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THE INITIAL COORDINATION OF SENSORIMOTOR SCHEMAS IN HUMAN INFANTS - PIAGET'S IDEAS AND THE ROLE OF EXPERIENCE.

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THE PURPOSE OF THIS STUDY WAS TO FIND OUT IF INFANTS WOULD EXHIBIT BEHAVIORS CONSISTENT WITH PIAGET'S OBSERVATIONS ON THE DEVELOPMENT OF RECIPROCAL COORDINATIONS AMONG THE LOOKING, SUCKING AND GRASPING SCHEMAS. A SECOND PURPOSE WAS TO SEE IF INCREASED LOOKING AT AND TOUCHING OF NEARBY OBJECTS BY INFANTS WOULD RESULT IN ACCELERATION OF THE COORDINATING PROCESS. EXPERIMENTAL SUBJECTS WERE A GROUP OF NORMAL BUT INSTITUTION-REARED INFANTS (1 1/2 TO 5 MONTHS OLD) WITH A CONTROL GROUP OF 43 WHO HAD BEEN SPECIALLY TRAINED. ONCE A WEEK EACH BABY WAS BROUGHT TO THE TESTING ROOM AND GIVEN 3 OPPORTUNITIES TO RESPOND TO THE PRESENTATION OF THE TEST OBJECT. EACH WAS THEN GIVEN THE OBJECT-IN-HAND TEST. SOME OF THE INFANTS HAD BEEN REARED UNDER CONDITIONS DESIGNED TO ACCELERATE SENSORIMOTOR DEVELOPMENT. THESE SUBJECTS SHOWED PRECOCIOUS VISUALLY-DIRECTED REACHING AND HEIGHTENED VISUAL ATTENTIVENESS DEMONSTRATING A FUNCTIONAL RELATIONSHIP BETWEEN REARING CONDITIONS AND DEVELOPMENTAL PROCESSES. THE RESULTS OF THE STUDY SUPPORT PIAGET'S THEORY OF SEQUENTIAL DEVELOPMENT AND RECIPROCAL COORDINATION BUT SUGGEST THAT (1) MANY MORE INFANT RESPONSES ARE IDENTIFIABLE AND (2) THAT ENVIRONMENT CAN AFFECT THE RATE OF SENSORIMOTOR DEVELOPMENT. (MS)

THE INITIAL COORDINATION OF SENSORIMOTOR SCHEMAS IN HUMAN INFANTS - PIAGET'S IDEAS AND THE ROLE OF EXPERIENCE[1]

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Footnote I

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During the last ten years, increasing numbers of American psychologists have turned to the study of human infancy. Characteristically, recent research done in this country has been carefully designed and executed. Another feature shared by most modern studies is the modesty of their scope. Visual orientation, auditory sensitivity, heart-rate patterns, conditioned reflexes, etc., typify the target phenomena under study. Valuable as these studies are, they seem to leave the student of human development in a state of deprivation. Some sense of how the entire human infant functions during his first encounters with the world is indispensible and yet not easily available. It would not be unfair to say that few American developmental psychologists have much first-hand knowledge about infant behavior beyond the scope of their admittedly narrowly defined studies. I think part of the enormous respect many of us have for Jean Piaget is due to his contribution to our understanding of the nature of the normally functioning human infant.

The Origins of Intelligence in Children (Piaget, 1952), is in my opinion, far and away the most outstanding body of work we have in human infancy. It represents the work of a truly remarkable observer, theoretician and experimentor. It is one of the few examples of behavioral research on a grand scale. Actually, the approach Piaget used is more familiar to biologists and ethologists ~~and~~ THAN psychologists. Defining intelligence as the prime human adaptive tool, Piaget traced the etiology of this vital asset from its first manifestations in the sensorimotor behavior of the newborn to the emergence of ideational forms at the end of the second year. He did this using a combination of fundamental scientific tools. The combination was a simple one; a) selection of the general topic - the ontogenesis of intelligence; b) general theorizing - e.g., continuous efforts towards adaptation involving assimilation, accomodation and schemas; c) observations - thousands of hours spent identifying the

multiplicity of manifestations of the processes under study; d) experimentation - e.g., on object permanence, means-ends behavior, etc; e) refinement and integration of the theory.

Along the way, Piaget identified behavioral signs of the emergence of several related fundamental processes such as: intentionality, curiosity, symbolic behavior, the transition from trial and error to insightful behavior, etc. It is truly amazing that virtually no one, (Charlesworth, 1966, excepted) has pursued subsequently the study of these processes in infants although it has been thirty years since Piaget's observations were published.

When one describes this work in 1967, one gets a feeling of remoteness from modern American studies. There is no mention of independent variables, operational definitions, elaborate experimental design, non-parametric statistics, etc., nor their counterparts of the 30's. Yet, neither is there a feeling of artificiality, arbitrariness and atomism characteristic of modern studies. Perhaps, the most unique contribution Piaget has made to the study of infancy is to suggest a viable alternative to the conventional approach used in our field.

Bear with me for a moment while I compare the tasks of understanding early human development and manufacturing a suit of clothes. Most modern studies are primarily empirical, restricted in scope and scientifically respectable. Such studies produce dependable findings. In the preparation of our suit of clothes, these well-shaped findings are comparable to fine cut lapels, or pockets, or buttonholes, or cuffs, or what have you. They are unquestionably excellently made but it is not as if we have all of the pieces which only remain to be put together. Rather, we have perhaps less than 5% of the total, and in fact, there are those producing such pieces, lapels perhaps, who would have us believe that the entire suit is simply a very large lapel. I find less to quarrel with with them, however, than

with others in our field who claim to have fine suits available when we know they haven't taken the time and trouble to procure any fabric let alone lapels or pockets. Their suits are splendidly advertised but seem to lack substance. Piaget, on the other hand, although admittedly having studied only one of several major developmental processes, and only in his own three children, has manufactured a complete suit. It is undoubtedly improperly cut. It would be miraculous if it were a perfect fit. Nonetheless, it has a general shape which probably bears a strong generic relationship to the product we seek. He has very few genuine competitors.

Let me make explicit what I have implied. There seem to be in current use three ways of studying infant development; a) empirical studies of high dependability and molecular scope; b) theoretical work, broad in scope but supported by negligible amounts of data (as for example, modern explanatory systems of language acquisition); and c) bold frontal assaults on the <u>total</u> course of the developmental process via intensive first-hand longitudinal observations combined with cumulative experimentation, and an irreligious attitude towards laboratory methods, experimental design, and statistics. It is my contention that Piaget's infancy work is an example of style c) and constitutes the single most important contribution to our understanding of early human intellectual development. It is the only system based on empirical evidence which addresses the question, "What does the human child know of the world during his first two years of life?" Perhaps, it is time we asked whether the traditional approaches in which we've been investing virtually all of our resources (styles a and b) have been sufficiently productive.

Personally, I find my professional bearings with Piaget's studies. Right or wrong, he offers a powerful framework for guidance in investigating human behavior; a framework which is sufficiently complicated for the obviously

complex creature involved, and one which pulls together the bewildering pieces of infant behavior into a believable system. I never cease to be amazed at how often my own observations on several hundred infants confirm Piaget's observations on only three.

Perhaps, the feature of Piaget's theory which attracted me the most was its focus on the intimate interaction between infant and environment. Here, after all, is where the processes that concern psychologists take place. Even though he didn't concern himself with possible optimal arrangements of environmental circumstances or "aliment," he did open the door for anyone who would care to sponsor schema development, complication and proliferation. The studies I have been involved with over the last several years (White, et al., 1964; Haynes, et al., 1965; White and Castle, 1965; White and Held 1966; White - In Press) have been oriented towards the determination of optimal rearing conditions for human infants. I have consciously tried to utilize both styles a and c in my approach to the problem. As a result, I feel my colleagues and I have gained some dependable knowledge about fundamental sensorimotor acquisitions like visually-directed reaching, accommodation and exploration. In addition, we believe we have gained some preliminary but dependable knowledge about the complicated interrelations between early experience and development.

In this report, I would like to present some hitherto unpublished data on one phase of sensorimotor theory. These data concern the integration of schemas or in Piaget's terms the "reciprocal coordinations" of the second stage. During a series of studies on the effects of differential rearing conditions, we routinely included an "object-in-hand" test. According to Piaget, the behavior seen when an object is grasped by an infant of one to five months of age reveals the degree of interrelationship among the grasp

sucking and looking schemas. The one-month old infant is capable of grasping a rattle, looking at it or sucking it. Further, each of these behaviors can be elicited if the rattle is used as directed "aliment," i.e., if it is brought to the infant's mouth, he will suck it; if it is pressed in the infant's palm, he will grasp it, etc. However, at one-month of age, according to Piaget, these schemas exist in isolation. This means that, unlike an adult, a one-month old infant will not look at something he's grasping, nor grasp what he is sucking, etc. During the months that follow, these schemas become coordinated. The steps as spelled out by Piaget (1952, pp88-122) are as follows:

a) 1-2 months* - The hand does not grasp an object which is being sucked, even though the hand itself is occasionally brought to the mouth and sucked. Further, the eyes do not regard the object grasped (or the hand). Vision is therefore not as advanced as sucking in regard to control of the hands.

b) 2-3 months - The eyes follow the motion of the hands but the hands are not under the control of the visual system; they move in and out of the visual field apparently independently. The hand does not try to grasp what the eye sees. Continuing the primacy of sucking as a controlling function, the hand brings grasped objects to the mouth where they are sucked rather than to the visual field for viewing.

c) 3-4 months - The hand grasps the object that is being sucked and reciprocally the object grasped is brought to the mouth to be sucked. However, if the object is in view before it is grasped, there is a delay before the object is brought to the mouth. In addition, vision seems to influence hand movements maintaining their presence in the visual field and "augmenting" their activity (Piaget, 1952, p102).

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*Ages cited are approximations.

d) 4-5 months - The hand grasps the seen object for the first time. Prehension results when hand and object are simultaneously in view.

e) 5-6 months - True visually-directed reaching emerges. After the object is grasped the infant routinely glances at it before bringing it to the mouth for sucking. Occasionally, viewing is prolonged and the object is not brought to the mouth at all. It should be noted that in sensorimotor theory the intersection of several schemas provides the basis for the emergence of object permanence. An object that is simultaneously looked at, reached for, and felt, as in the prehensory act, is more than a part of a single activity schema. It serves a truly unique function when it participates in three schemas at once, and it is from this special role that true object permanence normally develops. (Hunt, 1961).

The data to be presented in this paper address two questions:

a) Does the sequence described by Piaget fit the facts gathered on a larger group of subjects?

b) Do modifications in rearing conditions which accelerate the acquisition of visually-directed reaching affect other important steps in the sequence?

Unfortunately, placing an object in the hand of an infant is an inadequate test of the entire developmental sequence in question. For example, a test situation where an object (perhaps a pacifier) was placed in the infant's mouth would be necessary as well as a situation where the infant could view the object before he grasped it. Nonetheless, we may be able to learn something from this admittedly partial view of the situation when the results are combined with those of tests of prehension in the same subjects.

The test procedure:

Once each week, beginning at 36 days, each infant was brought to the testing room. After a five to ten minute acclimatization period, the infant

was given three opportunities to respond to the presentation of the test object (for details see White, et al., 1965). This procedure took about five minutes. The last phase of the session consisted of the object-in-hand test. The test object was a paper party toy. It was approximately five inches in length and one half inch in diameter along the handle or stem. At one end there was a wooden mouthpiece through which air could be blown to extend a red coiled section. To this coiled section was attached two feathers whose original function was to tickle a neighboring child at a party. When coiled, this section is surrounded by orange and yellow fringes. The overall diameter of this display was about one and half inches: The object is a common five and ten cent store item and was used because it is easily grasped and retained by young infants and features a complex contour field with highly contrasting orange, red and yellow lines previously found attractive to most infants (White, et al., 1964).

Subjects were physically normal infants born and reared in an institution. As part of a larger study, some of these infants had been reared in a variety of systematically varied rearing conditions designed to accelerate sensorimotor development. (For details see White and Held, 1966, and White, 1967). The data presented in this paper are from two groups: Forty three controls including eleven babies who had received extra handling during the first 36 days of life, and sixteen modified enrichment infants. In brief, the experimental group was reared under conditions designed to increase the occurence of certain forms of motility in sensorily-enriched surrounds. Such experiences produced markedly precocious visually-directed reaching and heightened visual attentiveness.

Hypotheses:

a) Control babies would exhibit behaviors consistent with Piaget's observations on the development of reciprocal coordinations among looking, sucking and grasping schemas.

b) Increased looking at and palpating of nearby objects (induced via enrichment procedures) would result in acceleration of the coordination process.

Results:

a) The normal developmental sequence:

On the basis of Piaget's discussion of the development of prehension schemas (1952, pp88-122) one would expect a developmental pattern somewhat like that described in Table I.

Place Table I here

Responses to the object-in-hand test in our control group are shown in Table II.

Place Table II here

Description of responses:

1. Retains only - The infant holds the test object for more than three seconds.
2. Views - The infant holds the test object and either glances at it one or more times or regards it steadily for up to two minutes.
3. Brought to mouth - The infant holds the object and without viewing, brings it to the mouth one or more times briefly or manages to keep it at the mouth and gum or suck it.
4. Monitored mutual play - The object is brought to the midline where it is simultaneously viewed and tactually explored by the other hand.
5. Views then to mouth - Responses (2) and (3) combined.
6. Views - other hand raised - The infant retains the object and extends and raises both arms while viewing the object.
7. Views - other hand - The infant retains the object and views the free hand.
8. Monitored mutual play - then to mouth - Responses (4) and (3) combined.

Table I

The Normal Developmental Sequence According to Piaget

Test	Object-In-Hand		Prehension
Age (months)	N	Response	Response
1-2	3	1) Retains only	-
2-3	"	1) Brought to mouth for sucking	-
3-4	"	" " " " " "	-
4-5	"	" " " " " "	Fourth stage reaching (if hand and object simultaneously in view)
5-6	"	1) Brief regard then brought to mouth for sucking 2) Prolonged regard	True reaching

Table II

The Sequence Exhibited by Control Subjects

Test		Object-In-Hand			Prehension	
Age (Months)	N*	Response	Subjects Exhibiting N	Response** Per Cent	N	Response
1 1/2 - 2	23	1) Retains only	22	95.8		
		2) Brought to mouth	5	21.7		
		3) Views	3	13.0		
2 - 2 1/2	27	1) Retains only	23	85.2		
		2) Views other hand	3	11.1		
		3) Views other hand raised	2	7.4		
2 1/2 - 3	25	1) Retains only	21	84.1		
		2) Views	18	72.1		
		3) Brought to mouth	6	24.0		
		4) Views other hand	5	20.0		
		5) Monitored mutual play	0	0.0		
3 - 3 1/2	27	1) Views	24	89.0		
		2) Retains only	16	59.3		
		3) Monitored mutual play	7	25.9		
		4) Brought to mouth	6	22.2		
3 1/2 - 4	25	1) Views	20	80.0		
		2) Monitored mutual play	13	52.0		
		3) Views then to mouth	7	28.0		
		4) Retains only	6	24.0		
		5) Brought to mouth	6	24.0		
		6) Views other hand raised	6	24.0		
		7) Monitored mutual play then to mouth	3	12.0		
4 - 4 1/2	21	1) Views	17	81.0	12	4th stage reaching (median - 120 days)
		2) Monitored mutual play	15	71.5		
		3) Views other hand raised	7	33.3		
4 1/2 - 5	16	1) Views	12	75.0	14	True reaching (median - 147 days)
		2) Monitored mutual play	9	56.3		
		3) Brought to mouth	6	37.5		
		4) Views then to mouth	6	37.5		
		5) Monitored mutual play - then to mouth	1	6.3		

Total N = 164 Total trials = 560

*Each test consisted of two trials. Average number of tests/subjects was 1.71. Average number of responses per trial was 1.21, increasing steadily with age.

**Only responses occurring in 20% or more of the subjects of either the control or experimental group are recorded.

Although fourth and fifth stage reaching occurred about as predicted by Piaget's work, this was not the case for the object-in-hand data. The number of response patterns seen was considerably greater than expected, the influence of the sucking schemas was much less than expected, and that of vision was strikingly greater than expected.

b) 1. Is the developmental sequence influenced by rearing conditions?

Table III contains responses to the object-in-hand test shown by the experimental group. Table IV indicates that the groups differ significantly.

2. Is the rate of coordination of schemas influenced by rearing conditions?

Place Tables III and IV here

Table V shows comparative data for the experimental and control groups. The schemas listed are not necessarily the only ones involved in the behaviors seen.*

Place Table V here

It is clear that the coordination of schemas as described in this analysis has been accelerated for the experimental group. With respect to prehension, the median dates of onset for stages four and five were 95 to 89 days respectively compared to 130 and 147 days for the control

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*Piaget doesn't give precise guidelines for assigning schemas to behavior. I have tried to be conservative in assigning schemas to the behavior patterns in question. There seem to be at least five schemas involved: a) the grasp schema-retention of the object; b) the visual schema-glances or prolonged viewing of the object; c) the sucking schema- the object is brought to the mouth for attempts at sucking; d) the tactual schema - the other hand joins with the hand holding the object to either feel it or take it away; and e) the "other" arm movement schema - the other hand is raised. This last schema reflects the ambiguities in assigning schemas to complicated behavior patterns. Since all behaviors require a schema in Piaget's system, and since hand-raising occurs rather often, I have postulated a schema for it. Actually, hand-raising is a part of another schema, bilateral hand-raising, which is a behavior pattern often seen between 7 and 11 weeks of age in our control group.

Table III

The Sequence Exhibited by Experimental Subjects

Test		Object-In-Hand			Prehension	
Age (Months)	N*	Response	Subjects Exhibiting N	Response Per Cent	N	Response
1 1/2 - 2	16	Retains only	16	100.0		
		Views	10	62.6		
		Brought to mouth	6	37.5		
2 - 2 1/2	16	Retains only	15	93.9		
		Views	10	62.6		
		Views other hand raised	5	31.3		
		Views other hand	4	25.0		
		Brought to mouth	4	25.0		
2 1/2 - 3	14	Views	13	93.0	13	True reaching (median - 89 days)
		Retains only	7	50.0		
		Views other hand	6	42.8		
		Monitored mutual play	5	35.7		
		Views other hand	4	28.6		
3 - 3 1/2	12	Views	10	83.6	8	4th stage reaching (median - 95 days)
		Retains only	7	58.3		
		Views other hand	6	50.0		
		Monitored mutual play	4	33.3		
		Views other hand	3	25.0		
3 1/2 - 4	12	Views	10	83.6		
		Monitored mutual play	7	58.3		
		Views other hand	4	33.3		
		Monitored mutual play then to mouth	3	25.0		
		Views then to mouth	1	8.3		
		Retains only	1	8.3		
4 - 4 1/2	11	Views	9	82.8		
		Monitored mutual play	9	82.8		
		Views other hand	4	36.4		
4 1/2 - 5	9	Monitored mutual play	8	88.9		
		Views	7	77.8		
		Views then to mouth	3	33.3		
		Views other hand	3	33.3		
		Monitored mutual play then to mouth	2	22.2		
		Brought to mouth	0	00.0		
Total N = 90		Total trials = 380				

* Average number of tests/subject was 1.90. Average number of responses/trial was 1.13, increasing steadily with age.

Table IV

Significance Levels for Differences Between Control and Experimental Subjects - Object-In-Hand Test

Response	Per Cent Subjects Exhibiting Response*		t	df	Significance Level (1-tailed tests)
	Controls	Experimentals			
Retains only	24.0	8.3	1.34	35	N.S.
Views	13.0	62.6	3.56	37	> .001
Views with other hand raised	7.4	31.3	1.90	41	N.S.
Brought to mouth	37.5	0.0	3.10	23	> .005
Views - other hand	20.0	42.8	1.47	27	N.S.
Monitored mutual play	35.7	64.3	2.79	27	> .005
Monitored mutual play then to mouth	12.0	25.0	0.93	35	N.S.
Views then to mouth	28.0	8.3	1.64	35	N.S.

*In this analysis the following procedure was followed:

a) Identify responses that occured in at least 20% of either group
b) Determine the number of age periods when each response occurred in at least 20% of either group
c) Calculate the probability of any single comparison between groups for any two week interval for an overall significance level of .05 according to the following formula:

$p=(1-\alpha_i)^n$ where n=number of 2 weeks periods where response occurred in at least 20% of either group

d) Test most extreme group differences against adjusted significance levels

N	1	2	3	4	5	6	7
α_i	.050	.025	.017	.012	.010	.008	.007

Table V

Distribution of Schemas as a Function of Age for Control and Experimental Groups - Object-In-Hand Test

Age (months)	Control Response*	Schemas Involved**	Per Cent Showing	Weighted Score	Experimental Response	Schemas Involved	Per Cent Showing	Weighted Score
1 1/2 - 2	Retains only	1	95.8	95.8	Retains only	1	100.0	100.0
	Brought to mouth	2	21.7	43.4	Views	2	62.6	125.2
					Brought to mouth	2	37.5	75.0
Group score				139.2				300.2
2 - 2 1/2	Retains only	1	85.2	85.2	Retains only	1	93.9	93.9
					Views	2	62.6	125.2
					Views other hand raised	3	31.3	93.9
					Views other hand	2	25.0	50.0
					Brought to mouth	2	25.0	50.0
Group score				85.2				413.0
2 1/2 - 3	Retains only	1	84.1	84.1	Views	2	93.0	186.0
	Views	2	72.1	144.2	Retains only	1	50.0	50.0
					Views other hand	2	42.8	85.6
					Monitored mutual play	3	35.7	107.1
					Views - other hand raised	3	28.6	85.8
Group score				228.3				514.5
3 - 3 1/2	Views	2	89.0	178.0	Views	2	83.6	167.3
	Retains only	1	59.3	59.3	Retains only	1	58.3	58.3
	Monitored mutual play	3	25.9	77.7	Views other hand raised	3	50.0	150.0
	Brought to mouth	2	22.2	44.4	Monitored mutual play	3	33.3	99.9
					Views other hand	2	25.0	50.0
Group score				359.4				535.4

Table V - Continued

Age (months)	Response* Schemas	Control Involved**	Per Cent Showing	Weighted Score	Response Schemas	Experimental Involved	Per Cent Showing	Weighted Score
3 1/2 - 4	Views	2	80.0	160.0	Views	2	83.6	167.2
	Monitored mutual play	3	52.0	156.0	Monitored mutual play	3	58.3	174.9
	Views then to mouth	3	28.0	84.0	Views other hand raised	3	33.3	99.9
	Retains only	1	24.0	24.0	Monitored mutual play	4	25.0	100.0
	Views other hand raised	3	24.0	72.0				
Group score				544.0				542.0
4 - 4 1/2	Views	2	81.0	162.0	Views	2	82.8	165.6
	Monitored mutual play	3	71.5	214.5	Monitored mutual play	3	82.8	248.4
	Views other hand raised	3	33.3	100.0	Views other hand raised	3	36.4	109.2
Group score				476.5				523.2
4 1/2 - 5	Views	2	75.0	150.0	Monitored mutual play	3	88.9	266.7
	Monitored mutual play	3	56.3	168.9	Views	2	77.8	155.6
	Brought to mouth	2	37.5	75.0	Views then to mouth	3	33.3	99.9
	Views then to mouth	3	37.5	112.5	Views other hand raised	3	33.3	99.9
					Monitored mutual play then to mouth	4	22.2	88.8
Group score				506.4				710.9

Group differences are significant beyond .02 level- Randomization test (Siegel- 1956).
* Only responses occurring in at least 20 per cent of the subjects are included.

** Schemas were assigned as follows:

Table V - Continued

	Response	Schemas Involved	Total Schemas
1.	Retains only	Grasp	1
2.	Brought to mouth	Grasp Sucking	2
3.	Views	Grasp Vision	2
4.	Views - other hand	Grasps Vision	2
5.	Views - other hand raised	Grasp Vision "Other Arm" Movement	3
6.	Views then to mouth	Grasp Vision Sucking	3
7.	Monitored mutual play	Grasp Vision Tactual	3
8.	Monitored mutual play then to mouth	Grasp Vision Tactual Sucking	4

group. These shifts are highly significant ($p < .001$ - Mann-Whitney U test Siegel, 1956).

Discussion:

The first hypothesis, that the sequences described by Piaget would be repeated in a larger subject group, was only partly confirmed. We did not find the sucking schema to be dominant in our groups. Further, the influence of vision was markedly greater than expected. In addition, the complexity of the sequence in terms of number of responses shown was greater than expected. Finally, the influence of postural factors such as the tonic neck reflex and the favored hand was both marked and unexpected. During the third month of life, a child would often view the object placed in his favored hand, and again view that hand when the object was placed in the other hand. Another manifestation of this asymmetry was seen a few weeks later when the infant would merely stare at the object in the favored hand (views object) but would bring the favored hand over to join or tactually explore the object when it was held by the other hand (monitored mutual play). Responses during the second month involved only one hand. During the third and fourth months there was steady increase in bilateral hand and arm involvement which paralleled the oft-noted reduction in the influence of the tonic neck reflex (Gesell and Amatruda, 1941). This paves the way for the coordination of the visual and tactual schemas of each hand with each other. It is of course possible that the fact that Piaget's children were breast fed, whereas the subjects in this study were not, would account for some or even all of the differences.

The second hypothesis predicting plasticity of development was amply confirmed. The results of both the object-in-hand and the prehension tests indicate important functional relationships between rearing conditions and the developmental processes in question. Further, it is to be noted that the

degree of acceleration involved in the experimental group is more than nominal even though the experimental modifications of rearing conditions were little more than first attempts. Of course, at this time no claim can be made for precise understanding of the role of experience; however, some discussion of the design of the experimental rearing conditions is in order at this point.

It is customary to select independent variables primarily on the basis of the theory underlying one's study. In experiments where the subjects are human adults for example, whether or not the subject is inclined to act as required during the experimental treatment is rarely a problem. If a subject should prove reluctant, he may be replaced. In our studies of infant development as in Piaget's the situation is different for two reasons. First, we are unable, and in fact, unwilling to demand actions of our subjects that are very different from what they tend to do normally. Second, we depend much more on induction in designing experiments than on existing theories. This latter fact means that we take pains to discover via extensive naturalistic observations what infants actually do in the hope that an analysis of actual experiences when meshed with general theoretical notions will yield experiments of definite relevance to human development. This process has a parallel in studies of the acquisition of language. For many years now, psychologists and educators have marvelled at how quickly all children acquire the complicated rules involved in understanding and producing their native language. It has frequently been noted that little or no active tuition is necessary. But, few, if any, investigators have attempted to learn how this remarkable natural achievement occurs. It seems most likely that we would learn a great deal about the learning processes involved were we to study the details of the experiences

involved. Is it not likely that the differential experiences undergone by extreme groups (very fast versus very slow progress in language acquisition) would provide a wealth of information about the processes involved?

During the first six months of life children are not usually able to locomote; in fact, they have limited abilities in most all developmental areas. In addition, their experiential histories are very brief. These factors combined, suggest that an analysis of the opportunities for learning is more feasible for this period than for subsequent ones. Piaget has provided some clues by describing the developing sensorimotor structures. Only lengthy longitudinal observations can complete the picture however. These, we have done for one population. We have observed several hundred physically normal, hospitally-reared infants for three continuous hours each week from birth to six months (White, et al., 1964, White and Castle, 1965). The favorite activities of these children when awake and not distressed or drowsy are visual exploration, especially of their own hands, tactual exploration, and combined visual and tactual exploration, again usually of their own hands. From about the fourteenth week or if given the opportunity, they will usually view areas several yards away. However, when placed in the prone position prior to that time, their visual and tactual interest seems to be restricted primarily to the 24 inches or so around them. On the basis of unsystematic observations, it would appear that home-reared babies do not differ radically in these respects. The major visual-motor activities of this time of life primarily consist of: the internal ocular adjustments of accommodation and position including convergence and pursuit, rotations of the head, movements of the arm, hand and fingers within the visual field, head rearing (in the prone position) and from about the fifth month on, turning of the torso from side to side and occasionally completely over.

Our modified enrichment group was given extra handling during the first 36 days of life when visual motor activities do not accupy much of the infant's day (White and Held 1966, White 1967). During the second month an attempt was made to optimize learning conditions for the acquisition of visual control over the hand which seems to be a major if not the major sensorimotor acquisition of the first half year of life. Visually-monitored batting and tactual exploration of nearby objects was induced (White and Held 1966, White 1967). During the third months, similar activities plus heightened visual scanning was induced by the presence of new viewable and palpable objects as well as routine prone placement of the subjects (White and Held, 1966, White 1967).

Obviously, we have dealt with molar experiences rather than isolated independent variables. The scientific task that awaits is the sorting of what is and what is not relevant within the gross experimental treatment. It is here that refined theory is sooner or later necessary;however, I do not believe that one should proceed hastily towards extended theoretical analyses. Rather, I would advocate modest theoretical distinctions followed by empirical test leading to new theoretical deviations slightly more specific, followed by test, etc.

Conclusion:

Piaget's general position which holds that infant behavior consists at first of sequential activation of isolated schemas and from the third month on, their reciprocal coordination, is amply supported by this study. On the other hand, two major amplifications are also revealed. First, that the number of schemas involved in prehensory development is, for the subject groups of this study at least, many times what Piaget saw in his own children. In addition, and of obvious importance for developmental

psychology, is the demonstration of the functional relevance of experience to the developments in question. Although this study requires replication, and is only an early attempt in a complicated area of investigation, it appears that major effects on the rate of development may be induced with ease using innocuous alterations in rearing conditions. Let me point out, however, that the design of enrichment conditions in this study or "the match" as Hunt would put it, presupposes dependable knowledge about infant capacities and preferences. This information is expensive to obtain coming as it does from hundreds of hours of naturalistic observations and the results of standardized test sessions.

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