A PIAGETIAN CONCEPTUALIZATION OF
THE VISUO-SPATIAL ASPECTS OF READING

by

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ABSTRACT

Piagetian spatial theory was used to analyse the structures underlying reading at the identification level. A set of eight Piagetian Tasks, derived from this analysis, was inter-correlated with eight Reading Tasks and the Peabody Picture Vocabulary Test. This battery of tests was administered individually to 60 Grade Two children. The pattern of correlation between the Reading and Piagetian Tasks indicates that the Piagetian spatial structures underlie successful reading performance. Performance on the individual items in the Piagetian Tasks followed the rank order predicted from a conceptual analysis of the complexity of the Piagetian structures underlying individual items within a task. A Stage Analysis, to determine the developmental level of each child across Piagetian Tasks, confirmed the Correlational Analysis in that no child who was in Piagetian Stage II was a good reader.
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INTRODUCTION

Overview:

The present research involves a structural analysis of reading in terms of Piagetian spatial theory. This analysis was tested by administering a number of reading and Piagetian tasks to a group of Grade Two children and determining the degree of correlation between the two sets of scores. Also, the Piagetian tasks were conceptually analysed to determine what Piagetian structures are involved in each task and predictions are made on the order of difficulty of items within the tasks. When common structures exist across tasks, it is predicted that the child will be consistent in his performance across tasks.

On the basis of the Piagetian analysis of reading, the major hypothesis of this study is that there will be a relationship between the level of functioning on the Piagetian spatial tasks and the level of reading proficiency of the child.

General Introduction:

Piagetian theory has provided a descriptive basis for the analysis of intellectual or cognitive development. Piaget's series of observations have indicated the existence of a qualitatively different kind of thinking by the child when compared to the adult. However, he has left considerations on
the applicability of his theory to other more experimentally oriented researchers, (e.g. Furth, 1966). The present research is an attempt to relate Piagetian theory to a specific practical problem and so to extend the theory into more applied fields. Specifically, Piaget's theory of the child's conception of space (1967) is used to analyse the basic structures required before a child can learn to read.

Because of the importance of reading skill to any kind of educational approach, it has been one of the most widely researched topics of any of the basic skills. However, the research has tended to be fragmentary and highly atomized. For example, research has been done on attention span of good and poor readers (e.g., Flax, 1967), on auditory acuity (Myklebust, 1962), and sequential memory (Atten and Davis, 1968, Buhr, 1971). While these are all aspects of the reading problem, their study in isolation makes them of very little immediate, practical use when confronted with a child who cannot read. Thus, it is becoming evident to researchers that there is a need for a more general theory of reading which can take into account these earlier studies but which goes beyond these studies and which interprets reading in terms of a more general theory of development. Consistent with this trend, the present research attempts to interpret reading within the broader framework of Piagetian theory.

Reading

It should be noted at the outset that the present research
is largely concerned with the Piagetian conceptualization of reading. A general overview of reading research can be found in an earlier paper by this author (Buhr, 1971). Only that reading research which is theoretically relevant to the question at hand will be considered here.

In a conceptual analysis of reading research Weiner and Cromer (1967) tried to clarify the implicit and explicit assumptions underlying the various types of research. They make a distinction between research dealing with identification (letters and words) and that dealing with comprehension. This distinction is closely parallel to a distinction made between research based on acquisition of reading skill and that based on accomplished reading. Most research involving accomplished readers (usually done on older children ten or eleven years of age and above) also studies comprehension while research on acquisition skills involves measures of identification. Moreover, research on reading comprehension is often linked to language development whereas identification research largely ignores language development although it is still implicitly involved. By making these distinctions clear, some of the conflicting research results are resolved because different abilities are being tapped depending on how reading is defined. Considerations of different levels or types of ability required at different stages in reading development is evident in recent research, (e.g., Satz, Rordin, and Ross, 1971). Satz, et al, postulated that problems of the visual-motor type would
be more pronounced in beginning problem readers up to about age eight and that language and cognitive operations would be the problem areas in older readers. In other words, as the developmental sequence continues to emerge, the problems causing reading difficulty will change. They suggest as a hypothesis for future research that the child who had visual-motor problems associated with reading as a young child, will likely no longer exhibit these problems when he gets older, but he will likely exhibit language comprehension problems and still have reading difficulty. Rourke (1973) is one of the first researchers to actually find experimental evidence that supports this theory of differing problems at different ages. Using groups of good and poor readers varying in age, he found that with younger children (around age eight), there were significant differences in the performance of good and poor readers on a test of attention span. However, when testing children eleven years of age or older, there was no significant difference between the performance of good and poor readers on the attention span test. In other words, although the children were still having reading problems, their early problem with attention span had disappeared.

The present research is being carried out at the identification level with beginning readers. That is, the primary concern is with identification of letters and words by the child who is just beginning to learn to read. It should be noted that
comprehension and identification are interdependent systems. Comprehension helps the child anticipate words and letters thus facilitating identification, and identification is useless without comprehension. However, at the level of the beginning reader, identification is more critical and levels of meaning and sublety assume less importance.

**Piagetian Structures**

In order for reading to be explained in Piagetian terms, it first is necessary to understand certain basic Piagetian structures which will be used in describing the reading process. There are two relevant dichotomies in Piagetian theory: one being the figurative-operative distinction and the other being the logical-infralogical systems of groupings. Further, it is necessary to understand what Piaget means by the symbolic system and the image.

In Piagetian terms, thinking can be divided into two complementary aspects, figurative and operative. "The figurative aspect is an imitation of states taken as momentary and static..." (Piaget, 1970a, p. 9) and is made up of perception, imitation and mental imagery. The operative aspect of thought, on the other hand, "...deals not with states but with transformations from one state to another" (Ibid., p. 9). In other words, the figurative aspect of thought is static (dealing with end states) while the operative aspect is based on actions. For Piaget, the figurative aspect is always subordinate to the
operative which is the essential aspect of thought. "Any state can be understood only as the result of certain transformations or as the point of departure for other transformations." (Ibid., p. 9).

It is necessary to discuss Piaget's distinction between logical and infralogical systems, because the Piagetian spatial system which is used in the present study to describe reading is infralogical while most of Piaget's other work is based on the logical system. Piaget views these two systems (infralogical and logical) as developing synchronously with every logical grouping having its infralogical equivalent but still existing separately. The basic differences between the two systems are that logical groups are concerned with discrete entities independent of spatio-temporal proximity, while infralogical groups are concerned with continuous measures and dependent on spatio-temporal relationships, (Flavell, 1963). In Piaget's words: "The term 'sublogical' (infralogical) does not imply that these operations are in any way less rigorous than logico-arithmetic operations. It simply means that their function is to produce the concept of the object as such, in contrast to collection of objects." (Piaget, 1967, p. 450). For example, the infralogical equivalent to the logical grouping for classes is the part-whole relationship. Thus, where the logical grouping is concerned with the relationship between objects, the infralogical grouping is concerned with the relationship of parts of an object to its
resulting whole object. In a sense, the distinction is one be-
tween intensive (infralogical) and extensive (logical) quan-
tification. In the logical system the concept of number re-
quires both seriation and class inclusion, it infralogical
equivalent, measurement, requires order and partitive addition.
In terms of developmental sequence, the concept of number is
established approximately six months earlier (Stage IIIA) than
the concept of measurement (Stage IIIB). Thus, the close
parallel between the two systems is apparent. Not only are these
systems closely parallel, but in some instances, they are also
inter-related. For example, the part-whole relationship reaches
its logical conclusion in the concept of continuity, i.e.,
given an object A what happens when it is subdivided an infinite
number of times, or increased to its largest possible size.
In order to be able to fully explain this task, the child
must have the logical concept of seriation (Piaget, 1967).
Thus, he must have both logical and infralogical groupings in
order to solve what is essentially an infralogical (part-whole)
task.

The previous paragraph should serve to indicate both the
essential differences between the two systems and their complex
inter-relationships. The exact relationship between the infra-
logical and logical systems still has not been completely ex-
plained. For this reason, testing is generally confined to one
or the other of the systems within which the sequence of
structures is clearly defined. Thus the present research examines the relationship between spatial constructs (infralogical) and reading.

Piaget's conception of the symbolic function can be defined as "...the capacity to represent reality through the intermediary of signifiers that are distinct from what they signify." (Sinclair-De-Zwart, 1969). His conception of the symbolic or semiotic function is broader than that normally held. He views language as only one part of a larger system.

The symbolic or semiotic function comprises, besides language, all forms of imitation, mimicking, symbolic play, mental imagery, and so on. Too often it is forgotten that the development of representation and thought (we are not as yet speaking of properly logical structures) is tied to this general semiotic function and not just to language. (Piaget, 1970b, p. 93).

Although the symbolic function plays an important role in development it must not be forgotten that it is the operations themselves and not their symbolic representation that are the basis of intellectual development. Language serves the function of allowing the operations to become abstract, but without the initial step of operations based on actions, the later stage would never evolve. Cognitive development must always be
analysed at the level of operations and not simply in relation to symbols for the symbol is only as good as the operations on which it is based. The symbol does not change the operation, the operation changes or defines that which can be symbolized. Thus in terms of both language and reading development, it is not sufficient to analyse their development in isolation, but they must also be analysed in terms of the underlying operational structures which they represent. Sinclair-De-Zwart's (1967) experiment with conservation and corresponding language structures is a good example of the relationship between these two systems. In this experiment, Sinclair-De-Zwart found that those children who could not solve a conservation problem, could also not use comparatives in speech (i.e., describing groups of objects in terms of "greater than" types of expressions). It was only after the child had mastered the conservation task that he was able to use these linguistic relationals. Piaget comments (1970b, p. 96): "It seems that on the level of 'concrete operations' operational structure precedes linguistic structure, the latter somehow growing out of the former to rely upon it subsequently."

The last Piagetian concept to be considered is the image which is both figurative and symbolic. Piaget defines an image as follows: "The visual image is a figural evocation of objects, relations, and even classes, etc. It converts them into a concrete and simili-sensible form, though at the same time it
possesses a high degree of schematization..." (1971b, p. 361). Imagery (internal imitation) even in its final anticipatory transformational state, is regarded by Piaget as an auxiliary system, which at the concrete and formal operational levels augments the system of operations and transformations but cannot be substituted for it. Thus thought without imagery can exist, but not imagery without thought. At the operational level, images and operations enjoy a sort of symbiotic relationship, imagery helping in abstract thought, and operations enabling images to anticipate transformations not already seen. However, at the pre-operational level, images are not sufficient pre-conditions to bring about operational thought. For example, in a conservation experiment a child may be able from past experience to visualize (have an image of) the level of liquid being higher in a narrow glass than in a wide one, but this does not enable him to explain why this is so or to understand the operation of compensation (height and width).

Reading and the Piagetian Structures

Briefly, reading within the Piagetian framework is viewed as one representative instance of the more general cognitive development of the child. In its figurative aspect (i.e., the letters), the image is the vehicle in which the individual letters have their schematic representation. At the operative level, i.e., as the system underlying the image, the operations required for the child to represent space, are hypothesized to be necessary
for the child to consistently identify and use letters and words. Thus, reading is viewed as a cognitive ability with the letters represented by images and the images operationalized in terms of the infralogical grouping involved in the child's conception of space. Reading failure is conceptualized in terms of a slowness or lag in the development of these images and the infralogical grouping. As the child increases in age, his failures in underlying operations would be at progressively more complex levels.

The unique position of the image in both the figurative and symbolic systems, makes it the logical candidate for the representation vehicle for the letters. The letters represent a symbolic system of their own, in that the symbol for one letter represents both auditory and graphic aspects of that letter. Moreover, the letter symbol system has its own rules of combination, orientation and order. Thus letters are both symbolic and figurative as is the image. "The image is not actually an element of thought, but like language, and, at least in the spatial sphere, with more evident success than language, it does serve as a symbolic instrument signifying the content of cognitive significations." (Piaget, 1971b, p. 379).

There are other aspects of the image which make it a good choice for the representation vehicle for letters and words. The schematization aspect of the image is important in explaining letter recognition. Since the images are considered to be 'simili-sensible', i.e., closely resemble the objects they
represent, the images would reflect the physical realities of the letters. However, because the image is a schematized perception, it would also be able to account for the recognition of the letter when the letter is presented in various scripts and handwritings. Moreover, it might be possible that the image would also contain individual, idiosyncratic information such as letter-sound combinations. This would be similar to the function of language, reflecting the social realities of common names for objects across people and yet, simultaneously adding private meanings and connotations to the words.

Perception and Reading

Considering the close relationship between perception and the image, the question could justifiably be asked as to why perception alone is not sufficient to describe reading in the sense of letter and word identification. Perception, in Piaget's terms, is probabilistic and as a result, perceptual distortions are often the result of inadequate sampling of the perceptual field or of centering on one area of an object to the exclusion of the rest. This type of error is not consistent since it depends on the moment to moment changes in the sampling behaviour. In Piaget's words:

In general there seems to be systematic differences between perceptual distortions (or illusions) and the distortions of reality characteristic of the images studied in this
book. Perceptual distortion results from the incomplete reconstruction: while attempting to reach the object as it is, perception makes shifts with a few information samples furnished by various centra tions and by partly chance encounters. The outcome is an entirely probabilistic kind of construct that takes in only a fraction of the elements or relations to be co-ordinated. In the case of the image, on the other hand, distortion results from exigencies of schematized figuration, and to a large extent also from liberties taken by the subject in view of the symbolic nature of schematized figuration. (1971b, p. 365-366).

Perception would therefore be inadequate to explain consistent confusions in only some letters. Moreover, the errors are largely those of orientation (left-right, up-down) and order (was-saw). This consistent type of error cannot be explained by perceptual sampling problems alone, given that perception is a probabilistic process which samples various aspects of the individual letters.

At the stage of concrete operations, the image is flexible and can be used to anticipate the results of transformations which have not been seen previously. Perceptions are totally
static in character and can only be applied to previously known and perceived things. Thus every drastic change in script would require that the child learn anew a perceived letter. However, in terms of anticipatory imagery, the child could anticipate the letter or group of letters on the basis of likely possible combinations, and he could generalize on the basis of his pre-existing classes for each letter.

It is the symbolic nature of the image which makes it the better instrument of representation. Thus the image is a simplified (schematic) model of what is perceived which facilitates anticaption and action on the perceived. Simplification implies the use of operative schemas rather than simple figurative schemes (Piaget, 1971b). It is just this schematization that is needed to represent the system of letters which perception does not have.

Another telling argument against perception as the sole means of letter representation lies in the orientation errors discussed earlier. Wohlwill (1967) in his review of perceptual research noted a number of studies which indicated that small children were much better than adults at recognizing stimuli presented at varying orientations including reversed and upside down. Moreover reading research has consistently confirmed the beginning reader's confusion with letter orientation (d, b, p, q) (e.g., Jackson, 1972). All this research indicates that orientation in space is not being considered in the young child's
perception of the object. It is only when the child is capable of imposing a co-ordinate system (vertical-horizontal) on the space, that direction and orientation become relevant dimensions. This co-ordinate system does not exist in the perception itself, or it would be present from the beginning, but rather, it is imposed on the perception of the child (operations). Thus perception alone is not adequate to explain the correct identification of letters and words.

Basically all the arguments against perception as an adequate system to represent letters make the same point. That is, in order for the perception of an object to improve or become more accurate, it must be acted upon by intellectual operations. Knowledge does not come from extensions of the rules of perception rather, the rules for perception are extended by the knowledge. Perception is directed by operations and not vice versa, and Piaget is careful to point out that the image derives from active imitation and not from the passive extension of perceptual schemes. Piaget continuously states that the child only imitates that which he understands or is on the point of understanding and he only remembers what he understands. Considering this in terms of perception, what the child perceives will only be meaningful or recognizable in terms of what schemes he has to assimilate the information. Where no schemas exist to assimilate the perception, the perception will be largely ignored.
There has been a series of experiments extending over a ten year period all attempting to apply Piagetian perceptual theory to reading (e.g., Elkind and Deblinger, 1969; and Elkind, Larson and Van Doornick, 1965). Elkind and his researchers have devised two tests to measure figurative performance with children. The first, the Picture Ambiguity Test (PAT), is largely based on the standard reversible figures type of stimuli with a few stimuli of the "find-the-hidden-face-in-the-tree" type. The second test, the Picture Integration Test (PIT), involves a system of pictures that can be identified by either their parts or whole (e.g., scooter made out of candy). These two tests, either alone or in combination, form the basis for almost all his research with reading. Elkind tends to bias his results in favour of a perceptual interpretation of reading by using a very limited reading task. In the majority of the studies he used a word recognition test as the only measure of reading ability. In word recognition tests, the child is shown a word and then is asked to find the same word in a short list of other words. This type of task can be interpreted in terms of simple pattern discrimination or even figure-ground discrimination and its relationship to reading is limited.

Using the tasks just described, Elkind et al, (1965) established that slow readers perform more poorly on the PAT and PIT tasks than average readers and that they benefit less from practice in these tasks than the normals when retested. However,
it should be noted that the pre- and post-test and the training all took place on the same basic set of stimuli. In another study (Elkind and Deblinger, 1969), using the same two tests as measures of perceptual ability and the recognition of altered word forms as the reading test, Elkind et al, established a group of good and poor readers. The two groups were matched in I.Q. and SES and then half of each group given training in perceptual tasks (using material similar to the perceptual tests). After fifteen weeks the groups were retested on Forms B of the perceptual tests and the altered word form test, and the training groups had improved over the other groups who had been given normal reading instruction from standard readers. The improvement in the performance of the training groups could be attributed to the high degree of similarity between the training and the test materials. Moreover, in both of the studies just described, there is some question that the differences found between the good and poor readers would remain if some other type of reading test was used as the criterion of reading ability. This is not to deny that there is a perceptual element in reading only that it is not the central element in reading that Elkind's research would suggest.

It is interesting to note that even when reading is being defined in such limited terms and Elkind's Perceptual Tests are so closely related to figure ground perceptual concepts, Elkind still finds it difficult to explain his results by strictly
perceptual theory. He explains letter and word confusions in terms of failure to accurately decenter from one aspect of the letter or word. However, he then goes on to explain letter-sound confusions in terms of the logical multiplication of classes and he states: "perceptual schematization...can be conceived as a semi-logical process." (1970, p. 142). The logical multiplication of classes is involved, according to Elkind, because different letters can give the same sound and the same sound can be elicited from different letter combinations. Thus, Elkind used the logico-mathematical operational system of Piaget to explain reading problems yet he continues to say that the reading system is perceptual. Moreover, his part-whole task, rather than being perceptual, seems to be an example of the topological part-whole concept involved in the development of the concept of space. Piaget (1967) points out that the part-whole relationship is the infralogical equivalent of classes in the logical system. Thus, Elkind's perceptual task is not really perceptual but based on operations instead. It seems then, that Elkind rather than using Piagetian perceptual theory to explain reading, is really using Piagetian operational structures to explain reading. This does not mean that there is no perceptual factor in reading (witness the predictive value of the figure-ground test), only that it is not sufficient to explain even letter identification.
The Spatial System

In the present conceptualization the hypothesized underlying operations for reading (in the identification sense) are those involved with spatial relations. Piaget considers three different types of space: topological, projective and euclidean. Topological concepts of space develop first and are followed by projective and euclidean space which develop simultaneously and which are interdependent systems. Topological space is concerned with the properties of the objects themselves and involves such concepts as proximity, enclosure, surrounding, order and continuity. Topological relationships are elastic in the sense that distance and amount of space occupied are not relevant, and neither are angles and lines (Piaget, 1967). Two objects are viewed as the same, if one can be made to fit on top of the other (homeomorphism) even if this requires some kind of stretching or rotating on the part of one of the objects. In a sense then, topology is uni-dimensional, objects are related to each other only in terms of overlapping neighbourhoods or surrounding, their relationship is never considered with respect to the perceived space. Space as a container with distances and co-ordinates, does not exist at this level.

Projective space is concerned with the object and a point of view. The basic projective concept is the straight line which cannot be distorted by changing perspectives. The child now takes into account the position of his body in relationship to
the observed object. Basic concepts underlying projective space are relationships such as before-behind and right-left.

Euclidean space is concerned with the relationship of objects to each other. Space is viewed as a container in which to place objects and location and distance are relevant. The key structure of euclidean space is the system of co-ordinates it presupposes. Objects are arranged with relation to vertical and horizontal axes and it is here that orientation in space can first really be considered. Objects can be located precisely in space in relation to each other because space can be measured and the system co-ordinates applied.

Projective and euclidean space cannot be viewed in isolation. Even if the child is considering the relationship between objects, he must be viewing these relations from a certain point of view and by altering his point of view, he alters the relationship. For example, if a child is asked what is to the left of the ball, it will depend on whether he is standing in front of the row of objects or behind. Thus these two systems are inter-dependent and both evolve from the simpler topological space simultaneously.

**Imagery and Spatial Concepts**

The close relationship between imagery and spatial concepts is acknowledged by Piaget. In describing the development of spatial notions Piaget points out that he is considering representational space and not perceptual space. He then notes that
representational space is not possible until the onset of mental images (Piaget, 1967). Although he clearly states that: "It is completely wrong to attempt to reduce spatial intuition to a system of images, since the things 'intuited' are, in the last analysis, actions which the image may symbolize but can never replace." (Ibid, p. 455), he does nevertheless admit to a special relationship between imagery and spatial concepts.

...it should be realized that throughout the evolution of spatial operations the image performs an entirely different function from that which it carries out in the case of logico-arithmetic operations. A spatial field is a single schema embracing all the elements of which it is composed and uniting them in one monolithic block, whereas a logical class is a collection of discontinuous elements linked by their resemblance, regardless of spatio-temporal location.

...the image of a spatial system is more or less directly comparable with the schema, since such a schema constitutes a single object and the image deals with this object as a product of the operations. Thus even though the image remains symbolic and does not replace the operations themselves, it is nevertheless comparable with the
object, whereas the image symbolizing the product of a logico-arithmetic operation represents only a very incomplete part of the whole system. (1967, pp. 456-457).

The general import of this passage is that imagery and spatial constructs have a much closer relationship than do imagery and logical constructs. This is congruent with the hypothesized conceptualization of reading in the present study where the letters are represented symbolically by the image and operationally by the infralogical system of space. Further incidental support for this conceptualization comes from the fact that as thought becomes more operational and eventually more abstract, the importance of the image declines (e.g., what is the image of a transformation performed on a set of earlier transformations?). This decline of the use of imagery corresponds to the later emphasis in reading on comprehension, i.e., when it is no longer necessary or practical to identify each letter and word in order to comprehend the sentence or paragraph as a whole.

Reading and Spatial Concepts

How can the spatial constructs discussed above be used to explain reading? The identification of individual letters seems to be largely explained by topological structures since these are the ones which consider the object in relation to itself. The basic concepts of proximity and separation (which in fact define when an object is viewed as one or as part of another
object), develop so early that they are present even in three and four year olds tested. (Piaget, 1967). The other topological structures (i.e., order, enclosure and continuity) develop at about the time the child starts school, being mastered around seven or eight, and all seem to have a rather direct relationship to reading letters and words.

The concept of surrounding or enclosure is concerned with matching objects in terms of their internal structures. Surrounding is also used to describe objects in the same proximity. Thus in a line ABC, B is between A and C and is, in a sense surrounded by them. In the same sense, a nose is surrounded by, or enclosed in, the face. Piaget uses a series of knots to test the concept of enclosure using taut and slack knots, left and right overhand knots, and false knots (e.g., two connected circles). The question asked the child is whether or not two knots are the same. This brings in the important concept of homeomorphism which means simply that two objects are the same if they can be superimposed on each other (e.g., slack and taut knots). In order for the child to be able to differentiate between the pairs of knots, he must attend to interior details, for example, which part of the loop of the knot encloses the end of the rope and so on.

Both homeomorphism and surrounding are important concepts in describing learning to read. The concept of enclosure or surrounding is useful in describing how children learn to
differentiate between letters in terms of internal features (whether or not one element of a letter is enclosed by another). The fact that the only identity element in topological space is homeomorphism, helps to explain one very common problem of beginning readers, the confusion in orientation (left-right, and up-down) of letters. Orientation in space is not a relevant cue for this kind of identity. Any two elements that can be made to fit on top of each other are the same. This explicitly permits operations such as rotation and reversal to make the identity correspondence. Thus, in terms of homeomorphism, b and d and p and q are the same element. The confusion in the beginning reader among these types of letters may be due to his inability to differentiate them on the basis of topological features. This homeomorphic identity could have evolved from the much earlier object permanence. Object permanence is the first primitive type of conservation of form, and it implies by its very nature that the child must learn that an object is the same regardless of its point of view or orientation. A good example of this, is Piaget's description of the baby being presented with his bottle upside down. At first, he does not recognize his bottle, but eventually he learns to turn the bottle over to get the milk. In other words, the baby has explicitly learned to disregard cues such as orientation when considering whether or not it is the same object he is being presented with. What he must learn then with the system of
letters, is that these are a separate set of object which do not follow his more general identity rule for objects. In fact, he must unlearn or learn an exception to, one of his most primitive set of operations when considering the specific sub-set of objects, letters.

Another topological feature relevant to reading, is order. This is the infralogical equivalent of seriation in the logical system. Order is partially dependent on the concept of surrounding in the sense that order is based on the idea of between which also implies surrounding. However, surrounding cannot really exist without order either, particularly if surrounding is linear. Order is a straight-forward concept requiring that the child be capable of reproducing a set of objects placed in a particular series. In order to truly demonstrate competence, the child must be able to reproduce the reversed order of the original set and also circular order. The infralogical concept of order is very similar to the logical concept of seriation, however, the logical grouping for seriation requires a class and a relation (in a sense it is hierarchical order) and spatial order does not. Thus, in seriation the items are arranged in a specific order, but order is determined by a type of relation between the objects. For example, sticks are arranged in order of height, either ascending or descending, and the relation involved is greater than, or less than. With the infralogical concept of order, all that is required is that the parts of a
whole (e.g., a whole pattern) are reproduced in the same order as those in a model. This concept becomes operational when the child is able to understand that reversing the order of beads implies looking at the same order from a different point of view and that this reversing does not change the between relations of any of the component elements. There can be little doubt that the order of letters is critical to the correct identification of words. Further, the primitive type of order based simply on "between" helps explain some of the early reader's confusions in identifying simple words, e.g., "was" and "saw". In both these words the 'a' is between the 'w' and 's' and thus the child is at least following the primitive rule of order or enclosure. However, order has not yet been operationalized to the extent that the beginning and end of the series have become invariant. Thus the topological structure of order seems useful in describing developing reading skill.

The third topological structure relevant to reading is that of part-whole relationship. This is the infralogical equivalent of class inclusion in the logical system. This structure seems relevant both at the level of the word and of the individual letter. Part-whole relationship implies both that the whole is the sum of its parts and that the whole can be subdivided into its parts. In terms of the alphabet we have certain basic shapes which are combined to form various letters. The child must determine which parts go to make up which letters and thus to
differentiate the letters. For example, a circle and a line go to make an a, b, d, and so on and by using smaller sections of the circle and line, you get letters such as n, h, f, etc. At the word level, it is obvious that the part-whole relationship is critical if the child is to identify the word. If the child fails to break the word down accurately into its parts and instead identifies the word by its general shape he is likely to make errors of the dog-boy type. Similarly, if the child is incapable of combining the individual letters into the word, he will be unable to recognize the word.

In terms of projective space, the right-left and up-down concepts are relevant to reading. However, in projective space, these systems of relations are only with respect to the individual's perspective. Thus, the points that go to make a straight line are either before or behind each other if the line is viewed from one end, or they are to the right or left of each other if the line is in the horizontal plane, viewed along its length. Thus the relationship is not based on a system of co-ordinates where an object is to the right or left of some given point, only that the points follow each other in a given direction which can be described by before-behind or right-left relations. These projective relations (which are mastered around age 7-8) represent the beginning of awareness of orientation but these are not sufficient in themselves to locate a series of objects in space and thus to fully identify letters. However,
they do represent an improvement over the total lack of these types of concepts in topological space.

In terms of geometric or euclidean space, the most critical structure for reading, is the establishment of a system of co-ordinates (mastered at age 8 - 9). That is, objects can now be located in terms of intersecting vertical and horizontal axes. It is only at this stage that representation of orientation in space can become accurate. It is not until the child can impose this co-ordinate system on his perceptions that he can correctly distinguish between and reproduce letters of the d, b type without error. Moreover, words and sentences can be more accurately recognized since space is now viewed as a container and hence intervals between objects are now considered. Intervals are relevant because the system of co-ordinates makes accurate location possible. The child can now use the relative separation between letters and words to help identify them.

If this link between reading skill and space concepts is viable how can this system be used to explain reading problems? Aside from the connection between retardation in the development of spatial concepts and reading, there is the more general factor of over-all cognitive development.

One thing that is exceedingly obvious about cognitive development is that it is influenced by experience and the environment. Cognitive development is both enriched by the experiences the child has been open to and limited by the demands and realities
of the environment. Dasen (1972) in his work with Australian Aborigines, has shown that if an Aborigine child is given both the opportunity to observe and the environment which emphasizes the need for these skills (i.e., raised in a European style home), he can and does develop the conservation skills at approximately the same time and at the same rate as European children. However, in the case of Aborigine children raised with little or no contact with Western influence, few, if any of the children progress beyond concrete operations. Many never even reach this stage. Dasen's argument is that, in a sense, the Piagetian stages are not universal but are limited by the cultural or environmental needs of the people involved. Likewise, it may be that there are some environments that are more conducive to the type of cognitive development needed for developing reading skill than others, either through lack of opportunity or lack of environmental necessity. Thus, a child might have the basic cognitive ability required to learn to read but never have developed it because of lack of environmental stimulus, or he might just be slow in developing these cognitive skills. Of course, he might also lack the basic ability.

Essentially then, for the purposes of this research, reading skill (at the visual identification level) is being viewed as dependent on the development of certain, basic cognitive structures. It is the major hypothesis of this study, that the basic spatial constructs as outlined above are required before the child can
successfully identify letters and words. The child's cognitive development in the spatial area must have reached the level of concrete operations in such fundamental skills as order, enclosure, and left-right orientation before he is able to successfully master this aspect of reading.

Research Using Piagetian Tasks

There has been very little experimentation addressed to this problem as it has just been posed. Aside from the series of studies carried out by Elkind which have already been discussed, there are only three studies which directly pertain to the Piagetian approach to reading problems and a few more oblique references to the possibility of this type of research.

One study by Lovell, Shapton and Warren (1964) included three Piagetian tasks in a whole battery of tests given to a large number of children (mean age 9 - 8). All the Piagetian tests used involved the axes of reference, (i.e., maintaining horizontality in relation to a reference point when a container is tipped, e.g., level of water in a beaker). All three tasks are variations on one specific spatial task involving conservation of horizontal and vertical planes. These tasks (taken together) were one of the indicators significantly differentiating the group of good and poor readers.

Another study done by Kershner (1971) was more directly concerned with Piagetian spatial tasks. He used a number of Grade One children to study the development of the vertical-
horizontal co-ordinate system. He employed a T-shaped runway with a C-shaped house at the central point of the runway to study the effects of mirror images and axial rotation. He generally concluded that spatial operations on reversed and rotated planes were more difficult than those on aligned planes. Although, he did not separate his subjects on the basis of reading performance, he did point out that his study had implications for children with reading problems since present remediation concentrates on too specific and immediate visuo-spatial problems rather than on more fundamental spatial structures.

The last and most closely related study to the one proposed was recently reported by Klees and Leburn (1972). In their study, they specifically differentiated between figurative and operative aspects of thought and explicitly set out to relate a series of Piagetian tasks to a group of dyslexic (reading problem) children. They gave the dyslexic children the test of horizontality (predicting the level of liquid in a jar), a seriation task (ordering sticks into a staircase), a classification task (are there more daisies than flowers?), and the test for conservation of liquid (is the amount of water the same if it is in a thin or fat jar?). All of these tasks they classed as tests of operational intelligence and these were compared with figurative tests (e.g., the Kohs blocks subtest of the W.I.S.C.). Klees and Leburn found that the poor readers had problems with the figurative tasks and were approximately one year retarded in their performance on
the operational tasks. One major flaw in this study is that the researchers compared their dyslexic group of Belgian children with the norms supplied by Piaget for Swiss normal children and not with a comparative group of Belgian normals. Moreover, the Piagetian norms were not recent, but were ones taken from studies done in the 1950's. The one-year performance difference then, between the normal and dyslexic children on the Piagetian tasks seems highly suspect on the basis of the comparison groups. In terms of the hypothesis posed in the present research, this study does little more than suggest the possibility of there being a relationship between reading problems and Piagetian tasks.

Inhelder (1961) does lend some support to the hypothesis that Piagetian spatial constructs should be related to reading problems. In a more general talk on the applications of Piagetian theory to problems in psychopathology, she refers to the one case of a dyslexic child being tested on Piagetian tasks. When the eight-year old child was given the problem of placing items on a rotated landscape, he responded at the pre-operational level ignoring the dimensions of right-left and up-down and using only his own body as a frame of reference. Inhelder described his general performance this way: "He passed perfectly all operational tests for his age, not only problems of conservation but also problems concerning the formation of logical classes. However, his spatial representation and more generally his representational ability, seems to be disrupted." (Inhelder, 1961,
p. 163). Note that this description contradicts the results of the last experiment cited. Inhelder stated that the boy was performing at the normal level on the conservation tasks while Klees and Leburn (1972) stated that their subjects were performing below the normal level on both the conservation and spatial tasks.

Inhelder's reference is the only one in the literature that specifically relates Piagetian spatial tasks to reading problems and hers is in the form of an anecdotal description. However, her encouraging results in terms of relating Piagetian spatial problems to reading problems, at least suggests some support for the presently hypothesized relationship.

A more vague type of support comes from Furth (1970). He states that in effect what schools are doing now with reading is teaching reading without thinking (p. 71). He points out that any reading taught in the first or second grade, regardless of method, is relying solely on rote memory and mimicery; since at that age the child does not have the schemas necessary to assimilate on logical, operational grounds those rules and meanings that are being taught. Although, Furth is not talking specifically about spatial constructs here, his general premise that the child does not have the Piagetian constructs necessary for reading at that age, is in agreement with the system of development discussed in this paper.

Considerations in Designing the Study
a) Testing Reading

The research presently available has not been designed to
determine the relationship between Piagetian spatial tasks and reading performance at the identification level. Determining the nature of the relationship is one of the primary goals of the present study. Although, it would be most useful (in terms of identifying and helping poor readers) to test this hypothesis at the beginning reading level, this early reading level also presents a problem. Until the child is truly reading, i.e., at the level of small stories and sentences, any test of reading is really only a test of reading readiness. The child is given tests such as figure-ground discrimination, holding a pencil or finding the article that is different, and then the scores on these tests are related to how the child will read at a later time. The obvious problem with this approach is that the relationship between reading readiness tests and reading per se is not exact. Some correlations between the two are only at the .30 level of lower (e.g., deHirsch Battery, 1966). Thus, it does not seem wise to introduce a confounding factor into the relationship being tested between reading and the Piagetian tasks. The earliest that children can be tested on a true reading test is Grade Two which is the age group studied in this research. It should be noted that, if the relationship between reading and the Piagetian tasks can be established, then it would be valid to generalize back to the beginning readers and test them on the basis of what is known about the established readers. Basically, the design for this experiment involves testing a group of Grade
Two children from a wide spectrum of reading ability and relating the children's reading ability to their performance on a group of Piagetian spatial tasks.

b) Intelligence

Intelligence is one variable which is known to confound to some degree, both reading ability and performance on Piagetian tasks. It seems reasonable to expect more intelligent children to read better and to perform better on Piagetian tasks. However, research on the relationship between I.Q. scores and performance on Piagetian tasks, has yielded quite mixed results. Goldschmidt (1967) found only moderate correlation between tests of conservation and I.Q., with the highest correlations being with M.A. He makes the point that there were large individual differences between subjects in the same age group even when I.Q.'s were similar, however, he also observed that the performance on the various conservation tasks were highly correlated with each other. Tuddenham (1968) using very poor methodology (different testers for each of ten Piagetian tasks done under limited time conditions) and a sample of children all of the same age, found very little correlation between different Piagetian tasks or between Piagetian tasks and I.Q. In his conclusions he states, "...the relative specificity and independence of the various items have extinguished whatever hope we might once have entertained that we could place each child on a single developmental continuum equivalent to mental age and from his score predict his perfor-
mance on content of whatever kind." (p. 323). Dudek, Lester, Goldberg, and Dryer (1969) did a developmental study of I.Q. and Piagetian tasks with children ranging in age from five to eight. Over the three year period, they found quite a high correlation between I.Q. and Piagetian tasks (e.g., r = .57). They also concluded that Piagetian tasks were equally effective (cf I.Q.) in predicting Grade I and II achievement.

When viewing these studies as a whole, it seems that Piagetian tasks only correlate highly with I.Q. when the age range is expanded over several years. At any given age, Piagetian tests correlated more highly with Mental Age (r = .30, Goldschmidt) than with I.Q., and the correlation is not high. This seems to suggest that there is some overlap between those abilities being tapped by I.Q. and those being tapped by Piagetian tasks. Perhaps this overlap is representative of Spearman's "G" factor of true ability. However, there is enough diversity between the two types of tests to expect that children with similar I.Q. scores could still perform differentially on Piagetian tasks. The differential performance on the Piagetian tasks might reflect differences in rate and level of cognitive development. Thus, it seems justifiable to take the children having similar I.Q.'s, and then test them on Piagetian tasks related to reading in order to see if there is differential performance on the Piagetian tasks according to the reading ability of the children.

With regards to the relationship between reading and I.Q., in
some cases reading has been viewed as a good measure of general ability (e.g., Garrettson, 1971), and used as a substitute for an I.Q. test. On the other extreme, are the dyslexic children who have normal or above average intelligence but who have almost no reading ability at all (e.g., Bannatyne, 1971). Thus, some studies consider intelligence as a major causative factor in reading problems (e.g., Ames, 1968) and others consider that there is practically no causative relationship at all (e.g., Coleman and Sandhu, 1967). Generally, however, it seems more reasonable to assume that there is some degree of relationship between intelligence and reading, but that this correlation is not high. As Rosewell and Natchez (1964) comment: "Intelligence is a determinant of reading achievement, but intelligence test scores do not necessarily predict the level of reading achievement." (p. 8).

For example, a study by Ackerman, Peters and Dykman (1971) found a correlation of .30 between W.I.S.C. verbal I.Q. and the Gray Oral Reading Test and a correlation of .23 between the full scale W.I.S.C. and the Gray. Generally then, some degree of relationship between reading and intelligence must be granted but as in the case of the Piagetian tasks, it seems that even if I.Q. scores were controlled, there would still be variations on reading ability within the group.

It seems necessary both from the Piagetian and from the reading point of view to get some measure of intelligence from the children being tests. This was necessary so that the effect of intelligence
could be examined and controlled. Thus each child tested was given an intelligence test, reading tests and Piagetian tasks.

Summary and Hypotheses

This introduction has been an attempt to place the visual-spatial aspects of reading into the context of the developmental theory of Piaget. Because the theory is developmental, it allows for different problems at different stages in development and thus eliminates one of the major causes of controversy in reading research. Moreover, consideration of reading in terms of underlying cognitive structures allows for the prediction of other problem areas not initially noticed due to the fact that the same underlying cognitive structure is involved.

The letters and words involved in reading have been conceptualized as images whose operational base lie in Piaget's spatial constructs. It has been hypothesized that the four basic constructs of topological space; proximity, separation, order and enclosure, are all necessary for the correct identification of words and letters. Also, the basic projective construct of multiple points of view reflected in the operational concepts of left-right and before-behind are considered essential. Finally, the geometric or euclidean construct of a co-ordinate system also seems essential to identifying the correct orientation of letters and words.
In order to test this spatial analysis of reading, a broad sample of Grade Two children were given a comprehensive set of reading tasks and the set of eight Piagetian tasks derived from the spatial analysis. Considering the possible relationship of intelligence to both Piagetian tasks and reading, a measure of intelligence was also administered.

In general, the theoretical relationship between Piagetian spatial theory and reading as viewed in this study would be the following. There are basic underlying spatial structures which are reflected in the child's performance on spatial tasks. The spatial structures are part of an integrated cognitive system which develops slowly as the child is able to assimilate more and more information by modifying and inter-relating his existing cognitive schemas. Thus success on individual Piagetian spatial tasks reflects the level of cognitive development of a child at that time. Given that these same spatial structures underlie reading success, the degree of success on Piagetian spatial tasks should be similar to the degree of reading success of the child. Thus, if the child has not reached the Stage of Concrete Operations in terms of the spatial structures, he will perform poorly, at the pre-operational level on the Piagetian tasks and likewise, he will be a very poor reader. As the level of complexity of the spatial structure that the child has mastered increases, so should his ability to read. That is, for example, until the child has the schemes to assimilate information
about the orientation of an object (i.e., when he can use the co-ordinate system) he will be unable to correctly locate objects on a landscape and he will be unable to consistently differentiate letters such as b and d. When this complex structure has been mastered, the child's letter identification problems (with regard to orientation), should disappear as should his difficulty in locating objects on a landscape.

This analysis of underlying cognitive structures can also be applied to the Piagetian tasks themselves. Thus, within any given task there are items that require only a minimum of operational structures and others that require very complex cognitive structures. For example, reversibility is one of the defining structures of the Stage of Concrete Operations and mastery of this principle is essential for success on all the Piagetian spatial tasks at their more difficult level. Yet, a child could be successful on some of the easier items in the spatial tasks without having mastered reversibility. Thus, items within a task vary in the amount of sophistication of cognitive structures needed to correctly solve them. This varying complexity of cognitive structure is present both within any given Piagetian task and across the whole number of Piagetian tasks. In effect, the developmental level (defined by the number and type of cognitive structure the child has mastered) of the child will be evident both in the level of success he has on any given Piagetian task, and on the overall level of his performance.
across tasks. Moreover, the child's level of reading success will also reflect this same level of cognitive structural development.

This general Piagetian discussion of the hypotheses of the present study can be expressed in summary form as follows.

1) The Piagetian spatial structures reflected in the Piagetian tasks will be related to reading ability. The relationship will be such that the more complex the spatial structure the child has mastered, the better the reader he will be.

2) Intelligence or general ability will be related to performance on both the Piagetian and reading tasks, but this relationship will not be sufficient to account for the relationship between reading and Piagetian tasks.

3) There will be consistency in the performance of the child across related Piagetian tasks.

4) There should be a stepwise success rate on any given Piagetian task based on the degree of difficulty of individual items, where the degree of difficulty is defined by the complexity or operativity of the Piagetian structure underlying the task item.
PROCEDURE

Subjects

Subjects were 60 Grade Two children taken from four Vancouver schools, two in the East End (38 children) of lower socio-economic status, and two in the Point Grey area (22 children) of upper-middle socio-economic status. The mean age of the children was 7 years 12 months with a range of 7-6 to 8-5. There were 29 males and 31 females in the study. Only children with signed parental permission (see Appendix 1) for whom English was their primary language were accepted for testing. There were no other restrictions on subject selection.

General Procedure

Each child was tested separately in a quiet room such as the nurse's office or library of the child's school. Testing took place on two consecutive days whenever possible. On the first day the child was given the general ability test and the reading tests and on the second day, he was given the eight Piagetian tasks. Altogether the two testing sessions took approximately an hour and a half per child. The first day's session usually took about thirty-five minutes and the second session usually from forty-five minutes to an hour. All scoring was done after the child had been completely tested on both sessions.

Piagetian Tasks

Due to the complexity of the Piagetian tasks and the need
to do both a Piagetian Stage analysis and a statistical analysis of the data, it is necessary to study each Piagetian task in detail. Thus in this section, each Piagetian task will be analysed in its theoretical context, conceptually analysing each item in each task in terms of the Piagetian structures involved. The actual materials and the breakdown of numerical scoring within each task will also be presented. The instructions given for each task are presented in Appendix 2 and the score sheets used in recording performance on the Piagetian Tasks are included in Appendix 3.

In general with respect to scoring, it should be noted that one point in the scoring for every item in each task was given as a confidence point. This point was a crude attempt to measure the confidence of any child in his answer. If, for example, the child was unsure and changed his answer several times before he arrived at the correct answer, he was not given the point. Also, if the child was unable to defend his answer, i.e., when asked why he chose a particular item, he said he "didn't know", or "just because", or something similar, he was again not given the confidence point. This scoring addition is an attempt to operationalize what Flavell and Wohlwill (1969) call formal and functional aspects of cognitive development. Certainly, the present attempt is crude, and in no way designed to test this distinction, however, it serves as one approach to reflecting the realities of performance on Piagetian tasks.
I) Topological Space

As discussed earlier, topological space is concerned with the properties of the object itself, and not with the idea of space as a container in which objects can be located. Topological space is concerned with establishing the boundaries of objects and with establishing the identity of two objects by means of homeomorphism (two things are the same if they can be placed one on top of the other even if one of the objects must be stretched or twisted).

There are five basic topological skills that Piaget discusses and these are: a) proximity, b) separation, c) order, d) enclosure and e) continuity. Of these five, the first two — proximity and separation are complimentary elements of the same skill as are order and enclosure. Finally, continuity is the result of the first four constructs taken together.

1) Proximity – Separation

Proximity is based on the idea of belonging or nearbiness, as Piaget says (Piaget, 1967, p. 458) "Linking items together on the basis of proximity results in unitary wholes..." Separation, on the other hand is concerned with imposing a division between adjacent elements in order to establish a separate identity for each element. Piaget explains separation in this way: "Two elements may be adjacent and not separate or adjacent and separate, separation being something distinct from non-adjacency since it depends purely on the circumstance of being differentiated through
some type of analysis (perceptual or logical) (Piaget, 1967, p. 144). It is evident from these descriptions of separation and proximity, how closely related these two concepts are - proximity being concerned with the bringing together of divergent elements to establish a whole and separation being concerned with the separating of adjacent elements to define a whole. Thus, both these concepts are necessary to define the boundaries of an object, and in a sense, to separate figure from ground. Piaget describes the relationship between proximity and separation this way:

"...when the process of subdivision becomes operational, intuitive separation is replaced by logical, conceptual separation based on the notion of proximity itself. (Ibid, p. 148).

These two complimentary constructs (proximity and separation) are the earliest spatial concepts to evolve, and in a sense, they form a basis for all later developments in space. In Piaget's words: "In the realm of psychology, it would be true to say that the relation of proximity, expresses the most fundamental characteristic of the actions by which the subject generates the notion of space." (1967, p. 80).

Because they evolve so early, it is impossible to test Proximity and Separation in their original form at the Grade Two level. In fact Piaget calls proximity a "given" (1967, p. 462), and so tests of its developmental history are hardly possible.
However, both proximity and separation have operational equivalents in the form of partitive addition, and subdivision of the whole into parts. In other words, although perceptual proximity and separation are well established before the child reaches school, conceptual proximity (partitive addition) and separation (subdivision) are not. Since these concepts are important in learning to read, (the child must be capable of breaking down words into letters and combining letters to make words) it seemed necessary to develop a test based on these principles.

a) Part-Whole Task

A suitable task was found in Piaget's *Mental Imagery* (1971b) book. In this task, called the Part-Whole Task, the child was shown the model of common geometric shape (a circle, or a square) and then asked whether or not a number of pieces glued on a board could be put together to make a shape like that of the model. The child could solve this task by two methods, he could either mentally subdivide the model to see if the pieces present could be made from the model, or he could mentally put the pieces together to see if they made the model shape. In other words, he could use either partitive addition or subdivision, or both to solve the problem. After the child had made the decision on whether or not the pieces go together, he was given the pieces and asked to test his decision. The reassembling of the pieces gave the child feedback on his decision and tested to see whether the child could in fact reassemble the pieces as he said he could.
The task involved ten items, five using the square and five the circle. The models were alternated beginning with the easiest and proceeding through various stages of difficulty to those most difficult in Piagetian terms. Thus there were both easy and difficult circle and square problems. Figure 1 shows the actual test items used. The model circle and square were both four inches in diameter and were made of red bristol board glued on white 8" x 8" cards. All the other pieces glued on the cards were made to scale so that the pieces could actually be placed on the model to make a shape the same size as the model. The pieces were also made of red bristol board and they were glued on 8" x 5" cards which were plastic coated. Each card in turn had an envelope on the back containing a duplicate set of the pieces glued on the front of the card. The pieces on the front of the card were glued on in random order and scattered across the whole area of the face of the card so that their placement was no help in allowing the child to reassemble the pieces.

If this Part-Whole Task is conceptually analysed in terms of those cognitive structures required to solve each item, it is possible to come up with a list of items ordered in difficulty. Piaget considers this task at its more difficult level an indirect conservation of form problem (1971b), since the child must decide if the pieces presented would go together to conserve the form of the model whole (i.e., the circle or square). The easiest items are those that maintain the form of the original, e.g.,
a large square is cut into quarters leaving four smaller squares. These present no conservation of form problems. This is interesting since it suggests a similar problem to that experienced by children in continuity experiments. Children at an early stage in continuity believe that the smallest piece that can be made from an object, will still resemble that object. In other words, the smallest possible part of a triangle will still be triangle shaped. This is an example of the pseudo-conservations evident at the pre-operational level. Considering this, it would be predicted that items that have few pieces and which generally maintain the shape of the model, should be successfully solved at the pre-operational level. Items one to four (see Figure 1) would fall into this group and as such should be successfully solved by Stage IIB (age 6 - 7). It should be noted that the simple halving involved in the first two items probably makes these easier and so probably the first circle and the first square could be solved at Stage IIA (age 5 - 6) using perceptual cues. Also Item 4, the square does not actually maintain the initial form of the square, but the fact that we are again dealing with a halving operation suggests that it could be solved without recourse to Piagetian operational structures. Circle 5 and Square 6 on the other hand are more difficult involving a larger number of pieces and being based on triangular (with or without curvilinear sides) rather than circular or square shaped pieces. In order for these items to be solved, the child must
be capable of performing transformations of the given data and so needs the reversibility characteristic of concrete operations. Piaget suggest that at this level the task involves the "...anticipatory transformation image by dissociation or by combined displacement and reassembly", (1971b, p. 336). While these two items, therefore, should not be solved until the child has reached the level of Concrete Operations, there are also still enough clues to allow the child to solve them early in Stage III, at Stage IIIA (age 7 - 8). The remaining four items all require a very sophisticated approach to reassembly, particularly the last square and circle items which are made up entirely of triangular pieces. The other two items are made more difficult because they are both negative instances. That is, although the required number of pieces were present, because of differences in size or curve, they could not be assembled to make up the model. These required special vigilance on the part of the child since all other items did in fact reassemble to the model. These four items then, should not be solved until Stage IIIB (age 8 - 9).

Each of the ten items of this task were scored out of four. The child was given one point if he was correct in whether or not the pieces would go together and a bonus confidence point if he could explain or justify his reasons for believing that the pieces would go together (or would not). The actual assembly of the pieces was also scored out of two. The child was given two points if he correctly assembled the pieces and only one point if he
correctly insisted that the pieces would go together but could not in fact assemble the pieces. Thus, each item had a total possible score of four and the Part-Whole Task (ten items) had a total possible score of 40.

b) Transformation Task

Another Piagetian task which involves in a somewhat more loose relationship, the concept of proximity, is one that was used to test the flexibility of imagery involved in making transformations. This task, also taken from Mental Imagery (1971b) uses four black sticks approximately two inches in height and a quarter inch in thickness, placed in flesh coloured plasticine and an elastic (one quarter inch in width). The four sticks were originally placed in the form of a square with each stick forming a corner. The child was asked what shape the elastic would make if it were put around the four sticks. The child was then asked what form would result if the sticks were moved in specific directions (e.g., to form a triangle, diamond, etc.). It should be noted that the sticks were never actually moved from their starting square, their displacements were only gestured. A series of eleven black line drawings (see Figure 2) were used from which the child was asked to pick the one that most looked like the shape that would result from the transformation in question. The child was always asked to name the shape first and then to point to the drawing. Since very few children know the names of all the shapes, e.g., rhombus,
Figure 2. Line Drawings Used in the Transformation Task.
the choice of picture was taken to be the main indication of whether or not the child actually understood the transformation. The children were given the option of drawing in the present study if they could not find a drawing for the shape they had in mind. However, this rarely occurred.

Proximity seems to be involved in this task since the child must establish a form by bringing together several points. However, proximity is only one aspect of the task since the child never actually sees any of the configurations beyond the initial square, and thus must rely on a mental image of the proposed transformation. Moreover, the image involved must be anticipatory, in the sense that it must anticipate the results of an imagined transformation. This task then, (called the Transformation Task) also tests the child's ability to go beyond the static configural aspect of the pre-operational image to the operational anticipatory image. It is interesting to note, that Inhelder also mentions this aspect of spatial representation in her description of the dyslexic boy, "...his imagery remains rigid and static and he is unable to transform configurations" (1961, p. 164). Thus the Transformation Task, although primarily concerned with measuring the child's ability to use transformational anticipatory images, also has a proximity aspect to it in the sense of bringing points together to form a whole.

The Transformation Task can also be analysed in terms of the difficulty of individual items in the task. Since the first shape,
the square can be read perceptually and since the child is actually allowed to put the elastic around the sticks, if he cannot immediately solve the problem, this item is not actually considered as part of the task, and so is not scored. The next shape, the enlarged square, is reasonably simple since shape is conserved (the square) and only the size is changed. Thus, it seems possible that this item could be solved without the introduction of Piagetian operations. However, it does require an anticipatory image since the shape is not actually seen, so it would most likely be solved at Stage IIB (age 6 - 7). The next two items, the diamond and rhombus require transformations in both size and shape and hence require an anticipatory transformational image relying on a flexibility only established once reversibility is present. Concrete operations are, therefore, required for these two items to be solved. However, both these shapes still use each of the four sticks as corners when creating the new shapes. This is not true of the fourth shape, the triangle. Since this transformation is much harder to imagine, the triangle should be the hardest item to solve. It is, therefore, suggested that the rhombus and diamond will be solved by the child at Stage IIIA (7 - 8) and that the triangle would be solved a little later at Stage IIIB (age 8).

Each item in this Transformation Task was scored out of six. When constructing the eleven line drawings from which the child was to choose the correct form, pilot studies where the children
were asked to draw the shapes they expected were used. This resulted in the inclusion of five open figures (see Figure 2) all drawn by the children. Since Piaget (1967) states that the distinction between open and closed figures is the earliest topological distinction made, it seemed necessary to recognize this fact in the scoring. Thus, a child was given two points even if he chose the wrong form if it was a closed form. The child was given four points if he chose a closed form which was near in shape to the one described. For example, if he chose the quadrilateral with four unequal sides for the rhombus, Five points were given for the correct choice with no explanation and six points were given if the correct choice could be properly justified (the one confidence point). Thus, each item was scored out of six and the Transformation Task had a total possible score of 24.

2) Order - Enclosure

The other pair of complimentary topological structures are order and enclosure and these are based on the earlier elementary structures of proximity and separation. For Piaget, (1967) "...order implies proximity, separation, and a constant direction of travel" (p. 86). The essential aspect of both order and enclosure is 'betweeness'. If B is between A and C, then the three letters form an order A B C, however, A and C also are the boundaries surrounding or enclosing B. In Piagetian terms "...the relation of between linking an enclosure with a dimension
is itself a relationship of order." (1967, p. 80). Obviously then, surrounding or enclosure, and order are interdependent systems with surrounding emphasizing the boundaries and order emphasizing the directional (in the sense of sequential positioning) component of the same spatial configuration. Piaget admits the close relationship between these two concepts, but seems inclined to view order as the more fundamental of the two notions, choosing to discuss it first. Also, he uses separate tasks for each concept, again indicating his view that although the concepts overlap, they still can be partially isolated for individual study.

c) Order - Bead

The order task Piaget (1967) uses involves beads on a string. For this task the child was given a box with a large number of different coloured wooden beads and a straight black stick slightly pointed at both ends. He was then shown the model, a string with five different coloured beads on it, and asked to reproduce the order with beads from the box placed on the stick. After each trial, all the beads were removed from the stick and replaced in the box. The model was also removed after each trial and then re-introduced at the beginning of each new trial. In the case of the beads being placed in a circular order, the two ends of the string of the model were threaded through two of the beads, thus making a circle whose beginning and end could not be readily determined. For every trial the child had to use the stick, so he had to mentally transform the circular model rather than
matching using another string. The trials were presented in the
order: straight reproduction of given order, reproduction of the
order in reverse, and reproduction of the circular order.

If this Order-Bead Task is conceptually analysed in greater
detail, it should be possible to rank order the items in the task
in terms of the Piagetian constructs underlying success on each
item. Generally, this task begins by asking for perceptual re-
production of an ordered series and ends by testing the child's
ability to operationalize the order concept by reproducing the
beads in reverse order. Reproducing the given order of beads on
the string is a task largely requiring a perceptual reading off
of the visually present objects. According to Piaget, the child
should be successful on this problem around the age of 5 or 6.
Thus, if a child can correctly perform this item, he is said to
be in the early pre-operational stage (Stage IIA). In order for
the child to be able to transform a circular order to a straight
order, his concept of order must contain the idea of betweeness
at a more advanced level. For example, he must know to put the
red bead between the blue and the yellow beads, but he must also
know that the yellow bead is between the red bead and the purple
one. In other words, he must have the concept of over-lapping
surroundings. If the child can correctly reproduce the circular
order, he would be at Stage IIB. Reproducing the order of beads
in reverse order to the ones shown requires the Piagetian
structure of reversibility which is only present when the child
reaches the Stage of Concrete Operations. Since reversibility is one of the earliest structures to develop in the Concrete Operational Stage, the child should be able to reproduce the reverse order of beads on the string at Stage IIIA (age 7 - 8).

On scoring this order task, each of the three items was scored out of six. One point was given for each bead in the correct place, and a bonus point was given for a good explanation of why the order was as the child had presented it. Thus, the one extra point was essentially a confidence measure to make sure the child was not simply guessing. The total possible score for the Order-Bead Task was 18 (six for each of the three items).

d) Order Tunnel

Since order seems to be such a crucial aspect in reading, both in terms of putting the letters in the right order to form a word and putting words in the right order to form a sentence, and since the task just described is supposed to be mastered by the time the child is seven, it was felt that it would be wise to use another order task as well.

The second order task involved order through rotation. This task was described in the Child's Conception of Movement and Speed (1969) and then modified in the Imagery book (1971b). Three beads were placed on a rod and the rod placed in a tunnel which was then rotated an even or odd number of times. The child had to predict the order in which the beads will emerge from the tunnel. This gets at the child's ability to imagine states and transformations as well as to understand the invariance of order. In the
Order Tunnel Task, the same beads and stick were used as in the Order-Bead Task. This time E placed three beads on the stick and then took three more beads of matching colours from the box and placed them in front of the child in the same order as those on the stick. After E had determined that the child knew that the two sets of beads were the same, E introduced a black cardboard tube about an inch and a half in diameter. She then placed the stick with the beads directly into the tunnel while the child was watching and asked him to predict which bead would come out first from the end of the tunnel. After the child had made his choice of order and given his explanation of why that order (he continued to have his three beads in clear view), the stick was then removed from the tunnel and the order of the beads observed. After each trial, the beads on the stick were placed beside the model three beads so that the child could determine that the two sets were again the same. With the other trials, E placed the stick in the tunnel and then rotated the whole tunnel while the child was watching, emphasing verbally the number of turns the tunnel had taken. When the rotation was complete, E indicated one end of the tunnel and asked which bead would come out first from that end. There were four trials in this task given in the following order: no rotation, 180° rotation, 360° rotation with end of tunnel reversed for questioning, and 540° rotation. After this part of the task was complete, the child was asked to describe how the beads turn in
the tunnel. He was then shown a set of eight drawings of the trajectory (see Figure 3) and asked which one best showed the path of the beads. These trajectories were taken from *Mental Imagery* (1971b, p. 140). If the child could not find a picture that he thought would fit the bead movement, he was allowed to draw his version.

The Order-Tunnel Task can also be conceptually analysed in terms of the degree of difficulty of individual items. Generally, with regards to the Order-Bead Task, predicting the order of the beads through the tunnel without rotation is at about the same degree of difficulty as copying the order of the beads on the string. Predicting the order of beads with rotation is just slightly more difficult than being able to reverse the order and reproduce circular order. However, predicting the trajectory of the beads during rotation is much more difficult. It requires the co-ordinate system evolved in Euclidean space since the beads must cross over the rotating middle bead (Piaget, 1971b). Thus, the successful description of the trajectory of the beads is not possible until the child is capable of using the co-ordinate system (at about age 8 or 9). If the order of difficulty of specific individual items is considered, predicting the order of beads coming from tunnel without rotation, requires only a perceptual reading off of the visually present model beads and thus should be successfully mastered at Stage IIA (age 5 - 6). According to Piaget (1971b), the 180° rotation is
also quite simple since it relies only on the end result of rotation itself ("... anticipation of the result of the rotation precedes representation of the trajectories themselves by 3 to 4 years." 1971b, p. 138). In Piaget's study one hundred percent of the six year olds could successfully predict the order of beads with a $180^0$ rotation while only eight percent could describe (by drawing) the trajectory of the beads. Thus, $180^0$ rotation should be predicted correctly in the present research at Stage IIB (age 6 - 7). Predicting the results of the $360^0$ and $540^0$ rotations is more difficult since the child must have some understanding of the effects of rotation and this can only come with the reversibility of Concrete Operations. However, if the child is not required to correctly reproduce the trajectory of the beads, he should be able to succeed on these items at Stage IIIA (age 7 - 8). In order to be able to correctly reproduce the trajectory of the beads during rotation, the child needs a sophisticated knowledge of the movement during rotation. Piaget (1971b, p. 139) states that this requires "...comprehending a displacement as distance covered, with its various characteristics — direction, measurable size, shape and orientation against reference systems or coordinate axes." Since the coordinate system does not evolve until late in the Concrete Operations Stage, choosing and explaining the correct bead trajectories should not be successful until Stage IIIC (age 9 - 10).

For the first part of this task, predicting the order of beads
Figure 3. Bead Trajectories Used in the Order Tunnel Task
coming from the tunnel, each item was scored out of four. One point was given for each bead in the correct order and a bonus point was given for the confidence of the answer.

Scoring for the trajectories was more complex. There were eight possible trajectories to choose from, increasing in the degree of accuracy in describing the trajectory. The first two drawings (see figure 3) were the poorest showing no definite direction or having the beads turn on themselves; therefore, if the child chose either of these two drawings he got zero points. The next two drawings (numbers III and IV) have the advantage of showing right-left directions and some consistency, however, they still are very poor representations of the trajectory and therefore, a choice of drawings III and IV was given only two points. Drawings V and VI are the first to show a curved path although the trajectories are still incorrect, particularly for the middle bead, thus selection of either of these drawings gave four points. Drawing VII is the first to have the correct trajectory of the middle bead, however, it still fails to represent the trajectory of the two outside beads as symmetrical about the horizontal axis. Selection of this drawing was worth six points. Finally, Drawing VIII, being correct in all aspects was worth eight points if chosen. Since the explanation of the trajectory was complex, the child was given four additional points if he could correctly explain why he chose the trajectory (part marks were given for less than perfect explanations). The trajectory part of the task,
then, was scored out of 12 altogether and the rotations through the tunnel out of 16, given an over-all possible score for the Order Tunnel Task of 28.

A Total Order score was also computed based on the child's performance on both the Order-Bead and Order Tunnel tasks. The total possible score for the combined order tasks was 46.

e) Enclosure

The complimentary structure of order is surrounding or enclosure which is also relevant for reading since attention to interior detail is important in discriminating letters and words. Piaget uses a task based on the simple overhand (reef) knot to test this concept. The child is asked if a knot tied tightly and one tied loosely are the same (i.e., tied the same). He is also asked to distinguish between true and false knots. For example, the child is shown two closed circles which are overlapping and is asked to compare these with two circles jointed together. He is also asked to distinguish between two knots, one which is an over-hand knot with its ends joined and one which is homeomorphic with a circle when untwisted. Finally, he is shown a left and right over-hand knot and asked if these two knots are the same. These knots are represented in schematic form in Figure 4.

The knots were all made from yellow nylon boating rope approximately one-half inch in diameter. In those false knots where a circle or ends of a knot needed to be joined together, the rope was fused together by heat. The knots were presented in sets of
Figure 4. Knot Pairs Used in Enclosure Task
two and the child was asked to make a same-different judgment and to justify his answer. In the first trial, involving the slack versus the taut knots, the child was given a piece of rope and asked to tie it in a simple knot. When he had successfully done this, he was asked to pull his knot tight (if he had not already done so) then E took another piece of rope and tied it the same way as the child while he was watching, but leaving the knot loose. Then E asked the child if the knots were the same. For the other trials, the knots were presented already tied since to do otherwise would eliminate the child's need to analyse the knots and discriminate them. For the two circles closed but only resting one partially on top of the other versus two closed circles actually joined together, the two "knots" were presented on a card having been assembled while the child was not looking. For the circle versus the overhand knot joined at the ends (making a clover leaf), the circle was twisted so that it resembled a knot with two loops. For the left and right over-hand knots, the knots were presented very loosely tied so that it was easy to trace out the path taken by either rope. For all of the knots, if the child got the answer wrong, he was asked to imagine that the knot was a road and that a little car was driving over the road. He was then asked to trace the path of the car with his finger. After the child had traced the path of both knots in question he was asked if the knots were the same. In all of the trials, the child was free to handle the knots as much as he
wished. The order of the trials was as follows; taut versus slack knots, left versus right overhand knots, two circles joined versus two circles not joined, and finally the twisted circle versus the cloverleaf. According to Piaget, at Stage IIA the child is capable of tying a knot but he cannot distinguish between any of the sets of knots presented. At Stage IIB (around 6 - 7), the child knows that the taut and slack knots are in fact the same knots (i.e., he has the concept of homeomorphism), but he cannot distinguish between any of the false knots or the left and right overhand knots. At Stage IIIA (age 7 - 8) the child is able to distinguish the false knots. He can do this because he is capable of following the path taken by the string and reproduce, in reverse, the motions involved in setting up the knot. In other words, the child now can use reversibility to solve the task. Solving of the left-right overhand knots does not come until early in Stage IIIB (age 8), this is because these knots require closer attention to detail and because the child must abandon his homeomorphic approach in order to solve this problem.

Each item in the Enclosure Task was scored out of six. Two points were given if the child gave the correct answer but gave the wrong reason; for example, if he said the knots were the same because the rope was the same colour. Three points were given if the child answered correctly only after the path of the car had been traced out completely on both knots and the same-different question asked again. Four points were given if the correct
answer was given after E explained the car path but before the child actually traced the path out. If the child gave the correct answer and a somewhat fussy or hesitant (i.e., easily talked out of his choice) explanation, he received five points. If the answer was correct and the explanation clear and confident, the child received six points per item. The total possible score for the Enclosure task was 24.

II) Projective and Euclidean Space

In terms of projective and euclidean space, it will be recalled that these two constructs evolve simultaneously from the earlier developing topological space. Thus, any tasks involving these types of space also involve topological space structures. Projective space is concerned with the object and a point of view and euclidean or geometric space is concerned with objects in relation to each other and involves things like measurement and co-ordinate system.

In terms of reading, the most relevant projective constructs are those of before-behind and left-right. These are important identification cues for letters and words. Before-behind and left-right are perspective cues which evolve only when the child is able to realize that he has a point of view, and that his point of view is only one of any number of other points of view. As Piaget says: "...global or comprehensive co-ordination of viewpoints is the basic pre-requisite in constructing simple projective
relations" (1967, p. 244). Until the time that the child is capable of this co-ordination of viewpoints, relations such as left-right and before-behind remain as "false absolutes" based on the child's egocentric perception of his own viewpoint, as the one and only relational system possible. In other words, until the child masters the basic projective concept of multiple points of view, left-right and before-behind relationships are defined only in topological terms, as specific and unchanging aspects of the object itself. Only when projective space constructs develop, does the relativity of these locational concepts emerge.

f) Airplane Task

A Piagetian task involving the left-right and before-behind constructs, is described in Mental Imagery (1971b). It involves an airplane and a vertically suspended circular track. The airplane is placed at the bottom of the track and the child is then asked to demonstrate the path of the plane around the circular track with particular emphasis on its location at the sides and top of the circle. At each of these locations, the child is asked to indicate the plane's position (on top or underneath the track), and direction (same as in the beginning or reversed). If the child can do this, he is then asked to predict the positions of the two pilots (placed either side by side, left-right; or one behind the other; before behind) as they fly the circular path. This tests the projective concepts of right-left and before-behind,
without introducing the need for the geometric co-ordinate system.

There were two airplanes which were metal planes approximately five inches in length, manufactured by Mattel. They were painted red on top and blue on the bottom to emphasize the top and bottom. Both had a horseshoe magnet attached underneath so that they could sit upright on a metal ring. There was a circular metal ring supported vertically by a wooden base. The ring was approximately one foot in diameter and was made of one inch wide metal stripping. One of the planes was placed on the metal ring next to the wooden stand, parallel and close to the table so that it could travel the circular path created by the metal stripping. This plane (called E's plane) remained in this position throughout the experiment. Then E first demonstrated that both planes were on magnets and could stick anywhere on the ring including hanging upside down. Then E placed her plane in the position just described and told the child how the plane could fly around the ring tracing the path with her finger. She then asked the child to take his plane, which had been sitting on the platform beside E's plane and facing the same direction, and put it on the place on the ring indicated by E. This was explained by asking the child to imagine that E's plane was flying around the ring and then stopped for a rest at the indicated point. The child was supposed to put his plane where E's plane would be. Then E asked the child to explain why that was where the plane would be especially emphasizing whether or not it was
facing the right direction. After this practice run, \( E \) asked the child to place his plane at each of three positions she pointed to (see Figure 5 for the actual locations), and to justify his placements.

When the child had completed this part of the task, \( E \) took two pilots and placed them one behind each other on top of her plane, and a duplicate set on the child's plane. The pilots were roughly triangular in shape and made of Styrofoam. The triangle had a small base, a long straight side and a long curved side (see Figure 5), it was approximately an inch and half in height and ahalf inch thick. Each "pilot" had a small magnet attached to the base so that it could sit securely on both the plane and the circular track. Each of the two pilots in the pair were painted differently. One had a red front (the curved side), and a blue back (the long straight side), and the other had a yellow-orange front and a green back. This was done so that it was possible to determine both whether the order of the pilots was correct and whether the pilots were facing in the same direction. The colours of the pilots were emphasized as they were placed on the plane. Again the circular path of the plane was described and then the child was asked to place the pilots on the ring the way they would be when the plane was at that point. The one set of pilots always remained on \( E \)'s plane as reference points and the child had to move his pilots. It should be noted that only the pilots were placed on the ring,
Figure 5. Schematic Drawing of Apparatus Used in the Airplane Task
not the plane plus pilots. Thus, the child had first to decide the direction and orientation of the plane at the indicated position and then how the pilots would be placed in relation to the plane, and then place only the pilots on the ring in the correct position. Once the three positions were completed with the pilots one behind each other, the same procedure was repeated with pilots presented side by side.

With regard to the difficulty of the Airplane Task, Piaget points out that this task is concerned with "...movements which have no external boundaries, which occur within a closed framework and in which any problems will be related to the orientation and position of the moving body." (1971b, p. 86). It is only when movement is considered in terms of crossing boundaries or taking place within a set of boundaries that the geometric coordinate system becomes involved. In terms of the relative difficulty of individual items within the task, the following order of difficulty appears justified. Placement of the plane itself is less difficult than placing the pilots since correct placement of the pilots presupposes correct placement of the plane. Considering the path of the plane alone, of the three positions tested (the two sides and the top of the ring), the top position (position C) is the most difficult for two reasons. First, it is the farthest away from the model plane which sits at the bottom of the circle throughout the test, and so is likely to have the plane's location distorted simply because of the
distance travelled. Secondly, the plane at position C must be inverted and this inversion is difficult for the child to imagine (How can the plane fly upside down?). Positions B and D (B just after the plane "takes off" and D, just before it "lands"), are somewhat easier than C with D being just a little more difficult than B since errors at C may cause continuation of this error at D. When considering the type of spatial constructs involved with the airplane alone, it is clear that we are dealing largely with a problem of topological space. Since boundaries are not really involved, the problem becomes one of maintaining a uniform direction around a circular path and this implies an ordinal succession of enclosures which implies topological space. Thus, a child should be able to solve all the positions with the airplane alone by the time he is in Stage IIB, (age 6 - 7).

Considering the tasks involving the pilots either one behind the other, or side by side, it is apparent that the tasks are more difficult. There is still a topological element in that the pilots must maintain their original order, but there is also a projective aspect involved. The left-right, and before-behind relations of the pilots are dependent on the point of view of the circling plane and the circular path. That is, the child must decide first what position the plane would be in and then what position the pilots should be in, in relation to the plane. Since the child cannot be aware of points of view until he has reached the reversibility characteristic of concrete operations, he should
not be able to solve the positioning of the pilots problem until Stage III. Piaget has consistently pointed out that the before-behind relationship is easier to establish than the left-right. (e.g., 1967). Therefore, it would seem reasonable to expect that the task of placing pilots one behind the other should be completed successfully before the task with the pilots placed side by side. Thus, the child should probably be able to master the before-behind pilots at Stage IIIA (age 7 - 8) and the left-right pilots at Stage IIIB (age 8).

In scoring the Airplane Task, five points were given for each of the positions of the airplane alone, and seven points were given for each of the positions involving the pilots. For the plane alone, two points were given for the correct direction (i.e., front-back, going around the circle) and two points for the correct orientation (i.e., up-down, on top or underneath the ring) of the plane. As with the other tasks, one point was given for the explanation of why the position was correct with the confidence necessary to keep the child from being talked into changing the position. For the pilots, two points were given for the correct relation of the pilots to each other (e.g., the correctly coloured pilot pilot being first in the before-behind relation). The correct orientation of the pilots to the ring (i.e., up-down, on top or under the ring) was also given two points. The direction of the pilots were also given two points (i.e., if the pilots were facing so that they could travel in
the correct direction around the ring). The seventh mark was for confidence as in the first part. Thus the total score for the airplane alone was 15 and for each of the pilot set ups (one behind the other, and side by side) was 21. The total possible score for the Airplane Task was 57.

g) Left-Right Task

The concept of left-right considered in this last Airplane Task is only one aspect of the more general left-right relation. In the Airplane Task, the left-right positions remained the same, that is, the same pilot was on the right side at position D as at position B. Thus, the task was concerned with maintaining an existing relationship. What happens when the child must establish this relationship himself? In this next task, called the Left-Right Task, the child was asked to locate right and left on himself, on the examiner, and with a group of three objects. He was seated facing E and asked to point out his own left and right hands, eyes and feet. He was also asked how he knew that it was his right hand, etc. Then, while still seated in the same way, he was asked to point out these same choices on E's body. The order of the questions was: right hand, left eye, left foot, right foot, right eye, left hand. Once these two parts of the task were completed, three objects were placed in a row in front of the child; a bead, a stuffed dog (from the Landscape Task) and a stick. The child was then asked what was to his right of the dog (which was in the middle) and how he
knew this. This question was followed by the remaining five positions, e.g., what is to the left of the bead, right of the stick and so on. If the child got the first position wrong, i.e., "to the right of the dog", E made sure that he was viewing the relations from his point of view and was not still using E's perspective, and then continued on with the questioning.

The development of these left-right skills closely parallels the development of the three types of space. Locating left and right on the child's own body, is essentially topological, having to do with the characteristics of the object itself. Locating left and right on the examiner, requires projective structures. The child must realize that left and right are relative locations and that with the examiner facing him, the left-right will be reversed in terms of those on his own body. When locating what is to the left or right of something, the child needs the geometric co-ordinate system. That is, he must be able to impose a set of vertical-horizontal axes on the series of objects so that one object can be described as to the right of one object and to the left of another. Thus, this left-right task, first described by Piaget in *The Judgment and Reasoning of the Child* (1926), and later used by both Elkind (1961) and Laurendeau and Pinard (1970), clearly differentiates the child's ability to handle the different types of spatial concepts. Locating, left and right on his own body, being strictly topological, should be mastered by the child early in the pre-operational stage,
Stage IIA (age 5 - 6). Both locating left-right on the examiner, and describing left-right relations, require reversibility, and so should not be mastered until Concrete Operations. Since awareness of the flexibility of view points evolves earlier than the co-ordinate system, which is one of the last geometric constructs to evolve, locating left-right on the examiner should be mastered first (Stage IIIA, age 7 - 8) and relational left-right is not mastered until Stage IIIC (age 9 - 10).

Scoring for the Left-Right Task was quite straight forward. Twelve points were given to each of the three main categories, left-right on self, left-right on examiner, and left-right relations. Within each category the child was asked to locate six positions and was given two points per position correct. One point was given if the position was correct and one point if the child was confident and could explain his choice. There was one aspect of the scoring which was designed to differentiate between the left and right labels and left and right concepts (Corballis, 1973, is one of the researchers who makes this distinction). If the child reversed the left-right labels consistently on both himself and the examiner (i.e., always called left, right), he was scored as though he was correct, loosing no points at all. In this case, it is assumed that he has the concept of left and right but confuses the labels (this rarely occurred in the testing). If, on the other hand, the child was reversed on himself but correct on the examiner, he was given no points for the examiner, even though
his answers were correct, since it is assumed that he is confused both conceptually and in labelling. The total possible score for the Left-Right Task was 36.

h) Landscape Task

As has already been discussed, the crucial aspect of geometric space for reading, is the co-ordinate system. It is only when the system of axial co-ordinates can be imposed on a set of perceptions, that orientation in space can be represented accurately. In other words, there should continue to be occasional errors in the orientation of letters and words in reading and writing until this co-ordinate system has been fully established. One possible reason that there are not more orientation errors, is the element of rote memory involved in learning to read, discussed earlier in relation to Furth's work.

There is one Piagetian task, described in Child's Conception of Space, that tests the child's ability to consistently use the co-ordinate system as well as testing the other major spatial concepts at the same time. This task, called the Landscape Task, involves the placing of objects on a schematized village layout. The exact layout used in the present study is more closely allied to that used by Laurendeau and Pinard (1970) than to that described by Piaget since Piaget is very vague on specific details and Laurendeau and Pinard are not.

The child is faced with two identical layouts, one in which the examiner places his animal and one in which the child places
his corresponding animal. The problem for the child is to put his animal in exactly the same place on his landscape as the examiner does on his own landscape. This problem is further complicated for the child by the fact that his landscape is rotated 180° from that of the examiner's. In other words, the child's landscape is upside down in relation to the examiner's landscape. The child must put his animal on the same place (e.g., near the same house) and facing in the same direction as that of the examiner.

Two identical landscapes were made (see Figure 6), one for E and one for the child. Each landscape consisted of a 14" x 22" white plastic coated board which was divided into four unequal quadrants by the intersection of a road and a set of railroad tracks drawn on the board in black ink. The houses were made from plastic bricks from a children's building set. There was a large blue house approximately one and a half by one inch and about one and a quarter inches tall, which was placed by position B, alone in one quadrant. There was also a long red house, about one inch by three inches and about one and a quarter inches tall. This was placed near the intersection of the road and the tracks, parallel to the railroad tracks and in the quadrant diagonally opposite to the one with the blue house. In the same quadrant as the long red house, in the far outside corner, were placed two small houses and a tree. Each house was the size of one brick, i.e., an inch by half and inch and a half inch high, one was red and the other yellow. Both houses were covered by large green roofs which partially
Figure 6. Landscape Task

Note: Arrows indicate direction of dog,
Letters indicate location of dog.
covered the brick part of the house. Between these two small houses was a three inch plastic model of a pine tree. The other two quadrants were left empty. Thus, each landscape consisted of four houses: one large blue one, one long red one and two small ones, one yellow and one red, and a green tree. All of these objects were secured to the board with small pieces of plasticine so that they could not slide.

A stylized dog was used as the object to be placed at various locations on the landscape. The dog had a pronounced nose and pot belly so there could be no doubt which was the front and back of the dog. It was made of rust coloured suede with a contrasting stomach of light beige. The dog stood approximately three inches high and was about an inch and a half in diameter at the base. The basic shape of the dog was somewhat pear shaped, thus giving a solid base which would not easily tip when the dog was placed on the board.

After several practice trials on the unrotated landscape, where it was emphasized to the child that he had to not only place the dog in the same place as that of E's dog, but that the dog had to be facing the same way as well, the child's landscape was rotated 180° while the child watched. The dog was then placed at twelve different locations on the rotated landscape (in the order B, H, I, A, F, C, G, L, D, J, K, E).

The landscape is a complex task requiring the child to understand the notions of left-right and before-behind, as well
as the co-ordinate system. It also relies on topological constructs such as proximity, separation and enclosure. Thus, this task is really a composite of all the spatial constructs. Although generally all of these spatial structures are required for this task, some positions on the landscape are easier to solve, and use more basic spatial constructs, than others. For example, position B (Figure 6) is located beside the big blue house. It can be solved largely on the basis of proximity since there is no other large blue house on the landscape. Only one spatial cue is required to correctly locate this position. One spatial cue is also all that is needed for positions C, (in front of the large red house), and E (between the big red house, and the group of little houses). Position D and A are a little more difficult to locate in that there is more than one possible position for them to occupy. For example, location A could be in front of either small house and still be correctly located in terms of one topological cue. However, there is still a very obvious cue which can make correct location quite simple. Position A is between the small house and the railroad track (surrounding or enclosure cue). Likewise, Position D can be characterized as between the road-track intersection and the big red house. Thus, although these positions are a little more difficult, since there is some chance of confusion, these positions are still relatively easy to locate. Positions F, G, and H all need two spatial cues to be located and so are more difficult since they require co-
ordination (and, therefore, need reversibility). For example, both F and G are topologically the same if considered only on the cue of "on the road" and thus there is a fifty percent chance of error if only this criterion is applied. In order to be correct, the child must use some other criterion as well, either topological or projective. Thus, the child could locate position H by considering it as on the road and near the small houses or on the road and closest to where the examiner is sitting. It seems evident then that positions F, G and H could not be located successfully until the stage of concrete operations, Stage III (age 8).

The remaining positions, J, I, L and K are the most difficult to locate and in fact cannot be accurately located without the co-ordinate systems. Position J is a little different from positions I, L, and K in that there are really only two quadrants (as opposed to four for the others) where it could be logically located, because there are only two empty quadrants. However, because J is located in the middle of an empty quadrant there are no topological cues that can be used to accurately locate the position within the quadrant even granting that the correct quadrant is chosen. Thus, some form of measurement must be employed, which thus requires the geometric co-ordinate system. With positions I, L and K, there are four possible locations based on the topological cue, between the road and the railroad track and, therefore, only a twenty-five percent chance of getting the position right on topological cues. In order to get all of these positions correct,
he must define the intersection further, in terms of, to the right or left of a distant cue and far or near the edge of the table. Thus, he must co-ordinate the horizontal and vertical axes of the landscape. These positions then, should not be successfully located until Stage IIIC (age 9 - 10).

In scoring the Landscape Task, an attempt was made to analyse all the various determinants that went into a correct placement, and one point was given for each correct determinant. The possible points were as follows:

1 point: dog in correct quadrant
1 point: dog facing right direction within a quadrant
1 point: correct enclosure (right neighbourhood)
   (e.g., between the road and railroad tracks)
1 point: correct distance from neighbouring objects
1 point: has left-right position correct with respect to neighbouring object
1 point: has before-behind position correct with respect to neighbouring object
1 point: confidence of placement.

Once this breakdown in determinants was established, each position on the landscape was analysed. It became apparent that not every position could be scored on each criterion. In fact, only Position A could be scored on all the criteria. Positions B, C and D, could be scored on all but one of the criteria (the left-right for B, and C and before-behind for D). For the remaining positions
both before-behind and left-right could not be scored because the before-behind or left-right dimension had to be in relation to something specific. This is not to say that these are not relevant dimensions for the other eight positions but just that things like before-behind are defined by the quadrant the dog is placed in. For example, if Position L is confused on the before-behind dimension, it would be placed at Position I, thus in the wrong quadrant. Since, in these positions, placement in the correct quadrant implies correct left-right and before-behind dimensions, for all the positions except A, B, C and D, the correct quadrant criterion was scored out of three (combining the individual points for the three criteria in the other positions). The before-behind and left-right criteria for the first positions are based on the dog's location within a quadrant in relation to an object present in that quadrant, e.g., a house. Since the other positions are not located near a specific object, these criteria do not apply. Thus, the final scoring system was the following: six points for each of positions B, C and D (lacking in one of the before-behind or left-right dimensions) and 7 points for all other positions. In Position A, one point was given for each of the six criteria plus the confidence point. For positions E, F, G, H, I, J, K, and L, three points were given for the correct quadrant and the scoring for the other criteria were the same. The Score Sheet (Appendix 3) has the exact list of criteria and their application to each location. Thus, the total score for the
Landscape Task was 31.

In summary, eight Piagetian tasks were used in this study:

1) Transformations - the elastic and four sticks
2) Part-Whole - parts of circles and squares
3) Order-Bead - five beads on a string
4) Order-Tunnel - beads rotating through a tunnel
5) Enclosure - knots
6) Left-Right - on self and examiner
7) Airplane - travelling a circular track
8) Landscape - placing a dog on a rotated village layout.

A summary table giving the Piagetian structures underlying all the items in the Piagetian tasks is presented in Table 1. The total possible score for all the Piagetian Tasks was 308.

General Procedure for Piagetian Tasks

It was found in pilot work that the two Piagetian tasks that most interested the children on first sight were the Landscape and the Airplane. Thus, since testing took quite some time, the Landscape Task was given first and the Airplane Task last, in order to maintain the child's interest throughout the testing period. The remaining tasks were given in the following order: Transformations, Part-Whole, Order-Bead, Order-Tunnel, Enclosure and Left-Right.

Throughout the testing session an effort was made to keep the child's interest both by stressing that each new task was something different ("And now we're going to do something else"). and by
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<tr>
<th></th>
<th>State II</th>
<th>Stage III</th>
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<tbody>
<tr>
<td></td>
<td>Pre-Operational</td>
<td>Concrete Operations</td>
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<tr>
<td></td>
<td>A</td>
<td>B</td>
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<td>Age</td>
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<td>6-7</td>
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<td>Co-ordinate System</td>
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</tbody>
</table>

### a) Part-Whole
- a) Circle 1 & Square 2
- b) Circle 3 & Square 4
- c) Circle 5 & Square 6
- d) False Circle 8 & False Square 7
  Circle 7 & Square 8

### b) Transformations
- a) Enlarged Square
- b) Rhombus
- c) Diamond
- d) Triangle

### c) Order-Bead
- a) Reproduce presented order of beads
- b) Transform circular order to linear
- c) Reproduce order of beads in reverse

### d) Order-Tunnel
- a) Predict order of beads without rotation
- b) 180° Rotation
- c) 360° & 540° Rotation
- d) Bead trajectory

### e) Enclosure (Knots)
- a) Can tie knot
- b) Taut & slack knot
- cc) False knot - 2 circles jointed & loose
- d) False knot - cloverleaf & twisted circle
- e) Left & Right overhand knots

### f) Left-Right
- a) Left-right on self
- b) Left-right on examiner
- c) left-right relations of three objects
Table 1 (Cont'd)  (a)

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<thead>
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Age
- 5-6
- 6-7
- 7-8
- 3-9
- 9-10

(a) Airplane
- a) airplane alone
- b) pilots one-behind other
- c) pilots left-right

(b) Landscape
- a) Positions B, C, E
- b) Positions D, A
- c) Positions F, G, H, J
- d) Positions I, L, K

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<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
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<tr>
<td>g) Airplane</td>
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<tr>
<td>a) airplane alone</td>
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<td>b) pilots one-behind other</td>
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<td>X</td>
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<tr>
<td>c) pilots left-right</td>
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| h) Landscape |     | X   |     |
| a) Positions B, C, E |     | X   |     |
| b) Positions D, A |     |     | X   |
| c) Positions F, G, H, J |     | X | X   |
| d) Positions I, L, K |     |     |     |
pacing. Pacing simply implies that long intervals between tasks caused by setting up the next task were kept to a minimum so that the child's attention would not wander. Thus, as much as possible, all the tasks were set up before the child came in, on a large table and then as each task was performed, it was removed. This also served to give the child a sense of accomplishment since he could see that the number of things left to do gets progressively smaller. Any pauses that could not be avoided in the flow of testing were filled with conversation so that the child's attention was always focused on the E. Also, to maintain the smooth flow, no scoring was done during the testing. The child's response was recorded and his explanation written down verbatim but not scored until after the child left. Throughout testing, the child was given encouragement on how well he was doing.

Intelligence Test

The Peabody Picture Vocabulary Test (PPVT) was given to each child at the beginning of the first testing session and took about ten minutes to administer. The child was shown a series of pages with four pictures and asked which picture most closely described the word given by the examiner. Testing continued until six incorrect responses were made in eight consecutive trials. The score was computed by subtracting the number of errors from the total number of items attempted. This raw score can be converted to an I.Q. equivalent and in the present study the norms for age 7 - 6 to 8 - 5 were used in the conversion (thus only one column of
the norm table was used).

Reading Tests

The basic reading test used was the Gray-Oral Reading Test. This test involved a series of paragraphs of increasing difficulty. The child continued to read until he made seven or more errors in two consecutive paragraphs. A score was given for each paragraph based on a formula of the number of errors made and the time taken to read the paragraph.

In order to increase the sensitivity of the reading test at the low end of the scale, eleven other reading items were also introduced. Materials for these tests were taken from the other oral reading tests (The Gates McKillop Reading Diagnostic Test, the Gilmore Oral Reading Test, and the Gray Oral Reading Check Tests). The alternate tests and their scoring procedures are described below.

1) One alternate measure introduced was the reading of sentences placed on individual cards. This Sentences Test seemed useful since it eliminated one source of error common to paragraph reading—that of picking up a word or letter from a higher or lower line of the paragraph than the one being read. The actual sentences chosen were the first sentence of each paragraph from a set of paragraphs increasing in difficulty (Gilmore, Form C). The first sentence from another paragraph set (Gates McKillop) was also used in order to increase the number of simple items. The five sentences that resulted from this selection method are in Appendix
Four. The five sentences were given a total possible score of ten and then any errors were deducted from this total at a rate of one mark off per error. The actual sentences were mounted on individual pieces of white plastic-coated cardboard using black half-inch block letters.

For both the Gray Oral Reading Test and the Sentences Test the following were considered as errors: a) substitution - of one word for another; b) reversals - of letters, e.g., b for d, and of words, e.g., was for saw; c) omissions - leaving out words or sentences; d) mispronunciation of a gross nature so that the word is unrecognizable; e) hesitation - of thirty seconds or more; f) aid - word given by E when the child could not read the word at all; and g) repetition - child says the word or phrase more than once when reading sentence or paragraph. Also, two other types of errors were considered for the paragraphs alone; disregard for punctuation - no evidence that the child recognizes the end of one sentence and the beginning of the next; and time in seconds taken to read the paragraph, a rough estimate of fluency.

2) Another short type of reading test was the Spelling Test requiring the child to spell his own name, and the words was, saw and boy selected because they frequently incur reversal errors. This part was scored simply with one point for each word that was correctly spelled. The actual letters used were of coloured plastic approximately one inch in height. They came from a set of Magnetic Letters, (Mattel). The letters were placed in a pile
in front of the child so that no hint was given as to the correct orientation of any of the letters. The child then had to find the letters he wanted and place them on the table to spell the required word. There was no time limit and the child was free to change the spelling as often as he wished until he was sure that it was correct.

3) Six Topological Reading Tests were designed in order to get a closer understanding of the relationship between the basic Piagetian topological structures and reading. The basic element of proximity is a bringing together, so words were presented with letters randomly spaced; for example m--an. The child was simply asked to say what word was on the card. The actual words used were extensively tested in a series of pilot studies in order to confirm that the words were in the Grade Two child's basic vocabulary and that any confusions were reduced to a minimum. For the Separation Task, the basic concept is imposing a separation on a group of letters that are not separated. This was done by eliminating as much as possible, the spacing between letters. In some cases the letters were actually put inside each other, for example, the "a" inside the "c" in catch. The child was again asked simply to say what the word was on the card. A combined task using both proximity and separation was also used. Here some letters were squeezed together and some randomly spaced within the same word.

The same procedure was followed for Order and Enclosure Tasks.
and combined Order-Enclosure Task. For Order, the letters were jumbled and the child was asked to re-arrange the letters to make a word. For Enclosure, at least one letter was left out and the child was asked to fill in a letter to make a word. For the combined task, the letters of a word were re-arranged and at least one letter was missing. It should be noted that for the more difficult words in these three tasks, the child was allowed to use the plastic letters from the spelling task to help him if he wanted to.

In each of the six sets of cards these tasks produced, the method was the same. The set started out with a simple two letter word and progressed through five cards with the length of the word increasing by one letter with each card shown, ending with a six letter word. Thus, within each set, the task increased in difficulty. The two combined tasks, Proximity-Separation and Order-Enclosure began at the three letter stage instead of two, since it was impossible to combine both problems in a two letter word. However, they followed the same formula for increase in length from that point ending with a seven letter word. All the words were presented individually on white 8" x 5" plastic coated cards using black half inch block letters.

Scoring for these tasks was simple, one point was given for each word correctly identified. This gives five points per task and a thirty point possible total. Scoring was very lenient, if the child identified the word but mispronounced it he was given
the point unless the mispronunciation was so great that it was not evident that the child had identified the letters involved. With order, any real word was accepted, for example, both 'tab' and 'bat' for letters t b a. Also, proper names were accepted in both order and enclosure even if the spelling was suspect, for example: for the letters gyar, the name "Gary" was accepted and for d-n-ey, "Dany" was accepted. Also, although the letters lletit were supposed to elicit the word "little", "tell it" was also accepted. As far as making words in the Enclosure Task, if the child said the correct word but put in the wrong letter, he was given the point. Only in the case of gross misspelling was the child not credited with the word; for example, given the item p--ce, one child put in two ee's to spell 'peece' and said that this spelled "peach". Other than that, any real word was accepted even if it was not the one originally expected. These general scoring rules also applied to the combined Order-Enclosure task as well. A copy of the exact words used for all of the Topological Reading Tasks can be found in Appendix 4.

9-11) Three subtests from the Gates-McKillop Reading Diagnostic Test were also administered to the children. One was the Letter Naming Test, where the child is simply asked to name twenty-six randomly presented lower case letters. This test can reveal confusions between letters, e.g., b and d as well as establishing whether the child has this very fundamental requirement for reading. The second subtest given is part of the category called
"Recognizing the Visual Form or Word Equivalents of Sounds", and given the sub-title of Nonsense Words. This Nonsense Words sub-test has twenty items, for each item a nonsense word is read to the child and he must listen carefully and select the "word" spoken from a group of words similar in form. For example, the child is given the 'word' askintell and asked to find it among: 'uskuntall', 'sakinvel', 'askintell' and 'asktell'. While this test obviously tests knowledge of sounding techniques, it is also a good test of the child's ability to discriminate between similar forms on the basis of internal features and, therefore, is related to the topological concept of enclosure. Also, children having problems with reversals both for the individual letters, and groups of letters, will have difficulty with this task.

The third Gates-McKillop subtest used was found in the "Word Attack" category, subtitled "Recognizing and Blending Common Word Parts", in the present study, the test is simply called "Sounding". The child is given a list of twenty-three made up words and is asked to sound out the letters to make the "word". The words are things like "frable". Here again the major concern of this test is with the child's ability to sound out letters, however, it is also evident that reversals and interior detail can be tested in this situation. For example, if the child always sounds the beginning of the word correctly but then makes up the rest on general shape, this tells as much about his ability to break down the word configuration as it does about his sounding ability. Also, if the
child says fradle for frable, he is having problems with reversals.

One point was given for each correct word in scoring the Nonsense-Words and Sounding Tasks, thus giving a possible score of twenty for the Nonsense-Words and twenty-three for the Sounding. For the Letter Naming Task, the possible total score was five, with one mark off for every letter wrong. All three of these tasks are represented on the Score Sheet, Appendix 5.

All of the Reading Tests and the Peabody were administered together on the first day of testing, giving nine individual scores (in the analyses, the total Proximity-Separation, and the total Order-Enclosure scores are used instead of the individual scores). The order of testing was standard for all the children tested. First the PPVT was given, then the three Gates-McKillop tests in the order Nonsense-Words, Sounding, and Letter Naming; then the Spelling and Sentences, next the Gray-Oral Reading and finally the Topological Reading Tasks in the order Proximity-Separation tasks and Order-Enclosure. The total score possible on all the reading measures excluding the Gray which has no exact upper limit in this context, was 92. The highest score anyone achieved on the Gray was 41, thus, the total reading score possible was 133.

In an attempt to at least reduce the experimenter bias involved in using one experimenter for both the reading and Piagetian tasks which were tested on consecutive days, no scoring of either the reading or the Piagetian tasks was done until the child had completed all testing. Also, after the child had been given the reading tests, his name was written on a Piagetian test
booklet and only the Piagetian test booklets were taken into the testing the next day. While, admittedly, it is possible to remember from day to day the general performance of any one child, the number of tests involved (the Peabody, reading and eight Piagetian) makes it almost impossible to remember individual test performances. This is particularly true when no scoring is done until later and seven children were tested in one day.
RESULTS

Results were analyzed in several ways. First a correlational analysis on all 20 variables was carried out. A general presentation of these results is followed by a specific presentation of correlations related to Intelligence, Reading and the Piagetian tasks. Then the inter-relations between the Reading and Piagetian tasks are considered. Finally, the order of Piagetian task difficulty is compared with the order predicted from the conceptual analysis and a Stage Analysis is performed on each child's performance across the Piagetian tasks.

General Correlation

Scores on all of the variables discussed in addition to the Total Reading Score (the sum of the scores on all eight reading variables), the Total Piagetian Score (the sum of the scores on all eight Piagetian tasks), and a Total Order Score (the sum of the scores on the Order-Bead and Order-Tunnel Tasks) were intercorrelated. The resulting 20 x 20 correlation matrix is reproduced in full in Table 1, Appendix 6. The means, standard deviations and upper limits for these variables are presented in Table 2.

Of primary interest for this study is the correlation between the reading scores and the Piagetian scores. The Total Reading and Total Piagetian scores were significantly correlated (r = .67; df = 58, p < .001). The individual reading measure most highly correlated with the Total Piagetian score was the Gray Oral Reading
Table 2
Means and Standard Deviations for all Twenty Variables

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<th>Variable</th>
<th>Total Possible</th>
<th>Mean</th>
<th>Standard Deviation</th>
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<tr>
<td>Intelligence</td>
<td>--</td>
<td>67.25</td>
<td>6.54</td>
</tr>
<tr>
<td>Sentences</td>
<td>10</td>
<td>8.72</td>
<td>2.16</td>
</tr>
<tr>
<td>Spelling</td>
<td>4</td>
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<td>8.83</td>
<td>2.87</td>
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<tr>
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<td>23</td>
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<td>5.89</td>
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<td>15.54</td>
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<td>Total Order</td>
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<td>7.39</td>
</tr>
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<td>Total Piagetian Score</td>
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<td>209.75</td>
<td>42.03</td>
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</table>
Test, \( r = .62; \) df = 58, \( p < .001 \), and the reading variable least correlated with the Total Piagetian scores was Letter Naming \( r = .31; \) df = 58, \( p < .017 \). The individual Piagetian task most highly correlated with the Total Reading score was the Order-Bead Task \( r = .53; \) df = 58, \( p < .001 \) and the least correlated was the Order-Tunnel Task \( r = .32; \) df = 58, \( p < .012 \).

**Intelligence**

The mean Peabody Picture Vocabulary Test (PPVT) score was 67.25 with a standard deviation of 6.54. A PPVT score of 67 has a corresponding I.Q. of 102 and a M.A. of 8-2 from the norms for children between the ages of 7-6 and 8-5. The range of PPVT scores was from 55(I.Q. = 81) to 80 (I.Q. = 124).

When the children were divided up on the basis of the Total Reading Score and the top 20 children (i.e., scoring the highest on the reading variables) were compared with the bottom 20, the mean PPVT score for the Good Readers was 69.05 (I.Q. = 105) and for the Poor Readers was 65.35 (I.Q. = 98). This difference is not significant using the Hotelling's T^2 test for large numbers of correlations (the Triangular Regression Package, U.B.C. Computer Center). The means for every variable for the Good and Poor Readers along with the differences in means and levels of significance (using Hotelling's T^2) are shown in Table 3.

The PPVT scores were significantly correlated with the Total Piagetian Score \( r = 43; \) df = 58, \( p < .01 \) and not with the Total Read Score \( r = .23; \) df = 58, \( p < .10 \). Intelligence was also
<table>
<thead>
<tr>
<th>Variable</th>
<th>Good Readers Mean</th>
<th>Poor Readers Mean</th>
<th>Differences Between Means</th>
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<td>Order-Enclosure</td>
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<td>4.85</td>
</tr>
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<td>31.05</td>
<td>12.75</td>
<td>18.30*</td>
</tr>
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<td>11.25</td>
<td>6.45</td>
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<tr>
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<td>.80</td>
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<td>63.85</td>
<td>49.80*</td>
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<tr>
<td>Transformations</td>
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<td>10.75</td>
<td>6.75</td>
</tr>
<tr>
<td>Part-Whole</td>
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<td>22.60</td>
<td>5.30</td>
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<td>Order-Bead</td>
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<td>4.95</td>
</tr>
<tr>
<td>Order-Tunnel</td>
<td>20.40</td>
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<td>4.80</td>
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<tr>
<td>Enclosure</td>
<td>17.25</td>
<td>9.80</td>
<td>7.45</td>
</tr>
<tr>
<td>Left-Right</td>
<td>28.40</td>
<td>19.15</td>
<td>9.25</td>
</tr>
<tr>
<td>Airplane</td>
<td>50.60</td>
<td>28.10</td>
<td>22.50</td>
</tr>
<tr>
<td>Landscape</td>
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</tr>
<tr>
<td>Total Order</td>
<td>37.80</td>
<td>28.05</td>
<td>9.75</td>
</tr>
<tr>
<td>Total Piagetian</td>
<td>245.35</td>
<td>172.25</td>
<td>73.10*</td>
</tr>
</tbody>
</table>

*p .05
significantly correlated with the Left-Right, Airplane and Landscape Piagetian Tasks ($r_{L-R} = .34; r_A = .40; r_L = .36; df = 58, p < .01$). Partialling out the effect of intelligence on all the measures, the correlation between the Total Piagetian Score and the Total Reading Score remained significant ($r = .65; df = 57, p < .001$). Partialling out intelligence also had little effect on the other correlations. Only when such an effect is evident will the partial correlations be mentioned in the following sections. The complete correlation matrix with intelligence partialled out is in Appendix 6, Table 2.

**Reading**

The mean Total Read Score was 90.17 with a standard deviation of 22.66 and with a range of 37 to 126. All the individual reading scores except the Letter Naming Task correlated with the Total Reading Score beyond the .70 level (i.e., $r \leq .70; df = 58, p < .001$). The single variable most highly correlated with the Total Reading Score was the Gray Oral Reading Test ($r = .94; df = 58, p < .001$), and the variable that least correlated with the Total Reading Score was the Letter Naming Test ($r = .45; df = 58, p < .001$).

In terms of the intercorrelation between reading tasks the Letter Naming Task was the variable least correlated with the rest of the reading tasks. It did not significantly correlate (i.e., $p < .01$) with Spelling, Read Order-Enclosure, and the Nonsense-Words. All the other reading variables were significantly correlated with each other. The Gray Oral Reading Test was the single variable
most highly correlated with all the other reading variables taken individually.

If each reading variable is considered in terms of the pattern of correlation of itself with other reading variables, some interesting relationships become apparent. For each reading variable, the three other Reading Tasks most highly correlated with it have been noted. These ordered correlations are presented in Table 4. It is apparent that neither Nonsense Words nor Letter Naming was most highly correlated (i.e., either first or second after the Gray) with any of the other reading variables. Moreover, after the Gray, Proximity-Separation and then Sounding are the most highly correlated with the other reading variables.

The two Piagetian Tasks most highly correlated with any given reading variable were also examined and the pattern of results is presented in Table 5. From this table it can be noted that none of the reading variables correlate most highly with the Part-Whole Task or the Order-Tunnel Task. The Order-Bead and the Left-Right Tasks are the tasks most frequently correlated with the reading variables.

The Reading Tasks were also analysed in another way. Based on the Total Reading Score, the children were divided into three groups: Poor Readers (Total Reading Score of 79 or less), Average Readers (Total Reading Score of between 80 and 99) and Good Readers (Total Reading Score of 100 or better). Then the mean scores of the Poor and Good Readers were compared on all of the
Table 4
The Three Reading Tasks Most Highly Correlated with any Given Reading Task

Read Variable Most Highly Correlated with Individual Read Variable

<table>
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<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>Sentences</td>
<td>.71(2)</td>
<td></td>
<td></td>
<td>.72(1)</td>
<td>.68(3)</td>
<td></td>
<td></td>
</tr>
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<td>Spelling</td>
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<td>.70(2)</td>
<td></td>
<td>.72(1)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Prox. Separat.</td>
<td></td>
<td></td>
<td>.72(3)</td>
<td></td>
<td>.78(1)</td>
<td>.76(2)</td>
<td></td>
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<td>.72(2)</td>
<td></td>
<td>.72(1)</td>
<td></td>
<td></td>
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<td>Gray</td>
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<td>.72(3)</td>
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<td></td>
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<td></td>
<td>.61(3)</td>
<td>.64(1)</td>
<td></td>
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<tr>
<td>Sounding</td>
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<td>.76(1)</td>
<td></td>
<td>.75(2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letters</td>
<td>.46(1)</td>
<td></td>
<td></td>
<td>.41(3)</td>
<td>.42(2)</td>
<td></td>
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</tr>
<tr>
<td>Total Read</td>
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<td></td>
<td></td>
<td>.44(1)</td>
<td>.38(2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Highest Correlation
(2) 2nd Highest Correlation
(3) 3rd Highest Correlation
Table 5
The Two Piagetian Tasks Most Highly Correlated with any given Reading Task
Piagetian Variable Showing Highest Correlation with Individual Reading Tasks

<table>
<thead>
<tr>
<th>Transf.</th>
<th>Part (Whole Bead Tun.)</th>
<th>Ord. (Enclos. Left Right)</th>
<th>Ord. (Plane Landsc Total)</th>
<th>Total Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sent.</td>
<td>.41(2)</td>
<td>.45(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spell.</td>
<td>.41(2)</td>
<td></td>
<td>.42(1)</td>
<td></td>
</tr>
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<td>Prox-Sep.</td>
<td>.46(2)</td>
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</tr>
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<td>Ord-Encl.</td>
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<tr>
<td>Gray</td>
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<td>.48(2)</td>
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<td>.49(1)</td>
</tr>
<tr>
<td>Nonsense</td>
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<td>.56(1)</td>
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<td>Sounding</td>
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<td></td>
<td></td>
<td>.46(2)</td>
</tr>
<tr>
<td>Letters</td>
<td>.34(1)</td>
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<tr>
<td>Total Read</td>
<td>.53(1)</td>
<td></td>
<td>.51(2)</td>
<td></td>
</tr>
</tbody>
</table>
variables. This comparison has already been mentioned with regards to the Intelligence measure. The ranges, means and Grade Equivalents for each of the reading groups on the Gray Oral Reading Test are presented in Table 6.

The Good Readers had a significantly higher Total Read Score than the Poor Readers using Hotelling's $T^2$ ($\bar{x}_G = 113.65$, $\bar{x}_P = 63.85$). All the means and levels of significance for the Good and Poor Readers are in Table 3. The difference between the Good and Poor Reading Groups on the Gray Oral Reading Test ($\bar{x}_G = 31.05$, $\bar{x}_P = 12.75$) and on the Sounding Test ($\bar{x}_G = 20.25$, $\bar{x}_P = 8.40$) were also significant at the .05 level. For all other reading means, the Good Readers did better than the Poor Readers, although the mean differences were not significant.

Although the number of males and females in this study was approximately equal (31 females and 29 males), the distribution of the males and females throughout the three reading groups was interesting. Of the 20 Poor Readers 13 were boys and 7 girls. With the 20 Good Readers 12 were girls and 8 boys. These differences were not significant using chi square.

**Piagetian Tasks**

The mean Total Piagetian Score was 209.75 with a standard deviation of 42.03, and with a range of 130 to 274. All of the Piagetian Tasks correlated significantly ($p < .01$) with the Total Piagetian Score. The Airplane Task was the most highly correlated
Table 6

The Means and Range of Gray Oral Reading Test Scores for the Three Reading Groups

<table>
<thead>
<tr>
<th>Reading Group</th>
<th>MEAN</th>
<th>Grade Equivalent</th>
<th>Lower Grade Equiv.</th>
<th>Upper Grade Equiv.</th>
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</thead>
<tbody>
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<td>12.75</td>
<td>1-8</td>
<td>7</td>
<td>22</td>
</tr>
<tr>
<td>n = 20</td>
<td></td>
<td>2-2</td>
<td>7</td>
<td>22</td>
</tr>
<tr>
<td>Average Readers</td>
<td>21.65</td>
<td>3-4</td>
<td>24</td>
<td>41</td>
</tr>
<tr>
<td>n = 20</td>
<td></td>
<td>2-2</td>
<td>7</td>
<td>29</td>
</tr>
<tr>
<td>Good Readers</td>
<td>31.05</td>
<td>3-4</td>
<td>24</td>
<td>41</td>
</tr>
<tr>
<td>n = 20</td>
<td></td>
<td>2-2</td>
<td>7</td>
<td>3-0</td>
</tr>
</tbody>
</table>
with the Piagetian Total Score \( r = -0.80; df = 58, p < 0.001 \). Left-Right, Landscape, and Total Order were also highly correlated with the Total Piagetian Score \( r \leq 0.70 \).

If the pattern of intercorrelations between the individual Piagetian Tasks themselves is considered, there are several important observations. The Part-Whole Task correlated significantly only with Enclosure \( r = 0.31; df = 58, p < 0.01 \), although it did correlate with the Total Piagetian Score as well \( r = 0.50; df = 58, p < 0.001 \). With the effects of Intelligence partialled out, even the correlation with enclosure was no longer significant \( r = 0.29; df = 57, p < 0.025 \) so that the only remaining significant correlation was the Total Piagetian Score \( r = 0.49; df = 57, p < 0.001 \). In other words, the Part-Whole Task did not correlate significantly with any of the individual Piagetian Tasks.

The two Order Tasks result in different correlational patterns. Order-Bead was significantly correlated with all the Piagetian Tasks except the Part-Whole, and the Airplane. Order-Tunnel, on the other hand, was significantly correlated with everything but Part-Whole and Enclosure. With Intelligence partialled out, the Order-Bead correlations remained essentially the same (and all still significant), while with Order-Tunnel, Left-Right was no longer significantly correlated at the .01 level. The two Order Tasks were significantly correlated with each other \( r = 0.33; df = 58, p < 0.01 \). It is also interesting to note that only Order-Bead was significantly correlated with Enclosure \( r = 0.38; df = 58, p < 0.008 \), its topological compliment.
Using a similar approach to that used with the Reading Tasks, it is possible to construct a table (Table 7) showing the two Piagetian Tasks most highly correlated with any given Piagetian Task. In constructing this table, the Total Order Score was not taken into account when arriving at the two highest correlations for either of the individual order tasks (i.e., Order-Bead and Order-Tunnel). The majority of highest correlations appeared with the Piagetian Tasks requiring combined skills, for example, the Airplane and Landscape Tasks.

When the same type of Table (Table 8) is constructed with the three highest Reading Tasks, the pattern is consistent with that of the Reading Tasks described earlier. As with the Reading Table (Table 5), after the Gray, the Reading variables most commonly noted as having a high correlation with any of the Piagetian Tasks were Proximity-Separation and Sounding.

**Reading and Piagetian Tasks**

It is interesting to note that in the tables just described (i.e., Tables 4 and 7), the same three Reading Tasks (i.e., the Gray, Proximity-Separation, and Sounding) were the Reading Tasks most frequently highly correlated with individual Reading Tasks and with individual Piagetian Tasks. These overlapping patterns are not present with regard to the two tables (Tables 5 and 8) dealing with the Piagetian Tasks. The Piagetian Tasks most frequently cited as highly correlated with individual Reading Tasks were Order-Bead and Left-Right. The Piagetian Tasks most fre-
Table 7

The Two Piagetian Tasks Most Highly Correlated with any given Piagetian Task

Piagetian Variable Showing Highest Correlation with Individual Piagetian Tasks

<table>
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<tr>
<th></th>
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Table 8
The Three Reading Tasks Most Highly Correlated
With Any Given Piagetian Task

Reading Variable Showing the Highest Correlation
with Individual Piagetian Tasks

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<td>.43(1)</td>
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<tr>
<td>Order-Bead</td>
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<td>.50(1)</td>
<td>.49(2)</td>
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<td></td>
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<td></td>
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<tr>
<td>Order-Tunnel</td>
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<td>.34(1)</td>
<td>.30(3)</td>
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<td>.45(2)</td>
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<td>Left-Right</td>
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<td>.44(3)</td>
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</tr>
<tr>
<td>T. Order</td>
<td>.45(3)</td>
<td>.49(1)</td>
<td>.46(2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T. Piaget</td>
<td>.59(3)</td>
<td>.63(1)</td>
<td>.60(2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
quently cited as highly correlated with individual Piagetian Tasks were the Airplane and Landscape Tasks.

The pattern of correlations between individual Reading and Piagetian Tasks indicate that some of the Piagetian Tasks were more highly related to reading than others. The Order-Bead Task correlated significantly with all eight of the Reading variables and was the single highest Piagetian correlator with the Total Reading Score \( r = .53; \text{df} = 58, p < .001 \). The Left-Right Task correlated significantly with all the reading variables except the Letter Naming Test and the correlation with Total Reading was \( r = .51; \text{df} = 58, p < .001 \).

The remaining Piagetian Tasks correlated significantly with the majority of Reading Tasks with the exception of the Order-Tunnel Task which was significantly correlated only with the Gray \( r = .34; \text{df} = 58, p < .01 \). This correlation was not significant when intelligence was partialled out \( r_p = .30; \text{df} = 57, p < .023 \). The Part-Whole task was also not as highly correlated with reading as the other tasks, although it did significantly correlate with Gray \( r = .34; \text{df} = 58, p < .01 \) and with Read Order-Enclosure Task \( r = .44; \text{df} = 58, p < .001 \). The correlations of the Piagetian Tasks with the Total Reading Score in order of decreasing relationship between the variables are presented in Table 9.

In order to further differentiate the pattern of correlation of the Piagetian Tasks with reading, a Multiple Correlation was performed on the Piagetian Tasks in relation to the Gray Oral
Table 9
Correlations Between the Piaget Tasks and Total Read in Order of Decreasing Significance

<table>
<thead>
<tr>
<th>Piaget Task</th>
<th>Correlation</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order-Bead</td>
<td>.53</td>
<td>.001</td>
</tr>
<tr>
<td>Left-Right</td>
<td>.51</td>
<td>.001</td>
</tr>
<tr>
<td>Airplane</td>
<td>.50</td>
<td>.001</td>
</tr>
<tr>
<td>Total Order</td>
<td>.49</td>
<td>.001</td>
</tr>
<tr>
<td>Transformations</td>
<td>.47</td>
<td>.001</td>
</tr>
<tr>
<td>Enclosure</td>
<td>.45</td>
<td>.001</td>
</tr>
<tr>
<td>Landscape</td>
<td>.43</td>
<td>.001</td>
</tr>
<tr>
<td>Part-Whole</td>
<td>.33</td>
<td>.009</td>
</tr>
<tr>
<td>Order-Tunnel</td>
<td>.32</td>
<td>.012</td>
</tr>
</tbody>
</table>
Reading Test which was the single best reading indicator. The simple correlation between the Total Piagetian score and the Gray was .62, by weighting the contribution of the individual Piagetian Tasks, (i.e., by using the Multiple Correlation) this correlation rose to .69.

If the two Topological Reading Tasks (Proximity-Separation, and Order-Enclosure) are considered, it is clear that these significantly correlated with the Total Reading Score ($r_{P-S} = .87; r_{O-E} = .78; df = 58, p < .001$). In fact, as was noted earlier, Proximity-Separation is one of the three most highly correlated Reading Variables both in relation to other Reading Tasks and to Piagetian Tasks.

It was expected that there would be a relationship between Piagetian and Reading Order and Enclosure Tasks. The Piagetian Order-Bead Task and the Reading Order-Enclosure Task were correlated significantly ($r = .34; df = 58, p < .01$). The Piagetian Enclosure Task also correlated with the Reading Order-Enclosure Task ($r = .31; df = 58, p < .01$). There was no exact Piagetian equivalent for the Reading Proximity-Separation Task, however, it was hypothesized that the Transformations and Part-Whole Tasks might be operational equivalents of proximity and separation. Transformations did correlate significantly ($r = .36; df = 58, p < .004$) with Reading Proximity-Separation Task, but Part-Whole did not.

It was also hypothesized that there might be a relation between the Nonsense-Words and Sounding Tasks and the Piagetian
Enclosure and Order Tasks. There was a significant correlation 
\( r = .44; \text{df} = 58, p < .001 \) between Sounding and Enclosure but 
not between Nonsense Words and Enclosure. The Order-Bead Task 
was significantly correlated with both Sounding and Nonsense 
Words \( r_s = .40; \text{df} = 58, p < .002; r_N = .49; \text{df} = 58, p < .001 \).

**Conceptual Analysis**

In the procedure an analysis was made of each Piagetian Task 
in terms of the difficulty of each item within the particular task. 
In order to compare this theoretical analysis to the actual dif­
ficulty of the items for the present children, the total number 
of children getting any given item correct was determined. Since 
many children got part marks in a given item, the total number 
of children getting an item totally correct or totally wrong, does 
not always total to the number of children in the study. Only 
those children who got full marks for an item or full marks minus 
the one confidence mark per item, were counted as having the item 
correct.

a) Transformation Task

As can be seen in Figure 7, the order of difficulty of the 
items was as predicted with the exception of the triangle. The 
triangle was supposed to be the most difficult item but it was 
easier than either the diamond or rhombus although it was more 
difficult than the enlarged square which is the major distinction 
since the enlarged square is Stage II and the rest are Stage III.
Fig. 7. Order of item difficulty for the Transformation Task.
b) Part-Whole

The order of difficulty of items as indicated in Figure 8 was as predicted with one exception. Circle 7, was similar in difficulty to Square 6 and Circle 5 and easier than the other three items it was hypothesized to be equal to. That is, Square 8, False Circle 8 and False Square 7 were the most difficult items as predicted and were also relatively equal to each other while Circle 7 did not fit with this group as it should have.

c) Order-Bead

The order of items on this task (see Figure 9) was as predicted although the difference between Straight and Circular Order was quite small and the drop between these two and Reverse Order, large in comparison. This is as it should be since Straight and Circular Order are both in Stage II while Reverse Order is Stage III.

d) Order-Tunnel

In the Order-Tunnel task, it is evident from the diagram (Figure 10) that there were three main divisions in the items. Straight Order and 180° rotation were the easiest (both are Stage II), 360° and 540° rotation were the next easiest (both need Stage IIIA), and the trajectory was the most difficult (needs Stage IIIC). This order was the order predicted. However, within these main groups there was one contradiction, 180° rotation was easier than the Straight Order and it was hypothesized to be more difficult. Generally though, the predicted order was confirmed.
Figure 8. Order of Item Difficulty Part-Whole Task.
Figure 9. Order of Item Difficulty in Order-Bead Task.
Figure 10. Order of Item Difficulty in the Order of Item Task.
e) Enclosure

The predicted order of item difficulty was not upheld for this task (see Figure 11). In fact, with the exception of the False Knot (two circles overlapping versus two circles joined), all of the items appeared to be of about the same degree of difficulty.

f) Left-Right

As can be seen in Figure 12, the predicted order of difficulty for this task was clearly upheld.

g) Airplane

In Figure 13 are indicated both the order of difficulty of the three sub-categories of the task (Airplane Alone, Pilots One Behind the Other, and Pilots Side by Side), and the difficulty of the different locations within each sub-category. The predicted order of difficulty for this task was confirmed as can be seen in the diagram, although the gradations in difficulty were more apparent across sub-categories than within.

h) Landscape

For the Landscape task two orders were constructed, one considering the location of the dog on the landscape and one taking into account both the location of the dog and the direction the dog was facing. Both these orders are represented in Figure 14. It is apparent from the diagram, that there really were few differences in difficulty of the items with the location of the dog alone, with the exception of the last three positions
No. of Ss getting item correct

Figure 11. Order of Item Difficulty in Enclosure Task.
Figure 12. Order of Item Difficulty in Left-Right Task.
Figure 13. Order of item difficulty - Airplane Task.
Figure 14. Order of Item Difficulty - Landscape Task.

- Location of the dog.
- Location and orientation of the dog.

Order of Increasing difficulty

Figure 14. Order of Item Difficulty - Landscape Task.
(Positions I, L, and K). That is, the only justifiable conclusion would be that all the positions except the last three were of about equal difficulty and that the last three were more difficult. The general result of introducing the direction of the dog into the scoring was to lower the number of children getting any item correct. However, it is interesting to note that this effect impaired performance far more with the difficult locations than the easy. Also, both Positions E and J where the dog was placed in the middle of a space, were more affected by the dog's direction than were the others which were near an object. In fact, the pattern of difficulty with the direction of the dog included was Positions B, C, D, A, F, G and H easiest followed by Positions E and J and then Positions I, L, and K as the most difficult.

Stage Analysis

On the basis of the conceptual analysis, it was also predicted that a child would have to be in a certain Stage to correctly perform a given item in a given task. It was possible then, to assign a child a Stage level on any given task on the basis of the number and particular items he did correctly. The conceptual analysis already described (see Table 1, Procedure) was the basis for the stage analysis with a few exceptions brought about by the actual order of item difficulty described in the last section. In the Part-Whole task, Circle 7 was put with Circle 5 and Square 6 since the three scores were similar to each other and different from the other more difficult items. The only other change was in the
Enclosure Task where the False Knot - two overlapping circles versus two joined circles was counted as the easiest item since 52 out of 60 children got it right and the next highest score was only 26. Aside from these two changes which will be considered in conceptual terms in the discussion, the analysis proceeded on the basis of the Stages outlined in Table 1. Each child was assigned a Stage level for each Piagetian task and then was assigned an overall Stage level on the basis of the Stage level achieved for each task. If the child was in one Stage in five or more of the eight tasks, this was the Stage assigned him. If there was a four-four split (i.e., Stage II on four tasks and Stage III on four tasks), the child was said to be in transition between the two Stages.

If the Stage Analysis is viewed from the point of view of the number of children in each Stage, the results are as follows. There were 19 children in Stage II (three in Stage IIA, 16 in Stage IIB). Of these 19 children, 15 were in the Poor Reader's Group, discussed earlier, (three in Stage IIA and 12 in Stage IIB) and the remaining four were Average Readers. There were four children in transition between Stages II and III, of these, three were Poor Readers and one was an Average Reader. The remaining 37 children were in Stage III (27 in Stage IIIA and 10 in IIIB). Of those in Stage IIIA, two were Poor Readers, 14 were Average Readers and 11 were Good Readers. In Stage IIIB, one was an Average Reader and the other nine were Good Readers. These
relationships are reproduced in Table 10. In other words, there is a very strong tendency for Stage III children to be Good Readers, particularly if they are in Stage IIIB. Likewise, if the child is in Stage II on these spatial tasks there is a very strong likelihood that he will have problems with reading (no child who was classified as being in Stage II was a Good Reader).

The distribution by sex of the children at the different stages was the following: 11 males and 8 females in Stage II; 3 males and 1 female in transition; and 14 males and 22 females in Stage III. None of these differences were significant using chi square.
Table 10

Number of Children at Each Stage and Their Reading Performance

<table>
<thead>
<tr>
<th>Stage</th>
<th>Total Number of Children</th>
<th>No. of Poor Readers</th>
<th>No. of Average Readers</th>
<th>No. of Good Readers</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIA</td>
<td>3</td>
<td>3</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>IIB</td>
<td>16</td>
<td>12</td>
<td>4</td>
<td>None</td>
</tr>
<tr>
<td>Transition</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>None</td>
</tr>
<tr>
<td>IIIA</td>
<td>27</td>
<td>2</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>IIIIB</td>
<td>10</td>
<td>None</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>
DISCUSSION

The Discussion will generally follow the order that has been presented so far. Thus, first to be considered will be specific issues raised within the various sections; for example, dealing with Intelligence, Reading and Piagetian tasks. Then, the results in relation to the Conceptual Analysis of the Piagetian tasks will be discussed. After these specific issues have been discussed, the results will be evaluated in terms of the original hypotheses of the study and then the applicability of these results to the practical field will be considered.

Specific Issues

a) Subjects

Although the number of males and females in this study was approximately equal (31 females and 29 males), the distribution of the males and females throughout the three reading groups was interesting. Of the 20 Poor Readers, 13 were boys and 7 girls. With the 20 Good Readers 12 were girls and 8 boys. The higher incidence of males in the Poor Readers Group is consistent with most research with reading problems. Various researchers have suggested that the ratio of males to females in reading problem groups have ranged from 2:1 (Lazure and Robers, 1970) to 10:1 (Budoff and Quinlan, 1964). Although the exact ratio involved is not agreed upon, there is a general agreement that there is a much higher incidence of male problem readers than female. The
data from the present study confirm this general trend, although the differences in number of males and females was not significant.

b) Intelligence

The research cited in the Introduction suggested that there would be some relationship between intelligence scores and performance on the reading and Piagetian tasks. The results confirm this relationship. The correlation between the Piagetian Total Score and the Peabody Picture Vocabulary Scores was higher than that found by Goldschmit (1967) using children from one age group ($r = .43$ versus $r_G = .30$) but lower than that found by Dudek et al when they used children varying in age up to three years ($r_D = .57$ versus $r = .43$). It seems that the relationship between Intelligence and the Piagetian tasks obtained in the present results are consistent with past research.

There was also some relationship between the reading scores obtained and PPVT scores although this was not as high as that with the Piaget scores. The correlation between the score on the Gray Oral Reading Test and the PPVT obtained in this study is remarkably similar to that obtained by Ackerman et al, (1971), mentioned in the Introduction. He found a correlation of .23 between the full scale W.I.S.C. and the Gray. The present study had a correlation of .25 between the Gray and the PPVT. Thus, it seems that the degree of relationship between reading and intelligence as derived from the present study is consistent with that found in other research.
c) Reading

When the intercorrelations between the individual Reading Tasks and between these tasks and the Total Reading Score are considered, it is apparent that the Letter Naming Task correlated least with the other Reading Tasks. Moreover, it did not figure in any of the highest correlations with the Piagetian Tasks. The reason for this could be that there was too much of a ceiling effect with the present population. Of the 60 children, only 16 made any mistakes at all on this Task. In the scoring, although there were 26 letters presented, the task was scored out of five and one mark deducted for each letter named incorrectly. In spite of this, the lowest score obtained was three. In other words, no child made more than two errors in the 26 letters.

In terms of identifying reading problems, it is probably a sign of reading problems if a child makes any errors in letter naming at the age of children in this study. However, in terms of determining a correlation between this measure and others, the small number of errors makes this determination very difficult. It may be that it would be better to just give a binary (has-has not) kind of decision on Letter Naming indicating whether or not a child can identify the letters, and that no score is appropriate. At any rate, for this particular study, it is apparent that the Letter Naming Task in its present form was of no specific predictive value. It should be noted that with younger children (e.g., Kindergarten) Letter Naming is considered
to be one of the best predictors of reading problems (e.g., Jansky, et al., 1972).

The high correlation (.94) between the Gray Oral Reading Test and the Total Reading Score, and the fact that the Gray was the single task most highly correlated with most of the other Reading Tasks, would suggest the central importance of this variable. In terms of parsimony, these results suggest that giving the Gray Oral Reading Test alone would give almost as much information as giving the whole battery of reading tests presented in this study. This is of value when planning future studies using a similar age group.

The pattern of inter-relationships indicated in Table 4 of the Results is also of interest. After the Gray, the two most highly correlated Reading Tasks were Proximity-Separation and Sounding. This is an interesting combination of tasks, one closely related to topological structures and one having a heavy visual-auditory component. However, as was noted in the Procedure, the Sounding Task also has a topological component in that confusions in internal features including orientation and order of letters would result in a low score on this task. Since these two tasks are different from the Gray and are highly correlated with the other Reading Tasks, a good future set of Reading Tasks might be the Gray Oral Reading Test, Sounding, and Proximity-Separation.

d) Piagetian Tasks

Looking at the relations between the Piagetian Tasks, one
variable seems less related than the others and this is the Part-Whole Task. This Task was significantly correlated only with the Total Piagetian Score, and it had the lowest correlation \((r = .50)\) with the Total of any of the Piagetian Tasks. With respect to the reading variables, the Part-Whole Piagetian Task was only significantly correlated with the Gray and Order-Enclosure Tasks. In other words, this Task seemed to be a poor predictor of reading problems and also to be representing different Piagetian structures than the other Piagetian Tasks.

In discussing the Part-Whole Task earlier, it was introduced as a possible operational equivalent for the topological constructs of proximity and separation. When this task was compared to the Reading Proximity-Separation Task which is based on the most fundamental definitions of these two concepts, there was no significant correlation. This would suggest that something other than operational proximity (partitive addition) and separation (subdivision) are involved in the Part-Whole Task. This interpretation is supported by Piaget (1971b) when he says: "...when the experimenter suggests which pieces are required, (i.e., by giving all necessary pieces on a board), the subject is indirectly provided with what amounts to a framework of conservation." (p. 342). This statement implies that the Part-Whole Task is actually a conservation problem thus relying on the logic-mathematical system. This may explain why the Part-Whole Task is not related significantly to any of the other Piagetian Tasks since they are based on the infralogical space system rather than the logical conservation system. At any rate,
because of the small amount of relationship of the Part-Whole Task with any of the other Tasks, either Piagetian or Reading, it would seem reasonable to exclude the Part-Whole Task from any future research of the present type.

Another interesting inter-relationship within the Piagetian Tasks was that between the two order tasks (Order-Bead and Order-Tunnel). While the Order-Bead Task was significantly correlated with all of the Reading Tasks, and in fact, was the single highest Piagetian Task to correlate with reading (r = .53), the Order-Tunnel Task was not significantly correlated with any of the reading variables. Moreover, with respect to the other Piagetian Tasks, Order-Bead was not significantly correlated with the Airplane Task, while the Airplane Task had the highest single correlation (r = .53) with the Order-Tunnel Task. It is apparent then, that the two order tasks are tapping different types of order, although there is some overlap between the two (the two order tasks significantly correlated with each other (r = .33). In fact, Piaget (1967) supports a distinction between these two types of order:

...in that case (Order-Tunnel) we were concerned with order in relation to movement of balls through a tube which was rotated about its center, a series of colours in a rotating cylinder, etc. As distinct from this, what is at present required (Order-Bead) is a study of order as such, separate
from movement, which is thus reduced to the relative displacements of the subject who follows with his steps, his eyes, or even his thoughts, the direct or reverse order of an array of objects. Thus, the experiments discussed below (Order-Bead) are completely different from those performed in the studies (Order-Tunnel) just referred to. (p. 81).

This distinction between order in terms of relative displacement versus order during movement, just alluded to, is supported by the varying correlation patterns of the two order tasks. The Order-Tunnel Task was most highly correlated \((r = .53)\) with the Airplane Task and then the Landscape \((r = .50)\), both tasks in which movement and rotation are involved. The Order-Bead Task correlated highly \((r = .40)\) with Left-Right and the Landscape. Left-Right is concerned with location without rotation and it is conceivable that Order-Bead correlated with the Landscape Task for different reasons than that of the Order-Tunnel Task. The Order-Tunnel connection with the Landscape Task could be a function of the rotation of the landscape and the need to mentally perform this transformation on the child's own landscape. The type of order involved in Order-Bead is also present in the Landscape Task in the sense of placing an object between or beside others in order to create an ordered succession of objects. In terms of the Reading Order-Enclosure Task, only the Order-Bead Task was
significantly correlated \( r = .33 \) with it and not Order-Tunnel. This is consistent since the Reading Task involved only displacement and not movement. Since only the Order-Bead Task was significantly correlated with all the reading variables, it would seem that it is this type of order that is involved in reading and not the type of order through motion as described in the Order-Tunnel Task. Thus, it would seem reasonable to discard the Order-Tunnel Task in future testing and use only the Order-Bead Task.

When viewing the pattern of correlations between Piagetian Tasks (Table 7), the variables most frequently cited as having a high correlation with the other Piagetian tasks were combination tasks. That is, tasks which were analysed in terms of more than one spatial construct, for example, the Landscape, Airplane, and Total Order Scores, were most frequently cited as high correlators. This pattern of correlation seems to support the analyses of these tasks which indicated a number of structures involved. This conclusion seems justified since a Piagetian Task based on one topological structure should correlate significantly with another, more complex task where the simpler structure was also involved.

e) Piagetian and Reading Tasks

One of the most important and interesting results to come out of the comparison between the two sets of tasks was the correlation pattern of the two Topological Reading Tasks (Proximity-Separation and Order-Enclosure). The fact that these two Piagetian equivalent tasks correlated so highly \( r_{P-S} = .87; r_{O-E} = .78 \) with the Total
Reading Score, gives a great deal of support for the argument that
the structures of topological space are necessary for reading.
This support is strengthened by the fact that these two tasks were
also significantly correlated ($r = .33$ for Order-Enclosure and
Piagetian Order, $r = .31$ with Piagetian Enclosure and $r = .36$
between Separation-Proximity and Piagetian Transformations) with
their equivalents in the Piagetian Tasks (with the exception of
Part-Whole discussed earlier). It seems then, that Reading
Proximity-Separation and Order-Enclosure are reasonable word equi­
valents of the topological structures involved and that these
word equivalents are very much correlated with success on other
reading variables. This is particularly true with Proximity-
Separation which correlated $r = .37$ with the Total Reading Score.

The Proximity-Separation Task is also a good example of a
Piagetian vertical décalage. In the conceptual analysis of the
Piagetian topological structures, it was noted that proximity and
separation were the earliest topological structures to evolve
and as such were already developed in the child before he reached
the age of children tested in the present study. Now by operation­
alizing these structures at the word level, the difficulty of the
task was increased such that not all children could successfully
apply these topological structures to the task. This is not to
say that these same children would not successfully solve problems
using these same structures in a more concrete way (as they did
in pilot work). It only implies that the structures have not been
mastered to such an extent that they are successfully applied in all situations. This is similar to the formal-functional distinction (Flavell and Wohwill, 1969) discussed earlier.

The significant correlation between Sounding and Enclosure \( r = .44 \) is of interest. This correlation was as predicted in the Procedure. The reason for this hypothesized relationship was that Enclosure was explained in terms of attention to the details of internal features. Sounding of made-up words could be affected by inattention to or lack of ability to discriminate on the basis of internal features. This explanation was born out by the performance of individual children. Some children when faced with a word which was not immediately recognizable to them, would immediately read the closest English word to the made-up word presented. This occurred in spite of repeated emphasis that the stimuli were not real words but made-up words, perhaps from another language. For example, "slidge" became "slide", and "floy" became "flow". In other words, the child would look at the general shape of the word and, most frequently what letter it started with, and then just ignore the internal details and make up his own word. That is, to use Piagetian terms, the child was not accommodating (reacting to the realities of his environment) his perception of the word to the realities of the letters being presented. Rather, he was assimilating (absorbing into his existing schema) only enough information from the presented word to enable him to identify a word already in his vocabulary. This was true not only for
substituting real words for nonsense words, but also substituting one nonsense word for another. For example, "frable" was called "fridelling". A similar type of response could be observed in the Enclosure Task. For example, when one child was asked whether two knots were the same, he said: "Yes, because there are loops." Since all the knots were made of loops and the same child had successfully differentiated an earlier, easier pair of knots on the correct criteria, it seemed in the particular case just described, that he was not differentiating sufficient detail in the knots. He was accommodating only to the general form of the knot and not to specific details and thus the assimilation of the relevant information was severely limited.

In the Procedure it was also suggested by virtue of similar reasoning that there should be a relationship between the Enclosure Task and the Nonsense Word Task. This relationship did not occur. It is difficult to explain exactly why this did not occur, but it might have been due to the type of response required of the child in the Sounding and Nonsense Word Tasks. In the Nonsense Words Task, the child had to choose (point to) an answer from one of four words in a list in front of him. This response method limited the number and type of answer the child could give. In the Sounding Task, the child was asked to read the word he saw. Thus, in a sense, he had an unlimited supply of possible answers. It could be that the fewer options available and one chance in four of guessing the correct answer, so limited the type of errors
the child could make, that errors of an Enclosure nature were not frequent enough to affect the correlation. It should be noted though, that for both the Sounding and Nonsense Words, the correlation with the Read Order-Enclosure Task was high ($r_S = .56$; $r_N = .52$). It seems then that the hypothesized relationship between Sounding and Nonsense Words and Enclosure was at least partially supported for the Nonsense Words and more fully supported for Sounding.

It has already been noted that Order-Bead was most highly correlated ($r = .53$) with the Reading Tasks, it is also of interest that the Left-Right Task was the next most highly correlated ($r = .51$) with the Total Reading Score. Reading research has consistently cited left-right problems in relation to reading problems (e.g., Money, 1962; Bannatyne, 1971). However, there has been a tendency to lump several different types of left-right problems together. For example, although all the researchers refer to left-right problems, some mean this in terms of lateral and mixed dominance (e.g., Orton, 1937), others mean that letters such as $b$ and $d$ are confused (e.g., Jackson, 1972) and still others mean the child cannot tell his left hand from his right hand (e.g., Harris, 1957). Moreover, Corballis (1973) has pointed out that research dealing with this last type of left-right problem consistently confuses problems in labelling left and right with problems involving the concept of left and right. The present research deals very clearly with the concept of left and right. Moreover,
it deals with progressively more complex and sophisticated concepts of left and right starting with topological structures and working through projective and euclidean structures. This has not been attempted before and it is therefore of great interest that this type of conceptual left-right is significantly correlated with reading.

f) Piagetian Conceptual Analysis

The Enclosure Task was the most notable failure of the conceptual analysis to successfully predict the order of difficulty of individual items within the Piagetian Tasks. From Figure 11, it is apparent that the only item that was different and easier than the others was the False Knot - two circles joined together, one resting on top of the other. From the explanations of the children, it was clear that this item had become perceptual. That is, using the one half inch rope made the difference between the two knots so obvious that the majority of the children just spontaneously lifted the ring resting on the other and said something like, "See, they're not joined." The thick rope had been chosen because in pilot work, using thin string, all of the knots had been very difficult for the children and no one had correctly identified the left-right overhand knot pair. By using the thick rope, it was hoped that the task would be made easier. What this may have done instead, though, was to bring the success rate of the left-right overhand knot up to that of the other knots without inflating the success rates of the other two items. At any
rate, the Enclosure Task presented problems from the earliest pilot work and these problems still exist in the present study. Since Enclosure in both the Piagetian and the word equivalent forms was significantly correlated with reading ($r_{OE} = .78$; $r_E = .45$) it seems justified to include an Enclosure Task in future research. However, the exact nature of the task to be included would have to be established through further pilot research.

There was one item in the Transformation Task that did not come out as predicted although the rest of the items were in the predicted order of difficulty. The triangle was easier than had been expected. This may have been because of the introduction of line drawings for the child to choose from. Piaget, in the original task, had allowed the child to draw the form he anticipated. In the line drawings, inevitably there were more four-cornered items than three (since all the other items tested were four cornered). This may have given the three cornered drawings enough distinctiveness to reduce the difficulty of the triangle form. It should be noted, however, that although the triangle was easier than the rhombus and diamond, it was clearly more difficult than the enlarged square. In conceptual terms, this is the critical division since the enlarged square was said to require only Stage II structures, while the other three shapes were all hypothesized to need Stage III structures. Thus, the essential division between the difficulty of items was supported.
There were two other individual items that did not appear in the predicted order in their specific tasks, but these discrepancies are minor. In the Part-Whole Task, Circle 7, was of about the same degree of difficulty as Circle 5 and Square 6 instead of being more difficult as was predicted. This can be explained by the high degree of similarity between the pieces in Circles 5 and 7 (see Figure 1, Procedure). Since Circle 5 was always presented first, there appears to be a practice effect accounting for the greater number of successes on Circle 7 than on the other last three items. Children who got Circle 5, i.e., who said that the pieces could go together, often justified their decision for Circle 7 by saying "Its the same as the other one, so it has to go together too". Thus, the child was using factors other than strictly logical addition in obtaining the correct solution for Circle 7. This is why in the Stage Analysis, Circle 7 was placed with Circle 5 and Square 6 instead of with Square 8, False Circle 8 and Square 7 where it was placed originally on logical grounds.

In the Order-Bead Task, the 180° rotation was slightly easier than the beads in the tunnel without rotation contrary to prediction. This again can be explained in terms of a practice effect, since the 180° rotation was always the second item in the Task. Because the task was novel, the first item, predicting the order of beads without rotation sometimes caused some problems simply because the child really had not thought of that type of problem before.
By the time the second item was presented (180° rotation), the child was thinking more consistently in terms of the problem, particularly since he had just had the visual feedback from the first trial. It should be noted that Piaget (1971b), in his results on the Order-Tunnel Task, found that 100% of six year olds were successful on the 180° rotation. Thus, there is really little surprise in the fact that 58 out of 60 of the children who were eight years old were successful on this item. Also, as with the last task, this Order Task maintained the essential divisions in task difficulty based on different Stages, and this one item is only a small deviation of item difficulty within a Stage.

The Landscape Task presents a little different problem in terms of the Conceptual Analysis. It will be recalled in referring to Figure 14, it was not so much that the order of difficulty of items was contradicted, but that only the last three items were noticeably more difficult from the others. This could be explained if it is assumed that the ascending item difficulty up to the last three items was masked by the ceiling effect on these items. That is, the majority of children had reached the stage where most of the items were within their grasp. It was only when the co-ordinate system was required (i.e., for items I, L, and K) that differences became apparent since a number of children had not yet mastered these complex structures. This explanation is supported by similar data reported by Laurendeau and Pinard (1970). They determined the age of accession (i.e., when 50% of Ss got the item correct)
for each of the positions on the rotated landscape. In their results, the age of accession for all the positions with the exception of Positions J, I, L and K was 7-3 or before (for Positions E it was 4-1). They did not include orientation of the figure (e.g., the dog) in their task.

It is interesting to note the effect that introducing the orientation of the dog had on the difficulty of the items. It is not surprising that the inclusion of orientation lowered the number of successes per item since this would require the child to assimilate more information simultaneously. What is interesting though, is the dramatic effect orientation had on the success rates of E and J. Although no predictions were made with regards to the effect of orientation, it does seem possible to explain Positions E and J in logical terms. Both these positions are in open spaces so that there is no object to give a cue direction. For example, in Position B, the dog is placed in front of the blue house, but this also gives the information that the dog has his back to the house and is facing out, no such clue exists for Positions E and J. Positions E and J require the child to use a much more distant cue and in fact the most reliable cue to use is projective. That is, several children who got these positions correct explained their choice by referring to how the dog was facing in relation to the examiner or himself. For example, for Position J, one child said, "Your dog is facing you so my dog has to face me". This explanation requires the understanding of
multiple points of view which is not mastered until well into Stage III. This same type of explanation based on multiple points of view is needed to correctly solve the last three positions as well. Thus, to get Positions I, L and K completely correct, including orientation of the dog, would require coordination of both the multiple points of view and the co-ordinate system. This seems to be a logical explanation for the low number of children getting these three positions completely correct.

**General Hypotheses**

The main hypothesis of this study was that performance on the reading tasks would be related to performance on the Piagetian spatial tasks. The results of this study support this hypothesis. The significant correlation \( r = .67 \) between the Total Reading and Total Piagetian Scores leaves little doubt that the two systems are related. Moreover, the Stage Analysis gives even stronger support for the importance of Piagetian structures to reading. The fact that no child who was classified as being in Stage II on the Piagetian Tasks, was a Good Reader, seems to be a telling argument for the need to have reached Concrete Operations (Stage III) on the spatial structures before being successful at reading.

The Stage Analysis emphasizes the developmental nature of reading skill, something that was discussed in the Introduction in relation to a Piagetian conceptualization of reading. Those children who have been slow to reach the Stage of Concrete Operations, have problems reading (even though they are of normal intelligence). This suggests that topological structures are not enough for
reading skill. Further, it might seem logical that those children in Stage II in the present study would continue to be behind at a later time. That is, they might still be in Concrete Operations when the other children had moved on to Formal Operations. Thus, although their problems in reading would undoubtedly continue, their problems would be at a later, more complex stage.

The correlational and stage analyses then, compliment each other and together are very strong evidence for a link between Piagetian spatial structures and reading skill.

The second hypothesis of this study was that there would be some relation between intelligence and performance on both the Piagetian and Reading Tasks, but that this relationship would not be sufficient to account for the relationship between reading and Piagetian tasks. This hypothesis was also confirmed. The correlation between intelligence and Piagetian Tasks was higher ($r = .43$) than that between intelligence and reading ($r = .23$) but the results were consistent with the literature cited in the Introduction. It is important that partialling out the effect of intelligence had little effect on the correlation between reading and Piagetian tasks. This result is the most relevant in confirming the present hypothesis. Intelligence was only an extremely small part of the relationship between the reading and Piagetian tasks which makes their relationship even more impressive.

It is interesting to note the wide range of Piagetian and Reading scores compared to the relatively small range of PPVT
scores. Moreover, the fact that all the children were within one year of each other in age, attests to the different rates of development occurring in individual children. In other words, chronological age is not that good an indicator of developmental level. The wide range of Piagetian scores within a limited age group is consistent with the research cited in the Introduction (e.g., Goldschmidt, 1967) in regards to intelligence and Piagetian tasks in a limited age group.

It can be concluded then, that the second hypothesis with regards to intelligence and Piagetian Reading Tasks was confirmed both with respect to the range and amount of relationship between the variables.

The third hypothesis of the present study was that there should be a degree of consistency in the performance of the child across Piagetian Tasks. The results of the Stage Analysis confirm this hypothesis. There were only four children in transition from one stage to another. The rest of the children were performing consistently within one stage (i.e., being in one stage on five or more of eight tasks). This is a high degree of consistency considering the possibility of decalages and the performance variables present in any task.

The final hypothesis of the study was that there should be a stepwise success rate on any given Piagetian tasks based on the degree of difficulty of individual items. With the exception of the Enclosure Task, this hypothesis was also confirmed. The
present hypothesis is closely related to the last hypothesis relating to consistency across Piagetian Tasks since the consistency was based on the Stage Level each child had attained on each task which is directly related to the difficulty of each item. Thus, the stage and conceptual analyses compliment each other in confirming the present hypothesis.

In general then, all four of the major hypotheses of the study were confirmed. Moreover, the central issue of the study, i.e., whether or not Piagetian spatial structures are related to success in reading, has been confirmed in two separate analyses. Both the correlational and stage analyses confirm that mastery of the spatial structures is related to success in reading at least at the identification level.

The four specific hypotheses which have just been discussed were derived from an extensive analysis of Piagetian spatial theory in relation to reading (see the Introduction). It therefore seems appropriate to return to discuss how the present results fit into the larger theoretical and practical picture. In the introduction, two main reasons were given for undertaking the present study: 1) to extend the applicability of Piagetian theory to a practical field and 2) to attempt to develop a more global, developmental approach to reading and reading problems. Both of these main aims have been realized, at least to some extent, by the clear results of this study. The application of Piagetian theory to an analysis of reading has been shown to be valuable. The fact that
competence (in the abstract sense of having mastered a structure) in Piagetian spatial structures is necessary for successful performance (actual overt act dependent on the underlying competence) on reading tasks is of great interest and importance to teachers of reading. The introduction of the Piagetian system has revealed a whole system of spatial structures which are basic to reading but which might not be immediately obvious to the classroom teacher faced with a poor reader. Thus, although a child's lack of competence on a Piagetian spatial structure may be reflected in a very specific performance problem, e.g., letter reversals, it is the underlying spatial structures rather than the specific letter reversals that should be concentrated on in remedial training. For example, the Piagetian structures of order and enclosure might be worked on instead of the specific reading problems of letter and word confusions.

Since Piaget has consistently maintained (e.g., 1970b) that the child only remembers what he understands or is on the verge of understanding, there is no point in trying to teach a child concepts and rules that are far too complex for him to assimilate. Thus, for example, if the child is not competent in the four basic topological structures, there is no advantage in spending long hours trying to train a child in a more complex task which requires a more difficult and later developing euclidean spatial structure. Put in its most general form then, performance on reading identification skills is dependent on competence in the Piagetian spatial
structures. In the Introduction, reading was described as being represented figuratively, at the letter-word level by the image and operatively by the Piagetian spatial structures. It is the operations and not the symbols which are fundamental. This is a whole new way of looking at reading and reading problems and it is only by applying Piagetian theory to a specific practical problem (reading) that this approach could evolve.

An important aspect of the Piagetian approach to reading which was reflected in the second aim of this study, is the fact that Piaget's theory is developmental. That is, Piaget has described a sequential stage theory of development which is invariant. Thus, the child must go through Stage II (Pre-Operational) cognitive structures before he reaches Stage III (Concrete Operational) cognitive structures. Each scheme and structure has a developmental history that must be followed. This same type of developmental approach can be applied to reading. The results of the present study strongly suggest that there is a minimum level of development necessary to be successful at reading, (no child who was in Stage II was a good reader). This same trend could likely be established with different age children. For example, it might be that no child in Stage III (Concrete Operations) could be successful in answering complex reading comprehension questions (which might require competence in the structures of Stage IV, Formal Operations). The importance of the developmental approach is that it presupposes different types of reading problems at
different development levels. Moreover, this approach does not imply that the poor reader's performance will be fixed, rather it implies that his rate of development will be different, perhaps slower, than that of the good reader. Also, the developmental approach does not imply that the poor reader cannot read, but rather that it would not be realistic or practical to expect the poor reader to profit from the same type and rate of teaching as the good readers. For example, Stage II children still view projective space egocentrically. They do not understand the principle of multiple points of view which evolves in Stage III. Thus, in the specific case of left-right, the child can identify left and right on himself but he does not understand that in order to identify left-right on someone facing him, he must reverse the locations in relation to himself. This has immense practical value when one considers the standard classroom situation where the teacher stands facing her class and teaches about letters such as b's and d's. A Stage III child would be capable of performing the necessary mental transformations in order to reconcile the teacher's point of view with his own, the Stage II child would not recognize the need for such a transformation and thus, would not be able to accurately accommodate to the details of information and so would assimilate either very little of the relevant information or inaccurate information. Either way, a lesson that would be useful and informative for Stage III children would be confusing and maybe even damaging (assimilating incorrect information)
to a Stage II child. This lengthy example should serve to show the contribution of a developmental approach to learning and teaching reading.

Implications and Applications

a) Causation of Reading Failure

The results of the present study support the Developmental Lag Theory of reading failure. This theory discussed in some detail by Bender (1963) and De Hirsch et al., (1966) suggests that one possible cause of reading failure could be a lag in the development of the child such that the child arrives at school age too immature to benefit from teaching in reading. The reason for this lag or slowness in development could be anything from genetic inheritance, pre-mature birth to some slight type of brain damage. This idea of a lag in development fits well with the developmental approach to reading taken in the present study. The fact that no child who was in Stage II of development was a Good Reader could be interpreted to suggest that the Stage II children had not reached a level of cognitive development sufficient to enable them to read. Considering that there were children of the same age who had reached Stage III and were Good Readers, it could be said that the Poor Readers were evidencing a lag in their cognitive spatial development. That is, the Poor Readers were taking a longer time to proceed through the sequential Piagetian structures than the Good Readers and thus were at an earlier Piagetian Stage of development.
b) Future Research

Throughout the Discussion there has been an attempt to evaluate the usefulness of individual tasks in relation to the total battery of tasks used. On the basis of these evaluations, it would seem reasonable to use a smaller battery of tests in any future research. On the Reading side, a suitable set of tests would seem to be the Gray Oral Reading Test, Sounding and Proximity-Separation. For the Piagetian Tasks, the Part-Whole Task and the Order-Tunnel Task should be excluded thus reducing the Piagetian Tasks to six from eight.

In any future research with the present tasks, it would be interesting to introduce some changes in the scoring of the Piagetian Tasks. It would be valuable to increase the sensitivity of the confidence measure introduced in the present study. The confidence measure was very vague, encompassing both the general level of explanation of the child and whether or not he was easily talked into changing his answer. In any future research, it would seem reasonable to introduce a double scoring technique for each task. One system would be the system used in the present study, including the confidence mark assigned on the basis of the child's refusal to change responses. Then the tasks should be recorded on the basis of the explanations given for the answer. Thus, in the Landscape Task, the explanations could be scored on the basis of what type of spatial structures were used in justifying the location of the dog. For example, for Position J, discussed
earlier, if the child used the projective explanation of why the dog was facing the way he was, he would get a higher score than if he used a topological explanation. Obviously, scoring explanations would be highly subjective and would introduce methodological problems (e.g., how do you know that the child does not know the projective explanation even if he only uses the topological?). However, the double scoring method would give a much more complete picture of the level of functioning of any given child, and it would make the tasks much closer to the actual method envisioned by Piaget.

If all these methodological considerations discussed above were implemented, then the question becomes what type of future research would be fruitful. The logical next step would be to attempt to move the testing down towards the Kindergarten and early Grade One level. It is most important to identify potential problem readers as early as possible since once standardized reading instruction begins the child with potential problems soon becomes so far behind the other children who are ready to read that not only is reading instruction not benefiting the child, but also, it might actually be hindering the child's progress (e.g., Bannatyne, 1971). The next step in research then, should be an attempt to measure the degree of relationship between performance on Piagetian spatial tasks and the reading readiness tests of Kindergarten and Grade One children. Moreover, the ideal study would be longitudinal, following the progress of children
tested in Kindergarten through the first few grades. A longitudinal study would be able to determine whether the present reading readiness tests or the Piagetian spatial structures are the better predictors of later reading problems. A study of this type would also help establish more firmly the contention discussed in the present study that reading problems at different ages would reflect problems at progressively more complex levels of cognitive structures. It should be noted that by applying the Piagetian Tasks to younger children, it may be necessary to use Piagetian Tasks requiring more basic and earlier developing Piagetian spatial structures, for example, proximity and separation.

Although it was suggested in the preceding paragraph that the Piagetian Tasks might be better predictors of future reading problems than the present Reading Readiness Tests, this was not meant to imply that only Piagetian spatial structures are involved in reading. Reading problems could also be caused by specific auditory or visual weaknesses or other specific problems. It is only being suggested that the spatial structures are also implied in the skills necessary for reading.

b) Applications

If the presently established relationship between reading and spatial structures is supported by future research, then the spatial structures should be included in remedial reading programs. The fact that no child who was in Stage II on the spatial tasks was a Good Reader would strongly suggest that until the child has
reached Concrete Operations (Stage III), he should not be taught or expected to read. Instead of basing a remedial program on specific letter reversals or visual confusions, it would seem wiser to concentrate on allowing the child to establish the basic spatial structures as described by Piaget. Once the child has developed to the stage of understanding at least the structures of topological space, then he should be taught to apply these structures to reading and not before.

Thus, if reconfirmed in future research, the present Piagetian spatial tasks could be used in both a predictive-diagnostic and a remedial way to help problem readers. The tasks would be predictive if the Stage Analysis is supported in future research. Then, by giving a child the Piagetian Tasks, a testor could predict with accuracy whether or not the child has reached a level of cognitive spatial development necessary to permit successful teaching of reading. Moreover, by identifying the pattern of performance on the Piagetian Tasks, it would be possible to tailor remedial work to the one or two spatial constructs that the child had special problems with.

The general import of these last few speculative paragraphs is that the Piagetian spatial system described in the present study could be of immense practical value in identifying and helping problem readers. It is the belief of the present author that the nature of the results in this study is a very strong indication that the spatial tasks, in fact, will and can be used in the way described.
SUMMARY

The present paper began by conceptualizing reading in terms of Piagetian structures. Thus, the letters were said to be represented figuratively and symbolically by the image and operationally by the infralogical spatial structures. The spatial structures were differentiated into topological, projective and euclidean space and within each of these systems the basic structures as they applied to reading were discussed.

The result of this theoretical analysis was a set of eight Piagetian spatial tasks which were tested for correlation with eight reading tasks and an intelligence test. On the basis of the correlational analysis, it was concluded that there was a strong relationship (r = .67 between the Total Reading Score and the Total Piagetian Score) between performance on the reading tasks and performance on the Piagetian tasks.

A conceptual analysis was performed on each of the Piagetian Tasks. The various items within a given task were ordered in terms of increasing difficulty based on the underlying Piagetian structures required to successfully solve the item. The theoretically predicted order of item difficulty was supported by the actual order of item difficulty experienced by the children with one exception of the Enclosure Task. A Stage Analysis based on the conceptual analysis was also conducted and there was a high degree of consistency in the children's performance across the Piagetian tasks. When the reading ability of the children at each Stage was considered,
it was observed that no child who was in the Piagetian Stage II was a Good Reader.

On the basis of all analyses considered, it was concluded that the Piagetian spatial structures did underlie and were predictive of the child's ability to read at least at the identification level. The application of this conclusion to practical remedial reading problems was considered.
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Appendix 2

Actual instructions for the Piagetian Tasks.

a) Landscape

E places the two landscape boards in front of the child with the child sitting facing E across the table. E says:

"We have two pictures here and they're the very same. See, there's a blue house (pointing) here and one here (waits for the child to acknowledge and then says), What else is the same on the two pictures?"

E then lets the child compare the two pictures and gives hints if the child has trouble until the child is sure the pictures are the same. Then E says:

"We also have two dogs (showing them), one for each picture (place one dog on each picture as this is said). O.K., now what we're going to do is this. I'm going to put my dog (indicating it) some place on my picture and I want you to put your dog on the very same place on your picture. O.K.? Let's try".

E places her dog on the chimney of the blue house and asks the child to do the same. Then E asks:

"How do you know that's the same place?"

If the child gives only a partial answer, E gives hints (e.g., by asking something like - "Well, why didn't you put yours over here?" - indicating on top of the tree, and so on) until the child describes specifically where the dog is including that he is facing the same way as E's dog. Then a second practice trial is given
to make sure the child can describe the location accurately (the second practice location is at the back of the large red house). Again, E continues questioning the child until he has described the location completely. E then says:

"Now we're going to make your're job a little trickier, I'm going to turn your picture around."

E then slowly rotates the child's picture $180^\circ$ making sure the child is watching during the process. E says:

"See, your picture is turned around. Now your green tree is down there (pointing) and mine's up here, and your blue house is way up here and mine's way over there (pointing)."

E makes sure that the child is aware of the changes by getting the child to describe other location differences and then says:

"Now, we're going to do the same thing again - I'm going to put my dog some place on my picture and I want you to put your dog on the very same place on yours. But, remember, your picture is turned around and so you really have to think about where you put the dog. (pause). Your dog has to be in the very same place as mine."

E then proceeds through the 12 positions indicated on the diagram Figure 6, asking after each placement if the child is sure that's where the dog goes and how he knows that is the right place to put it. The child is given some encouragement after each placement, e.g., "Good, O.K., fine, etc."
b) Transformations

E shows the plasticine with the sticks in it to the child and says:

"See, we have four sticks in the plasticine (pause - wait for the child to look and agree). Now, if I were to put an elastic (indicating the elastic with her finger) around these four sticks, what shape would the elastic make?"

If there is hesitation, the question is repeated and the figure vaguely traced with the finger. If there is still no answer, then the elastic is actually placed around the sticks so the child can see and then he is again asked what shape the sticks make. Once this part is done successfully, E indicates the movement of each stick with her finger and says:

"What if I put this stick here and this stick here and this stick over here, etc., and then put the elastic around all of the sticks, what shape would the elastic make now?"

If the child did not get all the movements, the imagined placement of the sticks was repeated. After the child has studied the shape for a while or after he says a shape name, E asks:

"Would it make any of these shapes?" (gives the child the card with the line drawings on it).

After the child makes a choice, E asks:

"Why is that the shape it would make?"

If the child cannot find what he considers to be an appropriate drawing then he is asked to draw the shape he thinks the
elastic would make and then the questioning continues as for the line drawings, i.e., asking why that would be the shape. The procedure for the other three items was the same.

c) Part-Whole

E takes the model square and circle and places them in front of the child and says while pointing:

"Now, here is a circle and here is a square."

E takes the first card (which is a circle) and places it over the model square so that only the model circle and the test card are visible and asks:

"Do you think that these two pieces (pointing to them) could go together to make a circle like this one (indicating the circle model)?"

When the child answers this question, E asks:

"Why do you think so?"

When the child's answer has been recorded, E says:

"O.K., why don't you try and see if the pieces go together, the pieces are on the back of the card."

When the child is finished putting the pieces together, E asks:

"So, do the pieces make a circle (square)? Why?"

The same procedure is followed for the other items always covering the model that does not apply on that specific trial.

d) Order-Bead

E places a string with 5 coloured beads on it in front of the
child and says:

"Here is a string with five beads on it. Now, what I want you to do is to take this stick (hands it to the child) and some beads from this box (places a box of loose beads in front of the child) and put the beads on the string so they look the very same as the beads on the string. (pause, then repeat) Put the beads on the stick so they look the very same as the beads on the string."

When the child has completed this task E asks:

"Are the beads the very same as the ones on the stick?"

When the child has answered, then E asks:

"How do you know they're the same?" After the child has answered, he says: "Good, now put your beads back in the box."

For the second part E says:

"This time I want you to put the beads on your stick so they look the very opposite to the beads on the string. (pause) So they go in the opposite direction."

The same questions are asked after the child is done as in the first part.

For the third part E presents the beads on the string lying in a circle made by threading the ends of the string through the two nearest beads. E asks:

"O.K., this time I want you to put the beads on the stick so they look like these beads would (indicating circle) if I pulled the string apart and made it into a straight line again (use gesture of hands to indicate the appropriate motion). Show me what the beads would look like if I pulled the string apart and made it
into a straight line."

The questions after the child completed this part were the same as for the other items.

e) Order-Tunnel

E removes the beads on the string but leaves the rest of the equipment and then says:

"Now we are going to do something different with the beads."

(E takes the stick from the child and suiting actions to words says:)

"I'm going to put a green bead, a white bead, and a blue bead on the stick and a green bead, a white bead and a blue bead in front of you."

E then places the stick with the three beads on it parallel and close to the three beads of the child and says:

"Now, you can see these beads are the very same (indicating the two sets of beads and waiting for the child to acknowledge this). I'm going to put these beads (indicating the beads on the stick) into the tunnel (follow words with actions). Now, which bead is going to come out first from this end of the tunnel (indicating end with finger)? Then which one, Then which one?"

When the child has indicated his choice, he is asked to justify his answer. When he has completed his explanation, the stick is removed from the tunnel so that the child can see in fact which bead would come out first. Then E again places the stick with the three beads on it beside the child's three beads and
"See, your beads and mine are still the very same. Now, I'm going to put the beads on the stick back into the tunnel (does it) and I'm going to turn the tunnel around (turns the tunnel $180^\circ$ very slowly while the child watches). Now, which bead is going to come out first from this end of the tunnel (indicating the desired end)?"

E then follows the same procedure as in the first part asking for justification of the child's answer. The other two items were done using the same procedure as this last item, then when all the items are done, E asks:

"Could the white bead (the middle bead) ever come out of the tunnel first? Why? or Why not?"

E then takes the card with the trajectory drawings of the beads rotating in the tunnel and asks:

"Do you think that any of these pictures show how the beads turn around in the tunnel? Why is that the best picture?"

If the child cannot find a picture that he thinks would fit, then he is asked to draw a picture of what it should look like and then justify his answer as with the already drawn trajectories.

f) Enclosure (Knots)

E gives the child a thick piece of yellow nylon rope and says:

"Can you tie me a simple knot like the kind you tie your shoes with?"

E waits for the child to finish tying the knot and if he has trouble E demonstrates how the knot should be tied and continues
until the child has tied a simple over-hand knot. Then she says:

"Good, now pull your knot really tight."

While the child is watching, E takes another piece of rope and ties it the same way as the child's but leaving the knot loose, and says:

"Are these two knots tied the same? (pause) Are the knots the same or different?" (after the child answers, she says) 'How do you know they're the same (different)?'

E then goes through the rest of the knots presenting them in pairs already tied and asking the same questions as above.

g) Left-Right

E is sitting directly opposite of the child and says:

"Show me your right hand."

E waits for the child to indicate his hand and then asks:

"How do you know that's your right hand?"

After the child has answered this question, E proceeds to ask the child to show her the child's left hand, right foot and so on, asking after each time how it is that the child knows that is the correct choice. When this part of the task is complete, E gives some encouragement and then places her hands face down in front of her on the table and says:

"Now, show me my right hand."

When the child has indicated his choice, E asks for justification of the choice and then goes through the rest of the positions in a similar manner to that used in the first part. When this section is complete, E places three articles in a row in front
of the child identifying each article as it is placed on the table and then says:

"Now, can you tell me what is to your right of the dog (which is in the middle)?" If the child seems confused E says: "Is the bead or the stick to your right of the dog?"

When the child has answered this question, he was asked to justify his choice. If it was not apparent from the justification that the child was using his own perspective rather than still using that of the experimenter, E asks:

"Show me your right hand. Now show me what is to your right of the dog."

If the child still got the answer wrong at this point, it was assumed that he just could not solve the problem and the questioning continued as for the other children. The child was asked to indicate and justify his choice for the rest of the positions, for example, to the left of the stick, to the right of the bead, and so on.

h) Airplane

The apparatus is moved into place and E says:

"We have two airplanes here (indicating them) and they're both on magnets so they can stick anywhere you want and won't fall down."

E then demonstrates by putting the plane upright on top of the ring and upside down hanging from inside of the ring and then says:
"You try with your plane and and see how the plane sticks." After the child has placed his plane somewhere on the ring E says: "Now try to pull the plane off the ring and you'll see how strong the magnets are." (this is done to insure that the child knows that the plane would not fall off the ring).

Once the child has tried putting the plane in several positions and is convinced that it will not fall off the ring E says:

"O.K., now this is your plane (indicating the plane beside the ring) and this is mine (indicating the plane on the track at the bottom). My plane can fly around the ring (indicating path with finger) and back down here (indicating the stationary position of the plane at the bottom of the ring)". After a pause E continues:

"Now what if my plane only flew part way round the ring to here (indicating position C) and then stopped for a rest. Could you show me with your plane where my plane would be when it stopped for a rest?"

There is a pause to let the child think and then E repeated with appropriate gestures:

"Put your plane where my plane would be when it stopped for a rest here."

After the child has placed his plane on the ring, E asks:

"Is that the way the plane would be facing when he flew around to here?" After getting the child's answer E asks: "How do you know that's how the plane would be when it stopped here?"
The same description is given for the other two positions on the ring and the same questions asked after the child places his plane. It should be noted that between trials the child's plane is always returned to the original starting position on the table outside of the ring. When this section of the task is complete E brings out the 'pilots' and says:

"Now, let's pretend that these are pilots. Let's put a red pilot and then a yellow pilot (one behind the other) on my plane (follow words with actions) and we'll put the same on yours. First there's the red pilot and then the yellow one. (pause) These pilots are on magnets too so they can't fall off (E turns her plane upside down and shakes it to show that the pilots are secure). They're wearing special safety belts so they won't fall off."

E lets the child try with his pilots until he is convinced that they will not fall off and then says:

"This time I want you to show me just where the pilots would be when the plane gets to here (Position C)." E traces the path of the plane to position C with her finger, pauses for the child to think and says: "What you have to do is take the pilots off the plane and put just the pilots where they'd be when the plane gets to here."

E waits for the child to place the pilots and then asks the standard justification questions making sure that the child understands that he must imagine that the plane is in the indicated position and the pilots are sitting on it. The same procedure is repeated for the other two positions then E removes the pilots
from both sets of planes and says:

"Now what if these pilots were special stunt pilots who flew on the wings of the plane? We'll put the red pilot over here (placing the pilot as close as possible to the body of the plane on one wing) and the yellow here (on the other wing), and we'll do the same with your pilots. First, we put the red pilot here and then the yellow one there. Now, these are stunt pilots with special safety belts so they won't fall off (again turns plane upside down and shakes the plane to indicate the security of the pilots)."

Once the child has again tested the pilots to make sure they will not fall off, E repeats the instructions as in part two with the same justification questions after the pilots have been placed on the ring.
Appendix 3

**Flexibility of Transformation**

<table>
<thead>
<tr>
<th>Shape Chosen</th>
<th>Closed Figure (2)</th>
<th>Correct (5)</th>
<th>Confidence</th>
<th>Total (6)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trial Square</strong></td>
<td>Don't Get</td>
<td>Only after elastic</td>
<td>Got right away</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Enlarged Square</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td></td>
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</tr>
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<td><strong>Rhombus</strong></td>
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<td><strong>Triangle</strong></td>
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</table>

**Total Score**

**General Comments**
2. Part-Whole (Partitive Addition)

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<th>Putting Pieces Together</th>
<th>Total Comments</th>
</tr>
</thead>
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</tr>
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<td>3. Circle</td>
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<td>4. Square</td>
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<td>5. Circle</td>
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<tr>
<td>6. F. sq.</td>
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<td>8. Square</td>
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<td>9. F. cir.</td>
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<td>10. square</td>
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Total Score .................

General Comments
3. Order
A) Beads on string

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<th>Green</th>
<th>Yellow</th>
<th>Purple</th>
<th>Orange</th>
<th>Confidence</th>
<th>Total</th>
<th>Comments</th>
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<td></td>
<td></td>
</tr>
<tr>
<td>Reversed</td>
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Total Score: ____________

General Comments

3 (B) Beads in the tunnel

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<th>Green</th>
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Total Score: ____________

General Comments

3. (C) Trajectory

Choose Drawing No.

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<th>Drawing</th>
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<th>Drawing</th>
<th>Drawing</th>
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<th>Confidence</th>
<th>Total</th>
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<tbody>
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<td>3 &amp; 4</td>
<td>5 &amp; 6</td>
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<td></td>
<td>(9)</td>
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Total Score: ____________

General Comments
4. **Enclosure**

Could tie knot: Yes No

<table>
<thead>
<tr>
<th>Cor. Ans.</th>
<th>Cor. Ans.</th>
<th>Cor. but</th>
<th>Confidence</th>
<th>Total</th>
<th>Comment</th>
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<tbody>
<tr>
<td>Wrong Reason</td>
<td>Aft. Bead</td>
<td>Fuzzy</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

1. taut vs. slack

2. lt vs. rt knot

3. 8 vs joined ends

4. cir. joined and not

5. cir. vs cloverleaf

Total Score

General Comments

5. **Left - Right**

<table>
<thead>
<tr>
<th>Lt.eye</th>
<th>Lt.eye</th>
<th>Lt.hand</th>
<th>Lt.hand</th>
<th>Lt.leg</th>
<th>Rt.leg</th>
<th>Reversed</th>
<th>Total</th>
</tr>
</thead>
</table>

on self

on examiner

Relations

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<th>Lt. Elas.</th>
<th>Lt.dog</th>
<th>Rt.dog</th>
<th>Lt.bead</th>
<th>Rt.bead</th>
<th>total</th>
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General Comments

Total Score
6. Airplane
   A) Plane - Alone

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<th>Up Down2</th>
<th>Confidence 1</th>
<th>Total (5) comments</th>
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</tr>
<tr>
<td>Posit B</td>
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</tr>
<tr>
<td>Posit C</td>
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<tr>
<td>Posit D</td>
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General Comments

Total Score

6. B) Pilots (one behind the other)

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<td>Posit B</td>
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<td>Posit C</td>
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<td>Posit D</td>
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General Comments

Total Score

6. C) Pilots (side by side)

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<th>UP-Down (2)</th>
<th>Face Rt. Direction (2)</th>
<th>Conf.</th>
<th>Total (7)</th>
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</thead>
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<tr>
<td>Posit C</td>
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<tr>
<td>Posit D</td>
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<td></td>
</tr>
</tbody>
</table>

General Comments

Total Score
Appendix 4

Sentences
1. A dog saw a hen.
2. The girl has a cat.
3. Mary has big brother.
4. Jane is just twelve years old.
5. Mother likes to cook for her family.

Spelling
Name:
was ___________ saw ___________ boy ___________

Proximity
1. on ___________
2. man ___________
3. come ___________
4. spell ___________
5. school ___________

Separation
1. if ___________
2. ran ___________
3. rock ___________
4. catch ___________
5. corner ___________

Proximity & Separation
1. got ___________
2. rake ___________
3. talks ___________
4. caught ___________
5. looking ___________

Order
1. so ___________
2. bat ___________
3. gray ___________
4. black ___________
5. little ___________

Enclosure
1. on ___________
2. sun ___________
3. pole ___________
4. peace ___________
5. donkey ___________

Order & Enclosure
1. pet (_pt) ___________
2. look (ol_k) ___________
3. brown (bwnq:) ___________
4. twelve (wt_v_e) ___________
5. brother (_r_rteb_) ___________
Appendix 5

Nonsense Words (Gates McKillop VI - 1)

1. tabe
2. hud
3. jipso
4. burall
5. elling
6. nettish
7. rimpick
8. fingle
9. hackand
10. spiness
11. whiskate
12. chimber
13. latago
14. askintell
15. pediflow
16. espincot
17. märgerbug
18. duzaleen
19. kashulide
20. cobisome

Word Sounding (Gates McKillop V - 1)

1. spack
2. drite
3. floy
4. cled
5. swick
6. tright
7. stade
8. plark
9. glacle
10. shemp
11. dween
12. chalk
13. bler
14. gring
15. slidge
16. frable
17. twock
18. prible
19. thasp
20. smew
21. whast
22. wrell
23. brome

Letter Naming (Gates McKillop V - 4)

owr akb emd y tux
f c i v g h j n q s z l p
Appendix 6

The following is the key for the two correlation matrices (Tables 1 and 2).

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<tr>
<td>2</td>
<td>Sentences</td>
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<td>3</td>
<td>Spelling</td>
</tr>
<tr>
<td>4</td>
<td>Separation-Proximity</td>
</tr>
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<td>5</td>
<td>Order-Enclosure</td>
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<td>6</td>
<td>Gray Oral Reading Test</td>
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<td>7</td>
<td>Nonsense Words</td>
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<td>Sounding</td>
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<td>9</td>
<td>Letter Naming</td>
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<td>10</td>
<td>Transformations</td>
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<td>Part-Whole</td>
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<td>Order-Bead</td>
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<td>Order-Tunnel</td>
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<td>Enclosure</td>
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<td>Left-Right</td>
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## APPENDIX 6

### TABLE 1

**CORRELATION MATRIX OF ALL 20 VARIABLES**

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