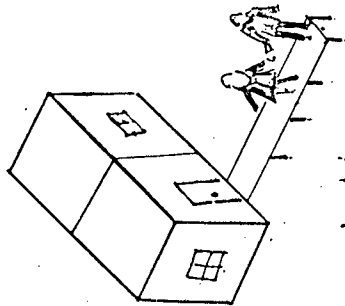


Cards Presented for Equivalent Three-Dimensional Space Task

2

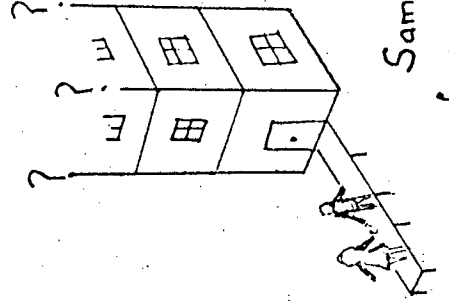


Ours has the same amount of space inside

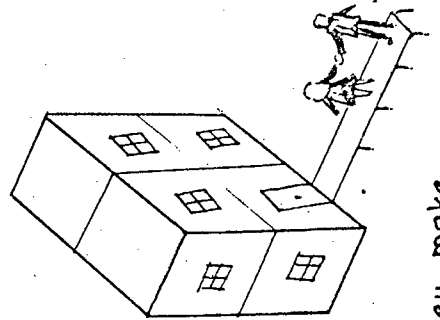


They build a house

4

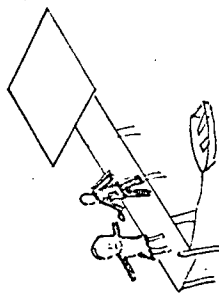


Same amount of space inside

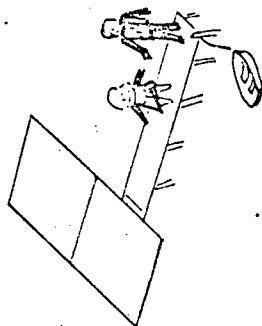


They make theirs bigger

1



This is our island



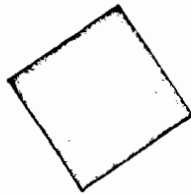
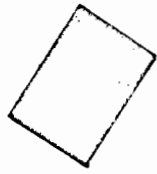
This is their island

3

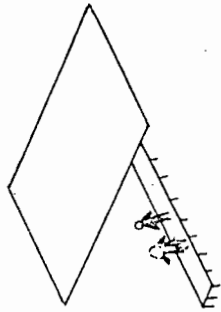


Figure 3 Continued

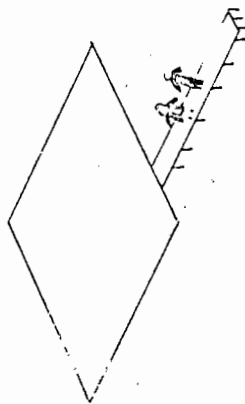
6



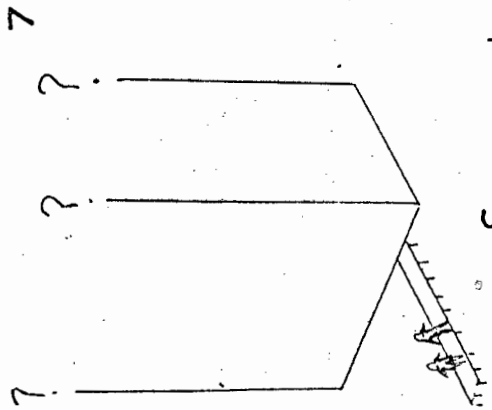
5



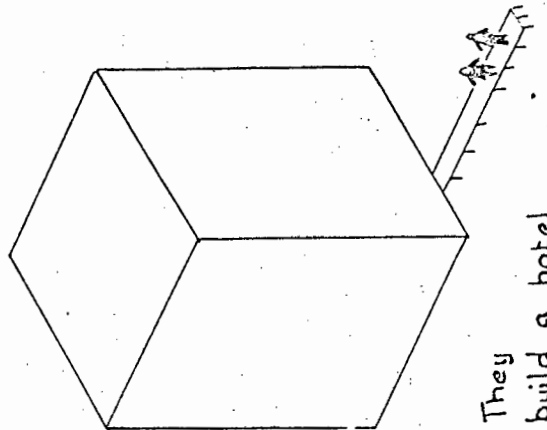
Our new island



Their new island



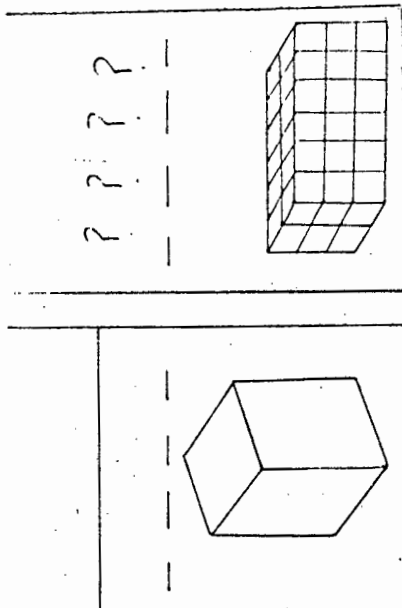
Same amount of space inside



They build a hotel

Figure 3 Continued

13



12

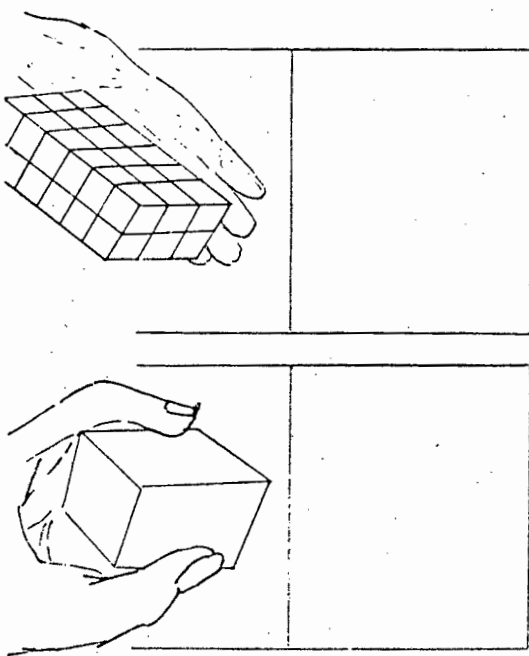
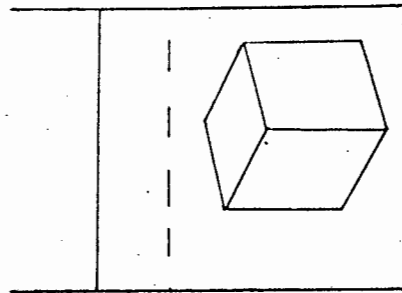
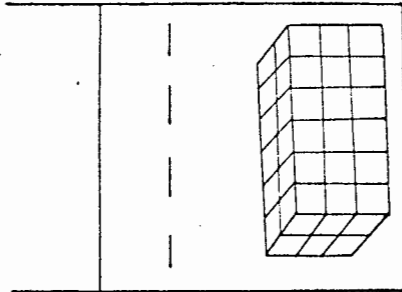


Figure 3 Continued

14



14

14

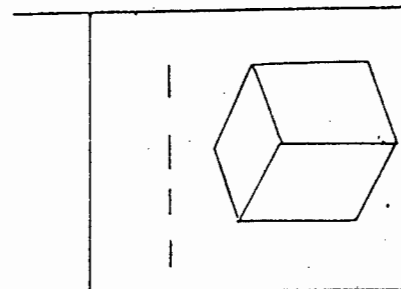
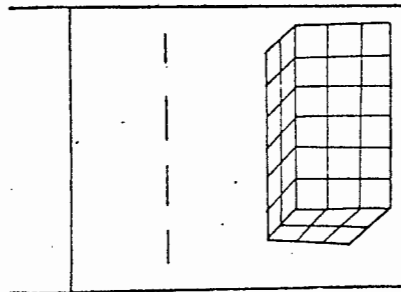
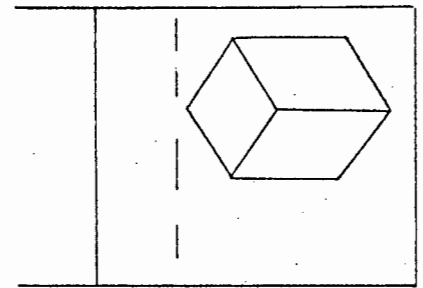
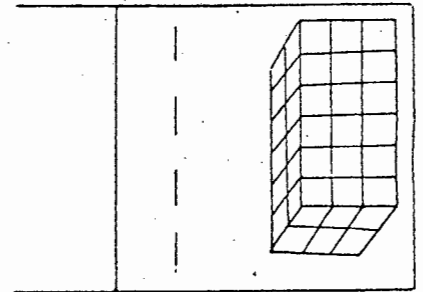


TABLE 3  
 APPLICATION OF MANN-WHITNEY U TEST TO SCORES  
 ON PARAGRAPH MEANING TEST

---

<u>Deaf</u>	<u>Hearing</u>
	24
	20,20,20,20
	18
	17,17,17
	15
	14,14
	13,13
10,10	
9,9	
7	
6	
5	
4,4,4,4	
3	

U = 0

Significant at .001 level

---



TABLE 4 (Continued)  
 APPLICATION OF MANN-WHITNEY U TEST TO SCORES ON SUB-TESTS OF WOODWARD NONSENSE TEST

<u>Parts of Speech</u>		<u>Subjects and Objects</u>		<u>Modifiers</u>	
Deaf	Hearing	Deaf	Hearing	Deaf	Hearing
	40,40		66		41,41
	38,38,38,38,38		63		37,37,37
	36,36,36,36		58		36,36,36
34,34	34		57		35
	32		56,56		34
	28		53		33,33,33
26,26			52		29
24,24			49	27	
22,22,22			48	25	
20			47,47	24	
18		41,41	46	21,21	
8		39	40	20	
		36		19	
		35,35,35		18	
		33,33,33		17	
		32		15	
		29		14	
	U = 5		U = 2	10	U = 0
	Significant at .001 level		Significant at .001 level		Significant at .001 level

TABLE 5  
 READING AGES ON PARAGRAPH MEANING  
 TEST FOR THE DEAF AND HEARING

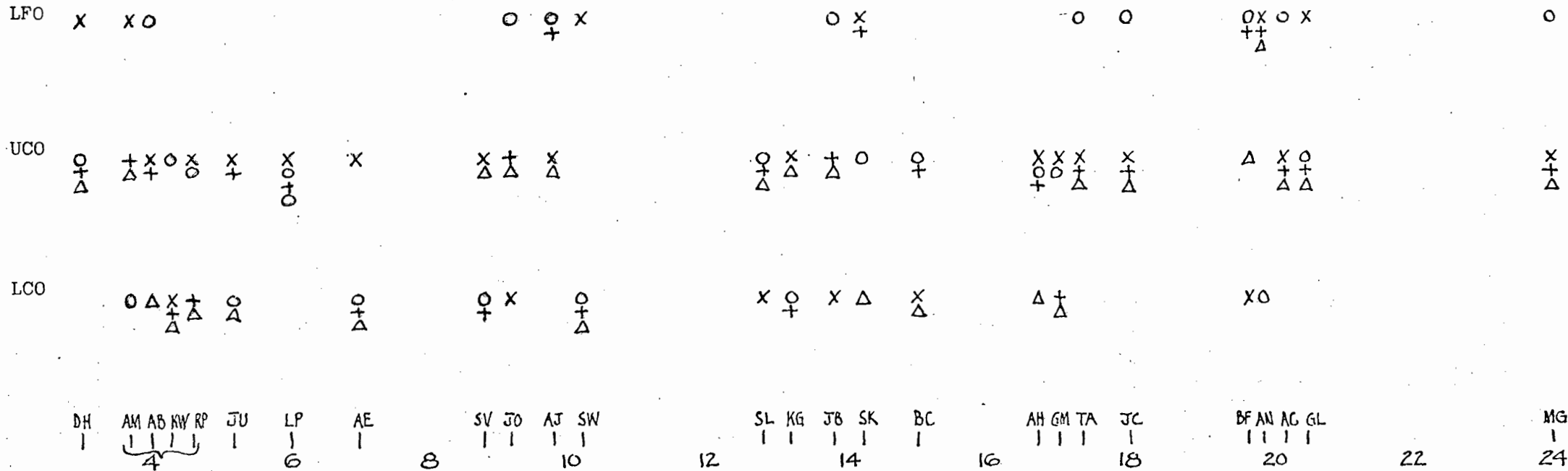
	C.A. <sup>+</sup>	R.A. <sup>+</sup>
DEAF		
S.V.	13:5	10:1
D.H.	13:10	Below 10
A.J.	14:7	10:4
S.W.	14:2	10:4
J.U.	14:10	Below 10
A.E.	13:0	Below 10
A.B.	14:7	Below 10
A.M.	13:9	Below 10
K.W.	14:4	Below 10
L.P.	13:7	Below 10
R.P.	13:3	Below 10
J.O.	13:1	10:1
HEARING		
M.G.	13:8	Above 15:6
B.F.	13:11	15:6
A.N.	14:7	15:6
A.H.	13:5	13:5
G.M.	14:1	13:5
B.C.	13:6	12:3
T.A.	14:1	13:5
J.B.	13:6	12:0
S.L.	13:9	11:7
A.C.	13:9	15:6
K.G.	13:0	11:7
G.L.	13:1	15:6
S.K.	14:9	12:0
J.C.	14:1	14:3

+ C.A. = chronological age  
 + R.A. = reading age

Figure 4 DEAF AND HEARING: OPERATIONAL LEVEL ON PIAGET-TYPE TASKS AND PERFORMANCE ON PARAGRAPH MEANING TEST

LFO = lower formal operations  
 UCO = upper concrete operations  
 LCO = lower concrete operations

Probability x  
 Volume o  
 Space +  
 Combinations Δ



DEAF

HEARING

Scores on Paragraph Meaning Test

