CHILDREN'S IDEAS ABOUT THEIR SENSES

by

TEREZINHA NUNES CARRAHER

A dissertation submitted to the Graduate Faculty in Developmental Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

1976

This manuscript has been read and accepted for the Graduate Faculty in Psychology (Developmental) in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

July 23, 1976

Chairman of Examining Committee

July 23. 1976

Executive Officer

Joseph Glick, Professor

Gilbert Voyat, Associate Professor

Michael Lewis, Adjunct Professor

Supervisory Committee

The City University of New York

ABSTRACT

CHILDREN'S IDEAS ABOUT THEIR SENSES

by

Terezinha Nunes Carraher

Adviser: Professor Joseph Glick

Children's ideas about what can be known by the different senses were studied in two situations. In the more concrete situation, the children were asked to describe an object which they could touch but couldn't see. Young children often reacted in this situation as if they knew everything about the object including its color. In the more abstract situation, children were asked about what other people (specifically, two clowns in a series of pictures) could know through their senses. In this situation, young children tended to overestimate the informational value of vision. A group of 4/5 year olds was taught the correct answers in this task but this training failed in bringing their performance to conform to the adult solution of the task. Instead, they improved their answers but essentially approached the behavior of 7 year olds, who tended to underestimate the role of touch and hearing in certain cases.

It is suggested that the conception of sensory systems as interchangeable means of picking up information is not understood until about the age of 11. Children who have not attained this concept are influenced by the sensory modality they are operating in and tend to overestimate its importance

as compared with other modalities. These results are interpreted as an indication that knowledge about the senses must be distinguished from knowledge acquired from the senses.

Tentative implications for Piagetian theory were considered in the discussion. Knowledge about the senses was viewed as belonging to the realm of causal structures since it requires both information about a content and a logical structure (which allows for the necessity of substitution once it is recognized that two systems provide overlapping information about the same variable).

ACKNOWLEDGEMENTS

I am grateful to my advisers, Dr. Joseph Glick, Dr. Michael Lewis and Dr. Gilbert Voyat whose support and advice were invaluable. I am also grateful to Sister Ann Veronica of St. Edmunds School, who allowed me to work with the children in that establishment, and to all the 72 children who made this work a source of pleasure; to Dr. Sharon Massey and Ann Marie DeSciora Agnello, who worked with great care in judging the transcripts; to all students in the Developmental Program, whose continuous support was always appreciated; and to my husband, whose patience in these months was beyond belief.

TABLE OF CONTENTS

	page
Abstract	i
Acknowledgements	iii
List of Tables	vi
I. INTRODUCTION	1
1. Amodal vs. modality specific aspects of perception	3
2. Possible prediction regarding developmental trends	5
3. The conception of sensory substitution in others	8
4. General description of the study	10
Footnotes	12
II. METHOD	13
1. Design	13
2. Subjects	14
3. Task I: Haptic-visual matching	14
a. Materials	14
b. Procedure	14
c. Measure of performance	16
4. Task II: Description of a haptically encountered	18
a. Materials	21
b. Procedure	21
c. Measure of performance	22
5. Task III: The conception of sensory substitution in others	23
a. Materials	26
b. Procedure	26
b1. Procedure for the testing group	27
b2. Procedure for the training group	28
Footnotes	31
III RESULTS	32
1. Preliminary analysis of non-significant variables: order and sex effects	32
2. Task 1: Haptic-visual matching	33
a. Choice responses	33
b. Other behavioral indices	34
3. Task II: Description of a haptically encountered object	36
a. Interjudge reliability	36
b. General results (analysis of the results in terms of pass/fail measures)	37
c. Age related changes in the approach to the problem of sensory substitution	38

Page

4. Task III: The conception of sensory substitution in others 40
A. Developmental trends 40
a. choice responses 40
a1. Age differences 40
a2. Item analysis 40
a3. Analysis of strategies 43
-description of strategies 44
-evaluation of strategies 46
b. Verbal responses 55
b1. Age differences 56
b2. Analysis of strategies 56
b3. Relationship between choice data and reponses 58
B. Training effects 60
a. Choice responses 60
b. Verbal responses 61
Footnotes 63

IV SUMMARY AND CONCLUSIONS 64
1. Summary of the findings 64
a. Ideas about information gained from sensory contact 64
b. Developmental sequences 67
2. Alternative hypotheses unrelated to the conception of sensory substitution 69
a. The problem of taking the perspective of another person 70
b. Linguistic form 71
3. Piagetian theory and children's ideas about their senses 72
Footnotes 80
Appendix I: Description of trials for task I 113

Appendix II.1: Description of task II 115

Appendix II.2: General Classification of answers on task II 117

Appendix II.3: Specific classification of answers on task II 120

Appendix III.1 Description of pictures in task III 123

Appendix III.2 Mean no. of mistakes in criterion phase 127

Appendix III.3 Response keys according to each strategy 128

Appendix III.4 Samples of classified responses 129

References 131

LIST OF TABLES

		Page
Table of contents		iv
Table 1:	Analysis of variance, Task I	81
Table 2:	Analysis of variance, Task I	81
Table 3:	Analysis of variance, Task II	82
Table 4:	Analysis of variance, Task II	82
Table 5:	Analysis of variance, Task III (choice responses as dependent variable)	83
Table 6:	Analysis of variance, Task III (choice responses as dependent variable)	83
Table 7:	Analysis of variance, Task III (verbal responses as dependent variable)	84
Table 8:	Analysis of variance, Task III (verbal responses as dependent variable)	84
Table 9:	Analysis of variance, Task I	85
Table 10:	Mean scores for each age level, Task I	85
Table 11:	Proportion of passes in each part of Task II	86
Table 12:	Analysis of variance, Task II	86
Table 13:	Mean scores for each age level, Task II	87
Table 14:	Frequency of subjects per number of correct responses in ST-2, Task II	88
Table 15:	Proportion of responses in different categories in the 11 year old group, Task II	89
Table 16:	Proportion of responses in different categories in the 7 year old group, Task II	90
Table 17:	Proportion of responses in different categories in the 4/5 year olds group A, Task II	91
Table 18:	Proportion of responses in different categories in the 4/5 year olds group A, Task II	92
Table 19:	Mean number of errors for each age level, Task III	93
Table 20:	Guttman scalogram analysis, Task III	94
Table 21:	Deviation scores for each strategy, Task III	
	a: 11 year olds	95
	b: 7 year olds	96
	c: 4/5 year olds	97
Table 22:	Analysis of variance, Task III	98
Table 23:	Deviation scores per strategy, Task III (for the 11 year olds)	99

		Page
Table 24:	Deviation scores per strategy, Task III (for the 7 year olds)	100
Table 25:	Deviation scores per strategy, Task III (for the 4/5 year olds)	101
Table 26:	Proportion of subjects per best fitting strategy	102
Table 27:	Analysis of variance with reliability errors as dependent variable, Task III	103
Table 28:	Mean number of reliability errors for each age level, Task III	103
Table 29:	Mean number of errors in each presentation for each age group	104
Table 30:	Mean number of correct verbal responses for each age group, Task III	105
Table 31:	Frequency of types of mistakes for each age group, Task III	106
Table 32:	Correlations between choice data and verbal scores, Task III	107
Table 33:	Correlations between choice data and verbal responses, Task III	107
Table 34:	Correlations between choice data and verbal responses, Task III	107
Table 35:	Comparison of the test and training groups, choice data, Task III	108
Table 36:	Analysis of variance, Task III	108
Table 37:	Deviation scores for each strategy, training group, Task III	109
Table 38:	Proportion of subjects per best fitting strategy	109
Table 39:	Mean number of correct verbal responses in test and training groups, Task III	111
Table 40:	Mean number of correct verbal responses in training and 7 year old groups	111
Table 41:	Mean number of correct verbal responses in training and 11 year old groups	111
Table 42:	Frequency of types of mistakes in test and training groups	112

I INTRODUCTION

We usually go through life without many doubts about what we see. Occasionally, though, we are confronted with situations in which we don't believe our eyes. It might be a simple situation such as cleaning a spot in a glass. We see the spot on the outside and try to clean it. When it doesn't disappear, we usually don't give up but instead feel for the spot on the inside. When we succeed in scratching it out from the inside, we confidently go on cleaning the glass. Then we know that the spot was really on the inside of the glass.

There aren't many situations in which we doubt our senses. But, when we do, we simply try to obtain confirmation of what we think we perceive by using a different sensory system. This attempt to confirm a perception by verifying it be different means represents, in some sense, an epistemological theory. This theory involves the assumption that our knowledge about the world might be biased by the means used in gathering information; when we suspect that such a bias might be operating, we attempt to verify the information by using a different method of obtaining the same information. This is a theory of knowledge about knowledge. It presupposes not only the ability to coordinate information obtained by different methods but also the recognition that this coordination is necessary if one wants to evaluate the veridicality of that information.[1]

The ability to coordinate information from various sensory modalities has been called intermodal responding, intersensory integration or sensory substitution. This ability can be looked at from at least two points of view: (1) one can investigate whether a subject is able to perform this coordination of information, and (2) one can study whether the subject understands when two sensory modalities can be coordinated.

The vast literature now existing in developmental psychology on intersensory coordination seems to have concentrated on the former aspect of the problem. For example, a child is presented with a haptic form and asked to identify it visually. What the experimenter is interested in finding out is whether the child can perform the coordination between haptic perception and visual perception. These studies concentrate (of necessity) on the amodal aspects of perception, i.e., those aspects of objects and events which can be known by more than one sense modality. Among the questions that have been asked are whether intermodal coordination is equally available to younger and older children (Birch, 1963; Abravanel, 1968), if developmental trends in intermodal ability can be explained by the developmental trends within the modalities involved (Milner & Bryant, 1968), if intermodal coordination depends on verbal mediation (Blank & Bridger, 1964; Ettlinger, 1967), to cite only a few. The explanations, whether they are modality oriented (e.g., Birch, 1963) or not (e.g., Gibson, 1969; Goodnow, 1971), have all focused on the amodal aspects of perception.

The question addressed in this study is of a different nature. This study does not simply involve the coordination of perceptual inputs from different modalities but rather focuses on how children conceptualize the relationship between the different sensory systems and the perceptual dimensions of objects. The literature on intermodal transfer has so far presented the child with a situation in which sensory substitution is possible and asked the child to perform this sensory substitution. The problem we propose to study involves both presenting the child with situations in which sensory substitution is possible and situations in which it is not possible and investigating whether the child is able to discriminate between the two types of situation. In order to clarify what is meant by the possibility or impossibility of intersensory substitution, one should examine the distinction between amodal and modality specific aspects of perception.

1. Amodal vs. modality specific aspects of perception.

Gibson (1966) has suggested that the relationships between the senses should not be conceptualized in terms of modes of sensations but rather in terms of acquisition of information. Conceptualizing perception in terms of modalities leads to the problem of how a visually encountered square, for example, can ever be related to a haptically encountered square. A conception of perception based upon the notion of acquisition of information, on the other hand, provides a framework in which one can discuss the equivalence of any type of information (for example, spatial information) picked up by

any modality (for example, the visual and tactual modalities). The possibility of coordinating different sensory systems depends upon the existence of overlap of information given by the systems involved. More specifically sight and touch can be coordinated because they both provide information with regard to shape, size and type of material of an object. This coordination becomes impossible when certain aspects of experience are considered, which cannot be perceived by both of the senses under consideration. If we consider color as an example, it becomes clear that sight and touch cannot be coordinated with regard to it, since tactual exploration does not yield information about color. The same might be said about the possibility of coordinating sight and touch with regard to the weight or temperature of an object. One cannot know the weight of a box by looking at it or (to the dismay of many mothers!) whether the iron on the ironing board is hot or cold. Since vision does not provide information about weight or temperature, there is no coordination of vision and touch with regard to these dimensions.

When intersensory coordination is possible, the observer who has the necessary amount of experience will be able to go from one sense to the other with a high degree of certainty. One does not have to claim that sensory coordination is given from the beginning or that everyone is equally proficient at it. However, the possibility of coordination is in some sense independent of the observer and relies more on the relationship between the perceptual dimension and the sense modality,

which are given.[2]

Even when two sense modalities do not overlap with regard to a specified dimension, a different type of coordination, which we may call a coordination judgement, is still possible. For example, if one identifies a toy rabbit haptically, one can reasonably expect it to be white, brown or gray rather than green or orange. This is a coordination judgement in the sense that it relies not on the possibility of going from one sense to the other on the basis of perceived information but on the evaluation of the probabilities that a particular object might be of a particualr color. A coordination judgement is possible in these cases where one knows of an association between different dimensions of objects but, in contrast to the situations in which actual intersensory coordination is possible, one should remain aware of the probabilistic nature of this judgement considering that a coordination judgement does not rely on the relevant perceptual information.

2. Possible predictions regarding developmental trends.

We can conceive of the processes involved in answering questions related to the possibility or impossibility of intersensory coordination in more than one way. First (and perhaps more simply), one can say that all that is involved here is a simple form of introspection of the part of the subject. In the case of coordination of touch and vision with regard to color (i.e., when the child is asked the color of a haptically presented object), all the subject has to do is ask himself:

"Am I seeing the color of this object?", and he will correctly conclude that this coordination is not possible, handling the problem properly. Since there is no reason to suspect that dimensions which are modality-dependent for adults could be amodal for children and vice-versa, there is little reason to expect age changes in the way children answer these questions. Even young children are able to use the simple introspective process suggested above, as one can see, for example, when young children (4 or 5) are asked the color of an object presented visually. In other words, it is suggested that the child can under certain circumstances draw upon his perceptions in order to answer questions and that, if this is the way in which such problems are treated, one should not find age related changes in the discrimination between amodal and modality-dependent aspects of perception. According to this hypothesis, young children are expected to perform at ceiling level when presented with a problem of this nature.

A second type of process that could be implicated in the performance on this type of task involves the development of notions about the senses rather than a simple introspection upon the perceptual experience. The child must form an internal representation of the sensory inputs and he responds not directly on the basis of the sensory input but on the basis of this internal representation. At the intuitive level of thought (from about 2 to about 7 years), the means by which this representation is achieved is the image of the object, which has specific characteristics perceived in the particualr

mode of examination of the object. This process could result in a mistake of over-specification, i.e., the child describes non-perceived characteristics of the object as part of his perceptions. Developmental changes could result from this process if the subject fails to distinguish between this internal representation and his own perceptions. According to Piaget, with the emergence of operational thinking images loose their importance as instruments of thought and this error of over-specification should tend to disappear.

It is unclear how much children know about their psychological processes. Very little work has been done in this area but Appel, Cooper, McCarrel, Sims-Knight, Yusses & Flavell (1972) have suggested, on the basis of memory experiments, that preschoolers fail to distinguish between perception and memory.

If we assume that children's ability to discriminate between amodal and modality specific aspects of perception is not the result of an immediate apprehension of their perceptual experiences, developmental trends in the performance in this type of task will also be predicted on the basis of the possible relationship between this ability and notions of probability. In fact, it was pointed out that an important distinction between actual intersensory coordination and coordination judgements is the degree of certainty which can be attributed to each of these two types of coordination. Sensory substitution is invested with a high degree of certainty while coordination judgements are necessarily probabilistic. Piaget & Inhelder's work on the development of notions of chance and

probability (1951) suggests that pre-operational children cannot appropriately distinguish between certainty and probabilty. These considerations suggest that even in a situation where the child can draw upon his experience in order to discriminate between amodal and modality specific aspects of experience, the young child might not appropriately distinguish between intersensory coordination and coordination judgements.

Finally, developmental trends are expected in this type of task if we assume (as Piaget does) that perceptual development is influenced by cognitive development. Perceptual activity is said to increase within modalities allowing for, among other things,better recognition of forms, for example. It is likely that the increase in perceptual activity also leads to a greater number of couplings across modalities, what would provide the child with more information about the relationships between the senses.

3. The conception of sensory substitution in others.

If the only process by which one can answer questions regarding the possibility of intersensory integration is simple introspection, it is questionable that one could ever deal with the same problem when it involves a second person. It is likely that at some point children form more general notions about the functioning of sensory systems which allow them to answer the latter type of question. Even if there are no developmental changes when one looks at children's ideas about their own ability to coordinate different modalities, responding

in the absence of direct experience might present a problem for young children. The hypothesis of a simple introspection process underlying children's notions of intersensory coordination leads to the following predictions: (1) no age differences exist when the child is actually attempting to perform the sensory substitution under consideration since even young children should perform at ceiling level; (2) age differences should be observed when the child is asked about someone else's intersensory integration. In fact, Piaget & Inhelder (1967) have found that young children who can perform well in a task which does not involve a shift in perspectives will be unable to perform in the same task if required to adopt someone else's perspective. Several studies by Flavell (1968) have also illustrated the young child's difficulty in switching perspectives and looking at games from the other person's point of view.

We are led to different predictions if we hypothesize that the child's notions of intersensory coordination are not the result of a process of direct apprehension of their perceptual experiences but depend rather upon the elaboration of ideas about the relationships between the senses and the qualities of objects. Even in a more concrete situation, where the child is actually allowed to draw upon a relevant ongoing experience, it is predicted that the young child (4 or 5) will not perform as well as the older children. These differences should be further accentuated in a more abstract situation, when children are asked to take the perspective of

another person.

Thus, developmental trends are predicted according to both hypotheses in relation to the child's conception of sensory substitution in others while only the latter position (i.e., that the conception of sensory substitution does not rely upon a direct apprehension of perceptual experiences) leads to the expectation of developmental trends when the child deals with this problem in a more concrete situation.

4. General description of the study.

This investigation of children's ideas about their senses has as its principal purpose to obtain some kind of description of the responses observed at the different ages considering the lack of information on this subject in the developmental literature. It consisted of two parts, described below in general terms.

Part I deals with the child's ability to discriminate between situations in which intersensory coordination is not possible and situations in which this coordination is possible in the context of the relevant experience. Two tasks were designed for this purpose, a non-verbal haptic-visual matching task and a verbal task, in which the child was asked to describe a haptically presented object. The results of this part of the study should allow us to evaluate the hypothesis that children's ideas about their senses involve the immediate apprehension of their perceptual experience.

--

Part II deals with the child's conception of sensory substitution in others. This part consisted of one task which provided the opportunity for obtaining both non-verbal and verbal responses related to the same stimuli.

FOOTNOTES:

(1) Subjectively speaking, any particular perception is always correct. It is only from an objective point of view (i.e., a point of view that attempts to establish something as independent of the observer) that one can talk about illusions.

(2) This discussion has centered on the coordination of "natural" sensory organs under "normal" conditions of functioning. However, a much broader view of the problem must be at least passingly mentioned here since sensory systems can be aided by many mechanical means. Youtz & Broome (1969), for example, attempted to develop a method which could potentially allow for brightness discrimination through tactual exploration. When stimuli made of the same material are brought up to the same temperature, the rate of heat exchange between the stimulus and the skin of a subject (whose hand is near but not touching the stimulus) varies with brightness. Since the subjects are able to reliably discriminate between these variations in heat exchange, it is conceivable that under these special conditions one might find cutaneous discrimination of brightness. The realization that the factor of major importance in the coordination of senses is the availability of information regardless of its form has also led to the development of "artifical" sensory organs. Bach-y-Rita (1972), for example, has developed a system of artificial vision which which transforms the visual images from a camera into sutaneous stimulation, allowing a subject blind from birth (after a certain amount of experience) to accurately discriminate form, distances and three different degrees of brightness.

II METHOD

1. Design

This study presenting the child with three tasks. Tasks I and II regard the child's notions about his own ability to perform intersensory coordination. Task III bears upon the child's view of other's ability to perform in this same situation. Each subject received all of the three tasks in a randomly determined order. The time spent with each subject varied approximately between 45 minutes and one hour.

The order of presentation was first counterbalanced, giving three order-cells, and each subject was randomly assigned to a cell with the restriction that all cells receive one subject per age level before any cell received two subjects in that age level. Each cell was assigned a total of six subjects, which gives a total of 18 subjects per age level. Three age levels were investigated, 4/5-, 7- and 11 years. In addition, a fourth group of subjects in the youngest age level (4/5 years) was sampled and randomly assigned to a training group for task III. Thus, the first decision when a subject in the youngest group was sampled was the assignment to a training or testing group for task III and the second decision in either case was the assignment of the subject to an order cell. The total number of subjects was, thus, 72.

2. Subjects.

The participants in this study were sampled from a

parochial school in Brooklyn, which is attended by a middle-class population. The teachers were asked to select the first students on their roll and the subjects were tested in that order. Two classes of 6th graders, two classes of 2nd graders, and two classes of kindergardeners participated in this study. Half of the subjects in the 11 and 7 year old group were girls; the other half, boys. In the 4/5 year old group, 20 subjects were girls and 16 subjects were boys.

3. Task I: Haptic-visual matching.

a. Materials: small toys, some of which are identical except for color (see Appendix I.1 for a complete description); a 12 x 12x 12 box, open on one side and covered by a curtain on the opposite side.

b. Procedure. The objects are given to the child for haptic exploration inside a box, which is open on one side (where the experimenter sits) and has a curtain covering the other side (where the child sits). The child places his arms under the curtain and the experimenter gives the object to the child from the other side. The instructions were as follows:

> (Child's name), we are going to play a game now. You will put your hands under this curtain and I am going to give you something to touch. You can touch it very well to make sure you know what it is but don't take it out, OK? When you know what it is, I will take it out from here (experimenter shows her side) and I will put three things over here (experimenter shows space next to the box). I want you to show me that you touched inside the box, OK? Ready? (experimenter gives an object to the child). Here we go, touch this very well but don't take it out. (experimenter gives the child some time to explore the object). Ready? Do you know

what it is? OK, I'll take it now. Show me what you touched. What was it?

The experimenter also places the other two objects which will be displayed in the array inside the box in order to avoid giving the child any indication about which object was the one touched by taking the toys in the array from different places. All three toys are removed from the box simultaneously and placed next to it. The child, then, indicates which toy he touched inside the box.

The series of stimuli is divided in two phases, a criterion phase and a testing phase. In the criterion phase, all of the stimuli placed in front of the child should be readily identifiable both haptically and visually so that haptic information is sufficient for the visual choice.[3] After the criterion series is finished - i.e., after the child reaches the criterion of five consecutive correct responses - the child is presented with the testing series. This testing series was chosen in such a way that some arrays allowed for haptic-visual matching while for other arrays the haptic information could not aid the visual choice. Thus, the testing series contains two types of stimulus-arrays for the child to respond within" (a) the arrays in which there is no possible single answer, since two of the three objects are identical except in color (which cannot be haptically perceived) and one of them was the one which the child had explored haptically; (b) arrays in which there is one single answer, since the object touched by the child is readily discriminable while the other two objects are identical except for color.

During both the training and the testing series the children were encouraged to go on through verbal reinforcement after each trial ("that's right", "you're very good in this game" etc.). In the training series reinforcement was contingent upon correct responding; however, reinforcewas not contingent upon correct responding during the testing series and was given after each trial.

The testing series consisted of 10 haptic visual matching trials, 5 of which allowed for a single answer while the other half did not. The order of presentation of the objects (and arrays, described in Appendix I.1) was randomly determined for each child. For each array of objects the experimenter took note of (1) which objects(s) was (were) chosen by the child, and (2) any comments that the child might have made about the duplication of objects.

c. Measure of performance. The purpose of this task was to obtain a non-verbal measure of the child's notion of the distinction between situations in which sensory substitution is possible and situations in which it is not possible. If the child is able to perform this discrimination, it is expected that the child should point to two objects when presented with arrays of the type (a) described above. Since two objects in this type of array are identical except for color and one of them was the one touched by the child, the child who understands the impossibility of touch-visual substitution with respect to color should either point to both objects or

indicate the impossibility of choosing one object only. It is possible that young children, who might not be able to articulate this discrimination verbally, could demonstrate their understanding of the problem in this matching task by pointing at the two identical objects.

The criterion phase in this task attempts to establish an equivalence in the behavior of younger and older children in relation to the task demands in such a way that the differences observed across age levels in the testing phase, if any, could be more easily attributed to different understanding of intermodal coordination rather than different understanding of the task.

In the criterion phase, the child is given a pass if he chooses the same object he touched during the haptic presentation. After 5 consecutive passes, the child starts the testing phase.

In the testing phase trials in which the haptic information was sufficient for a visual choice were excluded from the score since they did not involve any investigation of the child's ability to discriminate between amodal and modality dependent aspects of perception. When the array contained two suitable choices, a pass was assigned to a response which designated both of the identical objects or verbally expressed the impossibility of deciding between the two objects. Thus, a score in this task could fall between 0 and 5 even though 10 items had been presented to the child.

4. Task II: Description of a haptically presented object.

The purpose of this task is to investigate the coordination of the senses at the verbal level and in the context of relevant experience. It offers an interesting comparison with task I (haptic-visual matching) since it has been found that in many situations children who can perform well in a non-verbal task that involves a particular concept do not always perform well in a "similar" verbal task. The inclusion of a task of this type also attempt to explore more closely the possibility that children's interpretations of their perceptions cannot be considered the result of a direct introspection upon those perceptions.

The child is presented with situations in which sensory substitution is possible (for example, the child is touching an object and is asked about its size) and situations in hwich sensory substitution is not possible (the child is asked the color of a haptically presented object). We ask the child to perform this haptic-visual coordination in both types of situation and investigate the certainty with which he gives his answers.

The importance of assessing the child's certainty about his answers becomes clear when one considers the possible types of response in this situation. Two types of response can be observed when the child is asked to give the color of an object examined haptically. First, the child might name a color, and second, the child might not name a color. If

"it is a silly question, one has to see the object to know the color". In this case, it is clear that the child has some awareness of the problem of the coordination of the senses.

In summary, the child's possible answers to the questions in which sensory substitution is not possible can be schematized in the following way:

(1) <u>child names a color</u>: (a) child is certain of it; it can not be any other color;
(b) child is uncertain of it and either (b1) gives a personal justification for his choice or (b2) justifies it in terms of probabilities.

(2) <u>child does not name a color</u>: (a) child understands the impossibility of sensory substitution in this case;
(b) child does not understand the problem but does not know the color.

It is likely that responses of the type 1, b1 (responses in which the child names a color but claims to be just guessing) would be primarily motivated by some type of acquiescence, i.e., the child names a color to please the experimenter even though he realizes that he does not know the color. An analogous problem can occur in task I (haptic-visual matching) if the child chooses an object just because he knows he only touched one object during the haptic presentation. Even though the child realizes the impossibility of choosing one object only in some arrays, the response of choosing one object conflicts with the haptic information about number. Since there was no investigation of the child's

the child names a color, his response might be motivated by his lack of awareness of the impossibility of integration of touch and vision in relation to color or it might be motivated by other factors, such as some type of acquiescence or obedience in relation to the experimenter even though the child realizes the "sillyness" of the question. Questioning the child about the certainty of his answer and the process by which he thinks he arrived at it might help elucidate if the answer was motivated by his lack of awareness of the problem or by some other factor. It seems reasonable to expect that children who do not realize the problem of coordination of vision and touch with regard to color would be pretty certain that they were correct and would reject the possibility that the object could be of a different color. On the other hand, children who named a color simply because they were asked to might state that they are just guessing and accept the possibility that the object could be of a different color. A third type of motivation might appear, i.e., children might give a guess about the color, recognizing that it is only a guess based on the correlations between the type of object and the color it is usually seen in. This third possibility corresponds to what we have defined as a coordination judgement.

When the child gives no answer, the refusal to answer might also be motivated by different mechanisms. First, the child might not be aware of the problem involved even though he can recognize that he does not know the color of the object. Second, the child might refuse to answer because

certainty of his own answers in task I, that task did not allow for a discrimination between cases 1, a and 1,b above.

It is possible that a developmental trend might appear in the description of a haptically presented object according to which the child first gives a color with certainty, then refuses to name a color because it is not possible to know it, and finally names a color on the basis of its probable association with the type of object (solving the task by a coordination judgement), realizing, however, that this is only a probabilistic judgement.

a. Materials: a series of 5 small toys to be presented haptically (for a complete description, see Appendix II.1); a 12 x 12 x 12 box which is open on one side and covered by a curtain on the opposite side.

b. Procedure. The child is seated at the side of the box which is covered by the curtain and the experimenter sits on the other side. The child is asked two types of questions: (1) sensory substitution questions (such as "What is this?", "What is it made out of?" etc.), and (2) questions which serve to qualify the child's answers to the sensory substitution questions (by investigating the child's certainty of his answers and his justifications for them). The following instructions were given:

> (Child's name), we are going to play this game now. I am going to give you something to touch inside the box and you will touch it but without looking at it, OK? You can touch it very well but don't take it out. Here, you can touch this (the experimenter gives the

first object to the child). Don't take it out, OK? Now, tell me, what is it?

After the child answers this question, the experimenter asks the questions which are directed at investigating the child's certainty and reasons (see Appendix II.1 for a plan of the questions). Each of the other sensory substitution questions follows in a pre-determined random order.

The questions which aim at investigating the child's justifications of his answers were formulated in four different ways (see Appendix II.2) and one of these was randomly paired with the sensory-substitution questions. Since there were five sensory-substitution questions and only four forms of the justification questions, for each object one justification question was paired with two different sensory-substitution questions. If the child failed to answer when asked to justify his response (or if he simply said "I don't know"), a second form of the question was presented (either "how do you know it is ...?" or "how can you tell it is ...?").

c. Measures of performance. The score in task II was divided in two parts, one in which it was possible to solve the problem that was presented to the child (ST-1) and one in which it was not (ST-2). The responses to both types of questions were classified into three basic categories, (1) a response given with certainty, (2) a response given without certainty, and (3) a refusal to answer. Responses in the last two categories were considered a pass for questions in ST-2 and a failure for questions in ST-1; the reverse was

true of responses that fell in the first category. This classification of the responses into pass/fail gives scores comparable to scores in task I.

These basic types of responses were subdivided according to the type of reason presented by the child (see Appendix II. 3). This more specific classification was designed on the basis of the discussion of possible types of answer in this task (see page 19). The purpose of this more specific classification was to investigate further the child's understanding of sensory-substitution and explore the possibility of an association between age and different approaches to answering a question in which sensory substitution is not possible (see page 20).

Before the responses were classified by the different judges, each child's set of responses was divided in half and all of these halves were shuffled. This precaution was taken in order to avoid a halo effect in the classification of any child's responses.

5. Task III: The conception of sensory substitution in others.

The purpose of this task is to study possible age differences in children's understanding of sensory substitution in a more abstract situation. The abstraction here is related to the fact that the children cannot use feedback from their immediate experience in order to arrive at a judgement about whether a specific sense can provide a certain type of information.

The task further involves the difficulty of taking someone else's perspective in order to arrive at a correct answer but this problem will be discussed in greater detail where appropriate.

The experimental design involved randomly assigning two groups of 4/5 year olds to a testing group in this task was due to the following considerations: (1) methodologically, it was important to assess whether poor performance by the young subjects - if it was found- could be explained by task specific difficulties rather than a lack of understanding of sensory substitution; (2) thereoretically, it was interesting to verify if young children could be readily taught an adult solution to this problem.

By "task specific difficulties" we mean problems of subjects with respect to the specific form of the task rather than its content. According to this line of thought, subjects unfamilar with tasks of the nature presented might experience initial difficulty in paying attention to the relevant characteristics of the stimuli with the consequence that their scores do not accurately reflect their ability. Subjects might be more likely to become initially distracted by the experimenter's presence, such that they are not as well able to concentrate on the task at hand. The argument is essentially that social and non-social aspects of the testing situation may interfere with subjects' initial performance.

A sizeable effect of training would clearly indicate that basic cognitive advances do not regulate performance on

the task. In short, very strong training effects would argue against interpreting age differences in terms of their relation to the development of cognitive processes which presumable necessitate larger periods of time. At the same time, the effects would seem to indicate that age differences were related to a lack of practice or familiarity with the task.

The failure to find an effect of training would suggest that age differences are not due to task specific difficulties, although the conclusion is not logically necessary since it could always be argued that more training or training under modified conditions would facilitate performance.

Intermediate effects of training would also be a bit ambiguous since it could be argued that age differences reflect only task specific difficulties or such difficulties as well as true developemntal changes. In other words, in this case the two notions, "task-specific difficulties" and "developmental changes", would not represent mutually exclusive possible explanations for the data. Nonetheless, a careful consideration of the types of errors produced by subjects after training might provide additional support for the notion that age differences in the non-training groups are due to developmental changes. This would be the case, for example, if training resulted in younger subjects' employing a strategy associated with older children, but not with the adult model, upon which training feedback was based.

a. Materials: a series of pairs of pictures to be presented to the child. Each picture shows one character with one object and both characters were photographed in similar settings. In all of the pairs of pictures, the same two characters are present, "Frowny" and "Smily" (see Appendix III.1 for a complete description of the pictures).

The task contains two series of 20 stimuli each, a criterion series and a test series. The stimuli in the criterion series did not concern the coordination of the senses. In the testing series, all of the questions involved some problem in the coordination of sight and hearing or sight and touch.

b. Procedure. The task is presented to the child in the following way. The child is shown a pair of pictures and told:

> Here are Smily and Frowny. They both had birthdays today and got a gift from their Mommy. Now look at their pictures. Smily opened her[4] gift already and knows what she got for her birthday. Frowny did not open her present yet and so she does not know what she got. Now I will show you other pictures of Smily and Frowny and I will ask you some questions. In this one (still the example), tell me, can Smily tell what she got for her birthday, can Frowny tell what she got for her birthday, or can they both tell what they got for their birthdays?

If the child makes a mistake, the experimenter repeats the instructions and asks the question once more.

After the experimenter obtains a correct response from the child for this example, the child is shown the other stimuli. For each stimulus the experimenter tries to present some context (such as telling the child, in the example, that

Frowny and Smily had birthdays) in order to maximize the possibility of the child's attending to the picture.

If the child responds correctly, he is reinforced verbally by the experimenter (very good", "that's right" etc.) and if the child makes a mistake the experimenter corrects the child be pointing at the correct picture and explaining why that is the correct answer. For example, in picture 1 the child is asked: "Which one is going out?". If the child points to the wrong picture (Frowny), the experimenter says:

> No, Smily (experimenter points) is going out and Frowny is not. Look at their pictures. Frowny is sitting here eating a cookie. Now, look at Smily. She has her coat on, she has her hat on, and she is going to open the door.

The procedure is followed throughout the criterion phase, which will end when the child reaches a criterion of 5 consecutive correct responses. The testing phase follows immediately.

b1. Procedure for the testing group. The procedure in this group during the testing phase is a non-correction procedure and the child is verbally reinforced after each response. The order of presentation of the stimuli was randomly determined for each child both in the criterion and the testing series. The determination of the order in the criterion series involved a restriction that at least one item in any block of 5 trials must require the response "both of them". This restriction was met by independently sampling from items requiring this response whenever 4 items which required a

different response had been sampled consecutively.

After the child has seen all the stimuli in the testing series, he is given a second run of all testing stimuli but this time he is also asked to justify his answers. The stimuli are presented to the child in the same order of the first run and the experimenter tells the child:

> Now I am going to show you some of these pictures again and ask you some more questions, OK? Here look at this one (experimenter shows the picture). Which one ... (experimenter asks the appropriate question). After the child answers, experimenter asks: How come this one knows... and this one doesn't (or how come they both know ...)?

b2. Procedure for the training group. The children who were assigned to the training group received both parts of task III, the criterion phase and the testing phase. However, the testing phase did not follow the procedure described above. After the children in this group had attained criterion in the first phase of this task, the testing stimuli were presented without any change in the correction procedure. In other words, the children in this group were reinforced verbally if they answered correctly and were given the correct answer if they made a mistake. The correction, as in the criterion phase, was followed by an explanation of the answer.

It was important to design explanations which called the child's attention to the relevant aspects of this task (i.e., the senses being used by Smily and Frowny) without providing him with a simple rule for answering the questions (such as,

every time you are asked about the color you must check if Smily and Frowny are looking at the object or not). The procedure chosen here was to point at the correct picture and tell the child to pay attention to the senses by remarking on what senses the characters in the pictures were using. For example:

> Look at Smily, she cannot tell the color of her car and Frowny can. See, Smily is touching the car but Frowny is touching and looking at the car.

After the child had seen all the stimuli once he was told:

> Now I am going to show you the pictures again. Let's see how many you can remember, OK?

This second presentation followed the same procedure used in the testing group, i.e., there were no corrections and the child was asked to justify his answers. This second run was used to evaluate the effects of training upon the performance of 4/5 year olds.

c. Measures of performance. For each stimulus, the experimenter took note of the child's choice response in each presentation. The child was assigned a pass for each item he answered correctly twice. This procedure was used in order to introduce some correction for guessing. If one response was correct and the other was incorrect, the correct response was interpreted as a "chance hit" and the child failed that item. The total number of items passed by the child gave his score for the choice responses.

This criterion of responding correctly in both runs

could not be applied to the training group. Thus, in evaluating the training effects both groups of 4/5 year olds were assigned a score which corresponded to the total number of correct responses in the second run only.

The reasons for choice responses were analysed separately. The child was given a pass if he mentioned the use of the appropriate sensory system(s) or if he mentioned the existence of some barrier (such as the blindfold) preventing the other character from using that (those) sensory system(s). A failure was assigned if the child did not mention either of the above (for a complete description of the scoring system, see page 52; for examples of responses falling into each category, see Appendix III.2).

FOOTNOTES:

(3) The stimuli selected for this task were all readily discriminable by young subjects. Forms which other studies indicated might be too difficult for young children were not included in the stimulus arrays.

(4) The characters in the pictures were photographed dressed in a way that minimized the sex cues. The experimenter treated the two characters always as if they were of the same sex as the child and the appropriate pronouns and possessives were used.

III RESULTS

1. Preliminary analysis of non-significant variables: Order and sex effects.

As a preliminary step, separate analyses of variance were performed on the data from each tasks effect (i.e., the effect of performing in each task before, between, or after the other two tasks). The results of these preliminary analyses are presented in tables 1 through 8. These results indicate that in none of the tasks was there a significant main effect of either sex or order of tasks.

Order effects were further investigated with regard to tasks III since the practice in actual haptic-visual coordination provided by tasks I and II could prove beneficial to children in some age levels but not in others. Younger children might be able to improve their understanding of sensory substitution performed by others if they are given an opportunity to reflect upon their own sensory functioning.[5] So, a two-way analyses of variance was performed in order to study the interaction between age and order of tasks. This analysis (tables 6 and 8) yielded a non-significant interaction between age and order of tasks.

The results of this preliminary analysis indicate that the scores in the different tasks can be treated independently of sex and order of tasks and no further consideration will be given to these variables.

2. Task I: Visual-haptic matching

a. Choice responses.[6] The results of a one-way analysis of variance with age as main effect and the number of correct responses in this task are presented in table 9.[7] This analysis indicates a non-significant main effect of age.

The failure to reject the null hypothesis in this case could have been due to either a high-level of performance by the younger subjects or to a low-level of performance by the 11 and 7 year olds. In order to evaluate these two possibilities, the mean number of correct responses for each group was computed. These means are presented in table 10. An inspection of this table suggests that the failure to reject the null hypothesis in this case was most likely due to a poor performance by the older subjects than a higher level performance by the younger subjects. Since only one mistake appeared in arrays in which one single choice was suitable (i.e., the choice responses which did not involve the question of whether the haptic information was sufficient for a visual choice), it is possible that subjects felt it was not appropriate to choose more than one object when presented with the visual array. Even though the instructions were meant to avoid suggesting that only one object should be chosen the subjects probably had no difficulty in recognizing that they had explored only one object, what could have meant to them that only one choice should be suitable.

It is interesting to look at other behavioral indices which might clarify these results and to compare the findings of this non-verbal haptic-visual matching task with the results of task II, which attempts to look at the same problem from a different point of view.

b. Other behavioral indices. Other aspects of the reaction of the subjects in relation to the impossibility of distinguishing between the two identical objects were also noted by the experimenter. Among the 11 year olds, 15 out of 18 subjects expressed surprise at least once when they were presented with the array which contained the two identical objects, one of them having been examined haptically in that trail. Their reactions included laughing and/or frowning, scratching their heads, smiling, touching the objects for a period of time, and verbal comments such as "help!", "I'm just guessing", "I think this one has a bump just like the one I touched" etc. All 18 7 year olds reacted similarly to the arrays in which choosing one object only was not possible. However, among the 4 and 5 year olds, only 11 (out of 36)[8] demonstrated at least one of the above reactions. Many fewer verbal comments seemed to appear at this age level, where another type of reaction became more frequent: changing the choice from one object to the other and sometimes even back to the previously chosen object.

These observations suggest that the measure of performance employed in this study (i.e., the choice responses) does not seem to adequately reflect the subjects' ability to

understand when haptic information is not sufficient to guide a visual choice. One should look at other measures (such as emotional reactions, verbal comments, reaction time) more systematically before arriving at any clear conclusion regarding how children view this problem.

3. Task II: Description of a haptically encountered object

a. Interjudge reliability. The description of the different categories which is included here is Appendix II.2 was used to describe the response-categories to the 2nd and 3rd raters, the experimenter working as the 1st rater. Each rater was to place the responses into one category only, even then the response might seem to fit more than one category. The interjudge reliability was computed by taking the percentage of agreements between the first two judges (number of agreements x 100/ total number of responses). At the more specific level (i.e., using the 10 different categories as a basis) the percentage of agreements was equal to 90% and at the less specific level (i.e., pass or fail) the percentage of agreements was 99%.

In order to decide upon the classification of responses about which the first two raters had not agreed upon, a third rater was asked to evaluate a sample of responses which included both responses already agreed upon and disagreements. The third rater classified the responses without any knowledge of which categories had been assigned to any of the responses or whether they had already been agreed upon or not.

If the classification used by the third judge did not agree with either of the previous classifications, the response was considered unclassified. If her classification agreed with either of the first two judges, the response was placed in

the category agreed upon by the third judge and either of the first two judges. This process raised the percentage of interjudge reliability to 97% at the more specific level and 99% at the less specific level.[9]

b. General results: Analysis of the results in terms of pass/fail categories. It was hypothesized that the difference between the proportion of passes in ST-1 and ST-2 would be significant for the younger children but non-significant for the older children. If a child understands the question of sensory substitution, the child is expected to do just as well in ST-1 as in ST-2; if a child fails to understand this problem, his score in ST-2 will be lower than his score in ST-1.

The percentage of passes across children for questions in ST-1 and ST-2 are presented in table 11. The results for the 4/5 year olds who received training in task II are kept separate from the results for the other group of subjects in this age level. These groups are identified as group B and group A, respectively.

As expected, the difference between the proportions of passes in ST-1 and ST-2 was not significant for the 11 year olds but it was significant for the 7 and 4/5 year olds (both groups).

A one-way analysis of variance having age as main effect and the score in ST-2 as the dependent variable (table 12) yielded a significant main effect of age. However,

neither the difference between the mean scores for the 11 and 7 year olds nor the difference between the mean scores for the 7 and 4/5 year olds was significant (as assessed by a Tukey w test, presented in table 13. The difference between the 11 and the 4/5 year olds was significant at the .05 level.

Among the 7 year olds(the age at which it was hypothesized the occurence of a transition from not understanding the problem of sensory substitution to appropriately conceptualizing it in this particular task), 62.53% of the responses at this age level is presented in table 14. This distribution soes not contradict the hypothesis of transition in the understanding of sensory substitution at about the age of 7. A high percentage of the total number of mistakes in this group can be attributed to about 1/3 of the subjects, while the other 2/3 presented a total of 9 mistakes (in response to 48 questions). However, since there is a large gap in the age levels studied here, one cannot locate this age of transition with confidence.

c. Age-related changes in the approach to the problem of sensory substitution: A more specific evaluation. The distribution of the different types of answers for each age level is presented in tables 15 through 18 (see Appendix II.3 for a sample of responses in each category). At all of the three age levels, the great majority of the children justified their answers for questions in ST-1 on the basis of their senses, i.e., they asserted that they knew the size

of the toy they were touching, for example, because they were feeling it, because they were measuring it with their hands etc. However, while the 4/5 year olds often continued to justify their answers to questions in ST-2 on the basis of their senses (15% of the answers at this age level fell in this category), none of the 11 year olds did so and only 2.78% of the responses of 7 year olds were of this type. It must be recalled here that this type of justification was clearly improper for questions in ST-2 since haptic inspection does not provide information regarding color.

Another possible trend we would like to point out is represented by responses which consisted of refusing to name a color on the basis of a recognition of the fact that haptic inspection does not yield information about color. In the 4/5 year old group, 9.72% (group A) and 18.05% (group B) of the answers fell in this category, while among the 7 year olds 13.88% and among the 11 year olds 59.72% of the answers were of this type.

Finally, the response which corresponded to what was previously called a coordination judgement (category 7 in Appendix II.2) also indicated shifts in the percentages across age levels. Responses in this category represented 1.39% of the responses given by 7 year olds and 19.44% of the responses given by the 11 year olds. This type of response was not observed among the 4/5 year olds in group S and constituted 1.39% of the responses of 4/5 year olds in group B.

4. Task III: The conception of sensory substitution in others

The procedure in this task required that each subject should be presented with a criterion phase of a maximum of 20 trials and that the phase be terminated when the subject met the criterion of 5 consecutive responses. No child failed to meet the criterion in the allowed maximum number of trials. The mean number of errors in this phase for each age level is presented in Appendix III.2. These results do not need further consideration since it was assumed that by meeting the criterion of 5 consecutive correct responses any subject demonstrated a proper understanding of the task requirements.

A. DEVELOPMENTAL TRENDS

a. Choice responses.

a1. Age differences. An analysis of variance with choice responses as the dependent variable (table 6) indicated a significant main effect of age. Both the difference between the mean number of correct responses for the 11 and 7 year olds and the difference between the means for the 7 and 4/5 year olds were significant as evaluated by a Tukey w test (table 19).

a2. Item analysis. An item analysis was performed in order to investigate the possible hypothesis that some types of items might be consistently more difficult than others. The items were first categorized according to which senses had to be taken into consideration in order to respond

appropriately to the item. Twelve items which fell in three different categories were, then, selected for further analysis and the degree of difficulty of these categories was studied by a Guttman scalogram analysis.

A consideration of the demands placed upon the subject in order to pass each item led us to classify the items into five different categories. Category 1. (item 6 only) can be considered a control category. In this category both characters in the pictures are presented with no barrier to their sensory functioning, i.e., they are both pictured in such a way that they should be able to see, hear and touch the object. Category 2 (items 7 and 16) involve the comparison of applying two relevant senses vs. one relevant sense (vision vs. vision and hearing and vision vs. vision and touch). Both items, however, could be correctly answered if the child only took vision into consideration. Category 3 (items 1, 3, 4, 11, 15, 17, 18, 19, and 20) is formed by questions in which vision was the only relevant sense. All the questions in this category regard the knowledge of color and different types of barrier to the use of vision are used in the different items. Category 4 (items 8, 10, 12, and 14) contains items which require checking on the status of touch only for both characters, since the questions refer to either temperature or weight. Category 5 (items 2, 5, 9 and 13) is formed by items which involve a consideration of snesory substitution, i.e., one character in the pictures is using one relevant sense and the other character is using a different but also

relevant sense. The questions refer either to the identification of the object or to its size. The subject must realize that touch and vision are both relevant to these problems and that both vision and hearing allow one to identify an instrument being played.

Categories 1 and 2 are not included in the next phase of this item analysis since only 1 and 2 items fell into these categories, respectively. Since only 4 items were classified as type 4 and 5, four items were selected from category 3 for the Guttman scalogram analysis. Items 1, 4, 11 and 15 were selected on the consideration that they all involved the same barrier to the application of vision (i.e., in all of these items one of the picture-characters was blindfolded and the other one was not blindfolded). These items, therefore, should represent a homogeneous sample of items in category 3 even if non-significant task variables such as the type of impediment to visual perception play a role in determining how children perform in this item.

The four items in each category were combined into a single score, the cutting point for each category being set as equal to 3 (i.e., if a subject has less than three correct responses in one category, he would be assigned a failure; if he had 3 or more correct responses, he was assigned a pass for that category).

The Guttman scalogram analysis performed on these three categories is presented in table 20. The order of difficulty

of the categories, from least to most difficult, was categories 3, 4 and 5. The coefficient of reproducibility (which must be higher than .9 to indicate an acceptable scale) was equal to .9506. The coefficient of scalability (which should be above .6 if a scale is unidimensional and cumulative) was equal to .7037. These results suggest that different types of item did in fact differ in difficulty. In order to achieve a better understanding of these differences in levels of difficulty, further analysis was performed by looking at the specific responses given by the children. It seemed possible that mistakes in the more idfficult items might not be random but could reflect a conception of sensory substitution which differs from the adult one.

a3. Analysis of strategies. An attempt to uncover these hypothetical conceptions was carried out by creating a rule for generating responses, predicting the child's responses according to this rule, and verifying how many prediction errors were encountered in this way. In other words, it was hypothesized that each child was responding according to a certain principle, the child's responses were compared with a theoretical pattern generated on the basis of that principle, and the prediction mistakes yielded deviation scores for each child with regard to each principle. This score could then be used in an attempt to identify the child's actual principle(s) of responding. These principles (which are in fact heuristics of behavior) will be referred to as "strategies", and the adult's approach can be viewed as one of the possible strategies which could guide a subject's

choice-responses in this task.

It should be emphasized that the work of fitting strategies to observed responses must always be considered a tentative, rather exploratory effort. In fact, the number of strategies that could be created to describe the responses in any task can at least theoretically be considered infinite. The investigator can in actuality only select some strategies and study their goodness of fit.

The strategies included in this study were selected for several reasons. The adult model was included as the pattern of correct responses. Other models (which presuppose a complete or partial dominance of vision over the other senses) were developed on the basis of the verbal responses observed in this task. Finally, two more strategies were developed essentially as controls, one representing a negation of previously developed strategies and the other constituting a position stereotype.

Description of the strategies:

Strategy 1, the adult model, was generated on the basis of an analysis of the relationships between the quality involved in the question and the information which could be provided by the sense available to each character in the pictures. For example, if the question referred to color, the character(s) that could see the object should be chosen as the correct response.

Strategy 2 (vision is better than other senses) assumes

that vision is the only sense that provides information about the identity of an object or about its size. The role of touch and/or hearing in these cases is denied. Strategy 2 differs from strategy 1 in terms of the responses which are expected with regard to items 2, 5, 9 and 13. For example, item 9 depicts Smily and Frowny holding a small doll; Smily is blindfolded while Frowny is looking at the doll. The child is asked which one knows the size of the doll or of both know it. Strategy 1 generates the response "both" while strategy 2 generates the response "Frowny".

Strategy 3 (vision is the only important sense) assumes that vision is necessary for knowing all of the qualities investigated in this study. The role of touch is, thus, further denied with regard to its ability to provide information concerning weight and temperature. Strategy 3 differs from both strategies 1 and 2 with regard to the responses expected in items 8, 10, 12 and 14; it also differs from strategy 1 with regard to the responses predicted for items 2, 5, 9 and 13. For example, item 10 depicts Frowny looking at a box on a chair and Smily holding a box; Smily is blindfolded. The child is questioned about their knowledge of the weight of the box. Strategies 1 and 2 would predict the response "Smily" while strategy 3 predicts the response "Frowny".

A second form of this strategy (3a) was generated by adding the assumption that blindfolds are the only form of obstacle to the application of vision. This strategy was developed on the basis of the observation that children's

justification very often mentioned the blindfold. It was reasoned that the blindfold might have been the only salient feature of the pictures for certain subjects and that all of their answers consisted of checking if the characters were blindfolded or not (for the differences between the strategies, see a complete description of the patterns predicted by each strategy, Appendix III.3).

Strategy 4 is a position stereotype. It assumes that children are always responding either on the left or on the right. This strategy was developed considering that previous studies (Golson, 1972, for example) have found position stereotypes in young children in similar kinds of tasks. Each of the two position stereotypes was compared with the child's pattern of responses and the position stereotype which yielded the smaller number of prediction errors was the score used for further analysis.

Strategy 5 (touch and hearing are better than vision) was generated as a negation of strategy 2; it assumes that vision does not provide the information which one can get from either touch or hearing. This strategy was developed in order to verify if children differ from the adult model in either direction with regard to the role of vision or if one of the deviations was prevalent over the other.

Evaluation of the strategies:

The evaluation of how good a fit one must find before considering that a particular principle is or is not a good

description of the child's own strategy is a difficult matter. Two types of analysis are possible, an intra-strategy analysis and an inter-strategy analysis. The intra-strategy approach consists in evaluating the goodness of fit of a particular strategy per se. The inter-strategy analysis involves a comparison of the different strategies with each other.

Intra-strategy analysis. A first question which must be asked is whether a particular strategy constitutes a better predictor of the child's responses than chance. This question can be answered through the statistical evaluation of the null-hypothesis that there is no improvement in prediction when one uses that strategy as compared with chance level accuracy of prediction. Since the experimenter defined for the child three possible ways of responding in this task (either one character, or the other, or both of them could be the correct answer), the probability of predicting the child's responses accurately by chance is equal to 1/3. Using all of the 40 responses as a basis for this analysis, one can assume a distribution of hits in prediction by chance to have a mean of 13.33 and a standard deviation of 2.97. Using a stringent criterion for rejecting the null-hypothesis (the significance level of .001) and a correction for continuity, we can set the criterion of at least 24 answers predicted correctly by a strategy for its use to be considered an improvement upon chance in terms of accuracy of prediction of any subject's answers (i.e., no more than 16

prediction mistakes can be made if the strategy is to be considered useful). Table 21 gives the number of mistakes in prediction made by using each of the hypothesized strategies.

Inspection of table 21 (a through c) indicates that too many different strategies can be considered an improvement upon chance prediction when the above criterion is used. This situations is promptly understood if one takes into condiseration the fact that only a few items distinguish strategy 1 from 2 and 2 from 3. In other words, if one finds a perfect fit of the child's responses to strategy 1, the maximum number of mistakes in predicting the child's answers from strategy 2 must be equal to 8, which is a prediction still significantly better than chance. What would be necessary here is a comparison of different strategies among themselves directly, i.e., an inter-strategies analysis.

Inter-strategies analysis. Since these different strategies were not part of our initial hypotheses and their identification represents a result of the descriptive aspects of this study, the number of items which allow one to distinguish between the different strategies is not sufficient to yield significant differences in terms of an individual analysis. A perfect fit of strategyl, for example, gives 100% correct predictions for strategy 1; it also yields 80% correct predictions for strategy 2, and the difference between these two proportions is not significant in this situation.

A second attempt to evaluate these strategies was performed by comparing the deviation scores generated for each subject across strategies. If a strategy did not fit the results for any child better than all the others, this strategy was dropped from further analysis. Table 21 indicates that only one child has strategy 3a as the best fitting strategy for his answers and no child had strategy 5 as the best fitting strategy for his answers. Therefore, these strategies were excluded from further analysis and the subject whose best fitting strategy was strategy 3a was assigned the second best fitting strategy (strategy 3) for the purpose of further investigation. This criterion allowed for a reduction in the number of strategies to be considered but still does not allow for a rigorous comparison of the strategies among themselves.

Since it was clear that an individual analysis could not yield statistically significant differences, the third attempt to evaluate the strategies involved performing a group analysis. While the group analysis does not solve the problem of overlap of some responses predicted on the basis of the different strategies, it allows for the study of a larger number of responses simultaneously and for uncovering, in this way, a possible association between type of strategy used and age.

An analysis of variance (for a repeated measurements design) was performed having deviation scores as the dependent

variable; age level and type of strategy were considered main effects. It was reasoned that if there is an association between age and type of strategy used by a subject, a significant age by strategy interaction should emerge from this analysis. A significant main effect of strategy in this case can only indicate that some strategy (or strategies) approaches the pattern of responses better than others. A significant main effect of ages indicates that we have been more successful in predicting responses at some age level(s) that at other(s). These main effects have, therefore, lower descriptive value.

The results of the above analysis (table 22) indicated significant main effects of age and strategy and a significant interaction between age and strategy (as assessed by a conservative F test).

For each age level, the mean scores for each strategy were compared with the means for all the other strategies by using a Tukey w test. This analysis (table 23 indicates that, while one cannot distinguish between strategies 1 and 2 in terms of how well they fit the data for the 11 year olds, these two strategies were significantly better than the other two since they yielded a smaller average number of wrong predictions. Table 24 indicates that strategy 2 represents a better description of the data for the 7 year olds than any other strategy. Table 25 indicates that while one cannot distinguish between strategies 2 and 3 in terms of how well they describe the data for the 4/5 year olds, these two strategies are significantly better than the

other two in describing the choice data at this age level.

A failure to distinguish between strategies 1 and 2 in the 11 year old group and strategies 2 and 3 in the 4/5 year old group could be the result of two different situations: (a) neither strategy represents a better fit for any of the subjects, in which case the same total number of deviations for the group would be found, or (b) one of the strategies represents a better fit than the other for half of the group and the second strategy represents a better fit for the other half, in which case the number of deviations for the group will be similar.

An attempt to distinguish between these two cases was carried out by examining which strategy represents the best fit for each child and then computing the percentage of children per age level which fall under each strategy. Two points must be made in relationship to the construction of this table. First, if no strategy represented an improvement upon chance prediction for a particular subject, that subject's strategy was considered undetermined. Second, if two strategies seemed to equally fit the pattern of responding for one child, a half point was entered for each strategy in order to maintain the totals equal to 100%. Table 26 gives the results of this analysis.

In fact, our results suggest that a failure to distinguish between strategies 1 and 2 in terms of how well they fit the data for the 11 year olds could be explained

by the fact that the subjects in this group are distributed between these two strategies with a slight predominance of incidence of strategy 1 as the best fit. Again, the same seems to be the case with regard to the failure to distinguish between strategies 2 and 3 in terms of how well they describe the group data for the younger subjects; the same number of subjects fall in each of these cells.

Overall, the results of these group analyses suggest that it is likely that there is an association between type of strategy used by the subjects and age. The description of these strategies also suggests that children go from a lack of understanding of the importance of touch and hearing in providing any type of information (at about the ages of 4 and 5 years) to the achievement of a more complete notion of sensory substitution (at about 11 years) going through an intermediary period during which the role of touch is partially understood and partially still denied (at about 7 years). The role of vision as assessed in this task was understood even at the youngest age level studied, 4/5 years.

Another interesting observation can be made on the basis of the results presented in table 26. The number of subjects for whom it is not possible to find a strategy which fits their pattern of responding better than chance is inversely proportional to the subjects' age level. It is possible that other strategies could be found which describe the data for the 4/5 year olds better than the one hypothesized here. It is also possible that young children do not consistently

follow a rule in generating responses in this task, which would make it impossible to find a rule which describes their performance better than chance.

Even though these are not empirically verifiable hypotheses, one can attempt to study the second hypothesis in an indirect way. It was the procedure in administering this task to present each subject with all the stimuli twice in order to eliminate chance hits as much as possible from the results. We can, therefore, look at how each child answers the same question on each presentation and compute the number of times the child gives an answer to any item in the second presentation which differs from the answer given to the same item in the first presentation. These errors of reliability indicate that the child did not consistently deal with the item. Subjects who are not operating on the basis of a rule are likely to make many more such mistakes than subjects who are using a rule. In fact, the only way to be consistent in one's treatment of the item without a rule for generating the responses would be to remember what one had said previously. Since there were 20 items, it seems unreasonable to attribute consistency in the performance in the two different runs to pure memory processes.

The mean number of reliability errors for the 11 year olds was 1.50; for the 7 year olds, it was 1.94; and for the 4/5 year olds it was 5.55. An analysis of variance with age as main effect and reliability errors as the dependent variable indicated a significant main effect of age. The

difference in the mean number of error of reliability between the 11 and the 7 year olds was not significant. The difference between the mean number of reliability errors for the 7 and 4/5 year olds was significant at the .01 level (tables 27 and 28). Our increasing failure to find a rule to describe the child's pattern of responding as age level decreases might, thus, be due to the fact that some of the younger children (of about 4/5 years) were probably not using such rules at all.

A second hypothesis was raised which could account for the lower reliability in the younger children's responses as compared to the 11 and 7 year olds. It is possible that in a task such as this, which children are rather unfamiliar with, it takes the younger children a much longer time to adjust themselves completely to the task demands. Their errors of reliability could, therefore, be explained in terms of an improvement in their performance in the second presentation (due to practice effects and also due to the slightly different procedure in the second run, which required the child to justify his answers). If this hypothesis can explain the different patterns of error of reliability in the 11,7 and 4/5 year old children, we should find that younger children improved significantly in their performance in the second presentation of the stimuli while 11 and 7 year olds didn't. Separate t-tests for correlated samples were carried out comparing the children's performance in the first run with their own performance in the second run.

The results of this analysis (tables 29, a through c) indicate that while the younger children did show a significant improvement in their responses during the second presentation, the reliability differences between the age groups cannot be totally accounted for in terms of this improvement. First, subjects in the 11 year old group also showed a significant improvement in the second presentation and their reliability scores were still much higher than the scores of 4/5 year olds. Second, the gain in the younger children's score was of only 2.22 points while their reliability errors would lead one to expect a much higher gain (the mean number of errors of reliability for this group was 5.55).

b. Verbal responses.

The analysis of the justifications offered by the children for their responses in the second run was done in three basis steps, two of which parallel the treatment of the choice responses. First, an overall analysis was performed in order to study age related differences. Second, an inspection of the justification data was performed in order to verify if these results replicate the choice data with regard to the different types of strategy. Finally, the correlation between the performance in this verbal part and the choice responses was studies.

In evaluating the justification, one basic rule was formulated and applied to the different types of items: in order to obtain a pass the child must either mention the relevant sense(s) being used or mention the barrier (e.g., a

blindfold, a screen) to the use of the relevant sense(s) (a sample of responses is presented in Appendix III.4). This rule required that the child mention either the use of vision or the impossibility of seeing in items in category 3, the use of touch or its non-application for items in category 4, and the use of both touch (or hearing) and vision for items in category 5. Responses to category 2 items can be given a pass if they include mentioning vision only, vision and hearing (item 7) or vision and touch (item 16).

b1. Age differences. An analysis of variance indicated a significant main effect of age (table 6). The difference between the mean number of correct explanations for the 11 and 7 year olds was significant according to a Tukey w test while the difference between the 7 and 4/5 year olds was not significant (table 30).

A hypothesis consistent with the precious findings on strategies can be raised to account for the non-significant difference between the 7 and 4/5 year olds with regard to this measure. Responses in the group of 7 year olds were best described by strategy 2, which generates incorrect justifications, leading to an increased number of incorrect explanations of a particular type. This hypothesis can be evaluated when we look at the types of justification errors.

b2. Analysis of strategies. The study of strategies by examining the verbal responses cannot be as detailed as the one carried out with the choice responses since the

justifications into different types and by looking at the types of errors, one can come to some general confirmation or disconfirmation of the previous findings.

The explanations which the subjects gave for their responses were classified into the following categories. A pass was given according to the previously mentioned criterion and was entered as a 0-type error. Error type 1 (V T) consistedin mentioning vision in items which referred to temperature and weight and ignoring the sense of touch. Error type 2 (V T) consisted in mentioning vision only in sensory substitution items, in which touch or hearing were also relevant and required for a correct response. Error type 3 (T V) consisted in mentioning touch (or hearing) where vision was relevant and required. Error type 4 consisted in producing some type of mention of the senses but in ways not appropriate to the question. Error type 5 (V T) consisted of giving some response which made no reference to the senses or the barriers to their functioning. Error type 6 consisted of responding "I don't know". An illustrative example of responses in each category can be found in Appendix III.4.

The frequencies of each type of error are presented in table 31. Simple inspection of this table indicates that mistakes in category 2 are the most frequent by far even though these mistakes can only appear in 4 out of 20 items while other categories (such as 4, 5 and 6) can appear in any of the 20 items. Mistakes of the type 1 (consistent

with strategy 3) were most frequent among the younger subjects. These results do not contradict the results discussed previously with regard to the choice data.

b3. Relationship between choice data and verbal responses.

The analysis of the explanations given by the subjects which was presented in the previous paragraphs parallels the analysis of the choice responses and essentially replicates it. A different way of studying their convergence will be presented in this section, which consists of studying the correlations between the choice data and the verbal responses. If verbal responses involve a separate, independent level of competence in this task, the correlations between the two types of data should be small even if consistent age differences can be found in both sets of data. The intergroup analysis presented so far only points out the consistency of the developmental differences. In order to address the question of whether these differences have their basis in the same ability one must perform an intra-group analysis.

Several possibilities can be raised in this respect. First, one can hypothesize that performance in the two types of situation (choice and verbal repsonses) is related to two different abilities, in which case the correlations between choice and verbal responses should be low. Second, it is possible that the same ability underlies the performance in both tasks. If such is the case, a similar pattern of high correlations should be found in each of the three age levels. Third, one can hypothesize that, even though the same ability

is necessary for both tasks, performance in a verbal task requires a more advanced level of understanding or a greater degree of ability. If this is the case, correlations between the two sets of data should be at best moderate at all age levels. Tables 32 through 34 present the correlations between the total number of mistakes (total), the number of mistakes in the second run only (subtotal), and the total number of correct explanations (verbal score) for each age level. Note that the verbal score has been keyed in the opposite direction and that the correlations between verbal scores and choice responses are, therefore, expected to be negative.

The results presented in these tables indicate that there is no reason to suspect that different abilities underlie choice responses and explanations in this task. The correlations found between the verbal and the choice responses are just as high as the part-total correlations in this task and are all equal to or larger than .88. These findings suggest that requiring a verbal explanation of the subjects in this task does not place greater demands upon the subjects than the choice responses do. Verbalization can be concluded to represent here a task variable of minor impact upon performance. A conclusion of this nature is not inconsistent with some developmental theories but does challange an often suggested hypothesis that all verbal tasks place greater demands on the subject than comparable non-verbal tasks. One of the difficulities in testing this hypothesis stems from the difficulty in establishing such a comparability

a priori. The present study suggests that perhaps when this requirement can be satisfied, verbal tasks might not be any more difficult than non-verbal tasks.

B. TRAINING EFFECTS

a. Choice responses.

The effects of training upon the performance of the 4/5 year olds assigned to the training group were studied by examining the responses of both groups of 4/5 year olds only in the second presentation of the stimuli. A t-test (table 35) indicated that the training group performed significantly better than the testing group in terms of the mean number of correct responses. We can, thus, conclude that the experience that was provided to the training group allowed the 4/5 year olds to improve their performance in this task in a significant way.

In view of the reported findings on the different strategies, further analysis was performed in order to evaluate how well the different strategies fit the patterns of responses in these groups. An analysis of variance (for a repeated measurements design) was performed with subjects nested within conditions (conditions being testing or training). The main effects in this analysis were condition and strategy; of major interest was the condition by strategy interaction. A conservative F test indicated significant main effects of condition and strategy and a significant interaction (table 36). The Tukey w procedure was used to study the significance of

the differences between the means (table 37). Strategies 1 and 2 represented a significant improvement upon the other two strategies in terms of the obtained errors of prediction but did not differ from each other significantly.

Again, it was important to attempt to verify in other ways if the failure to distinguish between strategies 1 and 2 in the training group could be explained by an approximately equal number of subjects having each of those strategies as their best fitting strategy. Table 38 (constructed in the same way as table 26, see explanation page 48) indicates that this could, in fact, be the case.

It is interesting to note that even though children in the training group were instructed to perform according to strategy 1, their performance does not fit strategy 1 better than strategy 2. In fact, table 38 indicates that a higher percentage of children in the training group have strategy 2 as their best fit that any other strategy. These results seem to indicate that the performance by the training group is more comparable to the performance of the 7 year olds than to the performance of the 11 year olds. It is possible that training effects can described as advancing children from one level to the next (in terms of these strategies) rather than bringing their performance to a complete conformity with strategy 1, which they had been taught by the experimenter.

b. Verbal responses.

In order to examine the effects of training effect upon

the performance in the verbal part of this task, the training group was compared to the testing group by means of a t-test for non-correlated samples. The results of this test (table 39) indicated a significant difference between the two groups, suggesting that the training provided in this study was sufficient to improve the performance of 4/5 year olds in this task. The training group was also compared with the group of 11 and 7 year olds (tables 40 and 41). The results of these comparisons indicate that their performance was much more similar to the performance of the 11 year olds.

Finally, a comparison of the frequencies of the different types of mistakes in the verbal responses (table 42) suggests that training strongly reduces errors of type 1 (consistent with strategy 3). On the other hand, mistakes of types 2, 4 and 6 seemed more difficult to eliminate by training.

FOOTNOTES:

(5) Voyat & Piaget, (1968) have found that children in the pre-operational level were able to improve their understanding of the identity of a changing object when given an opportunity to reflect upon their own changes through growth. However, this effect could not be observed in the older children, who performed at ceiling level in the former task from the start.

(6) The criterion phase in this task yielded one mistake for all age levels (at the age of 7). The responses to items which did not involve the problem of sensory substitution were also all correct except for one (at the age of 7). The responses to items which involved the problem of sensory substitution consisted usually of choosing one of the items which could represent a suitable choice; only one child (at the age of 4/5) chose the third object two times.

(7) When the total number of subjects presented in the analysis of the results of this task is equal to 54, the training group has been excluded from the analysis (i.e., the results for the group which received training in task III). When the results for this group are included, this group is identified as 4/5 year olds, group B.

(8) Responses already classified by the first two judges were included in this sample in order to provide the third judge with a sample of responses which reflected the appropriateness of the categories in same way. If the third judge were presented only with responses not-agreed upon by the first two judges, she might find her task impossible if those responses were all actually unclassifiable.

(9) Responses which remained unclassified after this procedure were assigned a pass for further analysis, as a conservative measure, since they fell most often in the younger age levels. At the less specific level, they were categorized as unclassified, with other responses which had not received enough probing from the experimenter in order to be classified.

IV SUMMARY AND CONCLUSIONS

This section will attempt to summarize the findings of this study, evaluate the possibility that they might be an artifact of the methodology, and suggest what kinds of contributions they might make to a Piagetian view of development.

1. Summary of the findings.

a. Ideas about information gained from sensory contact.

In general, this study suggests that children's ideas about perception - i.e., what they think one can know by using a specific sensory system - can not be said to be the result of a somewhat direct process of introspection upon one's perceptions. Young children (at the ages of 4 or 5) in this study often asserted, for example, that they knew the color of a haptically presented object.

Further, the study suggests that dealing with these concepts in a more abstract situation (i.e., a situation in which the subject cannot draw upon his perceptions in order to deal with this question) constitutes a difficult task which cannot be readily solved by most children even at the age of seven.

The changes in the way children approach the question of sensory substitution appear to be systematic and related to age. At the ages of 4 or 5 children seem to be aware of the fact that the knowledge of the qualities of an object comes from the senses. Even when the specific relationship

between the sensory systems and the quality under consideration was not understood by the child, children's explanations of why someone knew or did not know something about an object very often involved an explicit reference to a sensory system (see table 31).

The children showed a contradictory pattern of responses in the concrete and abstract situations. At the ages of 4 and 5, when presented with an object haptically in a concrete situation these children were able to use the haptic information in order to identify the object and describe its size, softness and material. They also seemed to believe that information about color was available to them in that situation. However, in a more abstract situation, children at this age level were unable to recognize the role of touch in providing any information at all. The importance of hearing was often also not recognized. Vision was the only sensory system of importance for these children and it was attributed not only the power to provide information about visual qualities like color and size but also the ability to provide information about non-visual qualities, such as temperature and weight.

This contradiction may be resolved if we conceptualize the results reported above in a less specific way. It is likely that the specific sensory systems being used by the child (in the particular task he is engaged in) becomes in some way salient to him. In task II, where haptic perception

was attributed greater informational value than it actually has, the child was presented with objects haptically. In task III, where vision was attributed greater informational value than it actually has and the role of touch was denied, the stimuli encountered by the child were pictures. If the child does not yet appropriately analyse the relationships between the senses and the different perceptual dimensions, he is likely to be easily influenced by other factors, such as the modality he is himself operating in; he might not be able to "decenter" from it and take into account other types of perceptual activity.

At the age of 7, most children were able to recognize the inability of touch in providing color information and performed almost as well as the 11 year olds when they had an immediate experience available to them. In the more abstract situation, however, these children were still unable to realize the role of touch in the identification of an object and its size. Non-visual qualities, such as weight and temperature, were no longer treated as visual qualities at this age level.

The difficulty observed among children of this age level in understanding that the sense of touch can provide information about the identity and size of an object is rather instructive. The literature on cross-modal integration has consistently indicated that children of this age are able to perform well in such cross-modal tasks even when complex

geometrical stimuli are involved; their tactual exploratory strategies are reported to be rather sophisticated. The discrepancy between the performance in such cross-modal tasks and the performance in the tasks that refer to ideas about sensory substitution seems to suggest that "knowing size by touch," for example, and "knowing about knowing size by touch" might indeed be two different things. This discrepancy provides empirical support for the theoretical distinction that was previously drawn between "knowing" and "knowing about knowing."

At the age of 11, children performed at ceiling level when they were asked to describe a haptically presented object. In the more abstract situation, however, only about 61% of the children demonstrated an understanding of tactual-visual and auditory-visual substitution. Some of the 11 year olds still performed as the 7 year olds and failed to recognize the role of touch in providing information which allows for the recognition of an object and the estimation of its size.

b. Developmental sequences. An important question which should be addressed here is what type of evidence is available to suggest that these age changes can be considered "developmental" changes. First, the behavior of younger children (4/5 and 7 years) seemed to suggest that the notions they held were most likely their own achievements rather than notions they had been simply taught at

school. Their ideas about the senses differed enough from the adult model that it was unlikely that they had been the simple product of school instruction.

Second, the age changes were consistent and followed a specific pattern. The order of difficulty of the items as defined by the Guttman scalogram analysis was associated with achievements at the three different age levels. The changes in the knowledge about the senses seemed to go from a more global, less organized to a more articulated approach to the problem.

Finally, the attempt to teach an adult understanding of the senses to 4/5 year olds in task III was only partially successful. The results obtained with the training group suggest that even if task-specific difficulties may partially account for differences in the performance of younger and older children, the particular nature of the improvement in the training suggests that other factors are implicated in these differences. The young children who received training showed an overall improvement in their performance but they did not simply incorporate the feedback they had received. Even though the feedback was based on the adult model, these children's behavior resembled the behavior of the 7 year olds more than the behavior of the 11 year olds (see tables 37, 24, and 23), vision being considered by these children the only sensory system that provides information about the identification of an object and its size. The verbal justifications provided by the

children in the training group were consistent with this pattern of responses and thus reflected not a simple repetition of what they had been told by the experimenter but, rather involved some transformation of the explanations they had been provided. A finding of this nature strongly suggests that one is dealing with a developmental trend.

2. Alternative hypothesis unrelated to the conception of sensory substitution.

The greater difficulty of task III in comparison with task II has been so far explained by considering the understanding of sensory substitution in the absence of relevant experience a more abstract task than the description of a haptically presented object. However, since most of the findings discussed above originated from the analysis of the results in task III, it is important to consider specific aspects of the methodology used in this task and examine the possibility these may be artifacts which might determine the results we have been discussing.

Two aspects of this task stand out as introducing new difficulties for the child: (1) the requirement that the subject take the perspective of another person, and (2) the complex nature of the linguistic forms used in task III (e.g., the child was asked in task III "Which one can tell if her toy is big or little?" and in task II "Is this big or little?"). Each of these aspects will be discussed below in an attempt to examine the possibility that the

observed age trends could be explained by other aspects of the method which bear no relationship to the understanding of the sensory systems.

a. The problem of taking the perspective of another person. Most developmental theories would readily predict age differences in performance when the task under consideration requires that the subject take another person's perspective into account. Children under the age of seven are generally considered unable to take a perspective different from their own viewpoint. This prediction is held in general terms in the present study but a more specific consideration of the results of task III suggests that the difference in perspectives per se cannot account for the findings. Young children (4/5 year olds) had little difficulty in taking another person's perspective in this task when they were questioned about the other person's ability to know the color of an object. In the construction of the stimuli in this task there was a specific attempt to avoid a confounding of this type and most of the stimuli were designed in such a way that the child's perspective would not coincide with the correct responses in most items (i.e., the response generated by taking into account the perspective of the characters in the pictures). For example, in item 1 (see Appendix III.1 for a description) the child can see both objects in the pictures and, therefore, know the color of both objects. However, one of the characters is blindfolded and cannot see the color of her

own toy. From the subject's point of view the answer to the question "Which one can tell the color of her toy" would be "both" and the correct response is, of course, to point to the one who is not blindfolded. Three other items of this same form, which were included in the Guttman scalogram analysis, were item 4, 11 and 15. Out of a total of 144 possible mistakes (18 subjects, two presentations), only 22 mistakes were made by the subjects in the 4/5 year old group. On the other hand, the four items which involved sensory substitution (items 2, 5, 9 and 13) yielded a total of 136 mistakes. It is interesting to note that the response in some of these items coincided with the subject's point of view. Consider item 9, for example. Both Frowny and Smily are holding a doll; Frowny is also looking at it and Smily is blindfolded. The subject is asked which one knows the size of the doll. The correct response, "both," coincides with the child's perspective since the child can see both dolls and know their size. The most frequent response to this item, however, was "Frowny."

b. Linguistic form. It is possible to argue that some of the linguistic forms used in task III were too difficult for the young children and that the items had different degrees of linguistic difficulty. This might have led to the better performance by young children in some items as compared to others. Two points can be made with regard to this hypothesis. First, there was variation

in terms of content within the linguistic forms. It is not obvious why a question regarding size should have been more difficult than a question regarding temperature and weight, since they were presented to the child in similar linguistic forms (namely: "Which one can tell if her toy is - big or little; hot or cold; heavy or not"). Second, two items which had the same verbal form (the only two which had the same exact verbal form and fell into different categories) and were classified into different categories with regard to the required notions about the senses yielded a very different number of mistakes. Items 9 and 16 were presented to the child by asking the same question but item 9 was a sensory substitution question while item 16 could be answered solely on the basis of vision. Out of 144 possible mistakes (considering all the age levels together), item 9 yielded 109 mistakes and item 16 yielded 30 mistakes. If we look at the data for the young children only, 55.56% of the answers in item 16 were correct while only 2.78% of the answers in item 9 were correct. It seems, thus, safe to conclude that it is unlikely that the difficulty posed by some items was due to their linguistic form and unrelated to the type of item in terms of their content.

c. Piaget's theory and children's ideas about their senses. Piaget's theory (and specifically the aspects of his theory presented previously, see pages 7 and 8) suggested the hypothesis that developmental trends should be

observed when one investigates children's ideas about their senses. This hypothesis finds support both in the study of children's responses in a more concrete situation, where the relevant sensory experience could be used as a basis for responding, and in a more abstract situation, where the child's responses could only be guided by his conception of the relationship between the sensory systems and the perceptual dimensions investigated here. Two types of observation supported this hypothesis: (1) age related trends were observed both in the concrete and in the abstract situation, and (2) the attempt to teach the adult conception of the relationships between the sensory systems and perceptual qualities of objects (in the more abstract situation) led 4/5 year olds to perform at a level comparable to 7 year olds but did not succeed in equating their performance to the expected adult behavior. While the specific pathway followed by children before they achieve an appropriate conception of sensory substitution is still unclear (since it seemed strongly influenced by task variables), there is strong evidence to suggest that this conception of sensory substitution is not available to children until about the age of 11.

It is suggested that further consideration of Piaget's theory might be helpful in an attempt to accomplish a broader conceptualization of these findings. Piaget's theory is particularly interesting in this since it deals

with knowledge about knowledge, which is the problem we set out to investigate in this study. The data we have just summarized strongly suggest developmental changes in knowledge about the senses and their relationship to knowledge about reality. It must be remarked, however, that his analysis is still rather exploratory at this point. There is no strong evidence to support this particular approach, which can be at best illustrated by the findings of this study.

According to Piaget (1963), the beginnings of intelligence are to be found in the coordination of sensory-motor schemata. Great emphasis is placed upon the coordination of visual and haptic schemata not as an association of two perceived stimuli but rather as the formation of a new organization which allows for the externalization of perception and the achievement of object permanence.

In the period of representational or intuitive intelligence, one observes a new level of intersensory coordination. Children from 4 to 8 years (Piaget & Inhelder, 1967) are confronted with the problem of identifying visually forms they had examined haptically. While the children who have already attained concrete operations do not have any difficulty in performing this identification, one can observe a developmental progression in the way younger children solve this problem. One could, at first, be surprised with these results in view of the notion of reciprocal

assimilation of haptic and visual schemata, which is assumed to take place much earlier in the child's life. However, haptic-visual matching tasks involve, according to Piaget and Inhelder, the achievement of reciprocal assimilation at the representational level, which cannot be assumed to take place at the sensory-motor stage.

In this study, a new aspect of a developmental progression was observed, the progression towards the achievement of an abstract conception of the relationships between the senses as defined by the existence of overlap in the information they are able to provide. This abstract conception of sensory substitution seemed to emerge only at about the age of 11. The late acquisition of a conception of sensory substitution is rather unexpected when one considers that the ability to perform intersensory coordination seems to be well developed at the ages of 7 or 8. We are therefore led to suggest that the abstract conception of sensory substitution might be the result of the coordination of the different sensory systems at the operational level of intelligence. While intermodal matching is the result of a coordination at the representational level, the achievement of the conception of sensory substitution is the result of a coordination at the operational level.

The abstract conception of the relationships between the senses which we have been discussing seems to fall in the realm of what Piaget has called "causal notions."

Causality, according to Piaget, "expresses what the objects do as they act on one another and on the subject" (Piaget & Garcia, 1971). Causal transformations differ from operational transformations because they are tied to observations of empirical events, which constitute their specific content. However, causal explanations also involve a notion of conservation (i.e., the new aspects of a phenomenon must correspond to certain transmissions[10] from the initial stages), and in this sense they are similar to operational transformations. It seems helpful to conceptualize the notion of sensory substitution within this framework. This conceptualization highlights two interesting aspects of intersensory coordination. On one hand, a specific content is involved here and one could not develop a model for the relationships between the senses without a specific consideration of that content. On the other hand, the achievement of an abstract model for understanding these relationships leads to a certainty akin to the certainty of a logical conclusion. If one knows that two senses provide information about the same dimension, then one must conclude that they can be coordinated with regard to that dimension. This conclusion is not a matter of probabilities but is a necessary conclusion.

The pattern described by Piaget (1975) as being characteristic of the development of causal transformation involves the following phases.

(1) The child will first fail to observe the phenomenon appropriately. Even when provided with feedback which should contradict his conception of the problem, the child "discounts" this feedback as an anomaly and fails to take the new observation into account. Sometimes the observational error will be maintained even in the presence of this disconfirming feedback. This situation was replicated in our study in task II. Children were asked to describe a haptically presented object and, at the end of their description, were allowed to see this object. Young children often named a color in describing the haptically presented object, failing to note that no color information was available. At the end of the trial, when the object was shown to the children, they were often confronted with the fact that they had named the wrong color for that object. They were, however, unable to profit from this feedback and went on to describe the color of the next object during the haptic presentation.

(2) In a second stage, the child attempts to take disconfirmation into account and reconcile the new observation with notions previously held. Some instances of this behavior were observed among 7 year olds in our study in task II. Two subjects who started out by naming a color of that object changed their approach after receiving feedback at the end of the first trial. One of them was able to realize the necessity of vision to identify the color of the object

but attempted to do so by saying that he did not know the color because that was a hard question but knew what the object was because that was an easy question. It must be added that this subject had no difficulty in naming the color of the objects upon seeing them.

(3) Finally, in the last stage, the child is able to integrate possible variations into a deductive and explanatory system, which is both related to current observations (substage A) and also generalized (substage B), allowing for some type of prediction. This type of behavior was illustrated both in task II, where the 11 year olds were able to accurately observe the impossibility of perceiving color haptically, and in task III, since the understanding of sensory substitution in others involves essentially a prediction (rather than an explanation of observed events).

Piaget further suggests that there is neither primacy of operational over causal transformations nor a primacy of causal over operational transformations. Rather, there is an interaction between operational composition and causality; development proceeds by a progressive differentiation of these two systems, following conflicts as well as convergences between (and within) them. There is a clear convergence between the attainment of context-free operations and the realization that, while the phenomenological experience of perception is necessarily modal, the forms constructed from perceptual information can be viewed not only

as perceptually amodal, but conceptually external to the perceptual process as well.

FOOTNOTE

(10) Piaget uses the word transmission in order to indicate certain causal transformations in which a property of one object can be said to "pass" to the other object; for example, he discussed the transmission of movement; when one object hits another, setting it in motion, one can consider this event in terms of the transmission of movement.

TABLE 1

Task I: Visual haptic coordination

Analysis of variance with sex as main effect

Source of variation	df	Mean square	F	Sign.
Main effect				
Sex	1	.542	.128	N.S.
Residual	52	4.245		

TABLE 2

Task I: Visual haptic coordination

Analysis of variance with order as main effect

Source of variation	df	Mean square	F	Sign.
Main effect				
Order	2	2.674	.632	N.S.
Residual	51	4.234		

TABLE 3

Task II: Description of a haptic object

Analysis of variance with ST-2 as dependent variable

Source of variation	df	Mean square	F	Sign.
Main effect				
Sex	1	1.101	.544	N.S.
Residual	52	2.023		

TABLE 4

Task II: Description of a haptic object

Analysis of variance with ST-2 as dependent variable

Source of variation	df	Mean square	F	Sign
Main effect				
Order	2	.397	.192	N.S.
Residual	51	2.069		

TABLE 5

Task III: The understanding of sensory substitution in others

Analysis of variance with choice responses as dependent variable

Source of variation	df	Mean square	F	Sign.
Main effect				
Sex	1	21.437	1.048	N.S.
Residual	52	20.463		

TABLE 6

Task III: The understanding of sensory substitution in others

Analysis of variance with choice responses as dependent variable

Source of variation	df	Mean square	F	Sign.
Main effects				
Age	2	313.527	33.751	.001
Order	2	1.380	.149	N.S.
2-way interaction	4	7.650	.824	N.S.
Residual	45	9.289		

TABLE 7

Task III: The understanding of sensory substitution in others

Analysis of variance having verbal responses as dependent variable

Source of variation	df	Mean square	F	Sign.
Main effect				
Sex	1	36.265	2.422	N.S.
Residual	52	14.972		

TABLE 8

Task III: The understanding of sensory substitution in others

Analysis of variance having verbal responses as dependent variable

Source of variation	df	Mean square	F	Sign.
Main effects				
Age	2	229.590	29.230	.001
Order	2	1.286	.985	N.S.
2-way interaction	4	6.791	.900	N.S.
Residual	45	7.547		

TABLE 9

Task I: Haptic-visual matching

Analysis of variance with age as main effect

Source of variation	df	Mean square	F	Sign.
Main effect				
Age	2	7.148	1.77.	N.S.

TABLE 10

Task I: Haptic-visual matching

Age-level	Mean no. of correct responses
11 year	2.00
7 years	.78
4/5 years	1.11

Note: The total number of items was equal to 5.

TABLE 11

Task II: Description of a haptic object

Proportion of passes in ST-1 and ST-2 for each age level

Age level	ST-1	ST-2	z-value	Sign.
11 years	99.31	98.60	.568	N.S.
7 years	100.00	62.53	10.800	.001
4/5 yrs. Group A	98.96	37.50	13.720	.001
4/5 yrs. Group B	98.96	36.11	13.911	.001

TABLE 12

Task II: Description of a haptic object

Analysis of variance with ST-2 as dependent variable

Source of variation	df	Mean square	F	Sign.
Main effect				
Age level	2	27.185	26.691	.001
Residual	51	1.019		

TABLE 13

Task II: Description of a haptic object

Mean no. of correct responses in ST-2 for each age level

Age level	Mean no. of correct responses
11 years	3.99
7 years	2.50
4/5 years	1.50

TABLE 13a

Task II: Description of a haptic object

Differences between the means across age level

	11 years	7 years	4/5 years
11 years	-		
7 years	1.44	-	
4/5 years	2.44*	1.00	-

Note: The smallest significant difference at the .05 level according to a Tukey w test in this case is 2.426.

* p .05
** p .01

TABLE 14

Task II: Description of a haptic object

Frequency of subjects per number of correct responses in ST-2

	No. of correct responses				
Age level	0	1	2	3	4
11 years	0	0	0	1	17
7 years	2	2	2	9	3
4/5 years Group A	8	2	2	4	2
4/5 years Group B	4	6	4	3	1

TABLE 15

Task II: Description of a haptic object

Proportion of responses in the specific categories for 11 year old subjects

Classification	ST-1	ST-2
1	93.403	0.0
2	.694	0.0
3	0.0	0.0
4	.694	1.389
5	0.0	2.778
6	0.0	0.0
7	0.0	19.444
8	.694	2.778
9	0.0	12.500
10	0.0	59.722

Note: Responses from 1 to 4 were given with certainty, from 5 to 8 were given without certainty, and categories 9 and 10 indicate a refusal to give a specific answer.

TABLE 16

Task II: Description of a haptic object

Proportion of responses in the specific categories for 7 year old subjects

Classification	ST-1	ST-2
1	92.014	2.778
2	2.083	6.944
3	1.042	4.167
4	2.431	22.222
5	0.00	2.778
6	0.00	2.778
7	0.00	1.389
8	0.00	11.111
9	0.00	22.222
10	.347	13.889
Not classified	2.083	9.722

Note: Responses from 1 to 4 were given with certainty, from 5 to 8 were given without certainty, and categories 9 and 10 indicate a refusal to give a specific answer. Unclassified responses represent disagreement between the raters which were not resolved.

TABLE 17

Task II: Description of a haptic object

Proportion of responses in the specific categories for 4/5 year old subjects - Group A

Classification	ST-1	ST-2
1	64.236	15.278
2	18.750	12.500
3	2.778	8.333
4	11.805	20.833
5	0.00	1.389
6	0.00	2.778
7	0.00	0.00
8	0.00	4.167
9	1.042	12.500
10	0.00	9.722
Not classified	1.389	12.500

Note: Responses from 1 to 4 were given with certainty, from 5 to 8 were given without certainty, and categories 9 and 10 indicate a refusal to give a specific answer. Unclassified responses represent disagreements between raters which were not resolved.

TABLE 18

Task II: Description of a haptic object

Proportion of responses in the specific categories for 4/5 year old subjects - Group B

Classification	ST-1	ST-2
1	68.056	15.278
2	14.583	15.278
3	2.431	9.722
4	11.111	16.667
5	0.00	2.778
6	0.00	1.389
7	0.00	1.389
8	0.00	2.778
9	1.041	2.778
10	0.00	18.056
Not classified	2.778	12.500

Note: Responses from 1 to 4 were given with certainty, from 5 to 8 were given without certainty, and categories 9 and 10 indicate a refusal to give a specific answer. Unclassified responses represent disagreements between the raters which were not resolved.

TABLE 19

Task III: The understanding of sensory substitution in others

Mean no. of errors (using a criterion of a correct response in both runs for a pass) per age level

Age level	Mean no. of errors
11 years	4.22
7 years	8.67
4/5 years	12.61

TABLE 19a

Task III: The understanding of sensory substitution in others

Differences between the means across age level

	7 years
11 years	- 4.45**
7 years	-
4/5 years	- 3.94**

Note: The smallest significant difference according to a Tukey w test in this case is 2.084 at the .05 level and 3.017 at the .01 level.

* p .05
* * p .01

TABLE 20

Task III: The understanding of sensory substitution in others

Guttman Scale

Item	Vision		Touch		Coordination		
Resp.	0	1	0	1	0	1	Total
	Err						
3	0	0	0	0	0	0	0
	--------Err						
2	4	1	1	4	0	5	5
			------Err				
1	32	1	31	2	3	30	33
					------Err		
0	16	0	16	0	16	0	16
Sums	52	2	48	6	19	35	54
Pcts	96	4	89	11	35	65	
Errors	0	2	1	2	3	0	8

Statistics:

Coefficient of reproducibility = .9506

Coefficient of scalability = .7037

TABLE 21 a (for 11 year old subjects)

Number of mistakes in predicting responses by using each strategy

S	Strat 1	Strat 2	Strat 3	Strat 4	Strat a	Strat b
1	4	12	14	28	22	14
2	5	11	17	28	26	14
3	9	16	14	27	23	16
4	1	7	15	26	25	10
5	10	6	14	25	26	13
6	2	9	17	26	25	10
7	6	6	14	24	26	11
8	10	12	10	24	22	14
9	8	0	8	24	20	12
10	14	14	19	26	30	18
11	10	1	9	25	20	13
12	6	8	16	27	27	11
13	5	7	15	26	25	12
14	1	7	15	26	25	10
15	8	0	8	24	20	12
16	16	8	16	24	26	20
17	8	4	12	25	23	14
18	4	12	20	28	26	14

N of responses: 40

TABLE 21 b (for 7 year old subjects)

Number of mistakes in predicting responses by using each strategy

S	Strat 1	Strat 2	Strat 3	Strat 4	Strat a	Strat b
19	8	0	8	24	20	12
20	17	9	9	20	21	20
21	10	2	10	22	22	12
22	17	25	28	23	34	23
23	12	4	9	23	21	14
24	18	12	18	20	29	18
25	16	10	14	18	26	12
26	17	9	13	22	25	18
27	26	19	18	17	29	23
28	19	11	13	20	24	19
29	30	27	32	22	37	27
30	17	8	12	20	24	18
31	16	13	19	21	23	21
32	6	2	10	25	20	11
33	12	7	15	22	26	14
34	13	5	12	21	24	15
35	16	8	8	26	20	18
36	6	3	11	22	23	15

N of responses: 40

TABLE 21 c (for 4/5 year old subjects)

Number of mistakes in predicting responses by using each strategy

S	Strat 1	Strat 2	Strat 3	Strat 4	Strat a	Strat b
37	26	20	20	16	18	23
38	30	23	24	14	32	27
39	28	21	19	18	27	28
40	24	16	15	20	24	24
41	14	6	9	20	20	17
42	28	26	26	20	33	24
43	20	22	25	30	29	21
44	16	8	8	23	20	19
45	14	11	11	22	18	19
46	19	11	13	25	23	21
47	25	17	14	18	26	23
48	18	12	12	22	21	16
49	18	10	8	25	20	20
50	24	17	20	18	28	25
51	24	20	22	24	28	23
52	12	6	10	24	18	17
53	18	10	14	22	24	20
54	20	14	10	30	6	25

N of responses: 40

TABLE 22

Task III: The understanding of sensory substitution in others

Analysis of variance with prediction errors as dependent variable

Source of variation	df	Mean square	F	Sign.
Age	2	394.4490	5.435	.05
Subjects	51	72.5710		
Strategy	3	1417.8086	5.969	.05
Strategy x Age	6	1128.3302	4.750	.05
Subjects x Strategy	153	237.5388		

TABLE 23

Task III: The understanding of sensory substitution in others

Mean no. of prediction errors per strategy for 11 year old subjects

Strategy	Mean no. of prediction errors
1	7.05
2	7.22
3	14.06
4	25.72

TABLE 23a

Task III: The understanding of sensory substitution in others

Difference between the means across strategies

	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Strategy 1	-	-.17	-7.01**	-18.67**
Strategy 2		-	-6.84*	-18.48**
Strategy 3			-	-11.66**
Strategy 4				-

Note: The smallest significant difference according to a Tukey $\underline{w}$ test in this case is 4.818 at the .05 level and 6.976 at the .01 level.

*p .05
**p .01

TABLE 24

Task III: The understanding of sensory substitution in others

Mean no. of prediction errors per strategy for 7 year old subjects

Strategy	Mean no. of prediction errors
1	15.33
2	9.67
3	14.39
4	21.78

TABLE 24a

Task III: The understanding of sensory substitution in others

Differences between the means across strategies

	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Strategy 1	-	5.66*	.94	-6.45*
Strategy 2		-	-4.72	-12.11**
Strategy 3			-	-7.39**
Strategy 4				-

Note: The smallest significant difference according to a Tukey w test in this case is 4.818 at the .05 level and 6.976 at the .01 level.

*p .05
** p .01

TABLE 25

Task III: The understanding of sensory substitution in others

Mean no. of prediction errors per strategy for 4/5 year old subjects

Strategy	Mean no. of prediction errors
1	21.00
2	15.00
3	15.56
4	22.00

TABLE 25a

Task III: The understanding of sensory substitution in others

Differences between the means across strategies

	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Strategy 1	-	6.00*	5.44*	-1.00
Strategy 2		-	-.56	7.00**
Strategy 3			-	-6.44*
Strategy 4				-

Note: The smallest significant difference according to a Tukey w test in this case is 4.818 at the .05 level and 6.976 at the .01 level.

*p .05
**p .01

TABLE 26

Task III: The understanding of sensory substitution in others

Proportion of subjects who had each strategy as their best fitting one

	Strategy				
Age level	1	2	3	4	not determined
11 years	63.88	36.11	0.00	0.00	0.00
7 years	0.00	83.33	5.55	0.00	11.11
4/5 years	0.00	30.55	30.55	11.11	27.77

TABLE 27

Task III: The understanding of sensory substitution in others

Analysis of variance with reliability errors as dep. variable

Source of variation	df	Mean square	F	Sign.
Main effect				
Age	2	89.056	14.198	.001
Residual	51	6.272		

TABLE 28

Task III: The understanding of sensory substitution in others

Mean no. of reliability errors across age levels

Age level	Mean no. reliability errors
11 years	1.50
7 years	1.944
4/5 years	5.555

TABLE 28a

Task III: The understanding of sensory substitution in others

Differences across age level

	11 years	7 years	4/5 years
11 years	-	-.444	-4.055**
7 years		-	-1.662*
4/5 years			-

Note: The smallest significant difference according to a Tukey w test in this case is 1.4589 at the .05 level and 3.5845 at the .01 level. *p .05
**P .01

TABLE 29a

Task III: The conception of sensory substitution in others

Mean no. of errors in each presentation

in the 11 year old group

Presentation	Mean no. of errors	t value	Sign.
Run 1	4.00	4.01	.001
Run 2	3.056		

TABLE 29b

Mean no. of errors in each presentation

in the 7 year old group

Presentation	Mean no. of errors	t value	Sign.
Run 1	8.00	2.00	N.S.
Run 2	7.33		

TABLE 29c

Mean no. of errors in each presentation

in the 4/5 year old group

Presentation	Mean no. of errors	t value	Sign.
Run 1	11.61	4.82	.001
Run 2	9.39		

TABLE 30

Task III: The conception of sensory substitution in others

Mean no. of correct verbal responses

Age level	Mean no. of correct responses
11 years	17.33
7 years	12.278
4/5 years	10.56

TABLE 30a

Differences between the means across age levels

	11 years	7 years	4/5 years
11 years	-	5.055**	6.777**
7 years		-	1.722
4/5 years			-

Note: The smallest significant difference according to a Tukey w test in this case is 1.878 at the .05 level and 2.719 at the .01 level.

*p .05
**p .01

TABLE 31

Task III: The conception of sensory substitution in others

Frequency of types of mistakes per age level

Age level	Type of error					
	1	2	3	4	5	6
11 years	1	27	2	18	0	0
7 years	11	64	10	39	10	1
4/5 years	22	62	7	44	26	3

TABLE 32

Task III: The conception of sensory substitution in others

Correlations between choice data and verbal scores for the 11 year old group

	Total	Subtotal	Verbal responses
Total	1.00		
Subtotal	.97	1.00	
Verbal responses	-.93	-.91	1.00

TABLE 33

Task III: The conception of sensory substitution in others

Correlations between choice data and verbal scores for the 7 year old group

	Total	Subtotal	Verbal responses
Total	1.00		
Subtotal	.97	1.00	
Verbal responses	-.93	-.89	1.00

TABLE 34

Task III: The conception of sensory substitution in others

Correlations between choice data and verbal scores for the 4/5 year old group

	Total	Subtotal	Verbal responses
Total	1.00		
Subtotal	.95	1.00	
Verbal responses	-.88	-.92	1.00

TABLE 35

Task III: The understanding of sensory substitution in others

Mean no. of errors in the second presentation

Condition	Mean	t-value	Sign.
Test group	9.39	5.00	.001
Training group	4.89		

TABLE 36

Task III: The understanding of sensory substitution in others

Analysis of variance with prediction errors as dep. variable

Source of variation	df	Mean square	F	Sign.
Condition	1	70.840	6.4103	.05
Subjects	34	11.051		
Strategies	3	233.896	73.235	.01
Condition x Strat.	3	317.090	99.245	.01
Subjects x Strat.	102	3.195		

TABLE 37

Task III: The understanding of sensory substitution in others

Mean no. of prediction errors per strategy for the training group

Strategy	Mean no. of prediction errors
1	4.89
2	4.00
3	6.94
4	11.83

TABLE 37a

Task III: The understanding of sensory substitution in others

Differences between the means across strategies

	Strategy 1	Strategy 2	Strategy 3	Strategy 4
Strategy 1	-	.89	2.05	6.94
Strategy 2		-	2.94	7.83
Strategy 3			-	4.89
Strategy 4				-

Note: The smallest significant difference according to a Tukey w test in this case is 1.885 at the .05 level and 2.729 at the .01 level.
*p .05
**p .01

TABLE 38

Task III: The conception of sensory substitution in others

Proportion of subjects who had each strategy as their best fitting one using responses in the 2nd run only

	Strategy				
Group	1	2	3	4	not det.
Test group	5.56	44.44	27.78	11.11	11.11
Training gr.	27.78	63.89	2.78	0	5.57

TABLE 39

Task III: The conception of sensory substitution in others

Mean no. of correct explanations

Condition	Mean no. of correct explanations	t value	Sign.
Test group	10.556	3.42	.002
Training group	14.444		

TABLE 40

Task III: The conception of sensory substitution in others

Mean no. of correct explanations

Group	Mean no. of correct responses	t value	Sign.
11 years	17.333	2.98	.006
Training group	14.44		

TABLE 41

Task III: The conception of sensory substitution in others

Mean no. of correct explanations

Group	Mean no. of correct responses	t value	Sign.
7 years	12.278	2.15	N.S.
Training group	14.444		

TABLE 42

Task III: The conception of sensory substitution in others

Frequency of types of errors per group

Type of group	Type of error					
	1	2	3	4	5	6
Test group	22	62	7	44	26	3
Training group	4	44	6	23	22	0

APPENDIX I

Trial 1: The child touches a comb. Array: comb, car, ball.

Trial 2: The child touches a circle. Array: circle, ball, helicopter.

Trial 3: The child touches a triangle. Array: triangle, comb, lady-bug.

Trial 4: The child touches a mushroom. Array: mushroom, circle, car.

Trial 5: The child touches a rectangle. Array: rectangle, ball, car.

Trial 6: The child touches a pencil. Array: pencil, circle, rectangle.

Trial 7: The child touches a triangle. Array: triangle, ball, circle.

Trial 8: The child touches a lady-bug. Array: lady-bug, triangle, mushroom.

Trial 9: The child touches a helicopter. Array: helicopter, car, triangle.

Trial 10: The child touches a ball. Array: ball, triangle, mushroom.

TEST PHASE

Trial 1: The child touches a rectangle. Array: two rectangles, one ball.

Trial 2: The child touches a circle. Array: two circles, a car.

Trial 3: The child touches a comb. Array: comb, two helicopters.

Trial 4: The child touches a pencil. Array: two pencils, one circle.

Trial 5: The child touches a mushroom. Array: mushroom, two lady-bugs.

Trial 6: The child touches a triangle. Array: triangle, two balls.

APPENDIX I (cont.)

Trial 7: The child touches a car. Array: car, two helicopters.

Trial 8: The child touches a lady-bug. Array: two lady-bugs, one pencil.

Trial 9: The child touches a helicopter. Array: helicopter, two rectangles.

Trial 10: The child touches a ball. Array: two balls, one circle.

APPENDIX II.1

The child explores four objects haptically: a doll, a piece of terrycloth, a ball, and a bunny.

The following sensory substitution questions were asked in a random order:

(1) What is this?

(2) What is it made out of?

(3) Is it big or little?

(4) Is it hard or soft?

(5) What color is it?

Each of the sensory substitution questions was followed by two more types of questions, one which attempted to investigate the child's certainty and one which asked the child to justify his response to the sensory substitution question. The investigation of the child's certainty followed the pattern below.

(1) Are you sure it is (a ball, blue, big etc.)?

(2) I am going to say it is (experimenter says something different from what the child said). Do you think I am right or wrong?

Four forms of the question related to the justification were prepared, and the order of these was counterbalanced giving 4 order cells. The question paired with the first sensory substitution question was also paired with the last substitution question. Each child was assigned to one of these order cells randomly. The four forms of the question were:

APPENDIX II.1 (cont.)

(1) How do you know it is (a ball, blue, hard etc.)?

(2) How can you tell it is (a ball, blue, hard etc.)?

(3) Why do you think it is (a ball, blue, hard etc.)?

(4) Why do you say it is (a ball, blue, hard etc.)?

APPENDIX II.2

This part of the study consisted of the following task: the experimenter asked the children to touch some objects out of their sight and after giving them some time to explore the objects asked the child some questions about it. The following questions were always asked: (1) what is this?; (2) is it big or little?; (3) is it hard or soft?; (4) what is it made out of?; (5) what color is it?

Note that while the first four questions could be answered on the basis of the experience the child was being given, the last question could not be answered on the same basis.

After each of the above questions, experimenter asked a few more questions on the same problem in order to ascertain the child's confidence in (or certainty about) his answer. The experimenter would suggest that it was a different object or that it was, in general, different from what the child had answered (for example, if the child said something was hard the experimenter would say: I think it is soft and mushy like peanut butter"). Next, the experimenter would ask the child to justify his answer. Four different forms of the last type of question were used and if the child failed to answer the first time, the question was posed in a second form.

The evaluation of the child's performance in these questions will constitute an attempt to investigate whether children can discriminate between what could be known about the object in that situation and what could not be known. Further analysis of the child's answers might also indicate whether the children are aware of the fact that their knowledge in that case had to be provided by the sense of touch and, in the case of color, was at best a guess on the basis of the likelihood that an object be of a certain color.

The answers given by the children will be classified into one of the following categories.

a. The child gives an answer to the question (for example: is it hard or soft? C: It is soft.)
I.R. with certainty
When the child gives an answer, the child might feel confident that it was the correct answer or the child might feel that he is not sure. If the child seems to be sure that he is correct, categories 1 through 4 will be used to classify the child's response, depending on what type of reason the child provides for his answer.

1. The child is certain that he is right because he is using his senses - for example: I feel it, it feels soft, it doesn't feel that big, it wouldn't fit in this box, I feel the shape of it, I feel the wheels, etc.
2. The child is certain that he is right simply because he believes that he knows it - for example: because I know it, because it has to be this, because that's the way this is, because they made it this way, etc.
3. The child is certain that he is right because he has seen something like that once or been told that once. Examples: I have a ball like this, I have seen one in the store, my mother told me once, my mother has one like this. The emphasis here in on having seen one or some objects like this. If all objects must be like that, the child's answer does not fit this category.
4. Other: The child gives a personal reason (for example: it is my favorite color), gives no reason (I don't know), or gives a reason not described above.

In evaluating the child's certainty one should take into account (a) the child's answer to the question: "Are you sure?"; (b) the child's susceptibility to influence - when the experimenter says that it is different, if the child changes his answer and then decides he is no longer sure, the answer must be classified as being given without certainty; if the child changes the answer once, for example, but then sticks to his choice, the answer should be classified as an answer given with certainty.

II. R without certainty

An answer will fall in this category if the child answered the question but said he was not sure or if the child after having answered the question, changed the answer in face of the experimenter's suggestions and became unsure of both answers. When an answer falls in this category, it will receive a number between 5 and 8, depending on the type of reason offered by the child.

5. The child says he is simply guessing. Examples: I don't know really, I'm just guessing; this was just a lucky guess, etc.
6. The child has seen one object like this. The emphasis here, like in 3, in on having seen one object of that sort. Examples: My friend has a ball like this, I have seen one like this, etc.
7. The child justifies his answer by saying that most objects of that type are like this. Examples: I'll say white because most rabbits are white; I'll say made out of cloth because most towels are made out of cloth. The contrast between 6 and 7 comes from the difference between saying that most objects in that

category are like that as opposed to one or some.

8. Other. The child gives a reason not described above or gives no reason.

b. The child does not give an answer to the question.

An answer will fall in this category if at no point the child gives a specific answer to the question, i.e., the child might not answer at all, is not able to refute any of the suggestions proposed by the experimenter categorically, or gives many answers to the question indicating that no specific answer is appropriate from his point of view. Examples: This could be black, or brown, or purple, or green, any color; I don't know, I just can't tell, etc. If the child starts by giving no answer but then is able to reject some of the possibilities provided the experimenter, his responses to the experimenter's suggestions can be treated as answers.

9. Child says he does not know and cannot explain why.
10. The child says he does not know and explains that one cannot know that under the circumstances. Examples: I don't know the color because I haven't seen it yet; I don't know the color because this is behind the curtain, etc.

APPENDIX II.3

Sample of responses classified in each category

Category 1: S2: (what is it made out of?) Material. Or you could say fabric. (would it be paper?) No. (are you sure?) Yes. (why do you say material?) Because with paper, if you feel it, it would crinkle, you could hear it. See, you don't hear it crinkling when I squeeze it.

S7: (is it hard or soft?) Hard but you can still squeeze it. (could it be soft like peanut butter?) No, not really mushy. (are you sure?) Yes. (why do you think it is hard?) Cause I can feel it, I can tell because I'm squeezing it and it doesn't squeeze too easy. It was really mushy you could squeeze it like nothing.

S31: (what is it made out of?) I don't know. (could it be paper?) No. (are you sure?) Yes. I think it is plastic. (how can you tell it is plastic?) Because I feel it and it doesn't feel like paper.

Category 2: S30: (is it big or little?) Little. (are you sure?) Yes. (could it be big like this?) No. (how do you know it is not that big?) Because it aint that size, it's smaller.

S71: (is it big or little?) Little. (are you sure?) Yes. (could it be big like this?) No, it's not. (how can you tell it is little?) Because they made it that way.

Category 3: S31: (what color is it?) Red. (could it be blue?) Red, wrong. (are you sure?) Yes, say red. (how can you tell it is red?) Because, well, not all balls are red, this one is red. I tell you, I got a ball like this at home.

S24: (what is it made out of?) String. (could it be wood?) No, it's made out of string. (are you sure?) Yes. (why do you say it is made out of string?) Cause how come my grandma said it is made out of string. They make it out of string and send it to the store.

Category 4: S37: (what is it made out of?) Paper. (could it be glass?) It can't be glass. (are you sure?) Yes. You know why? (No. Why do you say it is not glass?) Cause then you got Mexican dolls.

S43: (what color is it?) The hair? It is brown. (are you sure?) Yes. (could it be blond?) No. (how do you know it is not blond?) Of course it's not, that's the color of my hair.

Category 5: S22: (what color is it?) It's a red ball. (could it be blue?) Yes. (are you sure it is red?) No, I think it is a red ball. (how do you know it is red?) I just think it is red, I don't know for sure. I'm just guessing.

S15: (what color is it?) Green. (could it be red?) No, I don't think so. (are you sure?) No. (why do you think it is green?) I took a guess, it could be any color.

Category 6: S19: (what color is it?) Blue. (could it be brown?) No, because I guess it would be wrong. (are you sure?) I guess. (why did you say blue?) Because sometimes little balls are blue.

Category 7: S9: (what color is it?) This too could be any color but I would say it was like a beige. (could it be white?) Yes. (are you sure it is beige?) No, it could be any color. (why did you say beige?) Well, because most rubber balls are beige. But it could be white too.

S13: (what color is it?) Mostly this kind comes in red. (could it be blue?) No, I wouldn't think so. (are you sure?) I don't know but I wouldn't think so, I think it would be red. (how do you know it is red?) I don't know, it could be blue but I think this kind comes mostly in red.

Category 8: S11: (what color is it?) I'd say blue. (could it be red?) The ears remind me of an elephant. I imagine elephants are gray but they remind me of blue. It could be red too. (are you sure?) No. (why did you say blue?) Because it reminds me of a blue object.

S22: (what color is it?) Yellow. (could it be white?) Yes. (are you sure it is yellow?) No. (why did you say yellow?) I don't know. (how do you know it is yellow?) I don't know.

Category 9: S38: (what color is it?) It could be any color. (could it be blue?) Yes. (are you sure?) I'm not sure. (why do you say you're not sure?) Cause it could be any color.

S21: (what color is it?) Blue? (could it be red?) Maybe. (are you sure it is blue?) No. It might be blue, or gray, or red, or green. Any color. (why do you think it might be any color?) I don't know what color it is. (why do you say you don't know?) I don't know.

Category 10: S27: (what color is it?) Red. (could it be blue?) So it might be blue. (are you sure?) No, I'm not sure. It can be any color. (why do you say it can be any color?) Because I can't tell, I can't see it.

S2: (what color is it?) Don't ask me that one. (could it be blue?) I don't know this, I can't see. I have this material here.

APPENDIX III.1

Example: Smily has a toy in her hand; next to her on the couch are wrapping paper and a ribbon. Frowny has a box in her hand, which is still wrapped and tied with a bow. The child is asked which one can tell what she got for her birthday.

Stimulus 1: S has a coat on and is walking towards the door, reaching for the knob; F is sitting on the floor eating a cookie (which one is going out?).

Stimulus 2: S is on the floor crying; F is standing next to a table and looking around (which one fell off the chair?).

Stimulus 3: S has a closed bag in her hands; F has a bag and is looking inside it (which one can tell what she got from her friend?).

Stimulus 4: S is all wet, has a raincoat and a rainhat on, and is standing by the door; F is playing on the floor (which one went out in the rain?).

Stimulus 5: S has a cardboard box and is looking inside it; S is doing the same (which one can tell what is in the box?).

Stimulus 6: S has a closed lunch bag in front of her and is looking straight ahead; F has an open lunch bag in front of her and is looking inside it (which one can tell what she has for lunch today?)

Stimulus 7: S and F have a napkin around their necks and a plate with food in front of them (which one is going to eat?).

Stimulus 8: S is sitting on the floor looking at a book; F is walking towards the door with a wrapped gift in her hands (which one is going to a birthday party?).

Stimulus 9: S is sitting on the floor playing; S is lying in bed (which one is sick today?).

Stimulus 10: S is playing with a mouse; F is looking at a mouse and moving away (which one is afraid of the mouse?).

Stimulus 11: S and F have a plastic bag with a toy inside (which one can tell what is in the bag?).

Stimulus 12: S and F have gifts and are walking towards the door (which one is going to a birthday party?).

Stimulus 13: S has a glass of milk in her hands and is smiling; F is pushing a glass of milk away from her (which one likes milk?).

Stimulus 14: S and F have books in their hands and are walking towards the door (which one is going to school?).

Stimulus 15: S has a napkin around her neck; F is playing on the floor (which one is just going to have dinner?).

Stimulus 16: S is in bed; F is walking towards the door with books in her hands (which one is going to school?).

Stimulus 17: S has a hammer and pieces of wood and nails around her. F is sitting on the floor next to a toy and playing (which one is going to build a truck?).

Stimulus 18: S and F are playing with puzzles at a table; F has almost all the pieces in and S only has one piece in place (which one will finish the puzzle first?).

Stimulus 19: F and S are at a table and have paper and crayons in front of them (which one is going to draw a picture?).

Stimulus 20: S is at the table with scissors in her hands and has paper and glue on the table in front of her; F is playing with a car on the table (which one is going to cut out some shapes?).

Test stimulus.

Stimulus 1: S is touching a ball behind a transparent screen; F is on the other side of a transparent screen with the toy but blindfolded (which one can tell the color of the ball?).

Stimulus 2: S has her back turned to a man, who is playing the guitar; F is looking at him (which one can te-l what the man is playing?).

Stimulus 3: S is touching a toy behind a cardboard screen; S is looking at the toy in front of her on the table (which one can tell the color of the toy?).

Stimulus 4: S is blindfolded and touching a ball; F is not blindfolded and looks at it (which one can tell the color of her toy?).

Stimulus 5: S is blindfolded and touching a truck; F is looking at the truck (which one can tell what she has?).

Stimulus 6: S is looking at a toy and holding it; F just looks at it (which one can tell the color of her toy?).

Stimulus 7: S is looking at a man who is playing a flute but has her hands on her ears; F looks at the man (which one can tell what the man is playing?).

Stimulus 8: S is looking at an iron but is not touching it; F is looking and touching the iron with her fingertip (which one can tell if the iron is hot or cold?).

Stimulus 9: S is blindfolded holding a toy; F is looking at and holding the toy (which one can tell if the toy is big or little?).

Stimulus 10: S is blindfolded holding a box; F is not blindfolded and just looks at the box (which one can tell if the box is heavy or not?).

Stimulus 11: S looks at a man who is playing a flute; F has her back turned towards the man (which one can tell the color of the flute?).

Stimulus 12: S looks at and holds a box; F is blindfolded holding a box (which one can tell if the box is heavy or not?).

Stimulus 13: S looks at a toy truck on the table; F is holding the toy truck but is blindfolded (which one can tell if the truck is big or little?).

Stimulus 14: S looks at a cup on the table; F is looking at and touching it with her fingertip (which one can tell if the milk in the cup is cold or warm?).

Stimulus 15: S looks at a man playing the flute and has her hands over the ears; F has the back turned towards the man (which one can tell the color of the flute?).

Stimulus 16: S looks at and holds a toy; F doesn't hold the toy but looks at it (which one can tell if the toy is big or little?).

Stimulus 17: S has a transparent screen in front of her and is touch a toy on the other side; F has a cardboard screen in front of her and is touching a toy on the other side (which one can tell the color of her toy?).

Stimulus 18: S is looking inside a bag which contains something; F has a toy in a plastic bag (which one can tell the color of her toy?).

Stimulus 19: S is touching a toy behind a cardboard screen; F is sitting on the other side of a cardboard screen and looking at the toy (which one can tell the color of her toy?).

Stimulus 20: S is touching a toy behind a transparent screen; F is sitting on the other side and looking at the toy (which one can tell the color of her toy?).

Note: The position of the characters (on the left or the right) was randomly determined with the constraint that each character appear on the left and on the right half of the time.

APPENDIX III.2

Mean no. of mistakes in criterion phase

Type of group	Mean no. of errors
11 year olds	.72
7 year olds	.83
4/5 year olds	1.28
Training group	1.16

APPENDIX III.3

Response keys according to each strategy (the deviations from the adult model for responsing in this task are underlined)

Item	Strat.1	Strat.2	Strat.3	Strat.4 Left	Strat.4 Right
1	S	S	S	F	S
2	B	F	F	F	S
3	F	F	F	F	S
4	F	F	F	F	S
5	B	F	F	S	F
6	B	B	B	S	F
7	B	B	B	F	S
8	F	F	S	S	F
9	B	F	F	F	S
10	S	S	F	S	F
11	S	S	S	S	F
12	B	B	S	F	S
13	B	S	S	S	F
14	F	F	S	S	F
15	S	S	S	S	F
16	B	B	B	S	F
17	S	S	S	F	S
18	B	B	B	F	S
19	F	F	F	F	S
20	B	B	B	F	S

APPENDIX III.4

Sample of responses which were considered appropriate in task III, the conception of sensory substitution in others

Item 1: (see Appendix III.1 for a description of the items). The child is asked "Which one can tell the color of her toy?" F is blindfolded and S is not.
S 61: F got a blindfold and S can see through this.
S 1: F can't see, she doesn't know.
S 9: F is blindfolded, she can't see.
S 43: F has a blindfold on.

Item 2: F is looking at a man playing a guitar; S is not looking but could hear. The child is asked "Which one can tell what the man is playing?"
S 3: S could hear and could tell. F is looking.
S 39: F is not blindfolded and is looking and S is listening.

Item 9: F is looking at and holding a doll; S is blindfolded holding the doll. The child is asked "Which one can tell if her doll is big or little?"
S 1: S could feel it, F is looking at it.
S 17: F sees and puts it in her hands and S can feel the length of it.

Sample of responses which were classified as the different types of errors

Error type 1:

Item 10: F is looking at a box on a chair. S is blindfolded holding the box. The child is asked "Which one can tell if the box is heavy or not?"
S 37: F knows, he sees it.
S 42: S doesn't know cause S is not looking and F is looking.
S 64: S has a blindfold on (he doesn't know).

Item 14: F is touching a cup and S is looking at it. The child is asked "Which one can tell if the milk in the cup is hot or cold?"
S 36: Cause S is looking and F is looking (C answered "both").

Error type 2:

Item 2 (described above).
S 16: She is looking (shows F) and she aint.
S 19: F is looking right at him.
S 27: S is turned around, she doesn't know.

Error type 3
Item 35: F is looking away from a man playing a flute; S is looking at him but has her hands over her ears. The child is asked "Which one knows the color of the flute?"
S 45: Neither of them. F is reading her book and S has her hands like this (shows the hands over the ears) and can't hear.

Error type 4
Item 35 (described above)
S 29: S knows; he hears it when his ears are closed.

Item 17: S is touching a ball behind a transparent screen; F is touching a ball behind a cardboard screen. The child is asked "Which one knows the color of the ball?"
S 31: Neither of them. F is behind the ball and S is behind this too.

Error type 5
Item 14 (described above)
S 38: Cause it's hot.
S 50: Cause milk is supposed to be cold.

Item 17 (described above)
S 41: They both know cause they learned.
S 70: Cause he always knows best.

References:

Abravanel, E. The development of intersensory pattern. Monographs of the Society for Research in Child Development, 1968, 33, No. 2.

Apperl, L. F., Cooper, R. G., MacCarrel, N., Sims-Knight, J., Yussen, S. R. & Flavell, J. H. The development of the distinction between perceiving and memorizing. Child Development, 1972, 43, 1365-1381.

Bach-y-Rita, P. Brain mechanisms in sensory substitution. New York, Academic Press, 1972.

Blank, M. & Bridger, W. H. Cross-modal transfer in nursery school children. Journal of Comparative and Physiological Psychology, 1964, 58, 277-282.

Birch, H. G. & Lefford, A. Visual differentiation, intersensory integration and voluntary motor control. Monographs of the Society for Research in Child Development, 1963, 32, No. 2.

Ettlinger, G. Analysis of cross-modal effects and their relationship to language. In C. Millikan & F. Darley (Eds.) Brain mechanisms underlying speech and language. New York: Grune & Stratton, 1967.

Flavell, J. H. The development of role taking and communication skills in children. New York: John Wiley, 1968.

Gholson, B. Phillips, S & Levine, M. Effect of the temporal relationship of feedback and stimulus information upon discrimination learning strategies. Journal of Experimental Child Psychology, 1973, 15, 425-441.

Gibson, E. J. Principles of perceptual learning and perceptual development. New York: Appleton Century Crofts, 1969.

Gibson, J. J. The senses considered as perceptual systems. Boston: Houghton Mifflin, 1966.

Goodnow, J. J. Matching auditory and visual series: Modality problem or translation problem? Child Development, 1971, 42, 1187-1201.

Milner, A. D. & Bryant, P. E. Cross-modal matching by young children. Journal of Comparative and Physiological Psychology, 1968, 71, 453-458.

Piaget, J. From noise to order. The Urban Review, 1975, 8 (3), 209-218.

Piaget, J. & Garcia, R. Les explications causales. Paris: Presses Universitaires de France, 1971

Piaget, J. The origins of intelligence in children. New York: Norton, 1963 (first published in 1952).

Piaget, J. & Inhelder, B. La genese de l'idee de hasard chez l'enfant. Paris: Presses Universitaires de France, 1951.

Piaget, J. & Inhelder, B. The child's conception of space. New York: Norton, 1967 (first published in 1948).

Voyat, G. & Piaget, J. Identite d'un corps en development en epistemologie et psychologie de l'identite. Paris: Presses Universitaires de France, 1968.

Youtz, R. P. & Broome, R. C. Cutaneous color discrimination (DOP) at two stimulus temperatures. Proceedings of the 77th Annual Convention of the American Psychological Association, 1969, 4 (pt. 1), 17-18.