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ABSTRACT

The aim of this project was to conceptualize and map cognitive processes and structural aspects, working mostly from video tapes of children in relatively natural clinical interviews, play and school situations (laboratory work, etc.). A conception of cognitive structure and an over-all perspective on cognitive functioning, which differ fundamentally from those of Piaget and all other investigators were developed and are presented, as is a new conception of the educational process. The three parts of the report proper are: I. Cognitive Structure and Education; II. Summaries of Individual Projects (A. Experimental and Theoretical Works on Four-Year-Olds (9 studies); B. Experimental and Theoretical Works on Twelve-Year-olds (4 studies); C. Theoretical and Format Work (2 studies); and D. Educational Problems (3 studies); and III. Publications, Theses, and Other Documents. The bulk of this report is comprised of the following 15 appendices: Guidelines for Balance-beam Interviews; A Protocol of a Balance-beam Interview; Structural Changes in 4-5 Year Olds; Comments on the Activity Structure in Elizabeth; The Representation of Cognitive Structures of Four and a Half Year Old Children; Representation of Perceptual State; A Study of Free Pretend Play; A Study of Children's Rhythmic Movement; Comprehension of Relative Clause Sentences in Children, Excerpt: Method and Results; The Representation of Cognitive Frameworks in Young Adolescent Science Students; Cognitive Deep Structure and Science Teaching; An Interview about Chemical Mixtures and Reactions: Selections from Interviews about Heat; Relational Representation; and A-1 Project. (DB)

PS

FINAL REPORT

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ANALYSIS OF COGNITIVE BEHAVIOR IN CHILDREN

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PREFACE

Perhaps the most important aspect of Piaget's monumental work is that he, for the first time, developed a useable conception of cognitive structure. He has described a variety of specific types of structures (sensory-motor structures like circular reactions and spatial groups; pre-operational structures like functions, equivalences; concrete operational structures like the _groupements_; and formal operational structures like the INRC group, the "complete combinational system", and the "all-but-one strategy"); he has created a rich system of concepts for cognitive functioning, and for cognitive development and structural change (e.g., assimilation and accommodation, equilibration, _abstraction simple_ and _abstraction reflechissante_); and he has theorized deeply about the role of cognitive structures in knowledge, from the epistemological point of view (also in terms of assimilation and accommodation).

We feel, however, that there are two major problems with Piaget's approach. One is methodology: his concepts are not related to data in a satisfactory way. The other is that his mathematics-inspired concepts, like systems of operations, groupements, and the formal level structures, seem to us to be somewhat arbitrary categories imposed on the experiments from above and do not arise naturally from the behavior of the child. In this project, our aim has therefore been to conceptualize and map cognitive processes and structural aspects, working mostly from video tapes of children in relatively natural clinical interviews, play and school situations (laboratory work, etc.). In our opinion, we have been successful beyond all expectations. We have developed a conception of cognitive structure and an over-all perspective on cognitive functioning which differ fundamentally from those of Piaget and all other investigators. As our ideas about cognitive structure and functioning were evolving, we were continually stimulated to rethink the great relationship to education and educational practice, and were thus eventually led to develop a new conception of the educational process.

PART I. COGNITIVE STRUCTURE AND EDUCATION

1. Cognitive Structures

(1) Cognitive structures are theoretical hypothetical entities, usually represented by mathematical objects of some kind (e.g. by relational structures).

(2) A cognitive structure in a given child is always treated as an object existing in the child for some period of time (which may be weeks, months, or years), similar to an organic functional unit.

(3) A cognitive structure in a given child can be said to be activated (or involved in the child's behavior) on some occasions, and not activated (not involved in his behavior) on other occasions. It is activated (involved in the child's behavior) in various situations, on various occasions, and inactive during the intervening time periods. In a given child, on any particular occasion, many cognitive structures are activated at the same time.

If at some moment of time a cognitive structure in a given child is activated, it can be said to assimilate certain aspects of the situation which surrounds the child at that time, and some aspects of the childs behavior at that time can be said to constitute evidence for the fact that it is indeed activated at the time. In practice, the structure is often informally described by listing some of the aspects of the real world which it assimilates, as well as some of the molar units of (observable) behavior or aspects of time patterns of molar units of (observable) behavior which constitute evidence that it is activated.

(4) Cognitive structures are of a variety of different types: sensory motor schemes in infants, frameworks and activity elements and activity structures in 2 to 6 year olds, physical deep structures in children and adults, and others. As a species of unit of organization over time, each type of cognitive structure has its own characteristic levels of dynamical coherence, which are reflected in the various time constants which characterizes the intrinsic operation of the structure as well as in the manner in which the structure is dynamically coupled to other structures of the same or of different type. Each type of structure is found in all normal human beings within certain age limits, or during a certain period of development, depending only on the type of structure in question. In every person there exists therefore many types of structures, depending only on his level of development; and within any particular person, there coexist many structures

of every type appropriate to his developmental level. Because typically small groups of individual structures (of the same type of or of different types) interact, or are dynamically connected, and sometimes form new structures, all structures that exist within a particular person will be imagined as being distributed through space. This facilitates singling out individual configurations and discussing them as having specificable effects in observable behavior.

(5) Cognitive structures, and types of cognitive structures, may be discrete or continuous. A given type of structure is discrete if the system of all individual structures of this type can be represented, in the sense of (1) through (4) above, by a finite mathematical object. In this case, real time functioning of the system as a whole can be described in terms of the extent to which subobjects of the structure are activated at different moments of time. On the other hand a given type of structure is continuous, if the whole system of individual structures of this type can be represented by a continuous mathematical object, such as a field in physics. In this case real time functioning of individual structures can be discussed in terms of "flowing" in time and continuous "spreading", and developmental changes in structure in terms of changes of a field over a constant domain, or changes of different fields over overlapping portions of their domains -- in other words, always in terms of propagation through or changes over some kind of base space. It should be emphasized that an answer to the question whether a structure is discrete or continuous is independent of the character of its dynamical coherence -- which is always continuous.

2. Summary of Types of Cognitive Structures

(1) Sensory-motor schemes are conceived of largely in the same way as in Piaget's Origins of Intelligence, at least in infants up to 8 or 9 months old. We are going considerably beyond Piaget, however (as well as beyond all other work in the Piagetian tradition) by explicitly exhibiting systems of sensory motor schemes as relational structures ((C-14),[1] excerpted in appendix 14), and as both relational structures and dynamical systems functioning in real time (A-10). As described in that paper, sensory motor schemes have time constants ranging from fractions of a second to half a minute or larger, and may change completely (be replaced) over a period as short as two weeks.

[1]Letters and numbers in brackets refer to the bibliography in Part III.

(2) Frameworks ((A-5) and (B-5)) were first seen to underlie the behavior of many of the four year olds in the balance beam interviews that were conducted for this project. (See Part II, (2)). In conventional terms, the existence of a framework in a subject's mind during our interview expresses itself through the fact that for a period of several minutes, he consistently assimilates all questions and other activities of the experimenter to a very limited system of expectations and conceptions involving the apparatus, that he only conceives of and makes certain uses of the apparatus and only interacts with it in certain ways. This system of expectations and general conceptions is thought of as a single cognitive structure in the sense elaborated above: essentially the same system of expectations and general ideas, the same limited uses of and interactions with the apparatii, occur in different sessions and with different but sufficiently similar apparatus, and the system dominates and in a sense drives the child continuously for periods of several minutes.

(3) To the extent that the child in the interview is allowed to initiate actions, and thereby show the analyst what he does with the apparatus and what the apparatus is good for, structures concerned with "purposive manipulation" of the apparatus came into view which we have called activity elements and activity levels and structures. ((A-7) and Appendix 4). Activity elements are conceptualized as discrete structures (elements), with time constants around 2 to 8 seconds, that correspond to actions and expectations that accompany these actions, at the primary level of cycling. Activity levels and structures are conceptualized as systems of activity elements, integrated by higher order activity elements and perhaps by action elements and other things, and correspond to ranges of manipulatory activity on the apparatus. Like frameworks, activity structures are active for periods of one to several minutes.

The framework phenomenon itself is still not sufficiently well characterized to allow us to decide whether an activity structure, corresponding to a coherent range of actions on a given type of physical object, say, should be considered as part of one or more frameworks for dealing with this type of object, or whether a framework for dealing with this type of object may be closely associated with it but is at the same time an independent structure, because the driving energy which resides in a framework is not ultimately derived from motor activity.

(4) Physical deep structure was introduced in (A-9). The paper shows how, what appear to adult introspection as intuitions or feelings about some physical phenomena, that have a strong kinesthetic aspect and recur and can be identified in diverse physical situations (e.g., a feeling of weight, or an

intuitive conception of a momentum, or of impact, etc.), can be conceived of as underlain by elementary units (called d.s.f.s in (A-9)) of a type of continuous cognitive structure, physical deep structure. In the process of watching and thinking about a physical phenomenon like a swing of a pendulum or a loaded cart rolling down an inclined plane, the full intuitive feeling for the inertia of the bob, for example, or for the momentum or the force or the energy of the cart, etc., etc., typically take a second or longer to develop, and for that reason d.s.f.s which underlie such "ideas" are attributed internal-turning-on times on the order of seconds.

(5) s-structures in children and adults will be described in a future paper. Very briefly they are continuous structures that are in many ways similar to d.s.f.s, and that in fact often involve physical conceptions and also visual forms or effects in a fundamental way. However, they also encompass symbolic and other aspects of verbal thought, and are combined into larger systems in a different way than d.s.f.s.

(6) Major units, described in Appendix 7, are regularities that can often be observed, in free pretend play among 3½ or 4 year olds; in simplest terms they are short play routines of a fixed form which the children go through a number of times. Such routines should be considered as due to cognitive structures of a specific type, which exist in the various participants of the routine. These structures are interesting because they have locked into them something of the character of plans. They should be compared to early general motor plans, which constitute a special form of sensory motor organization which can presumably be understood and modelled within the general framework of sensory motor schemes (i.e., within the framework of (A-10)).

3. An Emerging Conception of the Educational Process

Piaget's theory has been the only one that relates specifically to the conceptual problems typically faced by the child in school. The relevance of his theory to schooling traditionally has been seen to lie in the fact that the structures he deals with, as common human structures (seriation, classification, conservation), are at the same time accepted as fundamental to western science. This was claimed to provide support for two approaches to educational practice: First, the "stage" approach, in which acquisition of a structure is interpreted to constitute a readiness on the child's part to undertake tasks for which the structure is a prerequisite; and second, the "natural development" philosophy, found today in open education, for example, to the effect that, since the structures basic for science develop out of the activity of the child naturally anyway, formal instruction is little needed.

When the project began, we were taking an intermediate position and tended to see the educational task as one of building bridges toward the adult structures of knowledge, beginning with the child's own cognitive structures. We conceived the purpose of the project to be to describe the child's structures so that they could be built upon by the teacher or educational technologist. From this point of view, the task of assertaining what each individual child's structures are appears enormous. Nevertheless, if one starts from broadly conceived aims for an instructional unit, one can look for the types of structures that most children can be assumed to have and that would be useful in achieving these aims. A concrete example of this approach was worked out in some detail in (A-8).

As the dynamical processes of cognitive structures became more and more clear to us, we realized that we must let this very dynamics itself carry forward educational change. However, as a practical educational philosophy, this is only possible if one maintains a much more flexible attitude toward, and is not constrained by, conventional preconceptions about subject matter, both with respect to its internal organization and its educational importance. Some examples of this approach are given in Part II of (A-9). It is clear that this new philosophy puts great demands on the teacher -- indeed, few teachers have the extreme flexibility in subject matter required. And there is still the problem of sensing the student's conceptions. But we believe these difficulties may be overcome by adopting a new approach. Much of the time, we see teacher's and students' structures interacting <u>awkwardly</u>. If we think of both the teachers' and the students' structures as "dynamical substances" in the sense of (A-10), p. 35 (not as different systems of subject matter content), then this means they interact in an internally damaging way, disrupting their characteristic levels of coherence and dynamical functioning. Consequently, as far as practical educational philosophy is concerned, this point of view opens up the possibility that we could help teachers develop a perception-and-action responsiveness which minimizes such damaging interactions, even though the teacher may be unaware of the precise nature of the students operative structures.

PART II. SUMMARIES OF INDIVIDUAL PROJECTS

A. Experimental and Theoretical Work on Four-year-olds

1. Skills Analysis

The paper "Representatior [illegible] ive Processes and Cognitive Structure in Childr[illegible] part of which was submitted with the proposal for this project, contains the initial formulation of the "cognitive structure" paradigm summarized in part I and formed the conceptual starting point of this project. The paper was completed and has been published (A-4).

2. Balance-beam Interviews

Throughout the spring and summer of 1970, we continued to refine our technique of interviewing, both 3 - 5 year olds on the balance as well as with 6 to 7 year olds on other physical apparatus (P.S.S.C. carts, carts on an inclined plane, etc.). In general the aim was to get the child to expose as much of his own conceptions, presuppositions, expectations and desires, etc., as possible. To achieve this, the interviewer concentrated on increasing the child's total behavioral output, and controlled his own questions about the apparatus continuously and with great care. This interview philosophy differs substantially from Piaget's. To help our graduate students in learning it (usually a process lasting months) we produced a set of "interview guidelines" which are given in Appendix 1.

Throughout 1970 and well into 1971, about 30 interviews were conducted with the balance and put on videotape. About half of these were transcribed in detail and analyzed; a sample transcript is given in Appendix 2. (Another four transcripts appear in Knifong's dissertation (A-5).)

3. Frameworks

The first method developed for analyzing interview protocols is framework analysis, designed to read out the cognitive structures we have called frameworks. Essentially framework analysis involves postulating a structure (a framework), and then scoring certain experimenter-child interactions during the interview against this structure. The method is therefore aimed at discovering and elaborating what the child's frameworks are, rather than or determining which one of a prescribed set of alternatives the child fits into. A paper (A-5) describing the method, with an illustration, has been submitted for publication.

4. Activity Structures

A second analytical tool for analyzing protocols, which concentrates on behavior spontaneously initiated by the subject rather than on the subjects responses to the experimenter's questions (as does framework analysis), and which produces true structural descriptions rather than global verbal descriptions, is activity structure analysis. In this method, one begins by looking for short cycles and groups of similar cycles. Individual cycles are assumed to be underlain by "activity elements", and higher order structures, which are reflected in conspicuous "category constraints" across cycles and which, by underlying the initiation of new cycles, give a group of successive cycles its coherence, are assumed to be either again activity elements (of higher generality) or small nexuses of activity elements (activity levels and structures). An informal talk on the subject is reproduced in Appendix 4; (A-7) is the publication version.

The concepts of activity elements and activity levels and structures have proved to be absolutely essential in understanding any kind of semi-purposive behavior; in effect, it was these concepts that made our most ambitious effort, the A-1 project, possible. In addition the case study in Appendix 4 sketches a paradigm for structural change that has far reaching philosophical and educational implications. So far we have not really pursued these.

5. Digraph Representation of Frameworks

D. Knifong, in his dissertation (Knifong, A1971, B1971), developed a different technique for getting at frameworks and activity structures, utilizing classificatory relational criteria and representing the structures in question as "multi-graphs". In his dissertation, an abstract of which is given in Appendix 5, he applies the method to four children, and presents two or three frameworks for each child. Comprehensive comparative studies of frameworks of different children using the same apparatus, and of the same child across a variety of physical apparatus, are badly needed.

6. Representation of Perceptual State

A somewhat different analytical framework for looking at the protocols has been developed by R. S. Hart. Briefly, one starts with a description of a framework as furnished by framework analysis or by Knifong's method, and constructs, using as units elementary perceptual and relational terms which have been explicitly used by the child or are otherwise implicit in his behavior, what amounts to relational representations of larger portions of the childs perceptual state, such as "the washer is perceived to be hanging on the hook". In Appendix 6, Hart develops such representations with a view toward simulation of perceptual processes on a computer. Hart's work here makes contact with well known work in artificial intelligence at M.I.T., and with ideas of P. Weston's.

7. Study of Free Pretend Play

In the spring of 1971 we began to study pretend play in 4 year olds by videotaping groups of 3 to 4 children in completely unstructured, natural play contexts. An enormous amount of time was spent studying the transcripts, trying to see regularities and to identify types of structures, eventually with great success. Our analysis is described in Appendix 7. Attempts to reduce the analysis to a completely mechanical procedure were not successful, however. Nevertheless the results of this study are so important and suggestive that we feel the study should be repeated as soon as possible under more favorable and perhaps slightly more controlled conditions.

8. Study of Spontaneous Movement

Also in the spring of 1971, we began some pilot work on rhythmic movement in response to music in children age 3 to 4 years. A group of three (sometimes four) children met regularly once a week for several weeks. In every session they were played selections of classical and popular music and encouraged to "dance (or "move") with the music" in any way they wished. All proceedings were videotaped. Study of the tapes showed that (1) each child possessed a quite small repertoire of 15 ± 5 "movement elements", i.e., very characteristic and deliberate movements like kicking a foot out sideways, a particular pattern of gallopping, etc.; these elements occurred in the same child at different times in the same session as well as on different sessions, and in several cases the same element occurred in different children; (2) a few of the elements (mostly variously accentuated running patterns) were on some occasions varied deliberately to such an extent as to produce qualitatively new elements. Other aspects of this work are discussed in Appendix 8.

9. Comprehension of Relative Clauses

Finally, we also studied sentence comprehension in four year olds, using Sinclair's and Bever's technique of letting the children act out sentences with toys. The original idea was to regard semantic-cognitive structures like "actor-action-object", and mechanisms involved for example in understanding relative clauses, as discrete schemes or as mechanisms involving discrete schemes, and to construct relatively high level semantic representations (in terms of schemes) of the way individual target sentences were understood by a given child. (Such representations would at least be clearly based on behavioral data, in contrast to the great majority of semantic representations in the literature.) The data collected are described in Appendix 9 and convinced us that real time modelling was required. However, because of lack of time no major modelling effort was made.

B. Experimental and Theoretical Work on Twelve-year-olds

10. Student's Dynamical Concepts in an Open Science Classroom

Starting with some ideas on dynamical concepts of motion in preadolescents of J. Easley's (A-2), R. Driver carried out an intensive study to gain some overall perspective on how the student's conceptual frameworks concerning physical systems function in an open classroom setting, including the question of what other cognitive systems come into play.

Driver recorded classroom discussions on three instructional units (on springs, movements, and center of gravity, and forces, respectively) over a period of six weeks, and taped all laboratory work and interactions of two pairs of two students each (selected on the basis of preinstructional interviews). In her dissertation (B-2) she distinguishes physical from linguistic, logico-mathematical, and ideological strands of the children's thought, and sets up a cyclical scheme to represent the progress of a child's physical thinking during a class period. (See Appendix 10 for a more detailed abstract.) The dissertation includes extensive excerpts of transcripts (about 300 pages), with excellent and very sensitive comments. The unique importance of this work lies in the fact that the same children worked with a great diversity of physical apparatus; each child was exposed to the same type of physical system three times: in the preinstructional interview, during the laboratory work proper, and in the post instructional interview.

11. Physical Deep Structure

Working from Mrs. Driver's protocols, we wrote a paper (A-9) in which we illustrate how the child's physical intuitions and conceptions concerning momentum, interia, resistance, etc. can be conceptualized as a system of continuous structures (of "continuous dynamical forms"). In our opinion, this paper is one of the most important achievements of the project. It will be published in the proceedings of the conference at which it was delivered, possibly in French; we give the English text in Appendix 11.

12. Concepts of Chemical Mixtures and Reactions

To study student's conceptions of more complex processes as well as how these conceptions interact with symbol manipulation, we started interviewing high school students in beginning chemistry about chemical reactions. Subjects were shown the reaction of potassium iodide with lead nitrate and asked to explain what was happening. Initial results were very suggestive, c.f. Appendix 12, but the work was discontinued because of lack of personnel.

13. Interviews on Concepts of Heat

In the fall of 1971 we began to study conceptions of heat in 9 to 12 year olds. Most of the fall and winter and part of this spring were spent experimenting with different kinds of apparatus and generally trying to define what the problem really was. An idea of the kinds of phenomena that one runs into and of some of the problems can be obtained from Appendix 13. This work is continuing.

C. Theoretical and Formal Work

14. Relational Representation

A major advance in clarifying our conceptual foundations occurred in the winter of 1970-71, when we developed a rigorous definition of "relational configurations" (or "relational networks"). Speaking informally, a configuration is a kind of directed graph in which arrows are replaced by multiplace relational or functional symbols and in which at the same time the relational symbols are used recursively. Configurations have therefore both connectivity (like digraphs) and local hierarchical structure. Details, including basic properties of configurations and illustrations of the use of configurations in various fields, can be found in a set of notes on relational representation in the behavioral sciences and humanities (C-14). Two of the examples in these notes, dealing with representation of (systems of) sensory motor schemes in infants and of systems of perceptual schemes in older children, are reproduced in Appendix 12.

15. The "A-1 Project"

The A-1 Project is concerned with specifying mathematically, and then simulating on a computer, a large system of asynchronously functioning sensory motor schemes which mimics the behavior of a 9 month old infant. We believe it is one of the two or three most significant achievements of this project.

The A-1 project began as an effort to find out whether Piaget's conception of the child as an organized system of discrete schemes was at all feasible and consistent; the question was whether a system of the kind envisaged by Piaget, functioning in real time, could be specified and made to work at all. The initial idea was to simulate the activity structures that we saw in our balance beam interviews: we already had the videotapes (which are absolutely essential for any detailed simulation), and intensive study of the tapes had convinced us that most if not all aspects of the behavior that we saw on the tapes could be produced by a system of activity elements organized into activity levels etc., and functioning in parallel. This conception was therefore explained, in a never completed manuscript (C-15), by specifying a network concerned with manipulating objects (hanging them on the hooks of the balance, etc.). In this network a small number of higher order activity elements (like "get (this object)") are dynamically connected with lower order motor elements (like hand-closing, hand-opening or dropping, reaching, etc.) in such a way that the lower order motor events assemble themselves automatically into appropriate complex action sequences, depending on the pattern of activation in activity- and perceptual elements (i.e., the current intentional and perceptual state). (Appendix 15 is adapted from the preface of (C-15)). It soon became clear, however, that a situation would be preferable in which some of the schemes were already "known" and "recognized" at least by investigators with some conceptual contact with Piaget, and for which there already existed some descriptive literature. Consequently, we decided to study systems of sensory motor schemes in infants. In the fall of 1971, therefore, we carried out pilot work on visual behavior and prehension in 2 to 4 month old infants. This work served as experimental basis for a fundamental paper (A-10), which gives a full exposition of our approach to real time functioning of discrete systems of schemes.

D. Educational Problems

16. Individualized Instruction

Fairly early in the course of the project we produced a rather general statement on the implications of the functioning of preexisting cognitive structures in the childs mind for individualized instruction (A-6). The paper characterizes existing programs of computer-assisted instruction as being based on a paradigm of decision making on the basis of predetermined parameter values, and argues that this paradigm does not harmonize with any conception of cognitive functioning based on cognitive structures, such as Piaget's or our own, or more generally any conception which takes the structures of the child seriously. No attempt is made, however, to develop an alternative paradigm for CAI that is in harmony with such a conception.

17. Designing a Unit of Instruction on the Basis of Cognitive Models

A paper written with D. Goodwin, however, does attempt to take a more positive approach to the problem of how preexisting structures in individuals should be taken into account in the design and evaluation of an instructional unit. Taking understanding and active use of spatial prepositions as an example of an instructional goal, the paper analyses cognitive systems involved in different types of uses of the prepositions into natural units called "components", and discusses in detail preexisting sensory motor and conceptual knowledge that can be used to build up the components in question.

18. <u>A New Philosophy for Open Education</u>

As explained in section 3, part I, the constructive conception of education implicit in the preceding paper gave way to one of dynamic flow. Part II of (A-9) represents a first formulation of this new outlook.

PART III. PUBLICATIONS, THESES, AND OTHER DOCUMENTS

A. Publications Related to the Project

[1] Witz, K. G. "On Piaget's Grouping I". Archives de Psychologie, Vol. 15, pp. 37-49, 1971.

[2] Easley, J. "Some Preadolescent Dynamic Concepts of Motion". To appear in Lavatelli, C. (ed.), Proceedings of a Conference on Spontaneous Learning. University of Illinois Press, 1972.

[3] Knifong, J. D. "A Piagetian Analysis of Logical Abilities of Young Children". (abstract) Journal of Structural Learning, 1971.

[4] Witz, K. G. "Representations of Cognitive Processes and Cognitive Structure in Children". Archives de Psychologie. Vol. 15, pp. 61-95, 1971.

[5] Witz, K. G. "Analysis of 'Frameworks' in Young Children". (Submitted for publication)

[6] Easley, J. A., Jr., and Witz, K. G. "Individualized Instruction -- Observations from the Ivory Tower". Educational Technology. Vol. 12, March, 1972, pp. 50-52.

[7] Witz, K. G. "Activity Structures in Four Year Olds". J. Scandura (ed.) Research in Structural Learning. Vol. II, Gordon and Breach, 1972 (in press).

[8] Witz, K. G.; Goodwin, D.; and Easley, J. A., Jr. "Toward a Cognitive Model of Evaluation of a Unit of Instruction". Submitted for publication.

[9] Witz, K. G., and Easley, J. A., Jr. "Cognitive Deep Structure and Science Teaching". To appear in the proceedings of a conference on "Operations et Didactique" held at the Universite de Quebec a Montreal, Oct. 18-23, 1971.

[10] Witz, K. G. "Models of Systems of Sensory Motor Schemes in Infants." Submitted for publication.

B. Dissertations and Theses at the University of Illinois

[1] Barros, N. "Application of Piaget's Theory to Education -- A Critical Study". (Ph.D., Education, 1971)

[2] Driver, R. P. "The Representation of Conceptual Frameworks in Young Adolescent Science Students". (Ph.D., Education, 1972)

[3] Kamara, A. I. "Cognitive Development Among School Age Themne Children of Sierra Leone". (Ph.D., Education, 1971)

[4] Knamiller, G. "Perceptual Frameworks for Viewing Children's Expressive Activity in a Science Learning Environment." (Ph.D., Education, 1971)

[5] Knifong, J. D. "The Representation of Cognitive Structure of Four and a Half Year Old Children". (Ph.D., Education, 1971) (Abstract in Appendix 5)

[6] Winston, M. E. "Comprehension of Relative Clause Sentences in Children". (M.A., Psychology, 1971)

C. Other Documents

[1] Craig, B. E., and Witz, K. G. "An Interview About Chemical Mixtures and Reactions". (Appendix 12)

[2] Delaney, B., and Witz, K. G. "A Study of Free Pretend Play". (Appendix 7)

[3] Driver, R. P. "What's the Name of the Game? Some Remarks on Students' Alternate Theories". 7 pp. dittoed paper.

[4] Easley, J. A., Jr. "The Stage of Formal Operations". Part III of Piagetian Theory of Cognitive Development, Video-taped lecture sequence, Nebraska Educational Television Council on Higher Education, Lincoln.

[5] Easley, J. A., Jr. "Implications of Piaget's Work for Educational Technology". Address given to the Association for Educational Communications and Technology annual meeting, Minneapolis, April 18, 1972. Mimeographed.

[6] Goodwin, D. "Remarks on Activity Structures in Different Children". (Appendix 4)

[7] Hart, R. S. "Technical Memorandum I: Review of Luria's Speech and the Regulation of Behavior".

[8] Hart, R. S. "Technical Memorandum II: Review of the Literature on Coordination of Vision with Prehension".

[9] Hart, R. S. "Observations, Problems, Hypotheses on Perception". (Dittoed seminar notes, February 1970)

[10] Hart, R. S. "Representation of Perceptual State". (Appendix 6)

[11] Jensen, K. "A Study of Children's Rythmic Movement". (Abstract in Appendix 8)

[12] Witz, K. G., and Goodwin, D. "Guidelines for Balance-beam Interviews". (Appendix 1)

[13] Witz, K. G., and Goodwin, D. "Structural Changes in 4-5 Year Olds". Talk given at the Second Annual Meeting on Structural Learning, Philadelphia, Spring, 1971. (Appendix 4)

[14] Witz, K. G. "Notes on Relational Representation". (mimeographed)

[15] Witz, K. G., "A-1 Project". Manuscript, August 1971.

APPENDIX 1

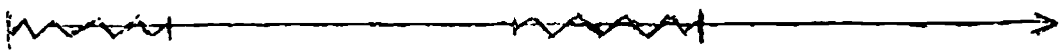
Guidelines for Balance-beam Interviews

Klaus Witz and David Goodwin

General Guidelines For Interviews

1. General Time Plan of Interviews

We assume that the general time pattern of the interview is like this:



noise	child's initial conception is dominant for some time	noise plus new aspects of the situation	new conception is dominant for some time

1. First, we want to determine the child's initial conception.

   a. Let the child introduce his own terminology to describe the balance, its behavior, and his actions on it. In particular, be sensitive to:

      (i) Whether the child speaks of the two arms or sides or whether he speaks of the whole beam.
      (ii) Whether the child speaks of the motion of the balance ("making it go up or down") or of the state of the balance ("it will be up here." or "it will be level.").
      (iii) Whether the child speaks of putting on, hanging, hooking on or adding more weights.

   b. Continue to use substantially the child's terminology, not your own.

   c. Try to frame your questions around the child's actions on the apparatus and your actions on the apparatus.

   But:

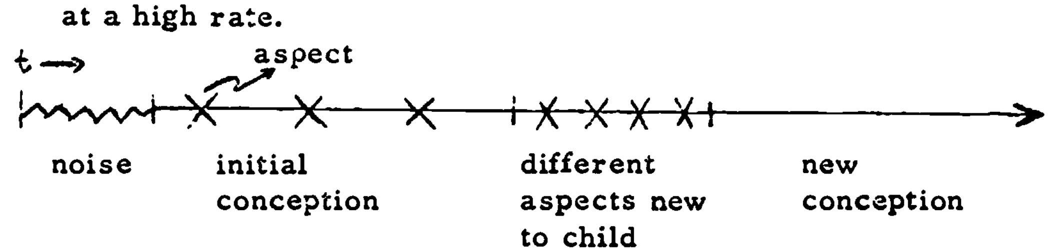
   b'. you may use some unfamiliar terminology and,

   c'. you should present the child with tasks that he does not react to properly (gives unusual response, is insecure, or wrong), a few times during this initial period.

2. Mix the types of questions to avoid building too much "set" and thereby allowing control of the interview to be relinquished to unwanted influences. Avoid "runs" of very similar configurations. (Be sure the questions are unambiguous.) Mix especially these types of questions:

   a. Achieve equilibrium vs. "Will it balance?";
   b. Difficult vs. easy;
   c. Where child observes the construction of the configuration (puts on or watches you put on washers) vs. where child doesn't observe the steps in construction but has to judge strictly from the appearance of the configuration;
   d. Where attention is focused on positions near the center vs. where attention is focused near the ends of the balance.

3. If the child's initial conception has been explored thoroughly, introduce new elements (new aspects and problem situations), at a high rate.



4. After learning has taken place and a new conception seems to have been reached, explore it as in 1. - 3.

II. General remarks on how to interact with the child.

   1. Maximize the number of usable expressive acts.

      a. Encourage verbal output.

         (i) Ask for explanations, especially at critical points.
         (ii) Avoid questions that permit yes-or-no answers. Say, for example:
         Tell me about it.
         How can you make it . . . ?
         Tell me another way.
         (iii) Encourage child's own summaries and general statements. Say, for example:
         How do you always know?
         How can you always tell?

b. Encourage motor output. Say, for example:
Show me.
Show me with your hand.
If you were the balance, ...
Show me with your hands the way you just started to.

2. Make sure the relationship between your questions and actions and those of the child are clear.

   a. Give the child time to react after a question (maximum of five seconds); avoid immediate reformulation of the question.

   b. If you aren't sure the child is doing something in response to your question, ask. For example:
   Is that what I asked you to tell me (to do)?

3. Be highly appreciative when the child takes an initiative, especially one related to the situation at hand, or more generally, any pertinent aspect of the apparatus. Follow through on his ideas.

4. Be especially sensitive to levels-of-generality and presuppositions you might have in forming your questions and what might be implied by them.

   a. Use the most general phrase with the fewest suppositions which you think expresses the task. Only if the child has trouble connecting, become more specific. For example:
   What will happen? ... vs. How will it go? vs. Which way will it go?
   Show me. vs. Show me with your hands.
   Where do you put it? vs. On what side (hook) do you put it?

But caution:

   b. Pay special attention to what implications your questions might have in light of your presuppositions.

   Given the balance in equilibrium, say one washer on each end:
   What will happen if you put it (a washer) somewhere else?
   vs. What if you moved it in here?

III. Miscellaneous.

1. Focus your attention on the child at all times. Avoid getting too involved in the child's reactions to your questions, i. e., maintain a little bit of reserve. Also avoid situations that would focus the child's attention on you, thereby disturbing the task context.

2. Be sure questions are absolutely clear. Clear up any unclear statemets of the child. If necessary, ask him to repeat himself again.

3. When there is reasonable doubt that a particular response is consistent with the rest of the child's repertoire, he should be given a second opportunity to see if the response is repeated.

Klaus G. Witz and
David R. Goodwin
July 20, 1970

The following suggestions serve as an appendix to "General Guidelines for Interviews."

1. Standard phrases for the balance interview.

Remark. While the following phrases have proved generally successful and hence occur frequently in interviews, they are not to be viewed as necessary constituents of the interview procedure, meaning that the interview should not be structured around the use of these phrases. Rather, they should be employed when the proper context is brought about by the child's responses or his spontaneous activity, otherwise they may cue or mislead him.

a. Determining child's initial conception.

What do you think that is?
Have you ever seen (that, anything like that, one of those) before? How do (did) you play with yours?
What do you think that might be good for?
Is there anything you can do with it?

Do you have a name for this (it)?
Do you think this will move? How will it move?
Show me (with your hands). Tell me.

b. Introduction of washers.

Do you know what these are?
What are these good for?
What do you call these?
What can you do with these?

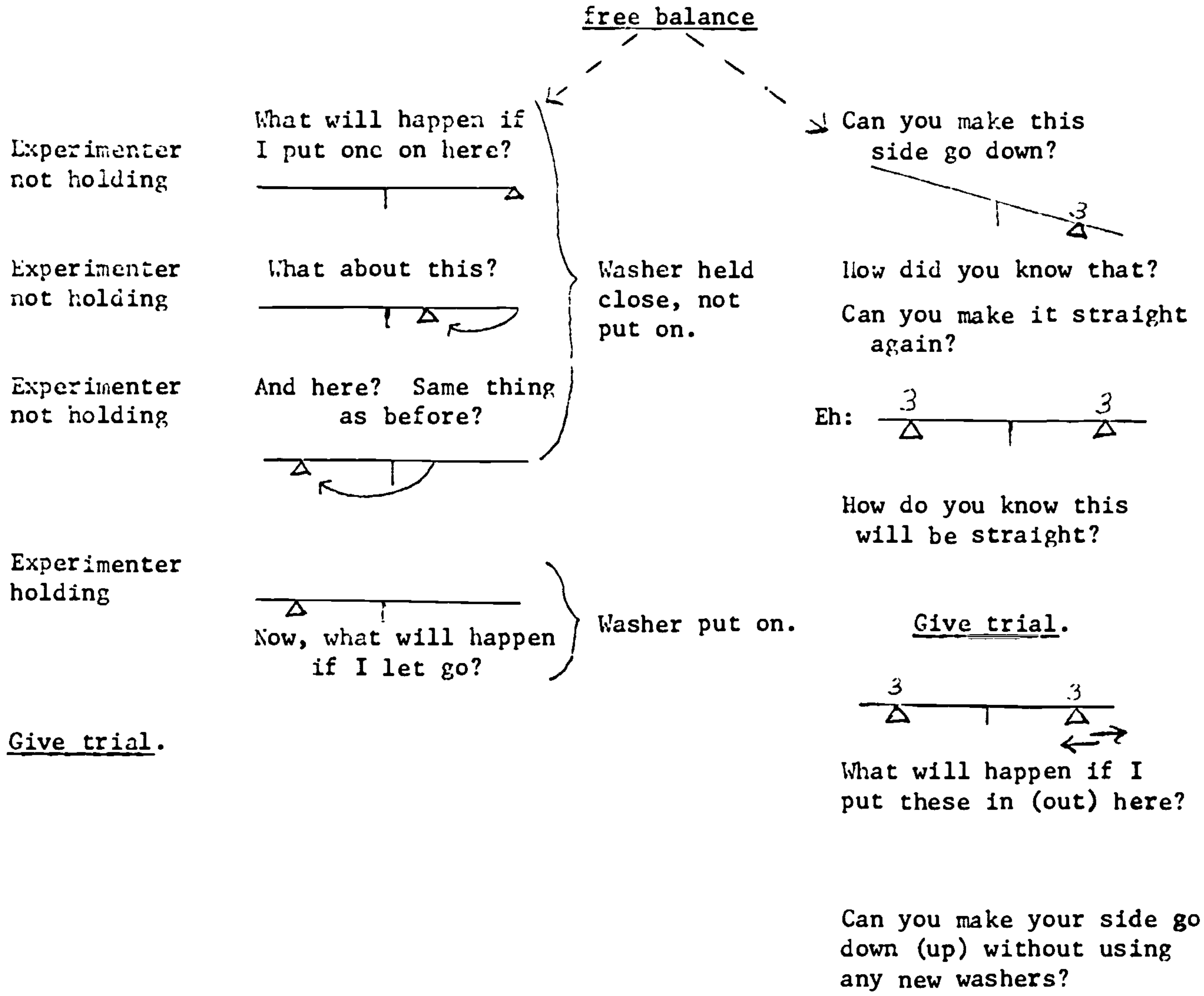
c. With loaded balance.

What will happen if you hang (put) <u>one</u> (child's term) on there?
What will happen if I let go?
Show me with your hands.

How can you make it balance (stay straight, etc.)?
How can you make this side go down (go up)?
How can you make it go a different way?
What else can you do? Show me.

Why do you think so? Why?
How can you (always) tell?
How do you know?
How does this (the balance) work?

2. Examples of behavioral sequences.



3. General remarks.

   a. Work out behavioral sequences and associated questions or statements in detail in the form of a highly structured interview from beginning to end including possible responses from children to your phrasings. This exercise helps conceptualize the experimental situation and gives one a substantial repertoire of things to say or do allowing the interviewer some security against being caught unawares by children's actions, while also keeping the interview moving along.

   b. If possible, study previous tapes carefully. Try to find the experimenter's errors, then think of what kind of action or phrase might have eliminated or not led to the error.

David R. Goodwin
January 25, 1971

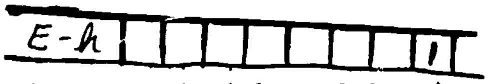
APPENDIX 2

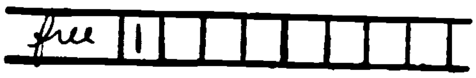
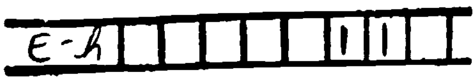
A Protocol cf a Balance-beam Interview

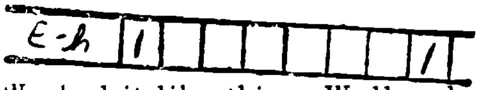
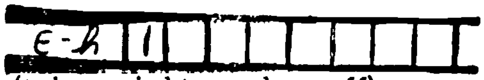
David Goodwin

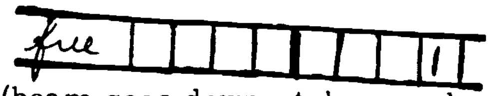
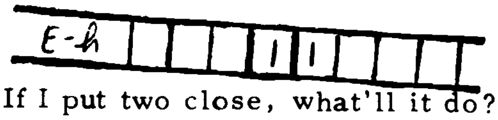
How old are you?		(puts up three fingers)
	0	
Three. Three and how many? Do you know?		Uhuh. (no)
No. That's okay. (handles ball) Know what this is?	1	A ball.
It's a ball. (holds ball up) What will happen? What will happen if I let go?		I don't know.
You don't know. Ohh, you can tell me. Can you show me with your hands?	2	Drop it.
Drop it. Well, what will it do if I drop it?	3	I don't know.
Well, can't you tell me just a little bit, hun? Well, let's see. (drops the ball)		(watches ball bounce)
Opps. It bounced.	4	It bounced.
Will it always bounce like that?		Yeah. (looks at ball then steadies it so it won't roll)
Yeah. (brings over beanbag) What do you think this is?	5	A beanbag.
A beanbag. That's pretty good. Well, (holds bean bag up), what will happen if I let go?	6	It'll drop.
It'll drop. Will it drop like the ball?		No.
No. Why not?	7	Cause...cause it's a beanbag.
Can you show me with your hands how it will go?		It'll drop on the...the...on the table, and then it won't go. (touches table when she says the word)
	8	
Then it won't go? You mean it won't go like the ball or, huh?		Yeah.
(drops beanbag)		(watches it drop)
	9	
Is that the way you want it to go?		(nods) Went that way and it... went that way.

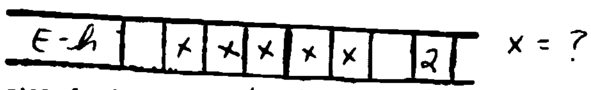
Hun?...Yeah. (gets feather) What's this?	0	A feather.
Well, (holds up feather), if I let it go, how will it go?		Up. Just like the beanbag.
Just like the beanbag. Well, can you tell me why it will do that.	1	Cause it's a feather...cause it won't drop like the beanbag.
Ohh. (drops the feather) Well, did it go like the beanbag?	2	Yeah.
Yeah? Pretty good. Did it go like the ball?		No.
No. What makes (points to ball and then the feather) these two different?	3	I don't know.
You don't know? Well, you're pretty good. You answer things real good. (points to big balance beam) What do you think this thing here is?	4	(looks at balance beam) I don't know.
Have you ever seen anything like that before?	5	No. (touches balance beam)
No. Well, what do you think it does?		I don't know.
You don't know. Well, do you think it'll move maybe?	6	Yeah.
How? Can you show me?		(leans up and looks across bar of balance beam) Maybe not.
Well, can you show me with your hands, maybe, how it'd move.	7	It'll balance.
It'll balance!!		Maybe.
Boy! Where did you learn that big word, balance?	8	I don't know.
Well, how do you mean it'll balance?		I don't know.
Ohh. You can say more than you don't know. Remember you talked to me about a bunch of things.	9	(is looking at the balance beam)

Can't you tell me how it will move?	0	Uhuh. (no)
No. Can you show me? You can touch it, if you want. I mean you can move up and play and everything if you want to.	1	Uhuh. (no)
No. Well, if you touch this thing here, (points to right end of beam), if you touch it, what will it do?	2	I don't know.
You don't know? Well, I'll tell you what, we have some things here. (brings over box of washers) What do you think those are for?	3	I don't know.
Ohh. You can say more than that. Why don't you try it. Why don't you play with them a little bit, if you want to.	4	I want to. That one there. (picks up a washer and hangs it on right end)
Now what will it do?	5	 (tries to push right end down)
(lets go)	6	(beam goes down and washer falls off--puts washer back on--lifts right side up so bar is straight--then lets right side go)
Well, by golly! Did you know it would go like that?	7	Yeah. (takes washer off and hangs two others on--beam goes down)
You did! And you didn't tell me. Oh, what are you doing?	8	 Goes that way. (holds bar straight and then lets it go)
Now what are you trying to do? Make it go this way? Well, why won't it go that way?	9	(holds beam straight, then tries to push left side down) Cause.

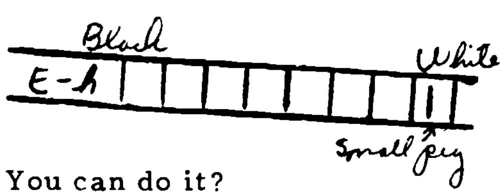
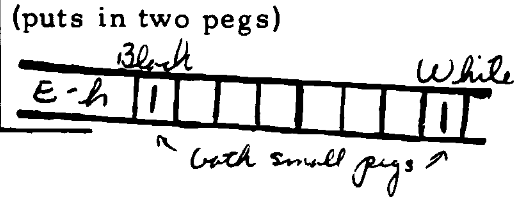
Cause why?	0	(beam goes down) Cause it doesn't.
Cause it doesn't. Well, what if we try something here. (takes washers off) If I put this in, (puts another washer on), what will happen if I let go?  	1	(playing with washers in box) I don't know.
Can you show me with your hands?	2	No.
No. Well, what if I do this? (moves washer to left side) What will happen if I let go?  	3	(leans over and grabs end from experimenter--lets go, lightly pushing left side down)
Oh, what happened? Well, why does it do that?	4	It went that way. (plays with left side, moving it back and forth) Cause.
Cause why?	5	I want that one off and a different one, (takes washer off), that one ..on.(gets another washer and hangs it in same position --beam goes down)
Yeah. You can show me how you do it differently. Can you show me a bunch of stuff on this? See what we can do with it, and maybe you can tell me how it works. Can you do that?	6	
	7	What'll it do with...if I have two on? (hangs two washers) 
Well, can you tell me. Can you show me.	8	I don't know. (takes experimenter's hand off end--beam goes down)
Well, why does it do that, huh?	9	Cause...I like it.

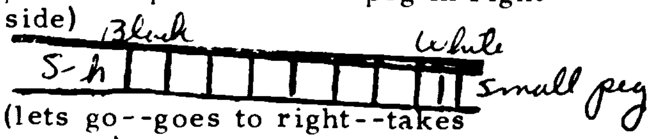
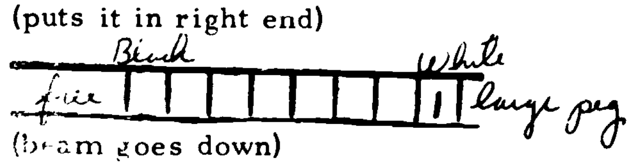
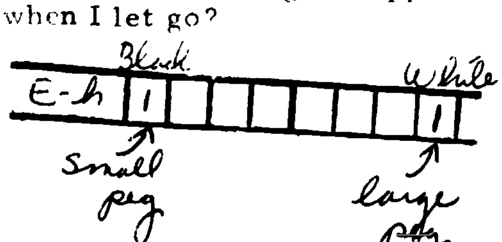
Umm...Uh-hun. (yes)		(playing with washers)
	0	I have two. (hangs two washers)
		
You have two. Well, what is it going to do now?	1	Go that way with two on. (indicates to the right)
Go that way with two on. Umm... Can you show me what you can do...Oh-oh!	2	(takes experimenter's hand off--looks at right side while lightly trying to push left side down--What'd it do?
I don't know. Can you tell me? It's not going down, is it? Why does it not go down like that? Well, what happened?	3	(takes left washer off)
	4	 (beam goes to the right) Oh...it...it balanced down. (accidentally)
It...it balanced down?!	5	(takes remaining washer off) Yeah.
Well...I'll be darned! Can I do something just a minute. (puts washers on left and right ends) 	6	
We had it like this. Well, what if you take that one off. (indicates one on right side)	7	 (takes right washer off)
What will first...What will first..		I don't know. (playing with washers)
You don't know.		Take your hand off.
Take my hand off. Well, if I let go...then what?	8	I don't know.
You don't know. Well...(lets go--beam goes down)	9	It went that way. (brings beam back to straight position)

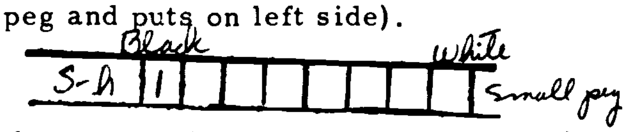
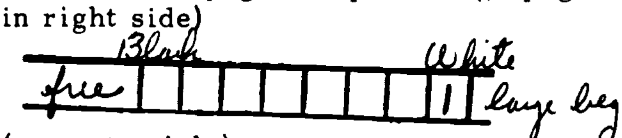
Yeah. Well, how can we make it go back down this way now? (points to right side)	0	Here...take that one off and maybe it'll go. (takes washer off and hangs another one on)
	1	 (beam goes down--takes washer off)
Then maybe it'll go. Well, that's pretty good. How does this thing work?	2	I don't know.
You don't know.	3	Goes up and down. (moves beam so it rocks up and down)
Oh...What makes it go up and down?		(handles a few washers) You have to put these on.
You have to put those on. Oh, yeah...Well, that's pretty neat. Did you know all this when you first saw that?	4	(handling washers)
		No.
You're finding out a lot though, aren't you. Well, maybe a little bit.	5	(nods) Yeah.
Well, can you show me some more things with this. Maybe you can think up a bunch more.	6	(hangs two washers)  If I put two close, what'll it do?
Well, what do you think it'll do?	7	It'll do, (takes experimenter's hand off end and tries to push beam to the right)...goes that way. (beam balances)
How does it go?		
It doesn't want to stay, hun?	8	Yeah.
Can you make it so it'll stay down like you wanted it to?	9	(takes both washers off and hangs another one) 

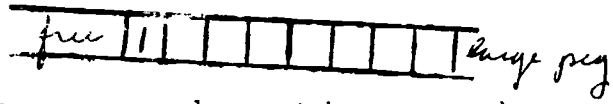
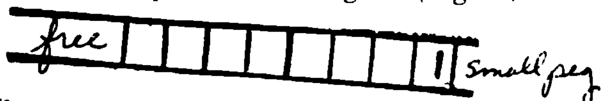
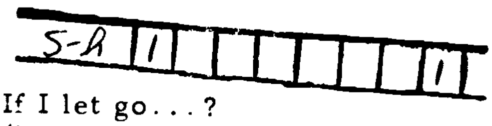
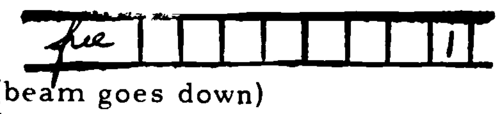
Oh...Yeah. Well, what if I do this. See, I got this many here, (shows her two washers), and I put those	0	(beam goes down--takes washer off)
nany there. (hangs washers) 	1	(gets a bunch of washers and begins to hang them) Put these over here.
Oh, you want to put a bunch on. Well, what's going to happen when you put all those on? Can you tell me? Can you tell me or show me how?	2	(hanging washers) Maybe.
Maybe. Well, what do you mean by 'maybe'? Oh, you've got a bunch, hun? Well, what will happen?	3	(finishes hanging washers) 
Well, can you show me first?	4	I'll do it now. (tries to take experimenter's hand off) I'll do it now. (takes ahold of end of beam)
Well, can you hold on and move it so it'll go?	5	(lets beam go--goes to the left) It went that way.
It went that way. Did you know it was going to go that way? Hun?	6	It went high. High. (takes washers off)
Very good. Well, what if I do this, (gets board), and I put this up like that so you can't see the other side, (places board in front of left half of beam), and I tell you, you can't look at the other side, and I put one here and I	7	
don't know if I'm going to do anything on the other side. (hangs washer on right side, and then one behind board)	8	(looks behind board)
 Now, don't look. You are not supposed to look. Now without looking, what do you think is going on here?	9	I don't know.

You don't know.		It's stopping.
It's stopping. Why is it stopping?	0	Cause it can't go.
It can't go. Well, is there another one of those behind here?		(looks behind board)
Don't look. Just tell me it you think there is.	1	Maybe.
Maybe Well, if there was one, where do you think if would be? You can point on the board for me.	2	Cause then it...then it won't happen.
What won't happen?		It won't go.
If there's one on, if there's one on, then it won't go?	3	Maybe not. Maybe you can't put it on if there's another one. (indicates washer on right)
On here?	4	Yeah.
Oh. Well, do you think there's anything on...back here, behind this? (indicates behind board)		(playing with washers) Maybe.
Well, see, I'm holding it now. What will happen if I let go?	5	I don't know.
You don't know. Well, let's see. (lets go--goes to left)		
My! Well, is there anything behind here now?	6	Maybe. (looks behind board)
Maybe.		There is. Yeah.
There is. Did you look?	7	No.
Did you see it?		Uh-uh, (no)
You didn't?		(looks behind board again)
Where is it at? You saw it that time, didn't you?	8	It was one of these. (holds up a washer from the box)
It was one of those. Oh, yeah. (removes board) Why there it is! Let me show you something else. We have another thing here that you might like. (removes balance beam)	9	

These right back here...we're going to take them all away. (removes box of washers)	0	Here.
Look at there. (brings out peg balance beam)		What's that? (touches it)
What do you think that is?	1	I don't know. (plays with beam so it rocks up and down)
Well, is it anything like anything you've ever seen before?	2	No.
Well, do you think it's like this? (points to washer balance beam)		No. (touches end of beam so it rocks)
Not at all?	3	Uh-uh. (no) Do you? (touches end again so beam rocks)
Well, I don't know. I'm trying to figure it out. Well, how does this thing go? It moves, hun?	4	Yeah. You have to put those things in there maybe. (indicates slots on beam)
Well, let's see. I've got a little thing here. (picks up a peg) Now if I put this in the white end, what will happen when I let go? (puts peg in)	5	
	6	I can do it. (tries to remove experimenter's hand)
You can do it?	7	Yeah. (continues trying to remove experimenter's hand)
Can you show me with your hands first?		Yeah. (continues trying to remove experimenter's hand--succeeds --beam goes to right)
Oh...my!	8	It doesn't take out...(?) (removes peg)
Uh-hun. (yes)	9	(puts in two pegs) 

Oh! You have two on. Well, what will happen if I let go?	0	I have two on.  I can do. (holds both ends of beam then lets go--beam balances)
Oh, you can d · ir. It won't do it? Well, what makes it do it?	1	It won't do it.
	2	(takes right peg out) Do it with the other one ... cause I like the other one. (indicates peg experimenter has in his hand--takes left peg out--places experimenter's peg in right side) 
	3	(lets go--goes to right--takes peg out)
Wow! That really works good, doesn't it? Well, what if I give you this. (gives subject a larger peg) What can you do with that one?	4	Yeah.
	5	(puts it in right end)  (beam goes down)
Well, why does it do that? Cause why? You don't know?	6	Cause. (takes peg out) I don't know. You can make a stack of it. (is making a stack out of pegs)
Yeah. Well, what does that do, when you make a stack of it?	7	If you have a tall one, it will fall down.
It will! Well, that's pretty neat! If I do this and now put that one in there, (puts smaller peg on left side, and larger peg on right side), what's going to happen when I let go? 	8	

	0	I'll do it. (tries to take end from experimenter)
Well, can you try to tell me first?		It'll drop, maybe.
What will drop...the white part or the black part?	1	The white part. (points to right end)
Why do you think it will drop?		Cause...
Cause?	2	Cause I want it to.
I want it to! Boy, you're pretty powerful!		(...?)
(lets go--goes to right) Well, it sure did, didn't it?	3	Yeah. (takes left end of beam and holds it down) I want the black part to do it now.
Well, how can you make the black part do it?	4	(lets go--beam falls hard to right--left peg flies out)
Opps...		I'll get it! (gets peg) Here.
Okay, thank you.	5	
Well, how can you make the black part do it now, Elizabeth? Hun?		I think you have to take that one out, (takes out peg on right side), and put that one on. (takes small peg and puts on left side).
	6	 (lets go--left, black side goes down)
My, golly! That's pretty neat. Can you make it drop by using this one? (gives subject large peg)	7	
	8	Yeah. (takes small peg out--puts large peg in right side)  (goes to right)
No. Can you make the black one drop by using that one?	9	Maybe.

Maybe. Yeah..	0	(takes large peg off right side and puts it in left side) 
Well...	1	(beams goes down--takes peg out) If I...if I put this one on... (starts to put small peg on right side)
What will happen?	2	It will drop that one. (gets peg in) 
Well, are these two the same then? (indicates small and large pegs)	3	(beam goes down) No.
It makes them both drop.	4	Well, that one's a little taller, (touches large peg), and these are small. (points to small pegs)
Oh, yeah. I've got another one here. (takes out more pegs) Can you use these here?	5	Well...they both'll...both do it... they're tall like both of them, (indicates large pegs), aren't they?... but the other ones aren't.
Will they both do it right? Maybe.	6	Maybe. (takes two new pegs--places one on each end)
	7	 If I let go...? (lets go--beam balances)
It won't go. Well, why does that happen?	8	It won't go. (takes peg off left side)
	9	 (beam goes down) It went...

Well, by golly. You're really learning. You really figured this thing out.	0	(takes peg out) Yeah. (gets a new peg--puts it in left side
	1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	

APPENDIX 3

Structural Changes in 4-5 Year Olds

Klaus Witz and David Goodwin

STRUCTURAL CHANGES
IN 4-5 YEAR OLDS

by

Klaus G. Witz

A talk delivered at the Second Annual Interdisciplinary Meeting in Structural Learning, April 2-3, Graduate School of Education, University of Pennsylvania, Philadelphia, Pennsylvania.

Notes prepared by Dave Goodwin

As you may know, Jack Easley and I are co-directing a project at the University of Illinois on mapping cognitive structures in children.[1] In this work our point of departure is the Piagetian tradition: we interview children a la Piaget, videotape the whole proceedings, and then spend a lot of time studying the tapes -- trying various analytical paradigms and generally doing a lot of theorizing and speculating. Like Piaget, we are interested in basic mechanisms and phenomena of cognition, and how to conceptualize them, and for this reason we tend to work with individual children. What follows is a sample of our current effort: I am not presenting you a completed study, but something more like a progress report to give you an idea of how things are shaping up. I think the best thing is to simply tell you what we do, starting at the very beginning.

The experimental setup we use is taken from Piaget's balance beam experiment but the actual interview technique is substantially our own. Our balance has four evenly spaced hooks on each side, and we use washers as unit weights, (see fig. 1). The child and the experimenter both sit on the same side of the table facing the balance and they talk about it. During the interview the beam may be held horizontal by the experimenter, or allowed to assume its natural position, or it may be manipulated by the child, and the child is asked to load it so that it will balance, or so that the other side will

[1] Research supported by a grant from the Basic Studies Branch of the U. S. Office of Education.

go down, or to predict what would happen if the beam were released, etc., etc. We make every effort to ensure that the interaction between the child and the experimenter flows smoothly: the experimenter avoids "setting up" problem situations; rather these should arise naturally during the interaction. The child is encouraged to take the initiative and express himself in any way he can, and he is given some freedom to manipulate the apparatus. However, we try to restrict the amount of new information that he can obtain during the interview: his predictions are often not verified, etc.

The first thing we do after taping is to prepare a detailed transcript. In figure 2 you see about one half of one page of a transcript of an interview of a little boy named Timmy (age, 4-7), prepared by Dave Goodwin. In general, transcripts are from 12-20 pages long, and take about 10 to 20 hours to prepare. (The interview itself typically lasts only 20 minutes or so.) As you can see we put in whatever seems significant: words, gestures time relationships, occasionally we comment on time lags, etc. The box () indicates the current loading of the balance, (for example, 

means there is 1 washer on the right end of the balance). We often add more information during the analysis. The important point is that our transcripts are fluid -- there is no predetermined "space of all possible transcripts". (Note the numbering from top to bottom, used for reference purposes.)

Now a frequent occurrence on Timmy's tape is the following: he does something with the apparatus with definite expectations or anticipations, for example. he puts on a washer and expects the balance to move, and after his expectation is met, or not met, as the case may be, he immediately does something else that is related, something similar with similar expectations. Hence, the action (including the implied expectation) followed by the experience of the expected effect, can be looked upon as a unit of some kind, and I will call it a cycle.

Such cycles are prominent in many of our video tapes -- there are usually several groups of 3 to 6 cycles in one interview. When you watch this on playback you can't help getting the idea that there is an internal organization at work that generates the cycles, that generates the variations and modifications in the cycles, and that propels or drives the child's behavior. Such an organization I will call an activity structure, and conceive it as a system of schemes in Piaget's sense. Figure 3 illustrates how components of this structure relate to a cycle. The elements above the horizontal represent schemes or organizations of schemes that are involved in the observed behavior at the time, while the observed behavior itself is recorded below the horizontal. "a" refers to specific action schemes like "putting a washer on a hook", "b" refers to perceptual schemes like "seeing the end go down". The "a ——(b" connection means that during the beginning of a cycle, although the child only does "a", "b" is already implicit in his behavior, it guides the activity during the cycle. "a' " represents action schemes related to the "a——(b" connection, for example, after putting a washer on, he may say, "take your hand off", or "let's see what happens". The "b" at the end of the cycle means that the child's anticipations are met (e.g., he perceives the balance going down and we see him watch it go down), the cycle is complete, and he goes on and initiates another cycle, (e.g., he puts a washer on a different hook, but with the same expectations).

There are two criteria for judging whether cycling is present, (fig. 4):

(a) Primary level cycling refers to the fact that a second cycle follows the first as soon as the hypothesized expectation in the first cycle is met, that is, the cycles must be back to back. For example, "putting a washer on a hook" might itself be regarded as an a⟶b pattern, (the a-scheme would be the motor activity in hanging the washer. and the b-scheme would be seeing the washer hang on the hook). But if we see the child put on a washer and then watch how the balance responds, (and if he talks about the beam going down, etc.). "putting a washer on a hook" is only the "a" part of the larger cycle which terminates with seeing the balance go down.

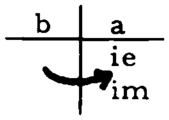
(b) There are category constraints across the cycles. By this I mean there are aspects with respect to which both cycles are similar. Let me illustrate this with the first group of six cycles in Timmy, (fig.5). At 4-8, he cumulatively puts seven washers on the left most hook and predicts it will go down. After the balance is released, he grabs it, returns it to level, and adds two washers successively to each of the remaining three hooks on his side and declares that the balance will again go down, (5-3). In these two cycles then, there is the common constraint that he always starts with the balance in a horizontal position. In addition, he always puts two or more washers on a hook, (He seems to think that it takes at least two washers to make the beam go down.), and he operates entirely on one side of the beam -- both constraints which are also carried through the next four cycles, in which he successively removes the washers from each hook. These constraints are not accidental, but in fact, are extremely significant. For example, in 7-1 the experimenter asks him whether he can think of something to do on the balance with one washer, and he says no. But when the experimenter asks, "Can you think of anything to do if I give you two?", he immediately responds, "Yes, I can throw them on." There are also several other examples later in the tape which bear this constraint. In every cycle, of course, Timmy is very interested in what he is doing, and gets visible satisfaction from watching the balance respond.

Figure 6 shows the analyst's worksheet for the same passage as the preceeding figure. Actually, what you see is a cleaned up and typed version of the real thing -- ordinarily it is more messy and filled with the analyst's scribbles (conjectures as to what is going on, etc.). The left column shows what S does much in the same way as the transcript, except here we have emphasized things we consider to be relevant; underlined phrases indicate repeating elements. The middle column shows a convenient classification of S's behavior: i=initiates, r=responds, e=executive (intends to accomplish something), and m=mentions. The right column shows the tracking of the category constraints. There are two basic aims associated with this kind of detailed examination of the data. First, by careful consideration of the category constraints, we try to arrive at some understanding of the a, b - scheme complexes. Remember that schemes are types of internal processes, whereas category constraints are our "objective descriptions" of regularities in the observed behavior, and such regularities may be described by different external observers in many different ways. The descriptions you see across the top of fig. 6 are simply descriptions which the analyst felt best represented the constraints inherent in the child's behavior.

The second aim is: we try to identify increasingly general but still coherent a—(b complexes of schemes. In figure 7 you see the same 6 cycles as before plus some superstructure in which the <u>nodes represent such identifiable a—(b complexes</u>. The superstructure is determined largely by transitions in the initiated behavior, using guidelines of the following form:

(1) A direct transition from one cycle to another of the form

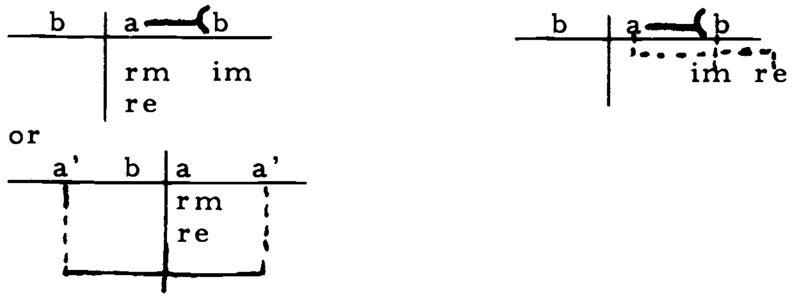
(1.1)



(time —>)

with largely the same constraints on both cycles and no new aspects specifically brought up by S, means that both cycles are realizations of the same a—(b pattern. The condition (1.1) may be weakened to

(1.2)



(2) A direct transition from a cycle a—<b to another, in which S introduces new aspects or violates (varies) some of the constraints on a—<b, suggests that both cycles are realizations of a higher order activity pattern a_1—<b_1 provided several significant constraints on a—<b are preserved.

Actually, figure 7 shows only complexes of action schemes; a more accurate representation is given in figure 8. There are three levels of organization of activity:

a --- putting substantial weight on one hook on one side.

a_1 --- getting a lot of weight on the hooks of one side.

a_2 --- taking the weights on one side off.

a_{11} --- operating on one side by putting on and taking off weights, and, there are only two identifiable levels of b-scheme organization:

b --- seeing the balance beam go down and come to rest.

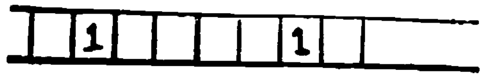
b_1 --- seeing the beam go down or return to normal.

Recall that the title of my talk is structural change. Let's look at figure 9 -- an overview of two-thirds of the interview. As you can see, some of the later cycles are related to activity structure I, (they are marked ~I in the figure). But there is also another activity structure, activity structure II, which has to do with putting on washers in symmetric configurations. Careful analysis along the lines sketched above shows that here the b-scheme is "seeing it symmetrical on the balance", and that the structure is initially unrelated to the structure in figure 8, (activity structure I).

Now I am ready to discuss one example of structural change. The crucial passage is the white part of figure 9, just before

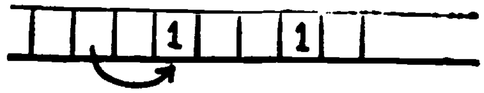
"I and II". The situation is this: with the balance loaded symmetrically, one washer on each hook,

(2.1)



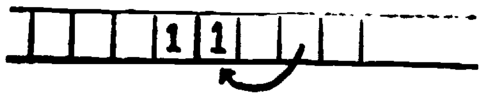
the experimenter moves the washer on the left to the inside hook, and asks Timmy what will happen if he lets go.

(2.2)



The child is completely baffled and says he doesn't know. The balance is released, and Timmy thoughtfully handles the washers on the beam, then looks up and down the balance, moves the outside washer to the inside hook

(2.3)

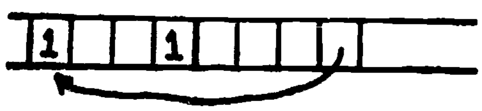


and says it will balance. As soon as the balance is released he moves the same washer to the outside hook,

(2.4)

states confidently that his side will go down, and when the balance is released he says. "Aren't you glad I did it?". Timmy then begins a third cycle by moving the outside washer to the opposite end of the beam,

(2.5)



and says, "What if I put one on this side?"

The implications of all this are diagrammed in figure 10. In the back of the picture you see our old friend, activity structure I, in the front, activity structure II (not elaborated further here). There is a new a→b pattern labeled "move to the end", which underlies the cycle beginning with (2.3) above. This pattern is a sub-structure of I, and was formed when the child watched the experimenter move around washers in (2.2). Consequently, we have here a pattern of cross-initiation in activity: from (a just created substructure of) I to II, and then from II back to I.

This transition, I—> II —> I (—>...), is not just a signal that structural change has occurred. but by our rules it must be the case that both I and II are now part of a common larger activity structure, represented by "X" in figure 10. This larger, more general structure represents, indeed constitutes, new knowledge, or a new conception. of what the balance really is, and represents a significant advance toward the adult conception. The "liberating influence" which made the fusion of the two structures into a larger one possible, (viz., the experimenter moving washers around on the balance). continues as the main constraint on the initiating activity into the third cycle, (example (2.5) above).

<u>Concluding comments.</u> First, it is true that the task situation in which the child is placed favors the expression of what I have called cycles, and it is also true that the way the interview is run favors the occurrence of "activity structure". Still I think we can say that activity structures are a basic form of knowledge in the child -- a lot of what we would want to call the child's knowledge <u>is</u> the a——(b structuring implied in his own motor (and verbal) activity. Second, I have suggested that "growth of knowledge" is an integration of activity structures into larger activity structures. A basic problem for us, is to explain the rise of an objective world like ours in the child; the suggestion, thus, is that this rise of an objective world

is accomplished by integration of motor activity into more and more encompassing structures.

In spite of these tantalizing suggestions, I should also say that, with Piaget, I believe that activity structures may only be a surface phenomenon. The conceptual apparatus I have used in this talk, the carrying through of category constraints, variations in their dimensions, and the introduction of new elements to get at structurally similar scheme complexes, and higher order cognitive elements and the whole conceptualization of scheme complexes as relational structures, is unfortunately, too limited to enable us to usefully discuss any deeper phenomena.

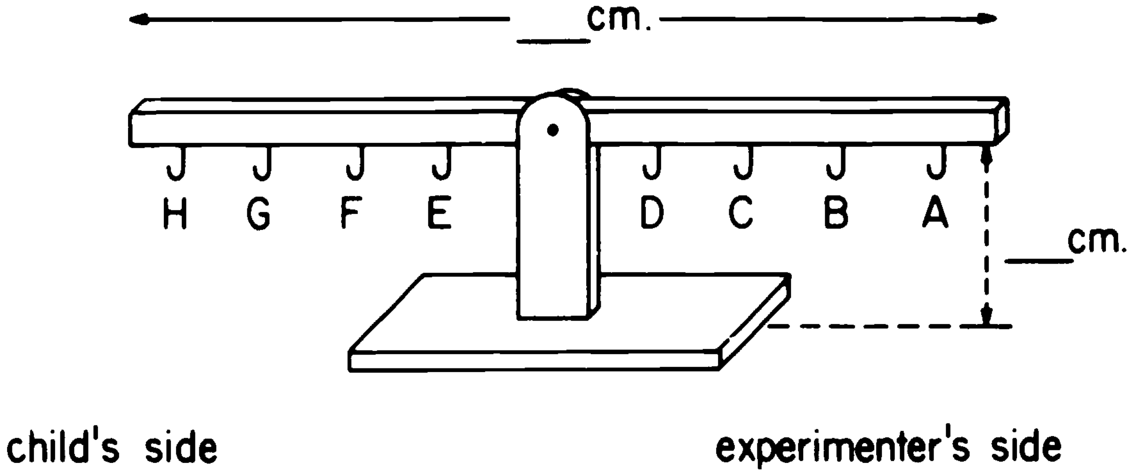


Figure 1

It will?	0	Yeh, if you let go of it. (S adds one more washer.) 7 E-h
Oh, if I let go of it. Do you think I, ah, I should do that?	1	See if it will go down .
Ok. You ready right now? 7 t	2	(S watches beam go down and hit the table, then looks to E.)
Mmmmm, wow, it sure did, didn't it?	3	You can put more on it. (S lifts balance to level and adds 2 washers.) 2 7 E-h
Yea, what happens if you put more on it?	4	It will still go down. (S adds 2 more washers.) 2 2 7 P↓
It will still go down, yea.	5	
Well how come you want to put more on it?	6	So it will go down. (S adds 2 more washers.) 2 2 2 7 P↓
	7	
	8	
	9	

Figure 2

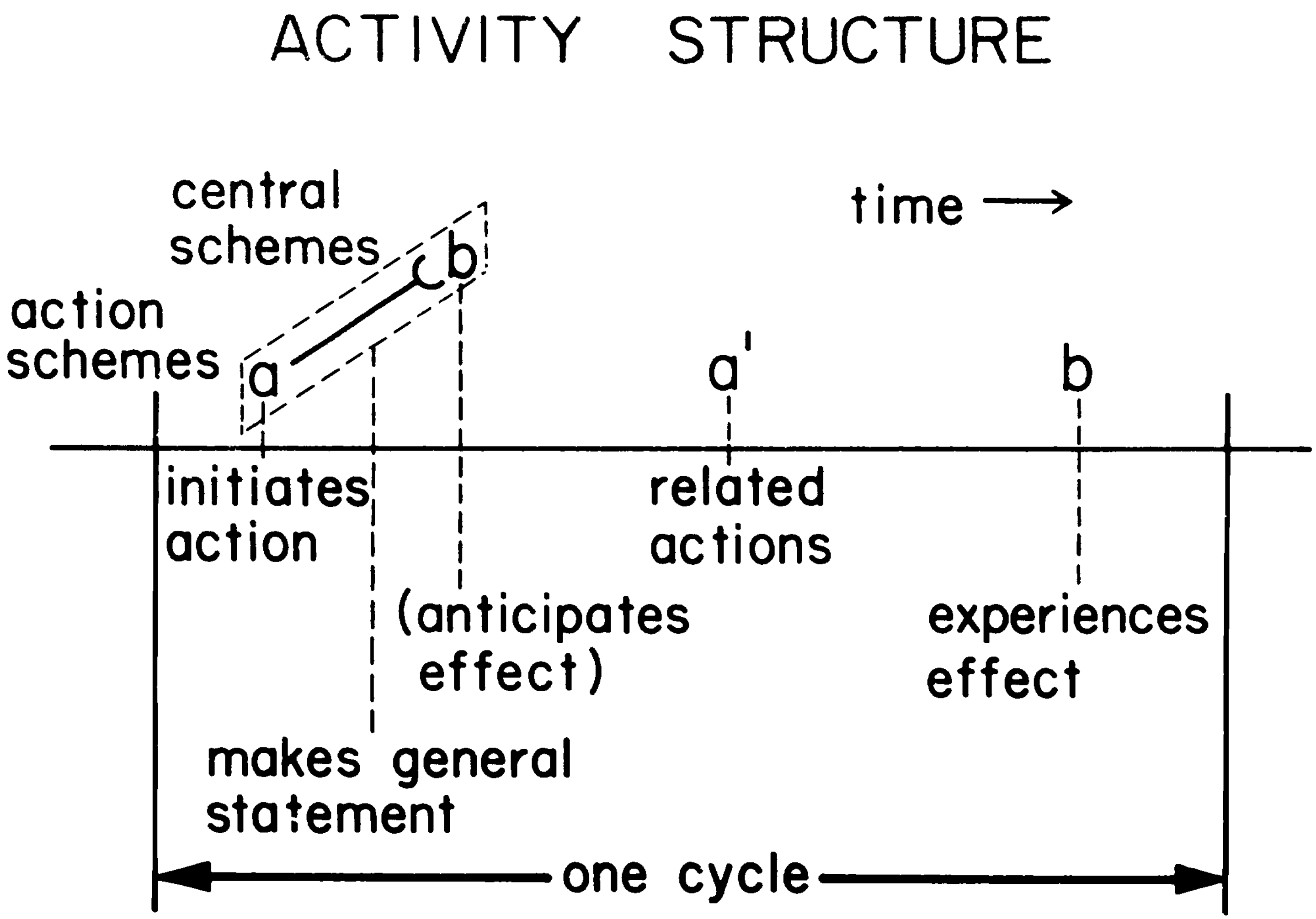

ACTIVITY STRUCTURE
central schemes
action schemes
a
b
time →
a'
b
initiates action
makes general statement
(anticipates effect)
related actions
experiences effect
one cycle

Figure 3

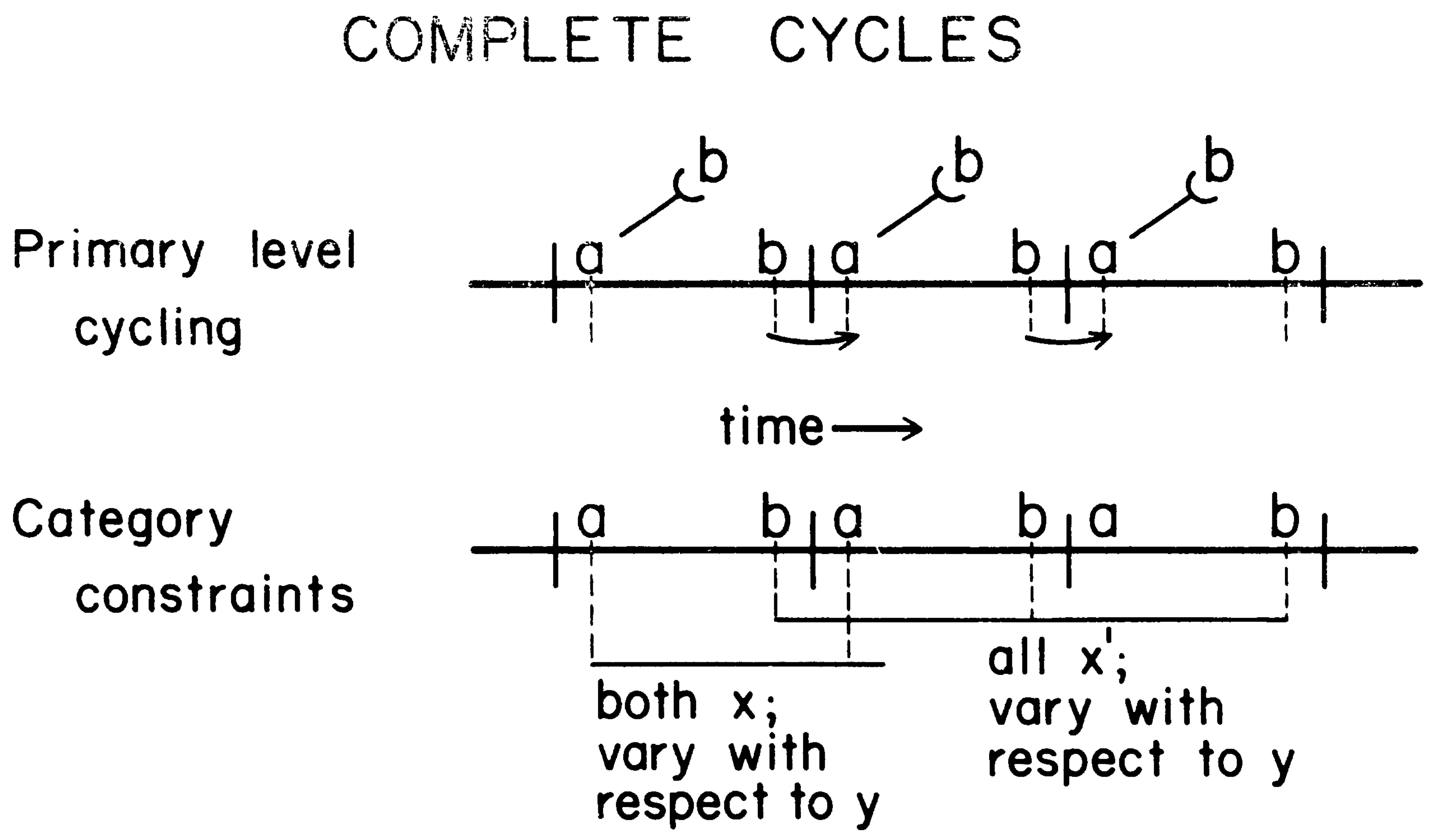

COMPLETE CYCLES
Primary level cycling
Category constraints
a
b
time ⟶
both x; vary with respect to y
all x'; vary with respect to y

Figure 4

TIMMY 4/7

Complete Cycles,

First Group

Activity Structure I

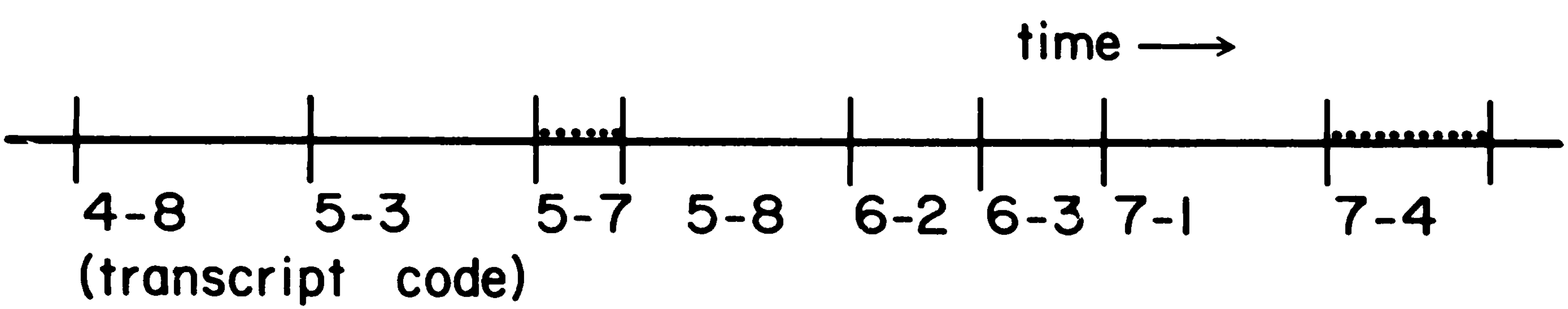


Figure 5

ANALYSIS WORKSHEET

Figure 6

E: What are w. good for?

S: (blank look)

E: Play with them?

S: Ok. Can we hang them on here?

E: Ok.

S: (adds 1+ 1+ ..)

I put more on it will go down.

E: It will?

S: Yes, if you let go.

E: Ok, if...Shall I?

S: See if it will go down.

S: You can put more on it.

Lifts bal.

Adds 2 w.

E: ? if I put more on?

S: It will still gd.

(adds 2 w.)

E: Why put more on?

S: So it will gd.

(adds 2 w.)

S: Starts removing 7 w. at end.

E: ?

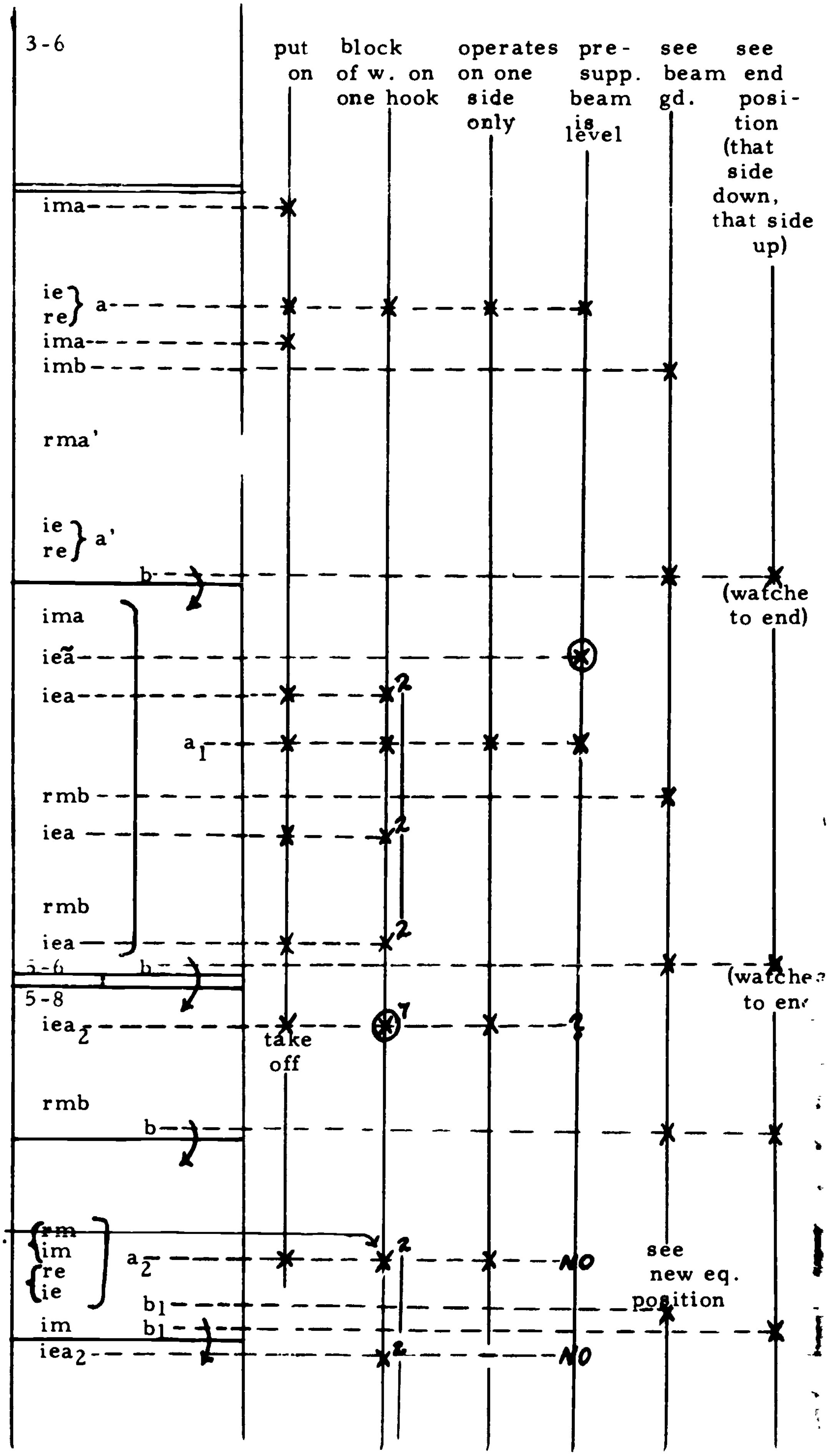
S: It will gd again.

E: If take all these off?

S: Let's take this one off.

(takes off next 2)

Still up, still down (takes off next 2) (bal. moves slightly, S. laughs)



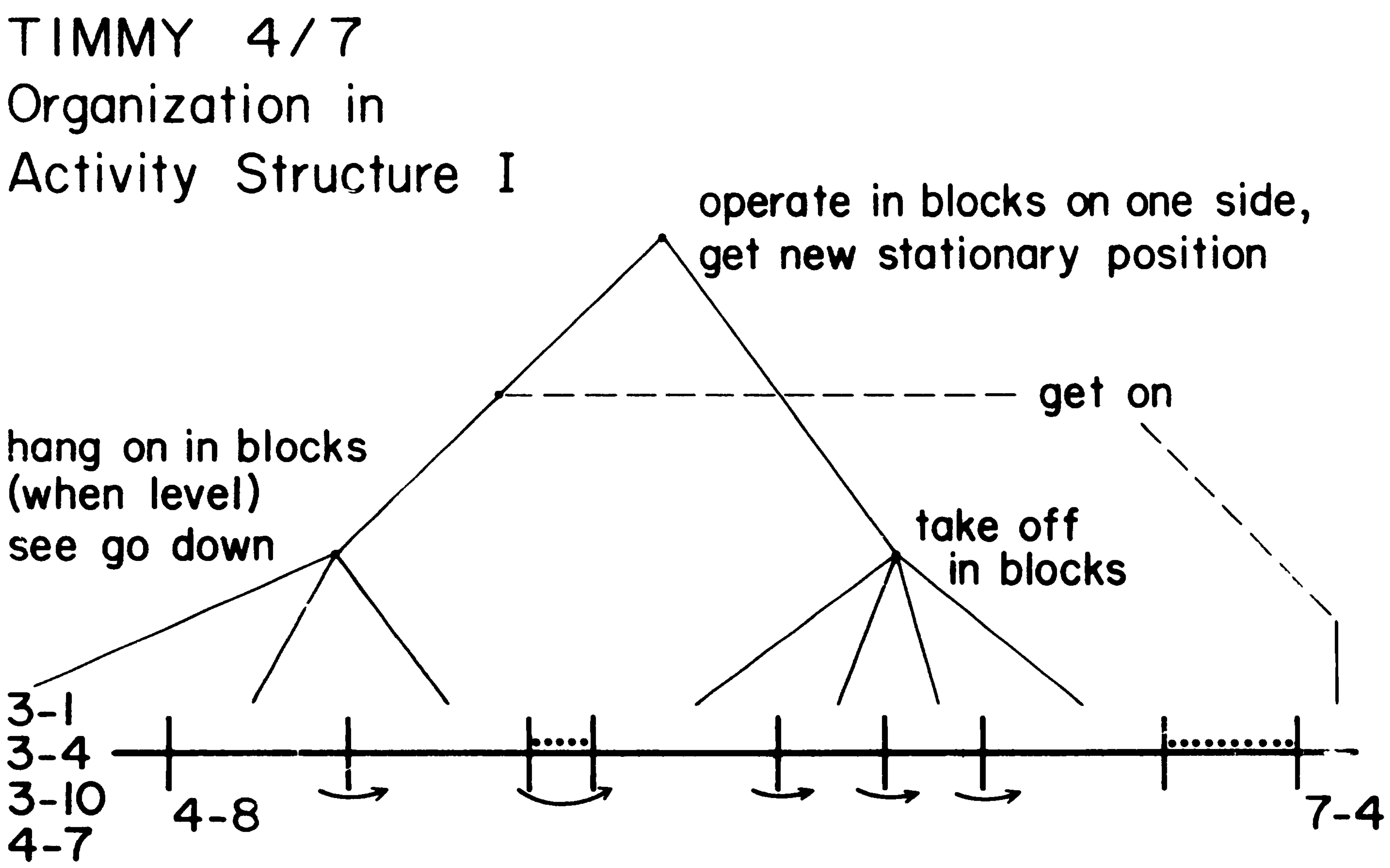

TIMMY 4/7
Organization in
Activity Structure I
operate in blocks on one side,
get new stationary position
get on
hang on in blocks
(when level)
see go down
take off
in blocks
3-1
3-4
3-10
4-7
4-8
7-4

Figure 7

TIMMY 4/7

Activity Structure I

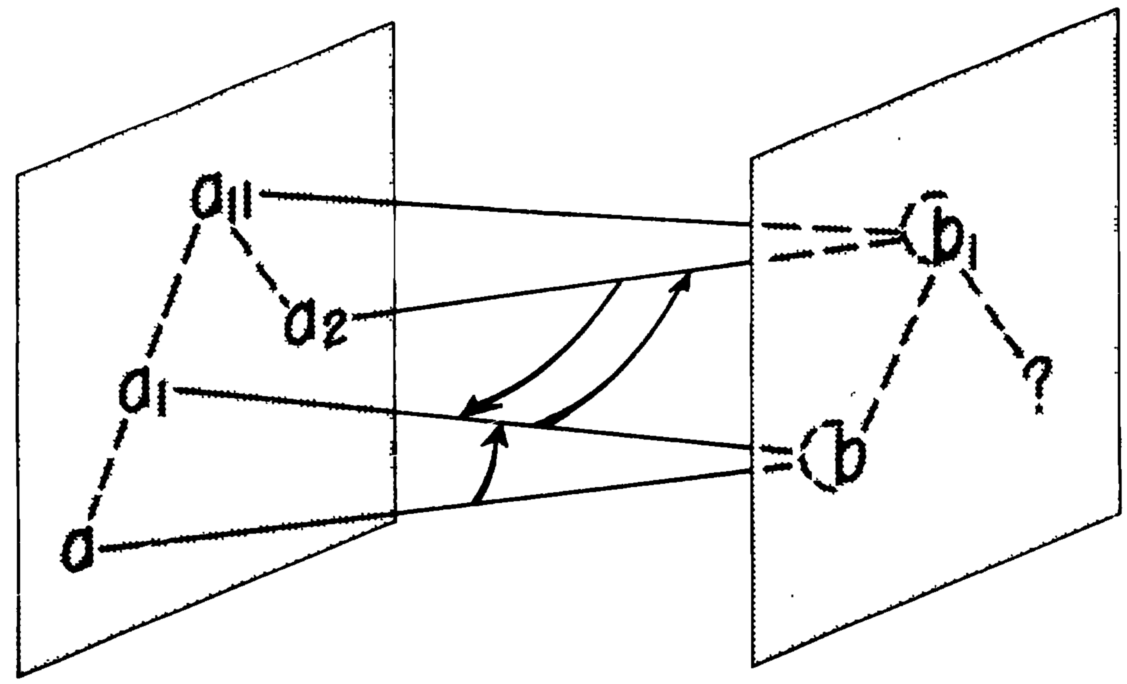


Figure 3

TIMMY 4/7

Summary up to 13-4

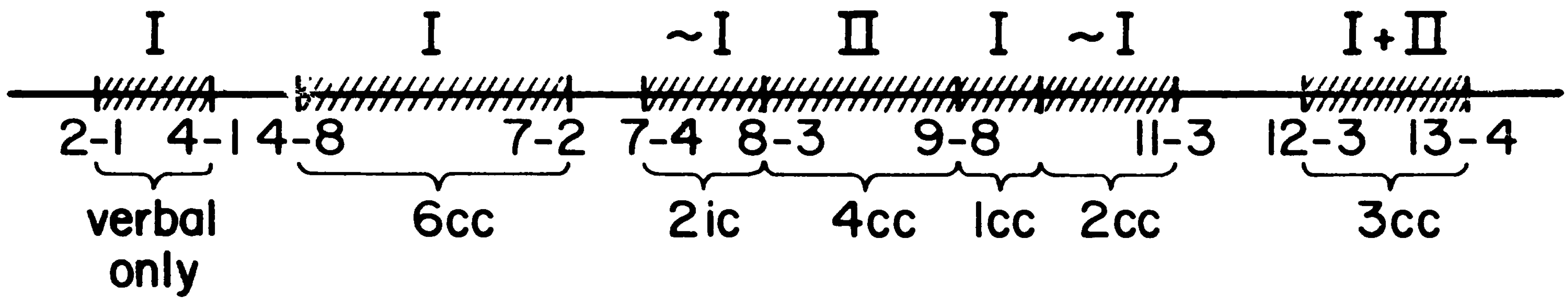


Figure 9

TIMMY 4/7

Changes in 11-14 to 13-4

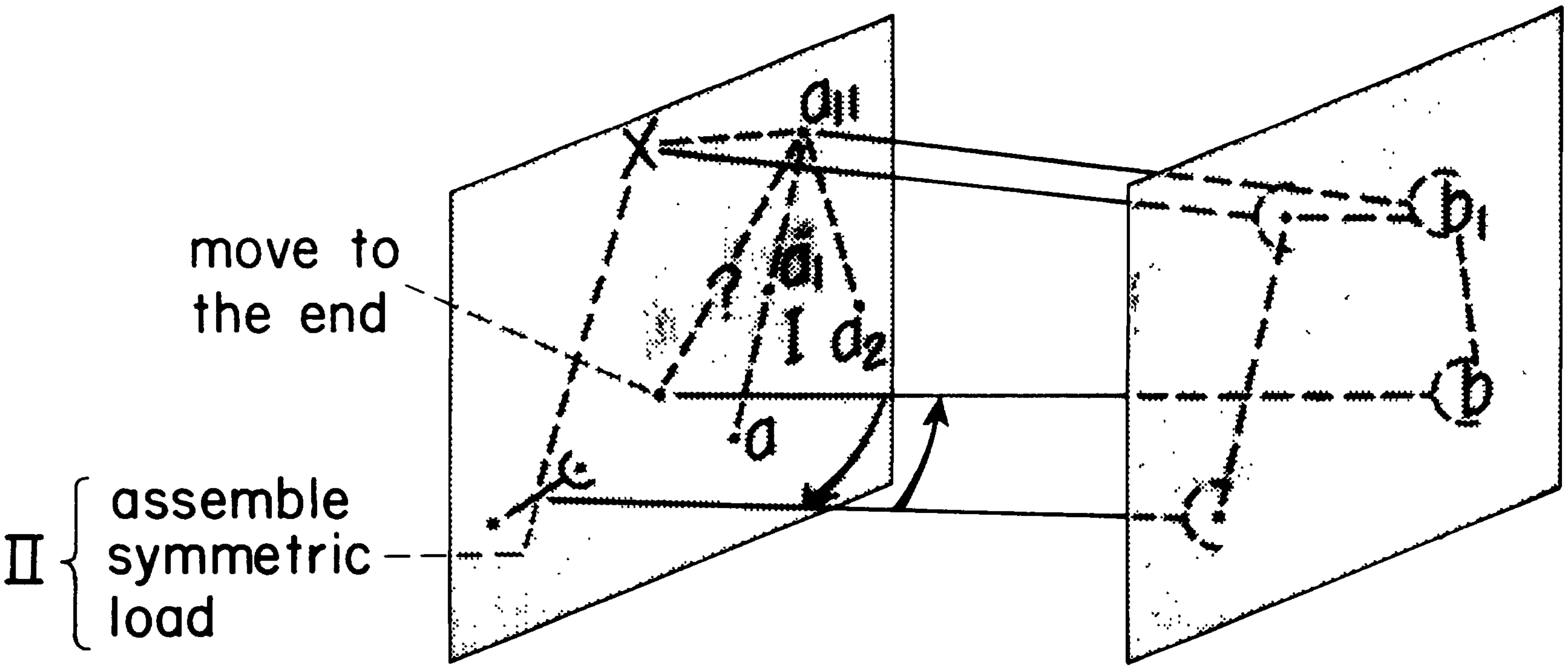


Figure 10

APPENDIX 4

Comments on the Activity Structure in Elizabeth

Dave Goodwin

Comments on the Activity Structure in Elizabeth

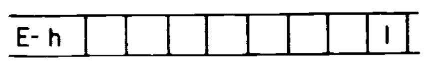
by

Dave Goodwin

We discuss very briefly two issues raised by the interview of Elizabeth (3;6). A transcript of this interview is given in Appendix 2; a description of the apparatus can be found in Appendix 3.

A. Primary Level Cycling and Elizabeth's Conception of the Balance

Very early in the interview Elizabeth goes through 9 primary level cycles, first a group of 5, (3-4 to 4-0 in the protocol), all concerned with making the balance go down, "to make it do it". We show the first group; for the others, see the transcript.

Ohh. You can say more than that. Why don't you try it. Why don't you play with them a little bit, if you want to.			
	4	I want to. That one there. (picks up a washer and hangs it on right end) 	Cycle 1
Now what will it do?	5	(tries to push right end down)	
(lets go)		(beam goes down and washer falls off	
	6	puts washer back on--lifts right side up so bar is straight--then lets right side go)	Cycle 2
Well, by golly! Did you know it would go like that?	7	Yeah. (takes washer off and hangs two others on--beam goes down) 	Cycle 3

You did! And you didn't tell me. Oh, what are you doing?	8	Goes that way. (holds bar straight and then lets it go)	Cycle 4
Now what are you trying to do? Make it go this way? Well, why won't it go that way? Cause why?	9	(holds beam straight, then tries to push left side down) Cause. (Lets beam go down) Cause	Cycle 5

Comments

(1) In these 9 cycles, Elizabeth hangs only one washer on a hook, never more. In addition, she never moves a washer from one hook to another, say from hook 1 to hook 2 but instead takes the washer off hook 1, puts it on the pile on the table, picks up another washer and hangs that on hook 1. This last constraint is not given up at any time in the interview, even when the interview shifts to the pegbalance (cf. 10-2)! and prevents her from using and learning new ways to make the balance move.

(2) Perhaps connected with (1), Elizabeth always brings the beam into a horizontal position before releasing or pushing it down, regardless whether she just loaded the beam anew or is simply using the load configuration from the preceding cycle. This constraint also holds throughout the entire interview. Thus, making the balance "do it" (her phrase) largely means to start with the beam level, put "new" washers on and let go.

(3) In cycles 3 through 5 at least it seems that Elizabeth is expecting that the beam would go down on the side on which she last put the washer -- or perhaps that she simply intended that side to go down and that this intent is not particularly related by her to any specific washer placement, cf. her frequent "I want"... But the problem is deeper. The passage at 4-9: Why does it do that, huh? -- "Cause...I like it", as well as her attempt to push the "intended" side down in cycle 5, suggest that the balance for her isn't an object with its own independent lawful behavior that one has to find out about and accept, but that the balance's behavior is still bound up with the b-portions of her activity elements, i.e., her own "intention-expectations". Put differently, intentions on the one hand and expectations of objective events whose occurrence she simply accepts on the other hand cannot now be separated.

Other cycles, not as clear cut as the preceding ones, occur between 6-1 and 7-5 and are consistent with and support this interpretation.

B. Assimilation of different apparatus by one and the same activity structure

A second important point of the Elizabeth interview (beside the point made at the end of A(3) above), is that the same activity structure which assimilated the balance beam in the first part of the interview also assimilated the peg balance in the second part (Figure 1). When this apparatus is first brought in, Elizabeth

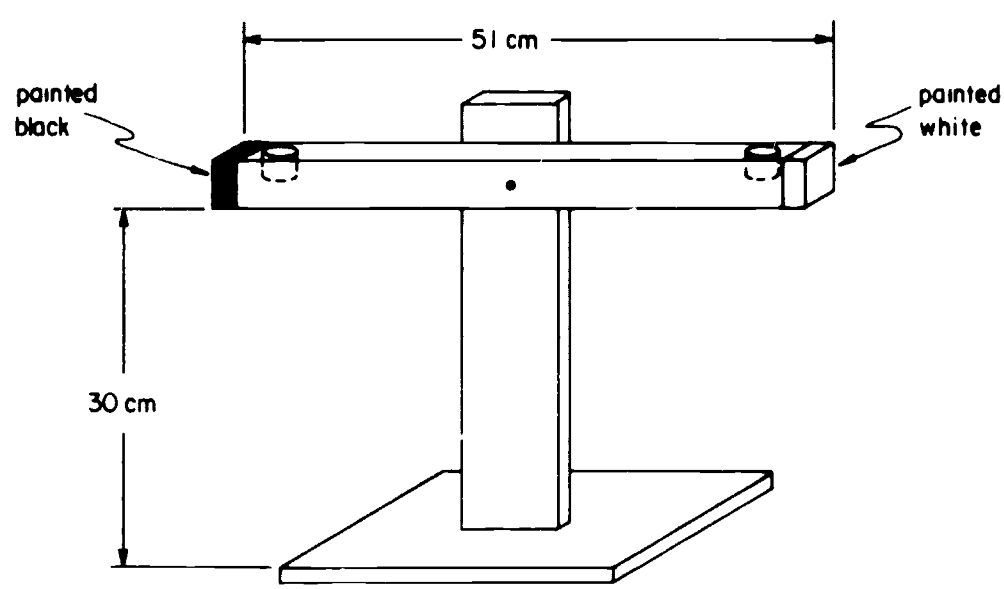


Figure 1. Peg balance.

Weights are 3/4" dowel rods of length 2.5 cm., 3.75 cm., and 5.0 cm.

isn't sure what she can do with it. However, as soon as she realizes how the beam moves, she comments that the pegs go in the slots, and very soon goes through 4 consecutive cycles (9-6 to 10-5). The main point is that in these cycles she maintains exactly the same constraints as before with the beam balance; she still uses new pegs for each loading, and holds the beam level before letting go;[1] in addition, there are still the same peculiar intention-expectations concerned with the behavior of the balance. The same activity structure is therefore involved as before with the beam balance.

[1]This information is on the tape, not in the transcript, which was of course prepared before any kind of analysis was undertaken.

APPENDIX 5

The Representation of Cognitive Structures of Four and a Half Year Old Children

J. D. Knifong
(Dissertation - Abstract)

The Representation of Cognitive Structures of Four and a Half Year Old Children

J. D. Knifong

Following Witz, "Analysis of Frameworks in Children", systems of schemes analogous to those which Piaget has described in infants are postulated to underly the responses of $4\frac{1}{2}$ year old children to configurations of and questions about a beam balance. Such systems are called "frameworks". A detailed representation of frameworks is developed, using the following representational devices and relationships:

addition of symbols e.g., X, XA, XA1	subscheme relationship; XA is a subscheme of X, XA1 is a subscheme of XA, etc.
and	represents the child's understanding of necessary co-occurrence of physical events or conditions
or	mutually exclusive or inclusive or (both similar to "and" above)
{ }	A grouping symbol which suggests that the relationship just prior to its occurrence applies to each scheme within the braces.
( )	Using to indicate that the location used to describe the scheme is that of the experimenter and not of the child.
if...; then...	represents the childs often vague understanding of the relationships between preconditions of the even and the event itself.
iahi	"it also helps if"; represents some of the uncertainty in the child's understanding of his world, when he thinks that some condition is not necessary but would help anyway.
sp	"sometimes probably"; similar to iahi above.

Other conventions used are illustrated in the following example.

> F1.5 (= fifth successive approximation in the formulation of framework 1 of Liza's, chapter 2).
>
> If A: things (in this case, washers) are hanging on (the beam) iahi [A1: (near outer end) aor A2: scoot it (washer) up a little (to the edge of the hook) aor A3: more (a lot of washers), on] and B: have to let go iahi A: push down; then C: it will fall down and C1: go bang sp D: fall off.

Four interviews of 4½ year old children with a balance beam as apparatus were analyzed and two or three FFR's were found for each child. The various frameworks of different children were compared with one another as well as with the published observations of Inhelder and Piaget in The Growth of Logic from Childhood to Adolescence, with very good agreement. The relationship between the internal structure of frameworks as formalized above and Piaget's used logic are also discussed. It is suggested that Piaget's logical forms may perhaps be "real" from framework regularities and representations.

APPENDIX 6

Representation of Perceptual State

by
Robert S. Hart

Representation of Perceptual State

Robert S. Hart

In protocols of 3 to 5 year olds working with a balance beam, we often see sequences of events like the following:

Seq:

(1.1)	E holds balance beam	→ Child removes E's hand	→ Balance arm is free
(1.2)	Child holds balance arm.	→ Child lets go of balance arm	→ Balance arm is free
(1.3)	No washer is on the right balance arm.	→ Child places one washer on a right-hand hook	→ Balance arm is free
(1.4)	No washer is on the leftmost hook	→ Child places a washer on the leftmost hook	→ One washer is on the leftmost hook
(1.5)	No washer is on leftmost hook	→ Child places washer at outside of left-most hook	→ One washer hangs at outside of leftmost hook
(1.6)	Washer hangs on inside of left-most hook	→ Child pulls washer to outside of hook	→ Washer hangs at outside of left-most hook

Each of these sequences can be reliably identified, and infact each happens to occur once or more times in the interview with Liza (4; 7) (Knifong, 1971).

Now all these sequences have a common form; schematically:

(2) (perceptual configuration) → (manipulatory behavior of child) → (new perceptual configuration)

$$\underbrace{\text{perceptual configuration}}_{S_1} \rightarrow \underbrace{\text{manipulatory behavior of child}}_{R} \rightarrow \underbrace{\text{new perceptual configuration}}_{S_2}$$

That is, in each case manipulatory behavior of the child serves to transform one perceptual configuration into a different one. This suggests that sequences of this type constitute in fact functional units of cognition. This idea can be found in Tolman (1932) and Arbib (1972). Functional units of this type will be called TALIs.

In an effort to obtain a more adequate conceptualization and some kind of representation of TALI's, we examine in more detail the nature of the perceptual configurations and their transformations.

A. Intuitive Description of Perceptual Configurations

Our first problem is to provide an intuitive description of that perceptual configuration corresponding to the balance beam. Starting from an adult, introspective standpoint, we suppose that the perceptual configuration corresponding to the total balance situation at a given moment has internal structure, consisting in the presence of a number of attributes (or features) which may be again structured internally: balance arm, hook, end of arm, end hook, E's hand, own hand, own hand on balance, washer on hook of end of balance, etc. Some aspects seem to be simple, having no further internal structure; these may be elements (hook, beam, hand, washer) or relations (on, at, end, near, in, is, of). More complex aspects are constructed recursively out of the simple aspects. At a given moment, there will be relations among relations (e.g.: right arm is up < > left arm is down); aspects of the whole complex will change over time and again there will be relations among aspects (primarily mutual exclusion W): right arm is (up W level W down); washer (on W off) hook; hand of (subject W experimenter).

B. Formalization of Perceptual Relations

We formalize this description somewhat by defining a class of Perceptual Structure Representations (PSRs). We consider a vocabulary consisting of

(a) A set of simple elements $E = \{e_1, \dots, e_n\}$,

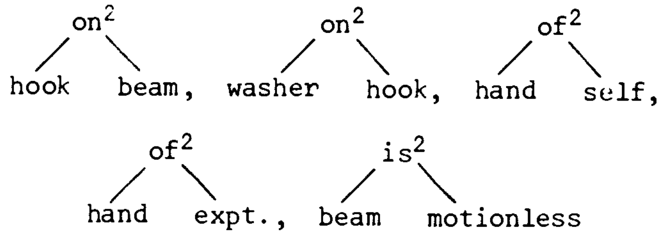
(b) A set of simple relations $R = \{r_1^{S_i}, \dots, r_m^{S_i}\}$, where the superscript S_i indicates that r_i has S_i arguments

Then any expression of the form

$$(3) \qquad r_i^{S_i}(x_1, \dots, x_{S_i}),\ \ x_1, \dots, x_s \in E$$

is a valid perceptual relation statement (pr) on the vocabulary (E,R). We denote the set of all pr's by P. In a concrete context, not all pr's will be meaningful, and one will restrict permissible pr's to a subset P' of P. E.g., if E = {hand, self, experimenter, beam, hook, washer} and R = $\{on^2, at^2, of^2, near^2, is^2\}$, then P' might be taken to be on^2 (hook, beam), on^2 (washer, hook), of^2 (hand, self), of^2 (hand, experimenter), $near^2$ (hook, end), is^2 (beam, motionless) . In general, pr's can be represented as oriented labelled trees; e.g., the pr's in P' can be represented by

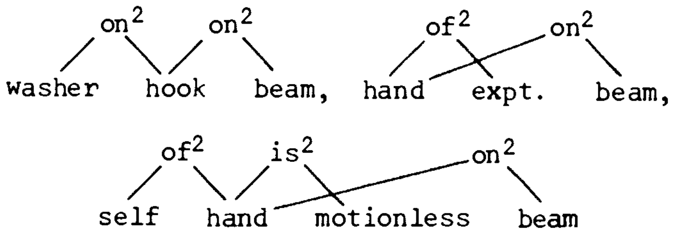
(4)



where it is understood that elements fill places from left to right.

A <u>conjunctive set</u> of pr's is formed by (a) a set of pr's drawn from P', and (b) some rule for declairing certain elements to be identical. Here we suppose that <u>only elements represented by identical symbols are identical</u>. Conjuctive sets of pr's are graphically represented as, e.g.,

(5)



<u>Both pr's and conjunctive sets of PR's are defined to be PSR's.</u>

C. <u>Identifying E and κ from data</u>

The following criteria may be helpful for selecting elements and relations to account for a given protocol. No one criterion need be either necessary or sufficient; each contributes a limited amount of evidence.

<u>Elements</u>

(a) Objects or regions of objects which are extensively manipulated by the child.

(b) Objects or regions of objects which are not modified within the context of the child's current activity (hook, washer, beam arm, hand remain unchanged regardless of child's manipulations).

(c) Objects or regions of objects named by the child, e.g.: hook, balance board (= balance arm), "this one" (= washer), the end (of the arm), the outside (of a hook).

Relations

(a) Relations between objects which the child changes regularly and in a systematic manner, e.g., putting washer on and off hook; moving washer to inside or outside of hook; putting own hand on or removing it from balance arm; removing experimenter's hand from balance arm; moving washer toward or away from end of arm. Such modifications indicate that the relation is being consciously monitored, and thus forms a part of the child's perception of the balance.

(b) Relations between objects which the child verbally names: out there (= at the end), got to get it out (to the end of the hook), put one on, take some off (washers), let go! (experimenter's hand).

D. Conjunctive Sets as Cognitive Entities

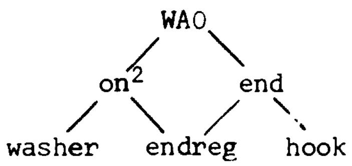
In the $S_1 \rightarrow R \rightarrow S_2$ sequences in (1), S_2 is a perceptual complex which functions as a coherent unit. Lisa believes that

> If a washer hangs at the end of the beam and at the outside of the hook and if the balance arm is free; then the arm will go down, and the washer will hit the table and fall off.

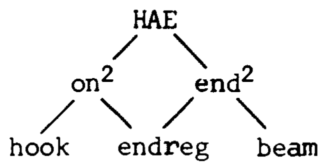
In other words, S_2 is the precondition for some result R. Lisa, who finds R interesting, repeatedly arranges the situation so that S_2 exists, carefully verifying that each condition is satisfied.

Such observations suggest that a conjunctive set of pr's, or perhaps a combination of several such sets, can function as a cognitive unit meaningful to the child. To formalize this possibility we introduce conjunctive set definitions C_i to be formal conjunctions of pr's. Conjunctive set definitions can be displayed graphically as shown in the following examples.

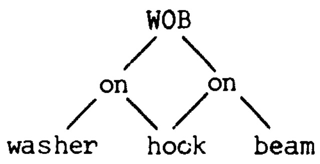
(6a)



(6b)



(6c)



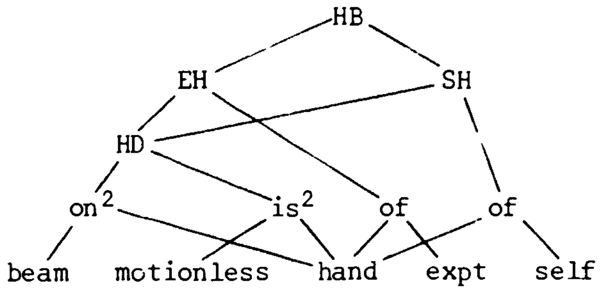
Here WAO for example is the definition of a conjunctive set corresponding to "washer at outside of hook"; similarly HAE corresponds to "hook at end of beam", and WOB to "washer on beam". In general, all conjunctive set definitions are defined to be P.S.R.s.

Expressions like

$$(7) \qquad C_i \wedge r^2(x,y) \quad \text{and} \quad C_i \wedge C_j,$$

where C_i, C_j are conjunctive set definitions, are new formal conjunctions, which will be also considered P.S.R.s and correspond to new conjunctive sets. This process can be repeated. As an example,

(8)



is a PSRs which can be taken to represent Lisa's perception of the held balance (HB). Here

HD = hand holding balance,

(9)

EH = HD of^2 (hand, expt)
= experimenter holding balance

SH = HD of^2 (hand, self)
= self held balance,

HB = EH SH.

Empirical reasons for introducing conjunctive set definitions to account for a given protocol must be similar to those for introducing elements and relations above: the child treats some set of perceptual relations as one unit, either verbally listing the relations, repeatedly constructing the set in a systematic way, or varying his response systematically against the two conjunctive sets (e.g., removing his own hand for SH vs. pushing the experimenter's hand away for EH).

E. Inferences on the Basis of One or More Given Conjunctive Sets

Let us now think of relations and elements as functions and constants within a functional calculus, say F^{1P} (see Church, 1956). An empirically motivated set of pr's can then function as a set of hypotheses from which, in conjunction with the axioms of F^{1P}, we can deduce other formulae involving pr's. But besides the purely logical axioms of F^{1P}, other logical relations, corresponding to the objective structure of the situation, can be postulated to hold among the perceptual constituents. These additional postulates then form a theory (in the technical sense) of the perceptual situation. For the balance beam task they seem to fall into two categories:

(1) Postulates corresponding to the basic (topological) structure of spatial phenomena, e.g.,

(10.1) $on^2(X,Y) \wedge on^2(Y,Z) \supset on^2(X,Z)$ (a part of a part of a region is a part of the region);

(10.2) $end^2(X,Y) \supset on^2(X,Y)$ (an end region of a region is part of the region);

(10.3) $on^2(X,Y) \veebar of^2(X,Y)$ (a region is either part of another region or it is not);

(10.4) $right^2(X,Y) \wedge right^2(Y,Z) \supset right^2(X,Z)$ (laterality is transitive).

(2) Postulates corresponding to the particular structure of the balance apparatus, e.g.,

(11.1) on^2 (hook, beam) (regardless of what the child does, every hook is <u>always</u> part of the beam);

(11.2) up^2 (left arm, table) $\equiv$ $down^2$ (right arm, table) (if one end of the beam is up, the other is down and conversely)

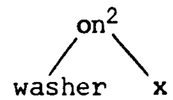
Let Σ denote a set of axioms such as (10) - (11) on (E,R). In simulating changing perceptual configurations on a computer, conjunctive sets of pr's that can be deduced in the formal system defined by Σ and F^{1P} can be made available as needed. The used deduction in this, formal system, however, only describes objective constraints on the perceptual situations in question; it does not imply that the child derives PSRs from cognitive operations resembling "logical inference". Note that Σ need not exhaust or even accurately represent the "objective" structure of the situation, and both Σ and the portion of F^{1P} used will normally vary from child to child (e.g., some children are aware of (11.2) and use it automatically, while others know nothing about the position of the opposite arm until they look).

F. Variations in the Perceptual Complex Over Time

Since both pr's and conjunctive set definitions can be thought of as formulae of F , they can be converted into forms by application of the λ-operation. For example

(13) $(\lambda\ \text{hook})\ \text{on}^2\ (\text{washer, hook})$

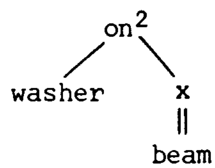
can be graphically represented by

(14) 

The substitution (binding)

(15) $(\lambda\ \text{hook})\ \text{on}^2\ (\text{washer, hook})\ (\text{beam})$

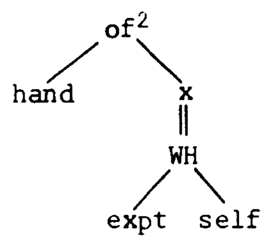
can then be represented by

(16) 

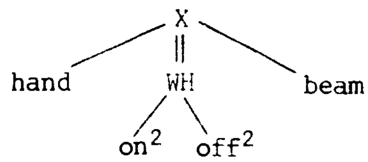
In order to denote elements or relations which are mutually exclusive in time we introduce a quasi-operator WH, of indefinite number of arguments

(17) WH (a, b, c, ...).

The value of WH at any moment of time is the single argument that is currently the case (as determined by some agency external to the perceptual complex). Thus in

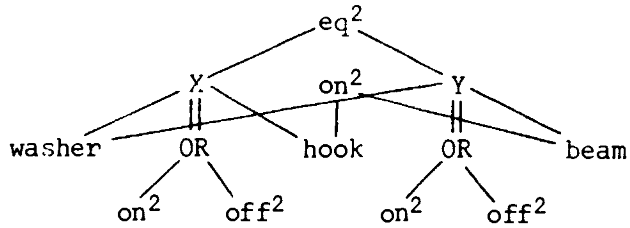
(18) 

or defines a field of 2 possible elements which can be bound to X. Likewise

(19) 

defines 2 possible relations which can unite hand and beam; only 1 can obtain at any given moment. Expressions of form (18) and (19) are defined to be PSRs.

This suggests that all temporally variant portion of a PSR be placed within the scope of WH operators, and that the process of transforming S_1 into S_2 be considered as a series of external (behavorial) resettings of WH values. The transformation problem remains non-trivial, however, since dependencies among the bound nodes will generally exist. Example:

(20) 

(eq^2 denotes X = Y, and thus requires F^{2P}). Even when the desired result and the prerequisite S_2 are well defined, the child may still experience difficulty in achieving the transformation $S_1 \rightarrow S_2$. Generally, in a simulation, the total $S_1 \rightarrow S_2$ transformation can be carried out as a series of part-transformations, each acting on one WH operator, of which (1.1) - (1.6) are examples.

Conclusion

We have suggested that at age 3 - 5 children's balance beam behavior is designed to transform an initial perceptual configuration into a subsequent "more desirable" one. Perceptual configurations consist of elementary perceptual relations and structured sets of perceptual relations organized so as to satisfy several categories of *a priori* structural constraints. Such models, though formulated here in terms of functional logic, are compatible with Witz's (1970) relational representations, and are ideally suited to computer implementation using the combinatory logic list-processing approach discussed by Weston (1972).

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APPENDIX 7

A Study of Free Pretend Play
by
Betty Delaney and Klaus Witz

A Study of Free Pretend Play

by

Betty Delaney and Klaus Witz

INTRODUCTION

Pretend play is one of the most common activities of children and is engaged in with varying degrees of sophistication by children from as young as two to as old as eleven or twelve years of age. Most of the previous work done on pretend play has concentrated on the function, as opposed to the structure, of play and has focused on children of from three to five years. The work has been largely dominated by two theoretical approaches: a role theory approach and a neo-Freudian approach. Role theorists regard play as serving a socializing function, whereas neo-Freudians regard it as satisfying certain affective needs.

The focus of this study is on <u>structure</u> in pretend play in small groups of children age 3 to 5 years. Our aim was to find regularities which would enable us to identify types of cognitive structures that are typically engaged in a pretend play situation. We were also interested in the developmental dynamics of pretend play and the changes in cognitive processes which could be observed over time. Astonishing regularities were observed, both in group play and in the play of individual members.

METHOD

Data Collection Procedure

We chose to work with children of approximately four years of age since our project had previously studied the cognitive processes of four-year olds engaged in other activities. Four is an ideal age because the children are quite verbal and yet spontaneous and uninhibited in their activity.

Children were selected for observation at two nursery schools on the University of Illinois campus. One was a cooperative day care center where mothers helped out one day a week, and the other was a nursery school run by the University for research purposes.

Groups of three to four children were selected during their free play period and brought into another room at the nursery school where they were video-taped. Children were chosen by the experimenter, with the aid of the teacher, on the basis of their ability to get along with each other and to engage in spontaneous play. Play objects were brought into the experiment room, and the children were asked to play with the toys. A small video tape camera was hidden in the corner of the room and flicked on when the children entered the room.

Twenty-four sessions were taped, but we were able to use only twelve of the tapes in the study. Two tapes did not turn out due to technical difficulties, and the other ten tapes were discarded because the children did not engage in pretend play. Either there were interpersonal conflicts within the group which inhibited group play, or the children were extremely shy and simply did not play spontaneously after they were brought into the experiment room.

Our original plan was to select two or three groups and video tape these twice a week over a period of two months. However, this plan did not materialize as it was discovered that the sociometrics of four-year olds change very frequently. Children did not want to play with others who had been their friends only a few days previously; in a few days they had already formed new social alliances. Out of six initial groups, only three would play together a second time and only one of those would play a third time.

The alternate plan we finally adopted was to tape as many of the same children over again as possible, but to allow for different group compositions. Most of the children were taped three or four times. /

Data Processing

Complete transcripts of the play sessions were made from the video tapes. All verbalizations and actions were recorded along with the name of the child who produced them. Time relationships between verbalizations and actions were preserved.

After prolonged study of the transcripts we finally settled on a basic unit of analysis which we have called a "Pretend Play Element" (PPE). An occurrence of a Pretend Play Element:

(1) consists usually of the utterance of a single phrase, often accompanied by a gesture, such as "I'm a fireman" along with the action of putting on a firehat;

(2) has a demonstrative component in the sense that it gives the analyst the impression that it is a proposal which is intended to be heard and accepted by the other children, i.e., it has a connotation of "let's be...", "you are...", "this is a...", "let's...", etc.;

(3) is appropriate to pretend roles, actions, situations, or objects.

When a PPE is introduced by one child and another child adds a new aspect to that PPE, the PPE plus the new aspect together are regarded as a PPE. For example, if one child suggests, "Let's be crocodiles", and another adds, "Let's be a crocodile family", then "crocodiles" and "crocodile family" are considered separate PPE's. If a PPE is intro- duced and a new aspect is added to it by the same child, the original PPE plus the new aspect is not considered a separate PPE, unless it is separated from the original PPE by a minute in time or more.

A second set of transcripts was prepared which included only PPE's along with the identity of the child who introduced them. Basic time relationships were preserved. Activities and verbalizations not included in the second generation transcripts include the following: (1) random motor activities, such as running around, (2) statements and actions which did not contain a make-believe component, such as "What are we doing in this room?", and (3) statements which were not necessarily intended to be heard by the other children, such as, "Oh, there's a doll".

STRUCTURES IN GROUP PLAY

(1) Themes

The largest unit in cooperative play we have called "Theme". There are usually two, but occasionally one or three, themes in a twenty- to thirty-minute tape. (This means that every PPE can be assigned to a theme.) Typical time structures of play periods in terms of themes are illustrated in Figure 1.

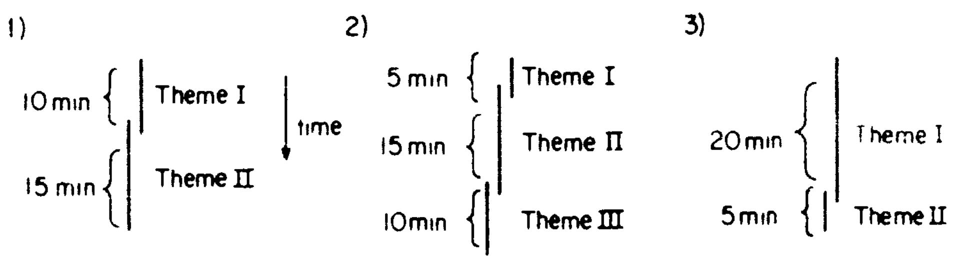


Figure 1

Themes are determined by either (1) roles, (2) a piece of equipment, or (3) a system of activities. If a theme is determined by pretend roles, such as "firemen", then these roles will remain constant during the theme. If a piece of equipment defines the theme, then its' meaning will be maintained; for example, if a theme is determined by a rocking vehicle which the children call a "boat", then the vehicle will continue to function as a "boat" throughout the theme. If a theme is a system of activities, then that system will have a certain structure which remains constant across occurrences.

The following is the list of themes and what determined them in the twelve tapes:

(1) Hilary, Karen R., Karen B., and Fiona

(a) Elevator (system of activities)

(2) Jennifer, Lara, and Meetu

(a) House (roles)

(b) Hospital (roles)

(3) Fares, Nashva, Angela, and Chris

(a) Fireboat (piece of equipment)

(4) Mark, Tommy, and Fares

(a) Housebuilders (roles)

(b) Firemen (roles)

(c) Ice/Water (piece of equipment)

(5) Mark, Tommy, Fares, and Chris

(a) Fireboat (piece of equipment)

(b) Water/Ice (piece of equipment)

(6) Mark, Fares, Angela, and Eyvin

(a) Family (roles)

(b) Alligator (roles)

(c) Housebuilder (roles)

(7) Amy, Robin, and Gerald (I)

(a) Fireman (roles)

(b) Monster (roles)

(8) Amy, Robin, and Gerald (II)

(a) Fireman (roles)

(9) Cindy, Alex, and Gerald

(a) House (roles)

(b) Policeman/Fireman (system of activities)

(10) Gerald, Alex, Andrea, and Io

(a) House (roles)

(b) Monster (system of activities)

(11) Jennifer, Lara, and Stephanie

(a) Boat (piece of equipment)

(b) Grocery store (roles)

(12) Jennifer, Lara, and Meetu

(a) Grocery store (roles)

(b) Witch (roles)

(c) House (roles)

It should be noted that there is some repetition of the same, or similar themes across tapes of the same group of children. The only correlation between themes and age is that themes are of a system-of-activities type only found in the youngest children (late three and early four-year olds).

(2) <u>Major Units</u>

A second type of structure in cooperative play we have called "Major Unit". In general,

(1) a given major unit may occur, with v.. [illegible] more times during a single play period (tape); different occurrences of the same major unit occupy time intervals anywhere from less than a minute to several minutes in length and may contain anywhere from 4 to 10 or more PPE's;

(2) in a given play period (i.e. on a given tape), major units do not cross theme boundaries.

Like themes, the same major unit may reoccur across tapes of the same group of children.

Individual major units (1) have internal organization based on content or an activity pattern; and (2) maintain a constant structure across occurrences. There are two distinct types of major units which we have called "Cycles" and "Linear Sequences", respectively. A possible third variety seems to be a degenerate form of a cycle.

(a) Cycles have the general structure shown in Figure 2.

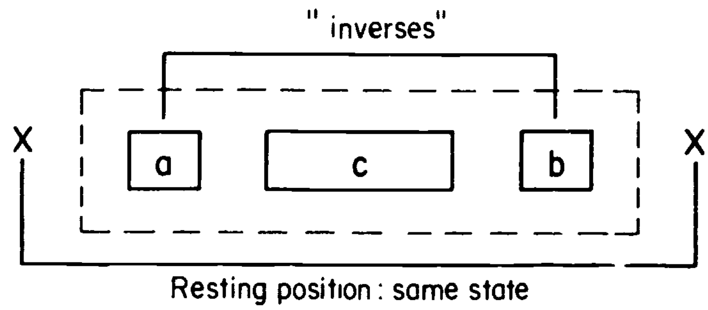


Figure 2

The boxes represent slots in which PPE's may be inserted in accordance with the requirements of a specific cycle. The "X's" indicate a "resting position" from which the child goes out and initiates the cycle, and to which he returns at the end of the cycle. A cycle has thus the following characteristics: (1) there is an initial slot "a", a terminal slot "b", and usually an intervening slot "c"; (2) the initial and terminal slots are filled by specific PPE's which are the inverse of each other; and (3) the PPE's in slot "a" signal a departure from the resting position and those in slot "b" call for a return to the resting position.

The medial slot "c" may be termed "optional" or "required" in the structural description of a particular cycle. The structural description of a cycle may also place "specific" or "general" requirements on the PPE's which can or must occur in the slots. A "general" slot indicates that PPE's must only relate to a certain activity; a "specific" slot, like "a" or "b" specifies which PPE's must occur if the slot is required or chosen.

The following are three examples of cycles:

Example 1: Gerald, Alex and Io tape (first occurrence of second distinct major unit in House theme)

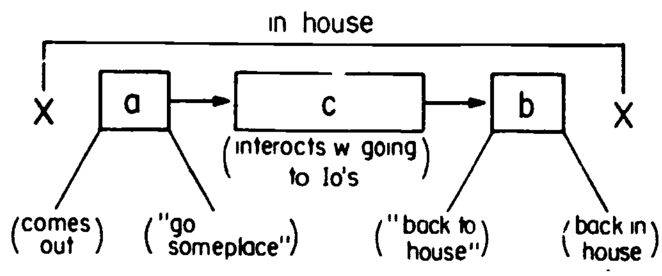


Figure 3

Positions in Cycle	Child	
a	(G,A)	(come out of house)
	(G)	"Maybe we'll have to go someplace"
c	(A)	"Why don't we go to Io's place."
	(G)	"Why doesn't everybody go in that house. Everyone go i that house, okay."
	(G,A)	(go over to Io's house)
b	(G)	"Let's go back in our house, ok_y."
	(G,A)	(go back to their house)

This cycle occurred twice in succession.

Example 2: Amy, Robin, and Gerald tape (I) (second occurrence of major unit in Fireman theme)

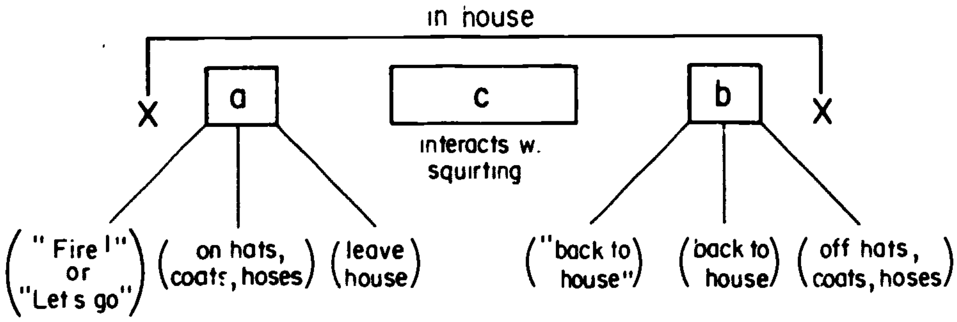


Figure 4

Position in Cycle	Child	
	(G)	"Let's go."
	(R,G)	(put on hats, pick up hoses, and leave firehouse)
a	(A)	"Forgot my firehat." (gets hat and hose, leaves house)
	(A)	"Firemen have coats, okay." (puts on coat)
	(R)	(puts on coat)
	(G)	"Hurry, have to get fire." (charges across room with hose)
c	(A)	(still putting on coat) "Need to get our heavy coats on."
	(A,R)	(pick up their hoses which they put down to put on coats)
	(R)	"Fire, fire, fire." (charges across room squirting hose)
b	(A)	"Go back to the firehouse." (goes back to house, takes off coat and hat, and puts down hose.)
	(G,R)	(go back to house, take off coats and hats and put down hose).

The cycle was repeated four times in succession, and once on a subsequent tape with the same group of children.

Example 3: Gerald, Alex, and Cindy tape (second occurrence of major unit in Fireman/Policeman theme)

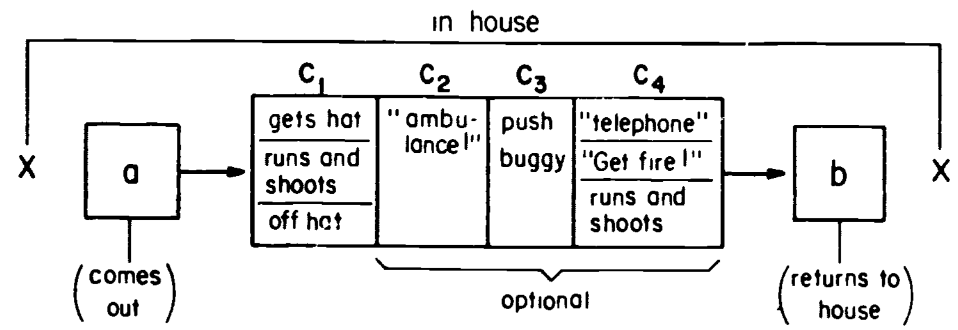


Figure 5

Position in Cycle	Child	
a	–(G,A)	(come out of house)
c_1	(G)	(gets hat out of buggy -- puts it on)
	(G)	(runs around shooting) "Bang, bang."
	(G)	(takes off hat -- puts it in buddy)
c_2	–(G)	"ambulance! Hurry, let's go in the ambulance."
b	(G)	(goes back in house) "Hurry!"
	(A)	(goes in house)

This major unit occurred nine times in succession on this tape.

(b) Linear Sequences have the general structure shown in Figure 6.

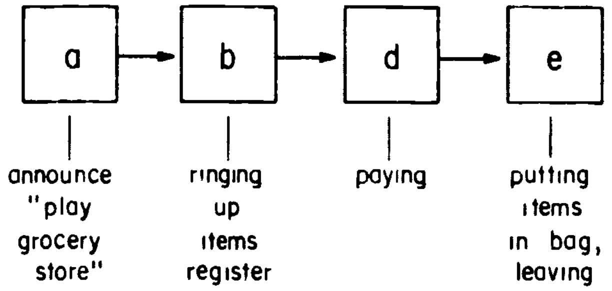


Figure 6

Linear sequences have thus the following characteristics: (1) the slots are ordered such that "d", for example, may only occur after "c", unless "c" is optional; (2) the sequence as a whole is usually announced in the first slot; (3) medial slots are filled with PPE's directed at the fulfillment of a general goal; and (4) the final slot involves completion of the sequence announced at the beginning.

Linear sequences are not symmetric, and the state of the children before the cycle and after its' completion are different. Any of the slots may be either "optional" or "required", and the PPE's in these slots may give "general" or "specific" requirements placed on them.

The following are three examples of linear sequences:

Example 1: Jennifer, Lara, and Stephanie (first occurrence of major unit in Grocery Store theme)

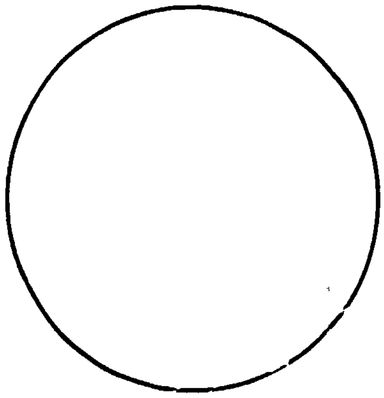


Figure 7

Position in Sequence	Child	
a	(J)	Want to be -- grocery store. (gets cash register)
	(L)	I'll buy groceries.
b	(J)	What do you have?
	(L)	Orange juice. (picks up imaginary O.J.)
	(J)	Orange juice. Okay. (pushes keys on cash register)
	(L)	Few apricots (picks up imaginary apricots)
	(J)	Try to get all of this. This is for 24. (pushes 24 on cash register)
	(J)	This is for 48. (pushes 48 on cash register)
	(J)	This is for 46, 21, 25, 22, 25, 23, 21, 26, 28, 24, 21. (pushes keys for each number)
d	(J)	Okay, let's see. (opens cash register drawer and gives L imaginary money)
	(L)	(takes money)
e	(J)	Put stuff in bag. There. (puts imaginary groceries in bag)
	(L)	(takes bag and walks over to rocking vehicle) Have to ride home in the boat.

This linear sequence occurred once on this tape and once on an earlier tape.

Example 2: Fares, Angela, Nashwa, and Chris tape (first occurrence of major unit in Fireman theme)

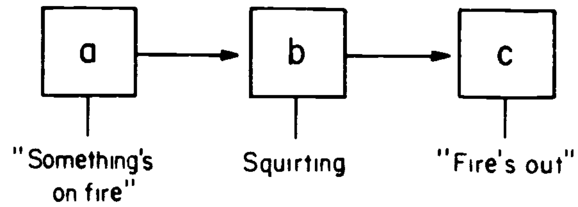


Figure 8

Position in Sequence	Child	
a	(A)	The building's on fire.
b	(A,F, C,N)	(pick up imaginary hoses -- bowling pins -- and squirt) Shhhhhhh!
c	(A)	Fire's out!
	(A,F, C,N)	(cease squirting)

This sequence occurred three times in succession on this tape.

Example 3: Jennifer, Lara, and Meetu (second occurrence of major unit in Witch theme)

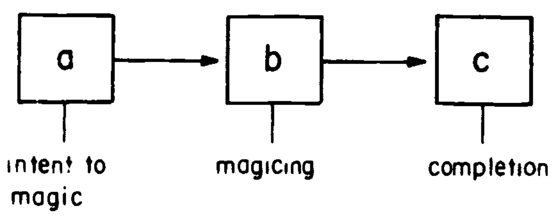


Figure 9

Position in Sequence	Child	
a	(M)	"Let's blow her dancing skirt, and then let's touch her, then let's magic her into a bad witch."
b	(M,J)	(carry out above stated activities while chanting "We magic her into a bad witch! We magic her into a bad witch!" several ti[illegible]
	(M)	She's a bad witch. (activity stopped)
c	(M)	We magiced her into a bad witch.

This linear sequence was repeated four times in succession.

Two types of variations appeared across different occurrences of cycles and linear sequences: (1) new PPE's were added to general slots, and (2) PPE's were expanded so as to create new PPE's. The former phenomena we call "additions" and the later, "expansions". Additions or expansions may take place across occurrences of a cycle or linear sequence within a tape or across different tapes. An example of an addition occurs in the second taping of Jennifer and Lara. The first time they play "grocery store" Jennifer simply takes imaginary groceries out of Lara's cart and rings up the prices on the cash register. The second time, Jennifer asks Lara, "What do you have?" and Lara responds, "Orange juice" and "apricots"; Jennifer then rings up some prices on the cash register. An example of an expansion occurs in the same tape, the second time that Gerald and Alex leave their house to visit Io. The first time, Gerald expresses his intention to go somewhere by stating, "Maybe we'll have to go somewhere." The second time, Gerald adds the roles of "Mommy" and "Daddy" to going "somewhere": "Mommy's going to somebody's house, okay. I'm going to visit, Okay, Daddy."

(c) Degenerate cases

Degenerate cases are special cases of cycles. Originally, there is the general structure of a cycle, but this becomes more and more abbreviated with each successive occurrence. The cycle is performed in a shorter and shorter period of time, and the structure breaks down as slots are deleted and the number of PPE's is reduced.

Example: Karen F., Karen B., Fiona, and Hilary

Child	
(K.F., K.B., & F)	(start pushing strollers around in a circle while chanting, "We're going to camp, we're going to camp!") (this goes on for about 2 minutes)
(H)	"Hold the elevator!"
(K.F., K.B., & F)	(all three run to their chairs and sit down)

After nine repetitions of the cycle, two of the girls drop out of play. Of the remaining two girls, one simply stands up from her chair, the other says, "elevator", and the first girl sits down.

(D) Descriptive Statistics

In nine of the twelve tapes, more than half of the PPE's occurred within major units. The percentage of PPE's taken up by a tape's major units ranged from 56% to 90% across the nine tapes. Of the remaining three tapes, one displayed no major units, and the other two each had one occurrence of the same major unit which accounted for less than 15% of the PPE's on either tape.

Cycles and degenerate cases occurred with groups of younger children, or with children who had little previous play experience. Very short linear sequences also occurred with these two groups of children. Longer linear sequences occurred with older children who were experienced in group pretend play. The absence of near-absence of major units was displayed by older children who had spent a great deal of time playing together previously,

Cycles typically increased in number of PPE's over the first several occurrences by means of additions and expansions, and then decreased in number of PPE's over the last few occurrences through deletion of optional slots. Linear sequences occurred less often within a tape than cycles, and the number of PPE's in linear sequences steadily increased both within the same tape and across tapes.

The largest number of distinct PPE's occurred on tapes of the older children (late four- early five-year-olds) who had played together for some time. These were the same tapes in which either no major units occurred, or else only one which accounted for less than 15% of total PPE's. The fewest number of distinct PPE's and the greatest number of repetitions of PPE's occurred with the younger children and those who had little experience with group pretend play. These were the tapes exhibiting cycles and degenerate cycles. The number of PPE's in tapes with linear sequences was midway between the number of those without major units and those with cycles.

STRUCTURES IN INDIVIDUAL PLAY; INTERACTION PATTERNS

(1) Frameworks and Bursts

We mentioned earlier that in a large proportion but not all of the tapes, the majority of all pretend play that occurred was stretched into major units. Some tapes showed a quite different make up, however, which became evident when transcripts were prepared in the format illustrated below. Initiation of each child are listed in a column, and time relationships are indicated by means of the standard conventions for reading text; i.e., from left to right and from top to bottom.

Example. Fares, Mark, Tommy, and Chris tape
(whole tape)

MARK	FARES	TOMMY	CHRIS
build firehouse			
		workman	
	firechief's hat		
	build me fire-house		
must help	Fares Burst I		
	build fireengine		
	where's fire-engine?		
building goofy firehouse			
	you build, I'll live in it		
will have to do all the work			
		here's hammer	
	the train		
	we have a train here		
get more trains	Fares Burst II		
	is it a train-station?		
	bring more trains		
	where's the engine?		
	this is a fire-engine		
	this is a fire-block		
	I am a housebuilder because put hat this way		
		forgot to hammer	
		that's the refrigerator	
	I'm going in firehouse		

MARK	FARES	TOMMY	CHRIS
I fell on house			
			gotto have a hat
if no hat, not a fireman			
		can't sit on refrigerator	
		forgot to hammer refrigerator	
		this is a fire-boat, you're in the water	
Mark Burst 1			
ice here			
I'm iceskating			
there's ice in the house			
ice out here			
forgot to take off hat			
I'm breaking ice			
			It'll turn into water
the ice broke			
		swim	
he's diving			
here's alligator cutting it			
	got him		
broke ice			
		you broke house	
			pooh-pooh broke it
		that's the refrigerator	

MARK	FARES	TOMMY	CHRIS
get off, I want to eat			
tornado outside			
		tornato can lift house	
			I caught him
you're going up too			
		too late...	
			I caught him
you're going right up to the sky			
		too late...	
	he's dead		
			he's caught
	he's dead		
can't kill tornado			
			if cut it, dead
		your dad can't cut up tornado	
you have to fight with it			
you have to kick it			
	tornado is up in the sky		
you can't fight it			
		you broke refrigerator, get off	
get off			
	that's chair		
(M. drinks from refrigerator)			
		that's milk	
		put it back	
		don't break up house	

MARK	FARES	TOMMY	CHRIS
	let's dive		water coming in house
	I'm swimming		
		whole house breaking up look there	
(knocks over blocks--tells F. to stop)			
	water in house (swims)		
		my typewriter	
			water's breaking up
don't break			water broke it
			water's coming in house
(starts building)			if door open, water can come in
			need a swim
	I'm diving		
nobody's building but me			
			water's coming in house
Only I can live in house because I built it			
	You'll go down in the water		
want to iceskate			
ice is so hard			
ice broke, skate			
tired of iceskating			

This example illustrates two phenomena, frameworks and bursts, which show up in two of the three other tapes which have no theme and major unit structuring. Phenomenologically, frameworks are characterized as relatively long periods (several minutes) in which an individual produces isolated PPE's separated by long intervals, suggesting prolonged internal preoccupation with some subject matter and for set of activities during this period. Frameworks in this sense are thought to be underlain by cognitive structures which are at least similar to, and very possibly identical with, the frameworks described in Witz, "An Analysis of "Frameworks" in Children". Bursts are somewhat of a group phenomenon. Phenomenologically they are characterized as brief periods of an extremely high rate of PPE production by a single individual, during which most of the other members of the group are at least half listening. This suggests intense imaginal activity in the individual in which the burst occurs, perhaps heightened by his awareness of his role as generator of new ideas for the group at that time.

GENERAL INTERACTION

When a child introduces a PPE, the other children's responses may be classified into six different types. The type of response is linked to the nature of the PPE and its positive or negative contribution to the ongoing frameworks of the other children. Four types of responses involve picking up of the PPE by the other children and two do not; four are positive responses and two are negative.

(1) Disregard: The other children may completely ignore one child's proposal. The first child will usually repeat his PPE until he obtains some type of response from the others. A PPE is generally ignored if it conflicts with the ongoing frameworks of the other children.

Example: Angela, Fares, Chris, and Nashwa tape--

The children are in a rocking vehicle which they are pretending is a boat; they are rocking the boat, pretending that it is moving. Chris yells, "The boat ran out of gas", but is ignored by the others, perhaps because acknowledgement would require that they discontinue rocking. Chris then repeats his statement twice, each time in a louder voice. Finally, Fares says, "No, we're not really out of gas", as the children continue rocking. (Fares' response is classified as "negation" which will be discussed later.)

(2) Acknowledgement: A proposal may not require that the others response to it either verbally or with some kind of action. The fact that the others have heard it is sufficient for the speaker; the others need only look at him and indicate acknowledgement.

Example: Angela, Fares, Chris, Nashwa tape--

The children are still in the rocking vehicle, but have stopped moving. Fares subsequently suggests, "I pushed the brake. That made it stop." The others acknowledge his statement, but do not respond verbally.

(3) Imitation: A PPE may be repeated by one or more of the other children; if it is accompanied by actions, these two may be imitated. Imitation usually occurs when all of the children are operating in pretty much the same framework.

Example: Karen F., Karen B., Fiona, and Hilary tape

The girls are playing with their strollers. Karen F. begins to push her stroller in a circle, exlaiming "I'm going to camp." The other three girls then get up and begin to push their strollers and chat, "I'm going to camp, I'm going to camp."

(4) Systematic Variation: A child may respond to a PPE by repating the predicate but substituting in a different object which, however, belongs to the same conceptual category. This type of variation usually occurs when children are operating within very similar frameworks.

Example: Karen F., Karen B., Hilary, and Fiona tape--

The girls are playing with purses, play clothes, and dishes. Fiona walks over to pick up a cupcake tin and states,"I'm going to make some cupcakes." Karen F. gets up immediately afterwards and picks up another dish, and suggests, "I'll make some jello." Finally, Hilary gets up a dish as she states, "I'll make butter."

(5) Negation: A PPE may be denied if it conflicts with the ongoing framework of another child. The second child may simply state that the PPE is not true or he may make a contradictory statement. Sometimes he will do both.

Example: Fares, Mark, Tommy, Chris tape--

Mark is in the process of building a house which the children pretend is surrounded by water. Chris knocks over part of the house and states, "The water broke it." Mark retorts, "No, it didn't" as he replaces the fallen blocks and continues building. Chris then knocks over a few more blocks as he suggests, "The water's coming in the house." Mark replaces the blocks as he maintains, "No, it can't."

(6) Appropriation: This type of response occurs when children are operating in separate frameworks which are not contradictory. The responding child will pick up a part of the new pretend situation and add something to it from his own framework, creating a new PPE. Often there will be a sequence of appropriations one child initiates something and a second responds by appropriation, the first child then appropriates in turn from the second and so on, often in a very creative way. The appropriations here can be displayed as follows:

A: good crocodile

F: (crocodile) + cat

A: (crocodile [to be eaten?]) + baby

F: (baby crocodile) + baby food

A: (baby crocodile, baby food) + big crocodile

F: --

A: (big crocodile) + grr, attack

F: (big crocodile, grr-attack) + good one

A: --

F: (good big crocodile) + food

A: ([good!] big crocodile) + devouring

Sequences of appropriations of this length and this level of creativity make up about 2/3 of two of the tapes, and presumably represent a structural feature of pretend play on a par with major units, and frameworks and bursts. They probably play an important role in the social development of the individual.

APPENDIX 8

A Study of Children's Rhythmic Movement

Karen Jensen

A Study of Children's Rhythmic Movement

by

Karen Jensen

This pilot study of children's rhythmic movement was begun in February 1971. The objective was to determine the young child's natural movement repertoire, to find out the cognitive structures which tie locomotor co-ordination to perception of beats, and to observe the development of rhythmic adaptation to different tempo.

My task was to work with a group of 3 or 4 children by encouraging them to move to musical stimuli without giving them cues of my own which they would imitate. I selected music that would both appeal to children and have a strong but uncomplicated rhythmic beat: German folksongs, songs by Burl Ives, Danny Kaye, and The Beatles, and pieces by Sousa, Prokofief, Khatchaturian, and Praetorius. Pieces were prerecorded in sequence on audiotape and played back without pause during the session.

Videotaping began with the second session, in which three children participated: Billy, 3;9, Johnny, 3;9, and Simon, 3;7. The tape shows many movement repertoire elements which also occur in later tapes, but the music seems to have had little influence on the children. For example, Simon moved with the beat of the music for only a short time in 4 of the 8 pieces.

The same children again took part in session 3 a week later. In this session I gave more definite and clearer directions. I said, for example, "Beat the drum the way the music goes" to introduce the idea of making definite movement to music. I briefly demonstrated "dancing" to music by rocking and showed the children how to move their feet to another song. The children began to improvise and continued throughout the session. At times during some of the selections their movements seemed to correspond with the rhythm in the music, but this happened infrequently. Other elements in music (dynamics, phrasing, and texture) seemed to have a greater influence on the way they moved than rhythm. The children often seemed to respond to a change in tempo by a corresponding change in their speed or level (standing or floor movement) even though their movements were not rhythmically accurate. Most of the time the children seemed simply to enjoy the movements they were making.

After preparing a protocol of this session, the periods of time Simon spent "moving with the music" and "involved in his movement" were measured on an event recorder. "Movement involvement" periods were defined as those times when he seemed to be very awareof the movements he executed. These movement ideas may have been initiated by the experimenter or another child but Simon did not continue to look to anyone else for cues. "Moving with the music" or "music involvement" periods were defined as those times when Simon seemed to be moving to the beat of the music or responding to the music's dynamics, phrasing, or texture.

Table 1

List of Movement Repertoire Elements
on Simon in Sessions 2 Through 4

simple run
not accompanied by special arm or leg movements, etc.

simple walk
not accompanied by special arm or leg movements

lifting arms
alternately lifting arms from hanging down position to a 60° to 90° angle laterally away from body

outstretched arms
holding both arms horizontal and stretched out laterally away from body

armswing, in phase
swings both arms together up and back parallel to the sagittal plane, so that the hands almost touch at the end of the upswing, swings are vigorous, from the 5 o'clock to the 10 o'clock position and back

armswing, out of phase
swings both arms simultaneously and in a common rhythm back and forth parallel to the sagittal plane, but out of phase, i.e., always in the opposite direction

forward gallop
torso faces forward, right foot is leading

side gallop (while galloping in a circle)
torso faces center of running circle right foot leading, left foot points into circle
Note: gallops sometime become accented runs

turning left foot out
while weight is on right foot, left foot describes small circle, with the heel the describing most of the outermost curve

torso
binds torso from waist up alternately to the right and to the left

twirling
usually at one and the same place, with outstretched arms

march

Table 2

Movement-Music Involvement
Session 3

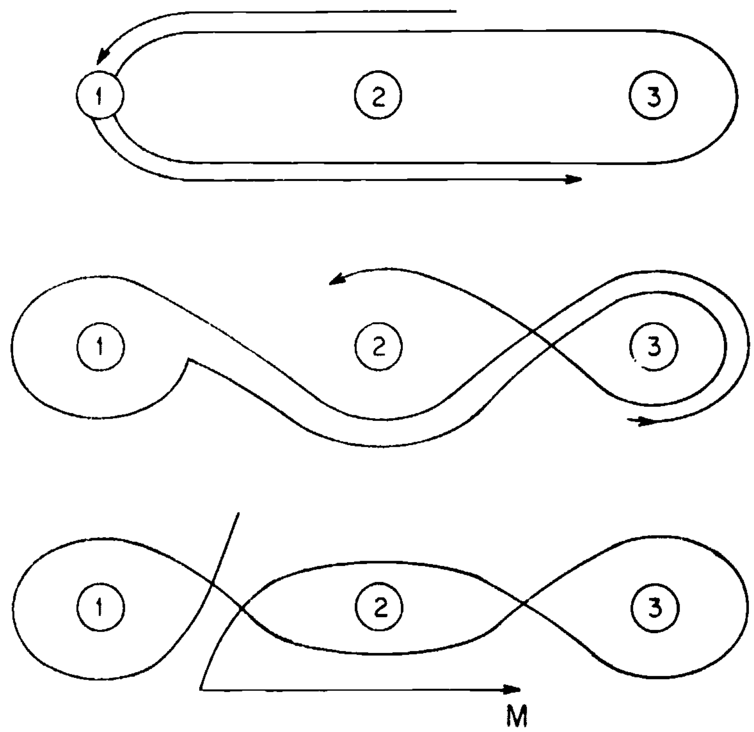
Music	(1) Length of piece (secs)	(2) Movement alone	(3) Music alone	(4) Movement + music involvement simulated (m+m)	(5) Total time involved in movement or music
Sousa	180	0	150	7	157
Copenhagen	70	32	0	0	32
Prokoviev	95	10	42	0	52
Wanderer	180	56	49	0	105
Khatchaturian	140	38	22	0	60
Prokoviev	95	31	3	6	40
Woodstock	180	26	64	25	115
Beatles	115	4	0	0	4

*Application of these categories was rather subjective and measurement was also inexact.

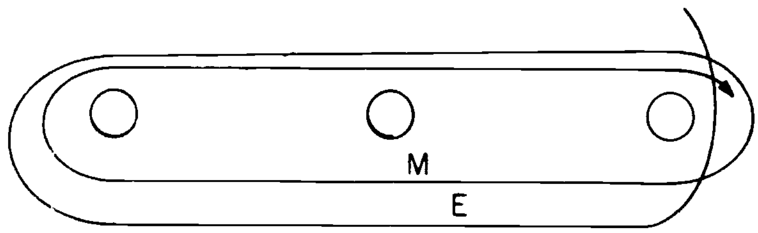
Unfortunately, I did not differentiate under the heading between the periods in which Simon moved to the rhythm of the music and the times when he responded to other cues. From the protocol notes, the music to which Simon moved rhythmically (at some time) was determined. Comparing this to the data above on percentage of music spent in movement involvement or musical response shows that Simon moved to the beat of the music in all of the songs where the music/movement involvement was over 50%.

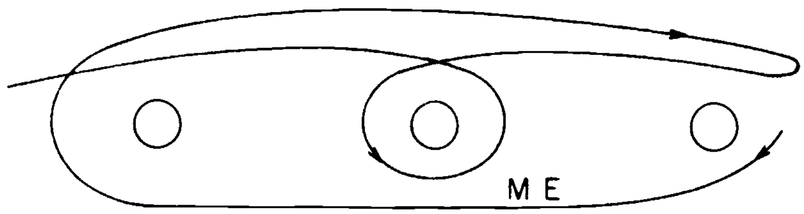
In this session the children often moved in circles, picking something in their environment as the center of their movement pattern. Simon and Billy chased each other or spaced themselves on the floor in relationship to one another's movement. They frequently tackled, pushed, kissed each other or just come up to touch each other. Johnny, who was a stranger to the other two and who was also shy, wasn't included as often.

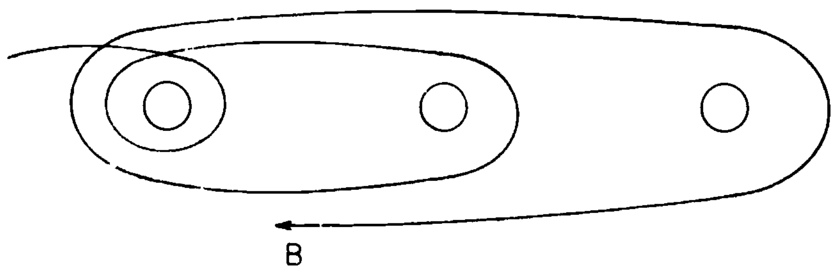
The fourth session was taped a week after the third. The same music was used as in the previous session, and the same children participated, this time joined by a little girl, Michelle. Since accidental objects in the environment had seemed to have an effect upon the children's floor patterns in session 2, we decided to place three "drums" (a metal pan, a large plastic tupperware container, and a drum) on the floor. The result was that the children, particularly Simon, spent a great deal of time moving between and around the drums. For example at the beginning of the first piece, a Sousa march, Simon traced out the following path, touching Billy twice along the way and kneeling down beside Michelle (M) at the end:



After getting up and walking twice around the room along the walls, touching walls and furniture as he was passing by, he resumed his running, gallopping etc. with respect to the drums, except that he included the experimenter and Michelle as additional centers:







There was a comparable quantity of patterns, but always different ones, in the next three pieces.

The fifth session another week later was moved by general disinterest in movement during the first half of the session. The children were distracted by the taperecorder and spent a lot of time imitating Michelle's thumb sucking. The experimenter danced with the children the entire session, and reminded them that they were to show her different ways of moving. Eventually this seemed to result in a better session.

APPENDIX 9

Comprehension of Relative Clause Sentences in Children
Excerpt: Method and Results

by
Morton E. Winston, M. A. Thesis
Department of Psychology
University of Illinois, Urbana, Illinois, 1971

Comprehension of Relative Clause Sentences in Children

Morton E. Winston, M.A. Thesis
Department of Psychology
University of Illinois, Urbana, Illinois, 1971

Method

Subjects: The subjects for this experiment were obtained from the Child Development Laboratory of the College of Education of the University of Illinois. They consisted of pre-school boys and girls between the ages of 3,5 and 4,9: Robin (3,5), Jamie (3,6), Sarah W. (3,11), Jodie (4,0), Gerald (4,3), Lisel (4,5), Jeff (4,5), Sarah N. (4,5), Julie (4,6), Navara (4,7), Angela (4,9), and Carl (4,9). Twelve children were used in this experiment; the majority of them are children of faculty members of the University of Illinois. They are all slightly above average intelligence.

Procedure: The method employed in this study was adapted from that used by Sinclair de Zwart and Bever (1968). Children are seated at a table on which there are various objects which will be used as concrete referents for noun phrases which appear in the test sentences. The objects used for this purpose were: a male doll "the boy", and female doll "the girl", a baby doll "the baby", a dog, a horse, a rabbit, a car, a boat, a truck, an airplane, a ball, a box, a chair, a shovel, and a bottle. Children were taken out of their morning classes by the interviewer (the author), and were led to a small room in which they were seated at the table. The room was equipped with a one-way mirror and a videotape camera; in the adjoining room, an assistant ran a Sony ½ inch video tape machine which recorded the entire interview.

Every attempt was made to put the subjects at ease. They were told that they were going to play a game with the toys on the table. The interviewer instructed the subjects that he was going to read them some sentences and he wanted the child to act out with the toys what the sentence said. The subjects had no difficulty in understanding these instructions and they all quickly mastered the task they were to perform with only one or two practice sentences. The interviewer then proceeded to read the test sentences to the children. When a child hesitated or seemed confused (in the interviewer's opinion), the sentence was repeated, and it was continued to be repeated until either the task was completed correctly or the child gave up on it. The judgment of the interviewer was also relied upon to some extent in the selection of test items. If a child seemed to have special trouble with one of the sentence types, he could repeat it until he was sure he had confirmed the existence of the phenomenon of interest. Occasionally, the task character of the interview was broken by the child's attention wandering or the interviewer stopping to ask the child some questions. After a brief period of informal interaction, the experimenter asked the child if he wished to continue with the game; if the child answered "yes", the test sentences were continued until all types were exposed; if the child did not want to continue the interview was terminated. Most all of the children had no difficulty sitting through the interview which usually lasted about 20 minutes, and many appeared to enjoy the task greatly.

Test Materials: The objects used as referents for the noun phrases which appeared in the test sentences can be divided into two types: animate nouns, either human or animal, and inanimate nouns. The verbs used in the test sentences can be divided into three types depending on the semantic constraints they impose on their ACTOR and OBJECT relations. All the verbs are transitive or were used transitively.

(I) verbs which can accept any kind of ACTOR and OBJECT

push	bump
lift	move
hit	carry

(II) verbs which must have an animate ACTOR

hide	drive
throw	chase
jump over	ride
kick	

(III) verbs which must have animate ACTOR and OBJECT

kiss	bite
hug	dances with
spank	

These verbs and the noun phrases already mentioned were combined in simple clauses, then in more complex sentence forms in order to obtain the test sentences. Semantic constraints on the interpretation of sentences derive both from the type of verb and from the selection of noun phrases, and pronouns if there are any.

(1) the car was bumped by the truck.

Sentence (1) has no constraints while (2) does.

(2) the ball was thrown by the boy.

In sentences containing multiple clauses and pronouns, the lack of semantic contraints results in ambiguity.

(3) The plane hit the car, and it was driven by the boy.

In sentences with relative pronouns, the sequential rules insure a single interpretation for adult speakers.

(4) The plane hit the car which was driven by the boy.

The general rule for interpretation of relative clause sentences is that the noun phrase directly preceding the relative pronoun is its antecedent.

Altogether 27 different types of sentences were presented to the subjects in this experiment. They will be arranged here according to deep structure types and transformational histories, in order to sensitize the reader to the structural complexities of the sentences. The transformational analysis presented here does not claim to be the most elegant and well-considered treatment of the data. It is a fairly standard treatment which employs rules and assumptions already familiar to the community of transformational linguists. The analysis attempts only to clarify the nature of these sentences as seen from the point of view of adult grammar, the grammar which produced them.

I. Simples

A. Simple active: this type is the simple clause of the subject-verb-object form.

(1) The girl kissed the boy.

B. Simple passive: the passive transformation is probably the most familiar. It operates on deep structure clauses in simple form. It inverts the NPs and adds "was" and "by". The ending of the verb is changed to PAST.

(2) The dog was spanked by the baby. (the baby spanked the dog) DS

II. Conjoined

A. Conjoined active: these consist of two simple clauses united under a single S and separated by "and". The transformation involved is labelled CONJ.

(3) The pony carried the shovel and the boy kicked the ball.

B. Conjoined passive: same as (A) except that one clause is passivised. Either clause may take passive.

(4) The box was hit by the boat and the boy kissed the pony.

C. Conjoined double passive: both clauses get PASS.

(5) The truck was driven by the baby and the ball was carried by the girl.

III. Pronominalized - these are sentences of two clauses with only three different NPs, i.e., one NP is shared by the two clauses. In one of the clauses, the second, the shared NP is replaced by its appropriate pronoun. There are four types, one for each deep structure configuration of NPs. The transformations are CONJ and PRO.

A. Pronominalized (0,0): here the object of each clause are identical.

(6) The girl cleaned the bottle and the boy carried it.

B. Pronominalized (0,S): the object of the first clause and the subject of the second are the same.

(7) The car chased the boy and he hit the dog.

C. Pronominalized (S,0): the subject of the first clause and the object of the second clause are identical.

(8) The pony knocked over the bottle and the girl spanked him.

D. Pronominalized (S,S): the subjects of both clauses are identical.

(9) The baby drove the boat and she hugged the dog.

E. Ambiguous Pronominalized (S,S/0,S): the ambiguity derives from the fact that either NP in the first clause can function as the antecedent of the pronoun.

(10) The dog bit the pony and he jumped over the chair.

F. Ambiguous Pronominalized (0,0/S,0)

(11) The plane flew over the box and the truck bumped it.

IV. Deleted Pronominalized - It is possible to delete the second of two identical NPs if each appears in the subject position on its clause. The passive applies to the four deep structure configuations in order for the deletion rule to apply. Subjects were tested on only one of these forms the (S,S) since their competence with PASS was tested elsewhere.

A. Deleted Pro (S,S)

(12) The boy spanked the girl and drove the car.

B. Verb Phrase Conjunction: this form is related to the deleted pro form because it can be viewed as the case where both the subject and objects of the two clauses are identical.

(13) The girl kissed and hugged the boy.

V. WH Relative Clauses - there are again four types of relative clause deep structure, but for each there are more than one transformational routes to surface structure.

A. WH Relative (0,0)

(14) The boy drove the boat which the dog chased.

The transformations involved are EXTRA (extra-position) which moves the second NP of the second clause to the front of the clause, and WH replacement, which substitutes a WH form for the extraposed NP and deletes "and".

(15) The truck carried the ball which was cleaned by the baby.

In this case PASS is used instead of EXTRA to move the NP to head position.

(16) The boat which the boy drove was chased by the dog.

PASS on second clause, EXTRA "boat" to beginning of first clause, SUBJECT raise "boat" out of second clause into first, EXTRA the subject raised "boat" to beginning of first clause, WH replace the second "boat".

B. WH Relative (0,S)

(17) The girl hugged the boy who cleaned the car.

WH replacement.

(18) The boy who was hugged by the girl cleaned the car.

PASS the first clause, SUBJ and EXTRA "boy" from second clause, WH replace. Note: another form can be obtained by applying

EXTRA instead of PASS to first clause, but applying PASS to both clauses yields the unacceptable.

(19) The boy who was hugged by the girl the car was cleaned by.

C. WH Relative (S,O)

(20) The rabbit who chased the truck was hugged by the boy.

PASS, SUBJ raising, EXTRA, WH replacement.

(21) The truck was chased by the rabbit who the boy hugged.

PASS, EXTRA, WH replacement. Note: another form can be derived here from double PASS.

D. WH Relative (S,S)

(22) The boy who spanked the girl drove the car.

SUBJ raising, EXTRA, WH replacement. Note: another one which was not tested is derived through use of PASS instead of EXTRA.

VI. Deleted WH - There are three types of WH sentences from which the WH pronoun may be deleted, the fourth, (S,S) becomes identical with the deleted pronominalized sentences and must contain the conjunction.

A. Deleted WH (O,S)

(23) The boy the girl hit drove the boat.

SUBJ raise, EXTRA, WH replacement, WH deletion. Note: the deleted WH sentences of the form (S,O) was not tested, and the one in the (O,O) form was only given three times, too small a sample to be included in the data.

VII. Time Adverbial Relative Clauses with "before" and "after". In these sentences, the WH form is replaced by the time adverbials. When this occurs, it is possible to transpose the clauses so that the pronominalized clause occurs first, and it is also possible to delete the pronoun. Eight types were tested but unfortunately, since they occurred at the end of the interviews, the sample obtained for each was small.

A. Before/After Pronominalized (S,S)

(24) The boy kissed the girl before/after he cleaned the truck.

(25) Before/After he cleaned the truck the boy kissed the girl.

B. Before/After Deleted Pro progressive (S,S): when the pronoun is deleted the verb changes to PROG.

(26) The baby kissed the boy before/after spanking the pony.

(27) Before/After spanking the pony the baby kissed the boy.

Results

Transcripts of each child's interview were made from the video tapes. The experimental format, the informal interview, was chosen to allow the child to interact freely with the task and the experimenter, and the tapes revealed that many interesting clues to the child's abilities are hidden in his moment-to-moment behavior during the completion of each sentence task. For this reason, it will be necessary to first present the data in a more or less anecdotal form, examining the results by sentence types and citing examples of the children's actual performance on them. The quantitative analysis of the data rests on the rather arbitrary criterion of error as those sentences where the experimenter had to repeat the sentence at least once. Obviously, in some cases, repetition of the sentence was only occasioned by the subject's momentarily forgetting part of it, and not because of any inherent difficulty in his grammar. In other cases, children performed the task surely thinking they got the sentence correctly, when in fact they did not, and the interviewer went on to the next sentence. For this reason, the data do not particularly lend themselves to sharp quantitative analysis; such analysis was made but it should be regarded as only reliable when indicating a large statistical preponderance, that is, merely as a guide to possible hypotheses which explain the results.

SUMMARY TABLE OF RESULTS:
Showing for Each Subject the Number of
Sentences of Each Type Presented and
the Number of Errors Made in Execution

Child	SS Age	Simple Active	Simple Passive	Conjoined Active	Conjoined Passive
Robin	(3,5)	2	2 1		
Jamie	(3,6)	3	2 1		
Sarah W.	(3,11)	3	5 4	1	2 2
Jodie	(4,0)	2	4 3	1	1
Gerald	(4,3)	3	1	2	1 1
Lisel	(4,5)	2	3 2		
Jeff	(4,5)	2	1 1	1	
Sarah N.	(4,5)	4	2 1	1	
Julie	(4,6)	2	2 1	1	1 1
Navara	(4,7)	1	1	1	1
Angela	(4,9)	2	1 1		
Carl	(4,9)	2	3 1	2 2	
TOTALS		28 0	27 17	10 2	6 4
PERCENT ERRORS		0	63%	20%	67%

SUMMARY TABLE OF RESULTS (continued)

Child	SS Age	Pro (0,0)	Pro (0,S)	Pro (S,S)	Pro (S,0)	Ambiguous Pro (S,S/0,S)	Ambiguous Pro (0,0/S,0)
Robin	(3,5)		1		1		
Jamie	(3,6)	1			1	2	
Sarah W.	(3,11)	1	2 1	1	1	1	1
Jodie	(4,0)		1 1		1 1		
Gerald	(4,3)	1		1	1 1	2	
Lisel	(4,5)			1		1	2
Jeff	(4,5)	1	1		1	1	
Sarah N.	(4,5)	1	1		1	1	
Julie	(4,6)	1					1
Navara	(4,7)	1	1 1		1		1
Angela	(4,9)	1	1	1	1	1	2
Carl	(4,9)						
TOTALS		9 1	9 4	4 0	8 2	8 0	9 0
PERCENT ERRORS		11%	45%	0%	25%	---	---

SUMMARY TABLE OF RESULTS (continued)

Child	SS Age	Deleted NP (S,S)	WH Relative (O,O)	WH Relative (O,S)	WH Relative (S,S)	WH Relative (S,O)
Robin	(3,5)	2 1		1 1	1 1	1 1
Jamie	(3,6)		1	2 2	1	
Sarah W.	(3,11)	2 2	1	1	2 2	2 2
Jodie	(4,0)	3	3 3	2 1	3 2	2 1
Gerald	(4,3)	1	1 1	1 1	2 1	1 1
Lisel	(4,5)		2 1	3		1 1
Jeff	(4,5)	1 1	2 2	2 2	2 1	1 1
Sarah N.	(4,5)	3 2	1 1	2	2 1	1
Julie	(4,6)	1	2	1	3 1	1
Navara	(4,7)	1	1	1	1	1 1
Angela	(4,9)	1 1	3	2	3	1 1
Carl	(4,9)	2 2	2	1 1	1	1
TOTALS		17 9	19 9	19 8	21 9	13 9
PERCENT ERRORS		53%	47%	42%	43%	69%

SUMMARY TABLE OF RESULTS (continued)

Child	SS Age	Deleted WH Relative (O,S)	Before/ After Pro (S,S)	Trans Before/ After Pro (S,S)	Trans Before/ After Deleted Pro (S,S)	TOTAL	PERCENT ERROR
Robin	(3,5)					11 / 5	46%
Jamie	(3,6)					13 / 5	39%
Sarah W.	(3,11)	3 / 3				29 / 16	55%
Jodie	(4,0)	2 / 2				28 / 14	50%
Gerald	(4,3)	1 / 1	1 / 1		1 / 1	21 / 9	43%
Lisel	(4,5)	4 / 3	1 / 1	1 / 1	3 / 2	24 / 11	46%
Jeff	(4,5)					18 / 10	61%
Sarah N.	(4,5)	2 / 2	5	1	2 / 1	30 / 9	30%
Julie	(4,6)	2 / 1	2	1		21 / 4	18%
Navara	(4,7)	2 / 2	1		1	17 / 4	24%
Angela	(4,9)					20 / 3	15%
Carl	(4,9)	2 / 2	1	1 / 1	2 / 1	20 / 9	45%
TOTALS		18 / 16	11 / 2	4 / 2	9 / 5	249 / 99	40%
PERCENT ERRORS		89%	18%	50%	55%		

APPENDIX 10

The Representation of Cognitive Frameworks in Young Adolescent Science Students

(Dissertation - Abstract)

Rosalind Driver

The Representation of Cognitive Frameworks in Young Adolescent Science Students

Rosalind Driver

The setting for this study was the subfreshmen science class at University High School in Urbana, a laboratory high school which is part of the Curriculum Laboratory of the University of Illinois. (Students in this school tend to be in the top 20% of the total school population in terms of academic ability.) For several years the science course offered to the subfreshmen has been oriented towards the students developing their own theories and models for phenomena through a process of experimentation and debate. The general plan of this study was to study this process in detail in individual children over a period of several months.

At the beginning of the semester every student in the class was given formal level tasks selected from Inhelder and Piaget's The Growth of Logical Thinking from Childhood to Adolescence, motion in a horizontal plane, motion of a pendulum, the shadow task, the chemicals task, and hauling weights up an inclined plane. After the students had spent several weeks in class and had had a chance to find partners they enjoyed working with, two pairs of two students each were selected which worked well together and which represented as broad a spectrum of performance on the formal level tasks as possible: Tom (12) and Carl (11), and Cathy (12) and Jill (11). From that point on, all activities of these students in the class were followed over a period of 14 weeks.[1] During this period the class went through three instructional units on balancing systems, on springs, and on force and motion, respectively, always according to the following pattern: After an initial orientation by the teacher, the students (divided into 2 man teams) were given apparatus and materials to interact with and experiment with on their own, and then the class would congregate and discuss the general ideas, models or theories they had developed. In many cases the students were also asked to write a paper on their work. During the class periods, the teacher would circulate freely among the groups, furnishing new materials and also suggesting questions the students hadn't asked before; in addition he gave short talks to the class in common problems that had come up.

In order to understand better the thinking of the 4 students in the area of each unit, each was interviewed on a set of tasks relevant to this unit (pre-instructional interviews). Similarly all four were interviewed individually at the completion of a unit on tasks selected on the

[1] In spite of the care used in selecting the subjects, Tom and Carl soon began to have difficulties in working together and Ricky (11) was chosen to replace Carl.

basis of what was done in the unit (post-instructional interviews). For example, for the unit on force and motion on horizontal and inclined planes, post-instructional interviews were given on tractor pulling cart, ball on track, exploding carts, block pulled by weight over a pulley, force on an incline (measured by spring balance), and motion down an incline. The total body of data thus collected for this study is summarized in the diagram on the next page.

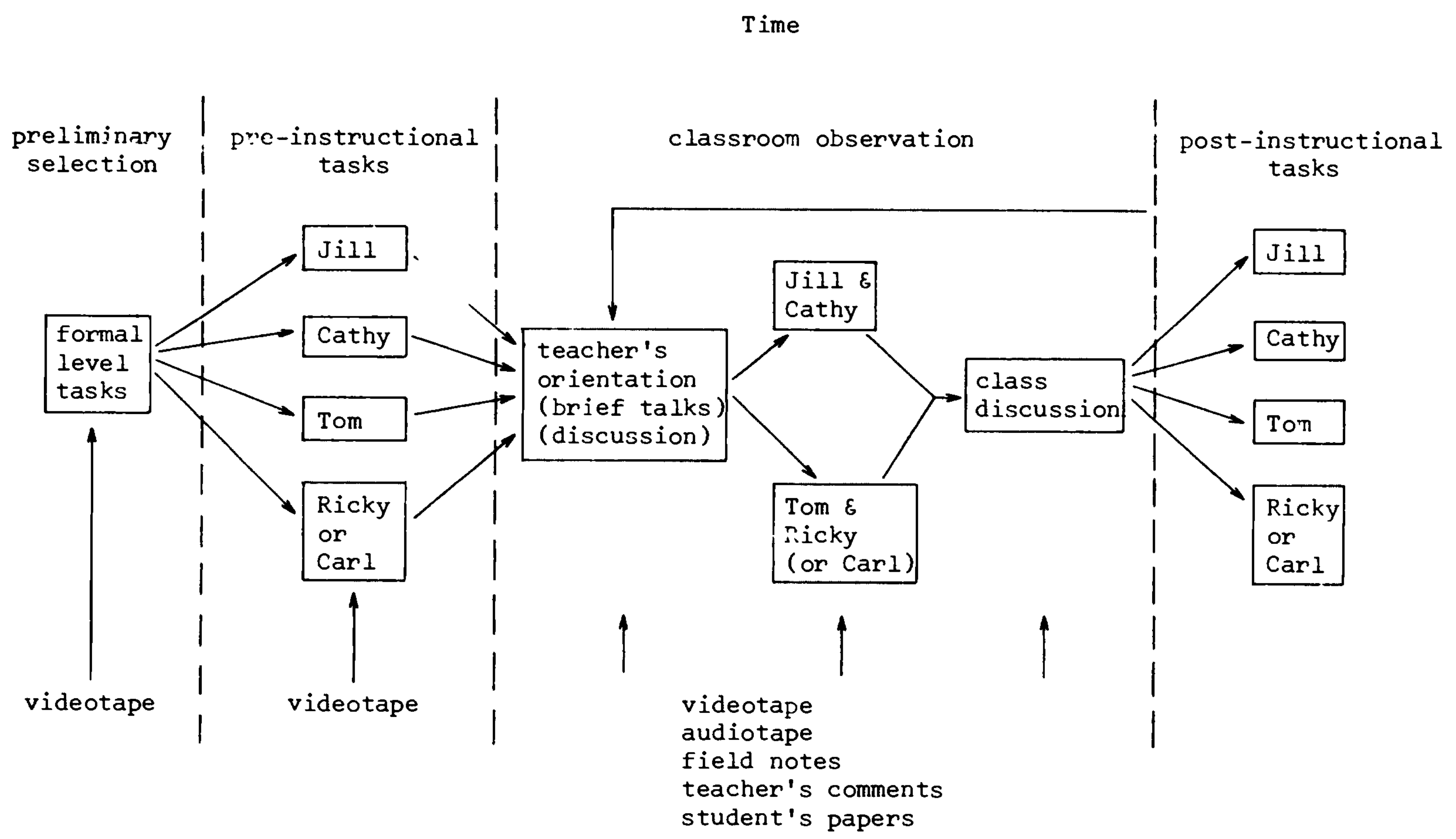
The aim of the study was to arrive at a coherent picture of the processes in the students mind during the course of a single class period that were concerned with models and theories about physical phenomena. To achieve this, first of all the student's overall cognitive systems are decomposed into four components: physical-causual knowledge, the logico-mathematical domain, the linguistic domain, and ideologies (school ideology, science ideology). Within the physical-causal domain, a detailed description of different types of conceptual systems then elaborated, and a cyclical model of the conceptual changes in any class period is developed, to the effect that the task, by affecting "inferrer" and "task-generator" components of the all-but-one strategy in the logico-mathematical domain, and a "general generator of variables" component of the logico-mathematical domain, brings about successive readjustments and restructurings in the system consisting of the current causal-conceptual system on the one hand and the sensory aspects of the apparatus which the child is currently paying attention to on the other. The bulk of the dissertation is devoted to a detailed presentation and discussion the protocols in these terms.

General conclusions of the study are that

(1) The subject's free interactions with physical systems are characterized by conceptual systems quite incompatable with those regularly assumed by science curriculum designers and teachers, and

(2) These conceptual systems develop in ways quite different from the trial and error, self-correcting processes usually invoked in discussing learning processes or scientific inquiry.

Both points are borne out innumerable times in the observational material.


Time
preliminary selection
pre-instructional tasks
classroom observation
post-instructional tasks
formal level tasks
Jill
Cathy
Tom
Ricky or Carl
teacher's orientation (brief talks) (discussion)
Jill & Cathy
Tom & Ricky (or Carl)
class discussion
Jill
Cathy
Tom
Ricky or Carl
videotape
videotape
videotape
audiotape
field notes
teacher's comments
student's papers

APPENDIX 11

Cognitive Deep Structure and Science Teaching

Klaus Witz and J. A. Easley, Jr.

COGNITIVE DEEP STRUCTURE AND SCIENCE TEACHING

by

K. G. Witz and J. A. Easley, Jr.
University of Illinois

Introduction

Traditionally the relevance of Piagetian theory to education for children ages 2 through 12 has been considered based on pre-operational and concrete operational systems (Harvey, 1969; Lovell, 1971). However, the role of concrete operational systems in mental development, and their explanatory power for much of what one sees children do during the day seems to us somewhat limited. The question why at a given time in the child's life he subjects certain aspects of a physical system to concrete operations and not others, and why certain aspects are subjected to concrete operations much earlier than others, Piaget only explains in very general terms, and in fact not in terms intrinsic to concrete operations at all (Inhelder and Piaget, 1955). More generally, one can raise the question why, at a given time in the child's life, always certain aspects of a physical system are isolated and referred to by the child, and not others, why the child sometimes prefers to think in terms of states of a variable, sometimes in terms of changes, and why there is always lack of differentiation or confusion between certain aspects, but not between others. Finally, the very raison d'être of concrete operations, their role in explaining conservation, can be questioned. As far as we can see, the particular system of operations involved in dealing with a physical system (e.g., balancing the arms of a horizontal beam) typically consists of only a small number of items (say 20), and it is hard to see how such a small structure, as a <u>structure</u>, can explain conservation if one doesn't attribute more meaning to the operations as individual entities.

By cognitive structures one means theoretical entities with which can be associated, or to which can be referred, specific patterns of behavior, or aspects of specific patterns of behavior, on different occasions over a period of weeks or months or years.

Piaget's schemes are cognitive structures in this sense. They can be largely conceived of, and in fact can be formalized and explicated, as finite relational structures in which some of the element- and relation-terms refer to (external or internal) actions. This is true of sensory-motor schemes (Witz, 1971c), of preoperational structures (Witz, 1971a), and particularly of systems of concrete operations which are explicitly thought of as operations on given data (Inhelder and Piaget, 1955, p. 249).

Now the fact that there are discernible patterns in the application of concrete operations, that there are natural conjunctions and nondifferentiations between certain variables and not others, etc., suggests that we envisage a new realm, a new level of cognitive structure that accounts for these facts. We will call this level physical deep structure. In the preoperational and the concrete operational child, physical deep structure is precisely a structuring in what Piaget, in the passage cited, calls given data, i.e., it is a continuous structuring of processes of perception and motor activity and cannot be represented by discrete relational structures. In what follows we first attempt to develop a conceptualization of physical deep structure, and then discuss some of the perspectives in mathematics and science teaching which it opens up.

Part I. Physical Deep Structure

Section 1

At each moment of time, physical deep structure is a nexus of identifiable overlapping parts called deep-structure fields (d.s.f.'s). When the child is interacting with a particular physical system, or when he contemplates one, a d.s.f. comes into play, gives rise to what appears in introspection as intuitive feelings of weight, momentum, inertia, etc., and strongly influences his externally observable behavior. Each d.s.f. will be conceived as a continuous dynamic form, or flux; it keeps its identity as a cognitive structure over a period of months, or years, but may be completely transformed in the course of development.

We discuss three examples.

Example 1.[1] Cathy, aged 12, is given several different lengths of string, a half dozen balls of different diameters and materials which can be suspended at the ends of the strings, and a support stand, for making pendula. As in Inhelder and Piaget (1955), she is asked to find out what makes the period change. After demonstrating the effect of length with a golf ball, she says:

C: "To make it come back faster you make the string shorter, and to make it come back slower you make the string longer." (Cathy stands looking at the experimenter as though she has finished the task.)

E: "Is that the only thing that will--?"

C: "Well, if you swing it faster like that (pushes the golf ball), it will come back faster, but if you just let go like that it will come back later." (She lets go from a small amplitude and watches it swing.)

Cathy tests a rubber ball. Next she tries out a metal ball on a long string, then hangs the golf ball on a short string, and sets both balls swinging.

C: "If it's lighter it comes back faster--and this one's heavier so it comes back slower."

---

[1]All observations quoted here and in the later sections of this paper were collected by Rosalind Driver and are reported in her thesis (1971). We are extremely grateful to Mrs. Driver for this material.

The most important features here are that the behavior is labile and generally subordinated to the task of controlling the swing; Cathy is obviously familiar with quite subtle aspects of the pendulum's operation and in fact she twice makes doubly sure she gets the desired result. (She contrasts pushing from a large amplitude with letting go from a small amplitude, and she contrasts a heavy ball on a long string with a light ball on a short string.) Now these features, together with the fact that a pendulum is a rather unique physical system (in the sense that sufficiently different variants, like a long heavy bar freely suspended at one end, are unlikely to be part of the child's experience), lead us to envisage a single d.s. field, P, that comes into play on this and similar pendulum occasions and that has as identifiable sub-d.s.f.'s (a) pushing, (b) just letting go, and (c) a concept of weight.

The d.s.f. P is typical of d.s. fields that underly the activity of younger children (ages 4 to 6) in situations involving specific types of physical apparatus, such as turning wheels on an axle, pushing or rolling larger objects, etc. These d.s. fields are specific to the type of systems involved, encompass many aspects of operations of the system as a whole, and contain relatively few subfluxes that are shared across many situations (like a feeling for weight).

Example 2. Ricky's concept of inertia. Ricky, aged 12, is working with several pieces of apparatus (horizontal track with plunger, P.S.S.C. carts with bricks, a toy truck and pendulum materials).

(On the horizontal track:)

(1) R: "Actually, the heavy balls might go farther because of their inertia. If they get started they are harder to stop--."

(2) R: (After he shoots several balls) "This must be a middle weight (pointing to the ball that went the farthest). It won't have too much friction and won't get too little inertia." (In other words the heavy balls will not go so far because of greater friction, and the light balls won't go so far because they have little inertia; hence, there must be an optimum middle weight.)

(On the carts:)

(3) R: (After pushing a cart and watching it coast) "Well, it's pretty /much/ pressed forward, and it got it moving (pushes cart) then the wheels begin to pick up on their own and they may--it took up a little bit. The force you have given it makes the wheels go, and once they have got rolling some of their inertia ... make(s) them go faster...."

(4) E: (Pushes cart slowly across table.) "Ricky, what are the forces on this cart?"

R: (He names several) "... and inertia would work two ways, it's trying to stay still now and once it is set going it's trying to keep going."

(5) E: "Inertia is a force, is it?"

R: "Not really."

E: "How would you describe it?"

R: (Pause) "A tendency--it's just something that would operate on a body that has no unequal force on it."

(6) E: (After Ricky had predicted graphically the results of "exploding" a system of two carts, one loaded with two bricks) "What would happen if you did this experiment in empty space?"

R: "I guess this one (with bricks) would still go slower. It needs more force to overcome its inertia."

(Concerning a picture of a truck pulled in opposite directions by two rubber bands (Fig. 1):)

(7) R: (What would happen if one rubber band were cut?) "... the truck will tend to stay still and then it will start to go faster..."

E: "What makes it do that?"

R: (Quickly) "Inertia."

(8) E: "What do you mean by inertia, Ricky?"

R: "Well, ... the body will stay right here unless you have unequal forces acting on them."

(9) R: "... inertia isn't strong enough to overcome the rubber band, so the rubber band pulls it. Actually this will all take place fairly fast."

(10) R: "... the inertia doesn't have much force in relation to a normal rubber band."

(11) E: "How could you increase the inertia of the truck?"

R: (7 second pause) "Make it heavier. So we could put a weight on there. But actually that might begin to tend on the friction."

(12) R: "... The inertia would not be enough to stop it at any force, because inertia is just the tendency to stay still when you have a force acting on it. So if you have a rubber band pulling however much inertia you have it would start coming. If there wasn't any friction, say in outer space, and you just had this rubber band here and let go it would go slowly but it would move."

(On the pendulum:)

(13) E: "Is there anything else that might make a difference?"

R: "I'm not too sure, but I think there is another equal weight balance like there was over there. There will be a middle weight where things will swing faster because when it gets too heavy the thing won't go very far after it will be caught. If it's too light it won't gather enough speed coming down to go up very far."

An ongoing conception of force applied to an object being met by the inertia of that object seems implicated in 7 out of the 13 comments ((1), to some extent (3), (4), (6), (7), (9), (12)), and in quite different physical situations. This leads us to envisage a d.s. field S_1 that underlies this conception and comes into play in the seven occasions mentioned. It is highly significant (and we will come back to this below) that S_1 is related by Ricky explicitly to both starting and stopping objects, and that inertia is treated sometimes as an intrinsic property of objects (like weight), sometimes as something they acquire (in (2)). Further according to (5) and (8), Ricky thinks of inertia primarily in a context where the object is subject to a balanced system of forces. From other interviews his conception of a balanced system of forces is a mobile one that is underlain by a d.s. field S_2, so that (7) and (8) indicates a common d.s. field S_0 which contains both S_1 and S_2 as subfields. Finally the fact that the comments from (8) to (12) are made within a span of two minutes about the same system allows us to speak of a still larger inertia nexus S, which contains S_0, S_1, S_2 as subfields.

Compared to Cathy, Ricky's understanding of the pendulum can be described not so much in terms of a single d.s. field concerned with aspects that arise naturally in manipulating the system, but rather as a multiplicity of highly identifiable and strongly interacting d.s. fluxes like S_1 and S_2. Although these structures have their origins in identifiable subfields of a d.s.f. for pendulum-type systems like Cathy's d.s.f. P, their strength and the multiplicity of their interactions has for all practical purposes obliterated the original d.s.f. (Ricky applies with ease 15 or so concepts to the pendulum.) Generally speaking, system-specific d.s.f.'s like Cathy's P seem to underly some of the structures in 4 year olds which we have described as frameworks and activity structures (Witz, 1970, 1971; Knifong, 1971). Indeed the method we have been using for identifying d.s.f.'s is reminiscent of the method for identifying frameworks described in Witz (1970).

<u>Example 3. Cathy's concept of inertia.</u>

E: "What will happen when I push this cart (a block of wood on wheels)?"

C: "It would go that way and stop, unless you push it again."

E: (Pushes the cart.) "How would you explain what you see?"

C: "Well, the force of your hand is stronger than the resistance this (the cart) has, so it moves."

E: "What is the resistance this has?"

C: "The block of wood."

Although we have only this single instance, we consider ourselves justified in postulating as a single d.s.f. a conception of inertia (she says "resistance") against attempts to move an object. In contrast to Ricky, this is not extended to stopping a moving object, and although attributed to the object (rather than to the experience of pushing as an undifferentiated whole) it is not considered a property of the object.

<u>Section 2</u>

When a lump of clay is put in a glass of water, 6 to 7 year old children will say that the water will rise because the ball is heavy. Why do they say this? Why do they bring in the notion of weight? Why do they think about the rising of the water rather than, say, the final water level? In the theoretical framework of the preceding section, we would say that the child has an underlying conception, a clearly identifiable d.s.f., t_1, that weight pushes water, or causes water to move, and that this d.s.f. is usually involved in common everyday situations such as immersing a big heavy object in water in the bathtub or in a sink and at the same time feeling and watching the water rise, or pushing a rubber ball under water, etc., etc.

We can expand this example to explain some of the behavior of nonconservers in the conservation of volume task. When the ball of clay is made into a pancake, the child may say that "when you spread it out it gets lighter." This by itself would indicate an identifiable d.s.f., t_2. In addition, t_2 seems to interact with t_1 to form a new d.s.f., t_0, which underlies the apparent inference.

We could go on in this way and try to understand why turning the submerged pancake from the horizontal to a vertical position <u>raises</u> the water level (rather than <u>lowers</u> it) and even perhaps why there is more water in the tall cylinder than in the wide one (rather than <u>less</u>)--all aspects of the child's thought which are of vital importance to education but which are not explained by operations. More generally we believe that many of the "incoherent" causal systems of preoperational children in the standard tasks--conservation, classification, seriation, etc.--can be understood in terms of deep structure and utilized constructively in cognitive growth.

Abstracting from the examples we have discussed so far we can say that two typical phenomena associated with d.s.f.'s are:

(1) natural confusions and mixtures of aspects (like the mixture of weight and water rising above)

(2) natural conjunctions when varying already well identified aspects of the system (like the conjunctions of pushing and amplitude, and of length and weight in Cathy).

We believe that it is possible to study d.s.f.'s by looking at patterns of mixtures, and at patterns of conjunctions within the same child across many different physical situations.

Section 3

By giving a physical analogy ("this is like when ...") or by employing concept terms like "heavy", "force", "resistance", "inertia" ("that's because it is heavier," "inertia keeps it going"), the child in effect asserts that the physical situation a_1 in front of him is in a certain respect equivalent, or similar to, other physical situations a_2, a_2', a_2'' .... The fact that such an equivalence or similarity is asserted with confidence, and is introduced spontaneously by the child, or in response to very general questions ("why?", "how does this work?", etc.)--in short, that a physical phenomenon has been identified by him as a unique whole that under ies many different situations--that fact poses theoretical problems of the first magnitude. We will argue that conventional conceptualization on this point is wrong-headed, and that one needs new theoretical entities like d.s.f.'s to account for the difficulties.

The conventional finite structural account of how physical equivalences, for example, come about is in terms of partial correspondences (isomorphisms). Schematically, if a child declares a situation a_1 to be just like some other situation a_2, one tries to distinguish in a_1 features, elements or relationships, which form a structured system A_1 isomorphic to a corresponding system A_2 of features, elements or relationships in a_2. One then assumes that there is a finite system of schemes which assimilate sub-structures of A_1 and A_2 in the same way, i.e., preserving the correspondence. The equivalence, then, is made because there are enough points of correspondence between the two situations which are assimilated by existing schemes of the child.

Let us examine this conceptualization in a concrete case: The judgements made by Tom (age 12) about scale readings for the same object under different circumstances. Tom predicts that a cart will give a greater scale reading on a spring balance near the top of an inclined plane than near the bottom (Fig. 2), and he expects that when an object is freely suspended, the spring balance reading would be higher if the object is raised higher up. While holding two marbles in his hands, one higher than the other, he explains:

T: "The higher it gets the more effect gravity is going to have on it because--um--because, like if you just stood over here and someone dropped a pebble on him it wouldn't hurt him. But like if I dropped it from an airplane it would be accelerating faster and faster and when it hit someone on the head it would kill him."

When asked what the spring balance would read if a thousand-gram weight resting on the table were lifted by means of the scale one foot above the table:

T: "... you won't get it to register until it (the weight) is up in the air and then, when it is up in the air, the gravity would have more effect on it. So I'd say about 1400 grams."

E: "Why?"

T: "Because it weighs 1000 but gravity --. That's just 1000 sitting on the table, and the table stops gravity from pulling down, but in the air there is nothing to stop it, so gravity can pull it down further."

Finally, in the discussion on free fall, E asks:

E: "If we hung an object onto the spring balance and we climbed up a step ladder to the ceiling and took a reading of the spring balance and then climbed down and repeated our readings on the floor, what can you tell me about those readings?"

T: "I think it would be equal--because gravity is pulling it down as hard as it can but it's being held up so it can't accelerate, it just has to hang there because of the spring."

We see that Tom has combined a conception of the effect of gravity with that of the possibility of movement of the object on which gravity acts. Now all three situations can be seen to involve essentially the same finite structural setup (A_1, A_2 above). See Fig. 3.

Instead of taking the conventional position that the child makes his judgements <u>because</u> there are demonstrable isomorphisms between the situations, we believe that the fundamental problem is to explain how the child invariably picks out a structured system of aspects (features, elements, relationships) which on later examination turns out to be the one most consistent with his other choices, and why his analysis of the situation doesn't fluctuate from moment to moment. In other words we would argue that, in view of the many possibilities of analysis of a given situation by existing schemes of the child, one has to assume a deeper, more global active organizing unit like a d.s.f. to explain the stability of his conceptions--the sureness of his judgements, their lack of fluctuation vis a vis a given situation, and their consistency across diversely related situations. Consequently, partial isomorphisms between situations are extremely valuable analytical instruments in that they document the equivalences which the child makes, but they do not explain them.

Similar problems arise when one tries to model, in real time, purely on a basis of objectively specifiable partial isomorphisms between situations, how it comes about that the child, when asked to explain one particular situation a_1, gives as analogy a physical situation a_2 rather than another one, a_2'. As a rule, the child is familiar with dozens of situations isomorphic to a_1 in the aspect he has in mind; why is it that he produces a_2?

Section 4

The physical judgements discussed in section 3 were of course based on verbal reports. When one asks for the earliest nonverbal behavior patterns which seem to imply or presuppose comparable "judgements" one is led to the tertiary circular reactions described in La Naissance d'Intelligence--the behavior pattern of the support, the behavior pattern of the string, etc. When the behavior pattern of the support appears, for example, it is suddenly generalized over an enormous range of object-on-support situations, and there is initiation of action and sureness of action by the child in diverse situations--precisely the characteristics we get when we extrapolate equivalencing based on d.s.f.'s backwards to less verbal age levels. Accordingly we identify the earliest d.s.f.'s with the tertiary circular reactions, and regard the relationships "x is supported by y," "the string is connected to x," and "the stick in my hand pushes x" as the earliest d.s.f.-based concepts.

Section 5

At this point we must consider a deeper issue which we glossed over in the considerations in section 3, namely, the mobility of deep structure concepts, ranging from mere analogy (identification of a type of experience, like Tom's airplane story) to a fullfledged physical property of objects (like Ricky's concept of inertia). There is no doubt that treating weight, resistance, inertia as properties of objects, or treating force, resistance, inertia, as properties of physical events, etc., constitutes an active achievement of the child that must be explainable in terms of specific internal dynamical mechanisms which deeply affect the correspondences the child makes.

We can arrange the above examples in a series according to apparent increasing mobility of the concept involved:

(1) Tom's airplane story: mere analogy, or identification by the child of a type of experience.

(2) Cathy's response that the resistance is "the block of wood": identification has progressed to localization of the phenomenon in a part of the situation in front of the child.

(3) "You get different results y because of x" (e.g., because it's heavier, because of the force, etc.): Here x is not yet a property of the object, or of an interaction between objects, but the child has a way of referring to it. Certainly much more is going on than that the child merely connects x with y.

(4) Ricky's notion of inertia as a property of objects.

In section 3 we lumped these behavior patterns together as all being expressions of physical equivalencing, of identification by the child "in his muscles" of a common physical phenomenon. We now propose further that formation of physical property concepts is intrinsically connected to the nature of d.s.f.'s, although syntactical elements may of course be involved. One line of evidence for this view is the fact, beautifully brought out by Piaget, that in tertiary circular reactions, which we have characterized as proto d.s.f.'s, the child's behvaior is for the first time directed by properties of objects (by "independent centers of forces," as Piaget says (1936, p. 277)). A detailed model for this shift from a world of completely action-bound happenings to a world "stocked with independent centers of forces," say a model in the form of a well-defined dynamic internal mechanism does not yet exist; we are working on this problem in the context of a detailed real-time parallel process simulation of systems of sensory-motor schemes in infants (Witz, 1971d). Insofar as d.s.f.'s seem to be essentially continuous entities, our previous considerations suggest that this shift is a global effect of continuous kinesthetic systems which cannot be usefully modelled in terms of reorganization of small discrete systems of schemes.

Perhaps closely connected with the preceding is a second property of d.s.f.'s which we also find in tertiary circular reactions: their generative power, that is, their capacity to drive and sustain the child's interaction with a given physical system. On the one hand Piaget's analysis (Piaget, 1936) tends to show that the type of exploratory activity that appears at the stage of tertiary circular reactions has qualitatively completely new characteristics which cannot be explained on the basis of earlier types of dynamics between schemes. (This is also a problem we are studying rigorously in the simulation project mentioned above.) On the other hand, at the level of four year olds the question of generative power of d.s.f.'s raises the question of the detailed dynamical integration of "deep structure" fields and "surface" activity structures into unified functional systems.

Part II. Cognitive Deep Structure and Math and Science Education

A half dozen of the most difficult problems in curriculum design and pedagogical practice, brought to light by the efforts of the past decade (particularly in science and mathematics education) can be approached from a much more promising point of view if one pays serious attention to cognitive deep structure.

In mathematics education, controversy has centered on three major problems which, as far as instructional practice is concerned, still remain largely unsolved (Easley, 1967): the justification of logic as a tool for understanding mathematics, the problem of incorporating heuristics into instruction, and the problem of teaching mathematics so as to make applications in other fields far easier than now seems to be the case. One approach to this last problem was considered by the Cambridge Conference on School Mathematics in its report (1968) on the correlation of mathematics and science education, but practical programs for bringing about a genuine resolution are still needed. In science education, the problem of identifying the processes of scientific thought is an old one whose current interest is illustrated, for example, in the debate between Atkin (196) and Gagne (1964), and Easley's review (1971a), and the question concerning the role of the teacher (Hanson, 1970; Ashenfelter, 1970) has been answered quite differently by Hawkins (196) and by Karplus (196).

By taking the nature and role of physical deep structure in psychological development into account, we believe that some progress can be made on all of these problems. In all of the above problems, physical deep structure, operational systems, algorithmic systems (formal calculi) enter and interact in different ways. The problem is to find out how they can best be utilized to help each other, and how each can challenge the other to get more educational growth.

Section 1

The traditional position is that operations are the most important intellectual achievement for the age levels in question (Piaget, 196 , Lovell, 1971), and educators have concerned themselves with operations in various ways (e.g., they have attempted to match the school experience to them (Hunt, 1970), to extend their applicability horizontally to other situations (Peel, 1964), thus removing the effects of <u>décalages horizonteaux</u>, and to accelerate their rate of development (Hooper and Sigel, 1969). Our position is that, instead of being primarily concerned with operations as an end, we think educators should be concerned with development and utilization of deep structure.

First, we would say that deep structure causes difficulties in school programs, even those which are designed around operations, because (a) it prevents the development of new paradigms (à la Karplus), or it may inhibit the acceptance of conclusions to which operations would otherwise lead, (b) it may prevent the application of operations which are already developed, and (c) through the effects of (a) and (b), it leads to frustration with some, if not most, of the academic work of schools and to self-abnegation, especially in mathematics and science.

To illustrate these points, in the science class which Mrs. Driver studied there were heated arguments on whether an object on a table is "held up" by the table or whether the table is "pushing up." Children that insisted on "held up" had considerable difficulties in assimilating the "balanced system of forces" paradigm even after several weeks of instruction. Or again, in Anderson's study (1965), children aged 6-7 mastered the all-but-one strategy in artificial tasks, in which independent and dependent variables were clearly identified, but they were typically unable to apply it to a natural physical system. We would say that this was due to various types of conflicts between the system-specific deep structure (and its sub-fluxes) and the operational system: "natural mixtures" may obscure the clarity of perception of variables needed in the strategy, "natural conjunctions" may override operation of the strategy, the dependent and independent variables in the strategy may not coincide with the aspects the child naturally manipulates and the results he seeks respectively in the system-specific deep structure, etc.

Section 2

We believe that a great deal more valuable growth is possible than is usually envisaged by educators--growth that is neither dependent on mastery of operations which children may lack nor on the acquisition of scientific paradigms, or algorithmic systems as ends or as tools. For example, ten year olds often are capable of extremely subtle and interesting explanations of the dynamics of a pendulum's swing (Easley, 1971b): They see momemtum, two or more kinds of weight, continuously changing velocity, angle, swing, force, and power, or energy, impulse, inertia, as well as the period and length, which are classically all that is studied.

Once it is realized that children have and can develop rich systems of deep structure to explain physical phenomena, one can develop experiments, not in the sense of systematic control of variables, but in a more naturalistic and open sense of finding various ways of experiencing and representing aspects of the physical system which would lead to the formation of new deep structure as well as deep-structure fused operational and algorithmic systems.

Put differently, we feel that curricula should be developed upwards utilizing what children demonstrate as their own way of thinking and own ideas about interesting phenomena, rather than downwards from pre-conceived objectives based on traditional paradigms, including systems of operations. Consider, for example, the 12 year olds in the science class who objected to the table "pushing up." Now, some of these children had a conception to the effect that the "holding up" of the table was a fixed characteristic of the table which did not vary with the weight placed on it. There appears to be no point either in instructing these children in Newton's postulate and its application to statics nor in postponing further study of mechanics until they might have discovered action and reaction on their own. Rather, one can adapt the instruction to fit their intuitions, encouraging a development of self-conscious analytic techniques. For example, one can start experimenting with certain types of flat materials which respond with a noticeable "give" to the application of heavy objects. In this way the d.s.f. underlying "holding up" is modified and embedded into a larger d.s.f. underlying "give" and, at the same time, the latter is fused with a reversible operational structure ("give" vs. "holding up"). As a convenient measure of the "give" of each piece one can then introduce the ratio of distortion to the weight applied, and in this way tie the d.s.f. to an algorithmic system (numerical ratios).

Now the d.s.f.'s underlying "holding up" and "giving", as explained above, are natural cognitive objects for carrying the concept of electrical resistance (and in a similar way, Tom's d.s.f. underlying gravity plus possibility of motion is a natural cognitive structure for carrying the concept of electrostatic potential). Accordingly the procedure above uses intuitive systems appropriate to electricity to understand mechanics. But this brings us back again to the fundamental issue concerning the whole approach we as educators should take to science. The reigning attitude in curriculum planning is to develop a subject-matter area like mechanics logically from the ground up as a separate compartment--that is to plan the curriculum downward, from pre-conceived and traditional objectives. We believe a different approach is needed--an approach that respects, not compartmentalization and preconceived logical or philosophical analysis, but the natural processes of the child.

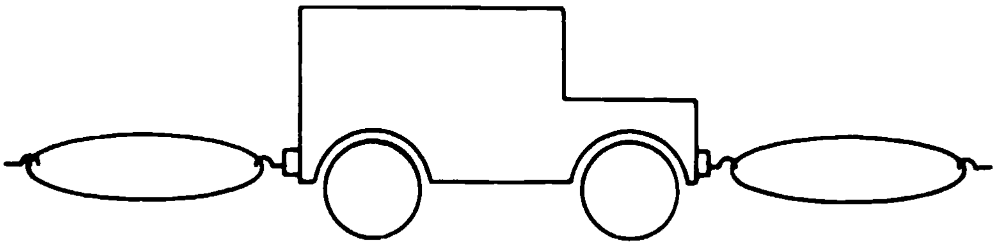


Figure 1

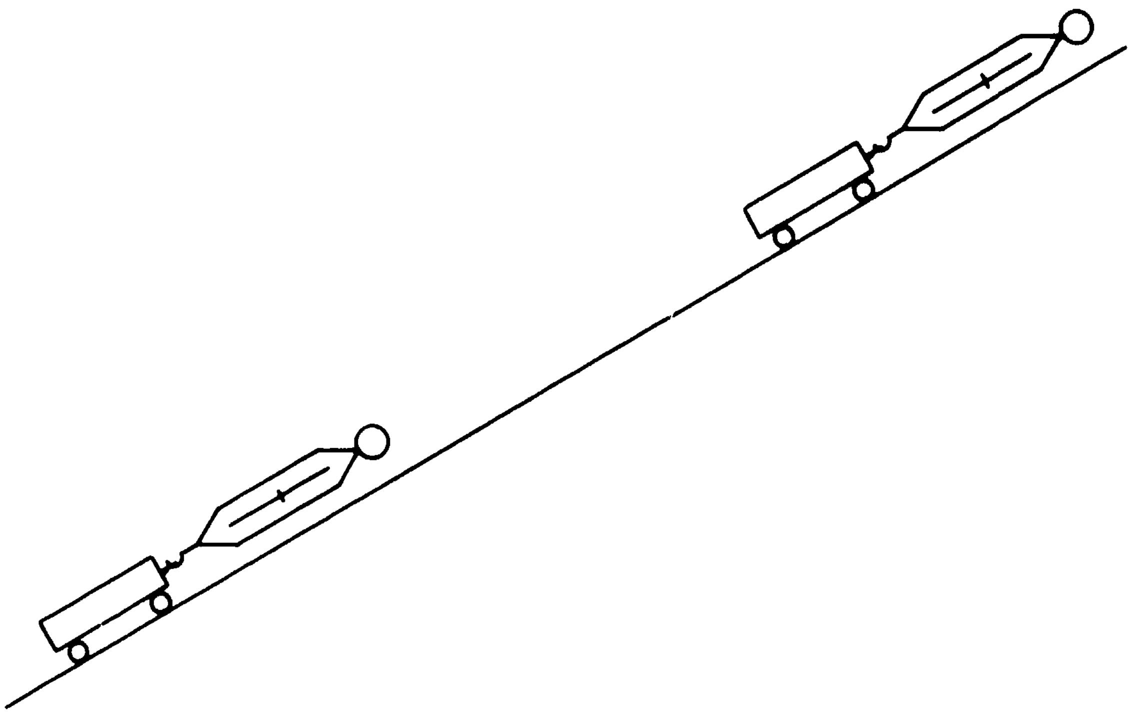
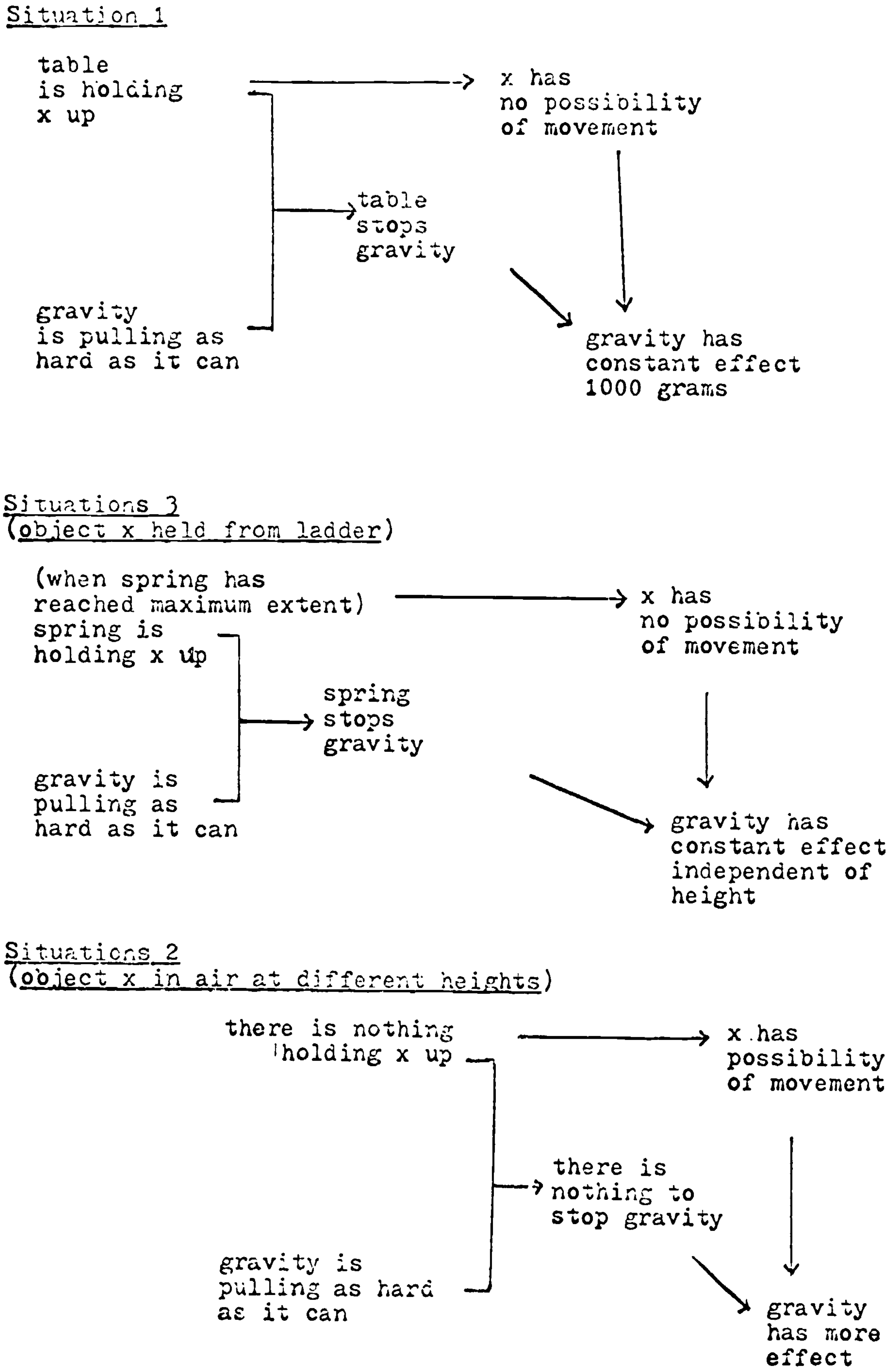


Figure 2

Figure 3


Situation 1
table
is holding
x up
x has
no possibility
of movement
table
stops
gravity
gravity
is pulling as
hard as it can
gravity has
constant effect
1000 grams
Situations 3
(object x held from ladder)
(when spring has
reached maximum extent)
x has
no possibility
of movement
spring is
holding x up
spring
stops
gravity
gravity is
pulling as
hard as it can
gravity has
constant effect
independent of
height
Situations 2
(object x in air at different heights)
there is nothing
holding x up
x has
possibility
of movement
there is
nothing to
stop gravity
gravity is
pulling as hard
as it can
gravity
has more
effect

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APPENDIX 12

An Interview About Chemical Mixtures and Reactions

Beryl Craig and Klaus Witz

An Interview About Chemical Mixtures and Reactions

Beryl Craig and Klaus Witz

Student: John S. (age 14)

Interviewer: B. Craig

John adds some solution C (potassium iodide) to solution D (lead nitrate) and observes the formation of the yellow precipitate.

S: This is water with a solid in it? The two solids react this way when they meet each other, when they are in solution.

I: Would they react this way if they were solids, not in solution?

S: No it won't happen, as there is not enough room for them to mix with each other to get into the spaces in between. There is solid at the bottom and liquid at the top. The solid is what won't dissolve. When they combine there is something left.

I: What do you think is "left"?

S: When they combined, there was one of the solids left because the spaces were taken up by the other one.

I: Both in the solution and when you poured them together?

S: One liquid is darker. It has more spaces filled up and the other doesn't -- just a few. So that when you pour them together D doesn't have place to go. (the darker, held all the space)

I: But didn't D have its own spaces in solution?

S: Yes. Both have spaces and each has a few filled up and when they combine some of the spaces will just naturally become filled up. Putting them together does it and it wouldn't do it of its own accord.

I: Does it look as though this precipitate came from C or D?

S: C, because of its color, but I'm not sure about D. Maybe its coming out.

I: Have you seen this before in class?

S: I think so, yes.

I: Lets go back to this question of the spaces being filled up when you pour the liquids together. Say, there are 10 spaces in solution C and 5 spaces in solution D. When you pour them together will there be 15 spaces in the mixture?

S: When the C and D are mixed together, some of the C goes into the D and some of the D into the C, and when they are mixed they won't be as close together. The substance going to the bottom -- there's not enough space for it, as spaces could change in size and distribution.

I: Just tell me one thing, when you pour these liquids together, you say the spaces change, but does the total volume change?

S: Oh no! Somehow the spaces just change.

Remarks on John's Interview by Klaus Witz, August 1970

Let

X = substance number one (KI)

Y = substance number two ($Pb(NO_3)_2$)
(regarded as solid particles)

A = solution of X

B = solution of Y
(in testtube in front of the subject)

until just before the end of the interview, John has three major conceptions:

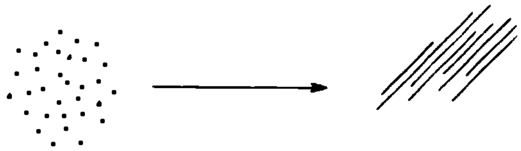
[1] A "general" conception of a substance in solution.

Z is in solution	means	Z-particles are distributed through the liquid
↓		↓ conception (1)
intensity ("darkness") of solution	covaries with	number of X particles in liquid (in a fixed volume)

We can suppose that this conception is derived from a macroscopic experience:

a region sprinkled with dots	becomes → (as you move away from it, or as you make it smaller)	a uniform smeared field
↓		↓
number of of dots (in a fixed area)	covaries with	darkness of the field

(The transition



is accomplished by an operation (moving away, etc.). The same operation can be carried out on different initial states, i.e., one can start with regions with different densities of dots, and get different degrees of darkness of the uniform field; hence "covaries".)

Conception (1) leads to

(1)' X particles of solution A

and

(1)' Y particles of solution B

[2] A more specific conception of a substance in solution.

(1) Z particles ↑ are distributed through the liquid ↑

(2) Z particles fill up (= are sitting in) spaces | are distributed through the liquid

The dotted lines indicate how conception (1) can be obtained from conception (2), but it is not clear that this transformation has any psychological reality.

Conception (2) leads to

(2)' solution A means X filled spaces and empty spaces are distributed through liquid

and similarly for B. This in turn leads to

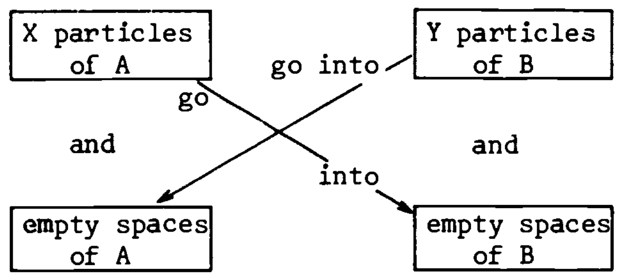
(2)'' X filled spaces
(2)'' and
empty spaces } of solution A

and similarly for B.

[3] A conception of mixing of solutions.

The conceptions we have listed leads naturally to John's conception of mixing of solutions.

(1)', (2)''



The subconception

(3.1) X particles of A —go into→ empty spaces of B

leads naturally to the idea that if there are more X particles than empty spaces of B, the excess of X particles has to come out as precipitate. The same holds for Y particles; John can't decide between the two.

APPENDIX 13

Selections from Interviews About Heat

G. Triplett

Selections from Interviews About Heat

G. Triplett

Anyone doing research on conceptions of heat and related aspects is immediately confronted with certain rather basic problems in cognition. Here is an example: Karl, age 7-2, explains and demonstrates with gestures that when a pot of water is heated over a gas burner, the heat rises up through the volume of the water. How did this conception in him come into existence? In general, conceptions of spatial effects involving heat are rather common. They are often quite sophisticated, and seem to incorporate components from a number of sources. We give some excerpts from the transcript of David M., age (9; 8). At station 2, an empty flask over a burner (not lighted), he is asked how "the heat would get to the thermometer?. (See note on page 7.)

S: Well, I think the flask would be heated and that would heat the air and the air surrounding the thermometer, and I think the thermometer would get hot. It's open at the top, and heat rises, so it's just a guess.

And a few moments later:

E: What would the fact that heat rises have to do with it?

S: Well, since the top of the flask is open, uh, um, the heated air would get out because hot air rises. And cold air falls.

E: Oh, uh huh.

S: So, it's just a guess.

E: So, what might happen?

S: The heat might escape through the top, before it heated the thermometer.

E. Oh, huh.

S: So, it's just a guess.

E: So, what might happen?

S: The heat might escape through the top, before it heated the thermometer.

E: Oh, I see. And then what? Then what would happen?

S: Well, the thermometer wouldn't get hot. Very fast, that is. Maybe if the top were corked, maybe, and if it were heated to a certain amount, then the thermometer might start going up.

E: Suppose we just left it on for a very long time, what might happen?

S: Corked?

E: No, no, just left the burner on for a very long time, then air might get out through the top, if it started getting heated down toward the bottom, then it started rising, the thermometer might get heated as the hot air was going up.

A few minutes later:

E: ...Well, what would happen here? Number 3?

S: Well, the alcohol burner would heat the metal and the metal would heat the air and, uh, the air would surround the thermometer, but like the air in number 2, the air might start rising before it got a chance to heat the thermometer.

E: Why would that be? Or just how would that work then? In that case?

S: I don't know. Uh, uh, I think this one would heat up a little, because, uh, the hot air, uh, the air gets heated right there (points to metal gauze) and as it goes up it will just go around the thermometer and it might get heated.

E: Yeah.

S: Possible. Just like that one's possible (#2) and the first one's possible.

E: Yeah, ok. Which one would you think might heat faster, this number 3 or that number 2?

S: Uh, I think number 2 might.

E: Why?

S: Because, uh, this one doesn't have a flask and that one might hold the hot air in longer because the air wouldn't go out as fast because it has a smaller opening and it's bigger down here (indicating bottom of flask) so it would take time for it to get out, and here there isn't any flask so it would just go out in all directions. (Gestures expansively with both arms.) That's my point of view.

Later David elaborates on this point of view.

E: So, which one of these four, now, would heat the fastest?

S: I still think number 2 might.

E: And why would it heat faster than this one, than number 4?

S: Well, I still think air would heat faster than water or metal. And since the flask has a small opening at the top and it's big at the bottom, the air would stay in here and it would - sort of like being - a class in a line, you know, it can't go out the door all at once, they have to go out the door single file. And so, that's how the flask works and I think number 2 would get hottest. Faster.

E: And it might be - like you said, the air would go past the thermometer without warming it up.

S: Yeah.

E: You still think that?

S: Sort of, and sort of not. (laughs)

E: Yeah. (laughs) Would that possibly be the case here - that the heat could go past the thermometer without warming it up?

S: I don't think so because the heat has to go around - has to - just heat up the whole block of metal, and metal stays hot pretty long, and, well, I still think number 2 would heat up fastest.

E: Yeah. OK. Well, how about number 3? Certainly the air could heat up real fast there couldn't it?

S: Yeah, but since there isn't any flask or anything incasing it in, the hot air would just go spreading out. I would just go spreading out upwards.

A second set of problems has to do with what kind of category heat is. Adults often think of heat as a substance which is distributed through some regions and flows into or is transmitted to other regions. In David, above, the notion of heat as a substance is limited to the case of rising heated air; when discussing "how the" heat gets from the burner to the thermometer, he only uses "x heats y" and "y heats up", never "heat gets transmitted from x through y to z" or something similar. Even considerably older children have difficulties with the notion of heat as substance. Diane B., for example, age 13; 8, had studied heat in junior high science. Referring to a jar half filled with water, she says:

S: ...then the air around the jar could have some effect on it.

E: Um huh. And could you describe exactly how that would work?

S: The -, it would heat the jar and then, in turn, it would heat the water.

E: Yeah, alright. Now, it would heat the jar; you're using the word heat there in a little different way. Can you use the word "heat" as a noun? What would happen to heat?

S: It would travel from the air to the jar to the water.

E: Alright. And uh, this would raise the temperature of the water then?

S: Um hum.

E: Very good. What would happen if I would put some ice in the water?

S: The temperature would go down.

E: "Well, the ice is colder for one thing, and then, there would be more stuff to evaporate.

Notice the quick way in which Diane switches from "heat" and "heat transfer" to "colder" to explain temperature change. A minute later the same thing happens again.

E: Describe what's happening.

S: Well, I think the ice is colder than the water and it's melting and it's affecting the thermometer.

E: Why is the ice melting?

S: Cause the water is, uh, hotter than the ice, and -

E: How does that make it melt?

S: Well, if something is hotter than the thing, it will melt it.

E: Why?

S: Cause it just does that, I guess.

E: Yeah, alright, but we're looking for reasons.

S: Well, hot things - well, can't -

E: Think about it in terms of heat, if you can. (pause) Is the heat doing anything?

S: The heat in the water is melting the ice, because it's - If you're using hot and cold, the water's hot compared to the ice cubes. So the heat was sort of worked on the ice cubes to melt them.

E: Um hum. And what is happening to the heat?

S: It's going down - in the thermometer.

It is clear that the substantive heat does not form a part of Diane's structure at all, and thus she reverts to her own perhaps simpler structures whenever the instructor allows her to do so.

Perhaps a precursor of the conception of heat as substance is the conception of heat as a "condition" localized at or near a point. Other work suggests that this latter conception is found regularly in four to eight year olds when they talk about the sun, about why people need heat, etc., but it seems to imply a sensation of radiation and is never applied to boiling water, or to the heating of something. In younger children the question what kind of category heat is, and why and how it is maintained as that category, becomes even more intriguing. Sometimes heat is a localized or non-localized condition, sometimes a non-localized property of objects, etc.

Finally we give some examples, again from David M.'s transcript, concerning the problem of how children incorporate into their thinking genuinely foreign conceptions like the molecular theory. On page 7, David explains expansion in terms of molecules.

E: Yeah, OK. Can you explain to me - I think you sort of did before - but just exactly why does a thermometer go up?

S: Well, uh, it starts getting heated, whenever it's surrounded by water, air or anything, uh, it causes the - I don't know what the liquid's called that's inside.

E: I think that's alcohol in there.

S: Well it causes it to expand, and when it expands it just has to take up more room, so it starts rising.

E: Um hum. And, uh, why does it expand, uh, do you have any idea about that?

S: Yeah. When it gets heated it causes the molecules to get spread apart.

E: Oh, uh, huh.

S: And when things get hot the molecules start spreading apart, and so, it causes it to expand, and that causes it to go up in the tube.

On pages 10-11 we find a little bit more.

S: Well, it's pretty hard to explain molecules but they're just little microscopic things that make up - everything. You can't really say what molecules are made up of - but they make up things.

E: Yeah, uh huh. Ok. Now, what would happen to the molecules in that iron then? Do you know? When we lit the burner?

S: Well, the burner would start heating it up and the molecules inside the iron, uh, when they're not heated they just sit there. When they heat up they start moving around, and they bump into each other, and when molecules start going real fast it starts getting hot, like a sidewalk on a summer day, if you ever walked on it barefooted.

E: Oh, how is that?

S: The sun heats it up.

E: And?

S: And the molecules inside the sidewalk start bumping into each other and they go faster and faster.

E: You mean they hit your feet?

S: No. (laughs) No, inside the sidewalk, some molecules bounce into other molecules and they bounce off each other, and they keep - it's like a crash course, they just bounce into other molecules, they keep going like little tiny super balls, and they just bounce real faster and faster until it gets hot.

On page 13 there is a short reference in which the molecules come spontaneously into an explanation of why air comes out of water when it is boiling. He is beginning to use the concept in a structural way.

S: ...well, the burner heats up the water, and the molecules start going real fast, like I said before when it picks the heat up, and it just, uh, there wouldn't be any room in there for the air any more, just, comes out.

On page 15 there is a discussion of water boiling over the top of a flask at station 1. As the water runs down the side of the flask and hits the hot screen below, it sizzles. David is asked what causes the noise.

E: Yeah, where does the noise come from?

S: When the water hits the hot - the hot part? When it sizzles?

E: Yeah, why does it sizzle?

S: Well, when the water touches something hot it just - (laughs)

E: Yeah, (laughs) yeah, it what?

S: Well, it always does that. I haven't really sat down and thought about it.

E: Well, you're sitting down right now.

S: Yeah.

E: Let's think about it.

S: Well, when it touches something hot, it heats up the water, and there's little water there so it just - heat it up and everything starts - since the thing is so hot - the screen is so hot that it just - sends the molecules all over and it just- in a split second it just - makes - the molecules are in there, going around real fast right now, and when it hits that thing real fast - hits the hot thing - it just makes them start going so fast it just - sort of explodes. (laughs)

<u>Note</u>

A number of interviews, including the interview with David discussed above, were conducted in a science laboratory with a set up of five stations. The stations all included an alcohol burner with a stand above the burner upon which could be placed a beaker or other apparatus. Supported by a string, an uncalibrated thermometer hung just above the stand. Differences in the stations was confined to the apparatus placed upon the stand. These differences were as follows:

#1. Flask with water	#2. Empty Flask	#3. No Flask, Open air	#4. Iron block with hole for therm.	#5. Wooden block with hole for them.

The interview technique consisted of using an inquiry approach to discuss each of the stations. The interview was begun with station #1 and progressed to the other stations. However, the alcohol burner was never lighted under the last four stations. From a discussion of station 1, both lighted and unlighted, the subject was asked to speculate, using his imagination and/or reason to answer questions about what happen at the other stations <u>if</u> the burner were lighted.

APPENDIX 14

Relational Representation

Klaus Witz

3.3 Sensory-Motor Structures in Infants[1]

In his beautiful book on the "origins of intelligence" in children,[2] Piaget outlines the development of sensory-motor structures in the infant from birth to age two years. The central concept is that of a scheme, roughly speaking, a unit of internal organization of perceptual-motor activity. Schemes are thus internal process-structure constructs, and the main thrust of the book is to conceptualize and elaborate certain aspects of schemes (assimilation, accommodation) so as to be able to identify a number of modes by which schemes are organized into larger structures (again schemes.) We now show how these structures can be expressed directly as generalized configurations over a relational base, with the modes of internal organization identified by Piaget as relational symbols.

Stage 1

E_0	collection of elementary schemes (sucking, impulsive grasping movements, gross movements of limbs, head, body)
x{y	x is preliminary activity surrounding elementary scheme y.

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[1] Material prepared for a talk to the Seminar on Congitive Studies, April, 1971.

[2] Piaget, J., The Origins of Intelligence in Children, Or. Fr. ed. 1945; Engl. International Univeristies Press 1952; Norton Paperback, 1963. All references are to the paperback edition.

Observations 2-4

reflex level

searching ----------------hu[s

sucking ---------------------

(Detailed structure of hu is omitted)

Stage 2

x-(y	circular reaction (x a motor scheme, y sensory feedback derived from execution of x)
x ǀ y	simultaneous coordination of x and y
x —> y	sequential coordination of x and y

Finger sucking

Observation 12

protruding tongue over upper lip } ------------pt ———————(ftl

feeling tongue on upper lip ----------------------

Observation 16-20

sucking -----------s ————(ff
feels finger ---------------------
hand movement (moves hand to mouth) } ---hm

Notes: s ——(ff...obs. 16 (sucking with finger in mouth)

s
|
hm -------obs. 17

hm —> [s ——(ff] ....obs. 20

Prehension

Circulatory reactions prior to coordination with vision

Observation 52

grasping ----------[--g ——(fo]

feeling obj. ----------------

holding ------------------

Observation 53

scratching with

fingertips ---------------[scr ——> [g ——(fo]]

tacitile exploration -------------------tex

This simplifies to

tex [[g ——(fo]]

Beginning Coordination with Vision

w ⊥ x	Watching execution of own motion (w' = attentive visual activity, x = the motor scheme which the child watches himself execute.)Drifting out of visual field, etc.
w I x	watching execution of own motions - no drift

Observation 60

Observation 63 (0;4 (4))

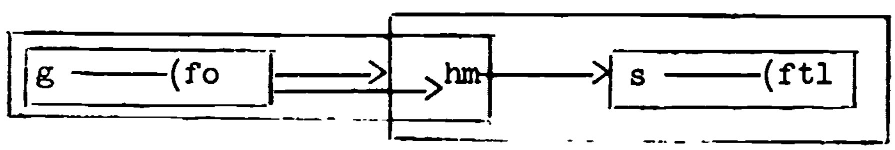
g ——(fo

and while still holding,

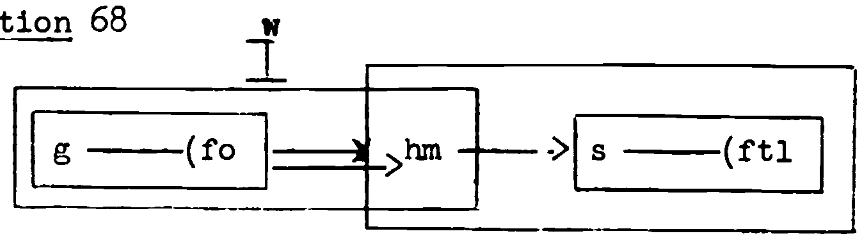
this is followed by

hm —> s ——(ftl

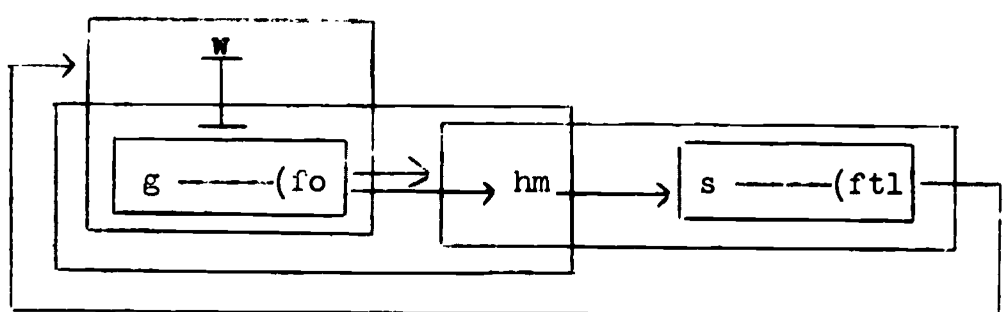
Observation 64



Observation 68

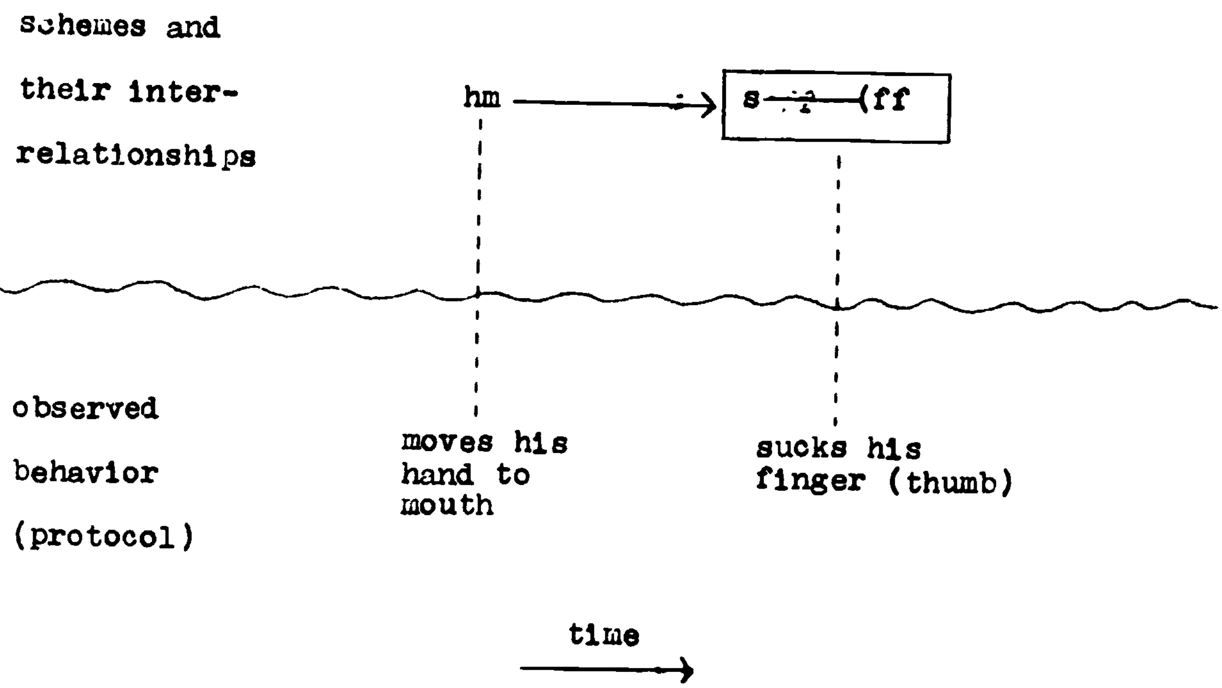


This is immediately replaced by



The examples could be continued; we confine ourselves to two remarks.

(1) Once the nature of the internal elements (schemes) has been elaborated and modes of internal organization have been identified, passing from observed behavior to internal structures which stand behind and account for this behavior is a relatively simple matter because at any age level, up to age 1 1/2, there is a rough 1-1 correspondence between schemes making up the gross time structure of a larger structure and observed individual actions of the sequence of actions which the larger structure accounts for. Example:



As a consequence, the configurations and generalized configurations representing the current state of internal organization ("current" for the day, or for a 3 or 4 day period) can also be considered as coded versions of observed behavior. Thus one can take a single child, make a record of observed patterns against time (starting at day 0), and analyse this record (looking for long term regularities or irregularities like clusting and local acceleration (spurts) in various areas of the total system of configurations, or measuring degree of connectedness or integration of the system of configurations, etc.), but always via analytical operations on current configurations. If this were done, an immediate problem would be whether and in what way earlier structures (= low depth subconfigurations of current configurations) change, get transformed, replaced, etc. (cf. Vanden Dale's paper[1], but there seems to be no experimental-observational work specifically addressed to this problem).

(2) There is the larger question in what sense it is that schemes and internal modes of organization have in fact been usefully identified, what evidence might lead us to prefer a different vocabulary, and indeed whether the relational approach is at all adequate. These questions arise for example when Piaget discusses "intentional behavior" in the third stage. He asks in what sense the child can be said to exhibit intentional behavior, and his answer

[1]Van den Dale, L.,

is, essentially, that intention can be said to be present in observed behavior whenever the configuration of schemes underlying that behavior reaches a certain complexity and has a certain form. In view of the close correspondence between schemes and observed activity this is very "behaviorist": Piaget relies largely on the previously established circular reactions and coordinations and refuses to introduce new theoreitical constructs, like special "control mechanisms," or "tension-systems", or what not, which might conceivably lead outside the relational approach.

Example 3.4 Representations of Perception[1]

We next sketch a fragment of a formalism for describing subjective perception of objects in 4 year old children. As in the preceeding example our representations will be generalized configurations over a relational base, (E,R), representing organized systems of perceptual schemes. In contrast to the last example however, schemes here will be thought of as (in principle physically specifiable) internal processes, or aspects of internal processes corresponding to the perception of (sometimes simple) physical aspects of the object like the slant of a rod. It is understood that a single primitive scheme (= element of E) corresponds to "perception of the current value of variable X" (rather than to "perception of a specific single value x_0 of X"), and that it is independent of, and keeps its identity over, a considerable range of states which the subject can be in, as well as over a considerable range of stimulus situations: the same scheme, say corresponding to "the perception of the slant of ℓ (a straight line)" is involved in the perception of the gabled roof of a house, the edge of a table top, a pencil lying on the table, etc., and this scheme is independent of the position, the current activit , etc. of the subject. In other words, the same internal process, or the same internal process aspect, is active in all cases.

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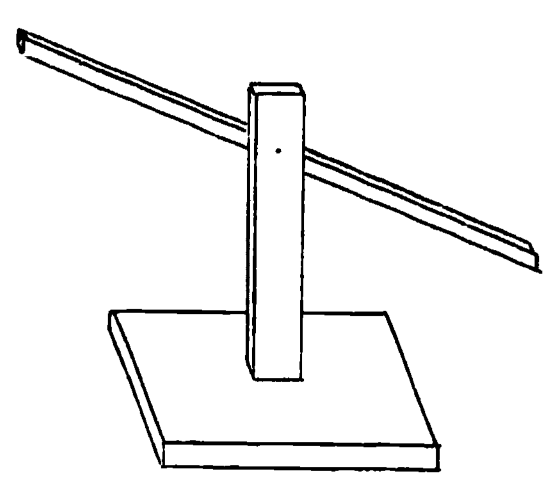
[1]Based on a talk given to the Project on Cognitive Behavior in Children, in the spring of 1970.

Details in what follows were suggested by observations with real children and by other considerations. Nevertheless the analysis as a whole is still armchair because no unambiguous procedures for associating with real behavior perceptual structures which would account for that behavior are worked out. (The mathematics of passing from observable behavior to such representations will be developed in later chapters of these notes.) Elements of E and some simpler configurations are assumed to be of two mutually exclusive types: schemes for the perception of stationary states (type S), and schemes for the perception of movement and rate of change (type M). Depending on the type of scheme involved, we postulate various modes of integration (lower case letters denote relational expressions or configurations, i.e., perceptual schemes, and the corresponding capital letters denote physical aspects of an object that are assimilated by the schemes.)

As an example consider a child's perception of a pivoted beam supported on a simple stand:



We concentrate first on the perception of the end portion of the beam and its relationship to the table top. Introduce the following primitive perceptual schemes:

s...slant (of end of beam)

$\dot{s}$...change in slant

p...poisition (of end of beam, with respect to the subject only, e.g., as indexed by the direction of his look)

$\dot{p}+$...upward movement

$\dot{p}-$...downward movement

d...distance (of end of beam) to table top (in generalexed sense - not length of the perpendicular).

x-y	fixed field integration: perception of X and Y simultaneously as one aspect (of the same object, or in the same area of the visual field) (x,y type s)
x=y	perception of covariation of X and Y as aingle aspect (x,y type M)
$\begin{bmatrix} x \\ y \end{bmatrix}$	change integration: perception of X and Y simultaneously as one aspect (x type M, y type S)
$x \rightleftarrows y$	perception of alternation of X and Y
x ⟶ y	sequentially integrated perception of X followed by perception of Y (a single perceptual act).

(Samples of behavior in which these schemes might be involved:

s...glances quickly from end of beam along beam and back; traces with fingers along beam to end)

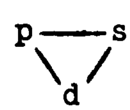
$\dot{s}$...imitates change in stunt with his hand and arm

p...looks at end of beam only

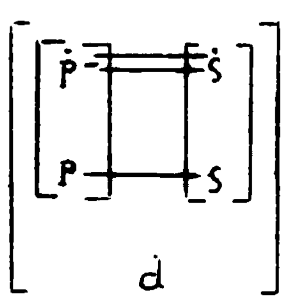
$\dot{p}+$ }
$\dot{p}-$ }...follows end of beam with eye while it moves (with or without head movement); says "its going down"

d...says "its that high" and/or indicates height with his hand)

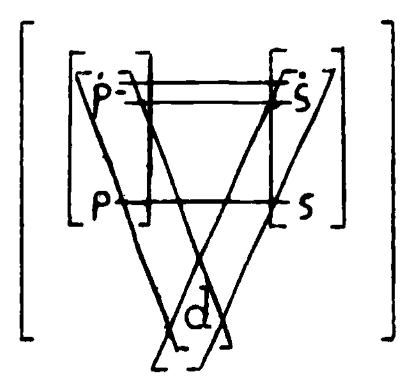
Then perception of the beam in a stationary position might be handled by the configuration



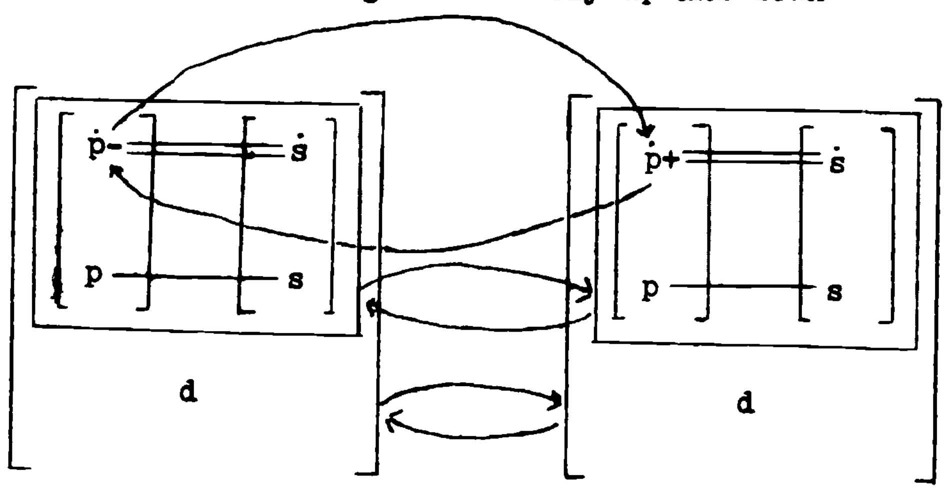
perception of the end of the beam moving down,



or

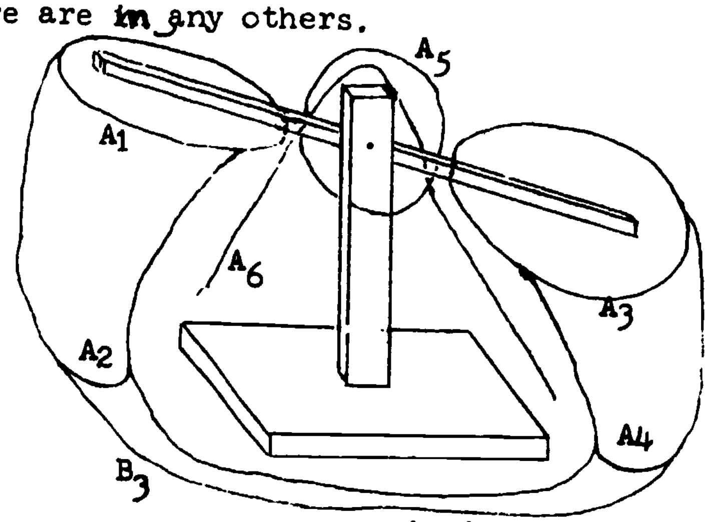


perception of the beam moving alternately up and down



and so on.

So far we have concentrated on perception of only one aspect of the apparatus: the left end of the beam and its relationship to the table top, labelled A_2 in the figures below. There are many others.



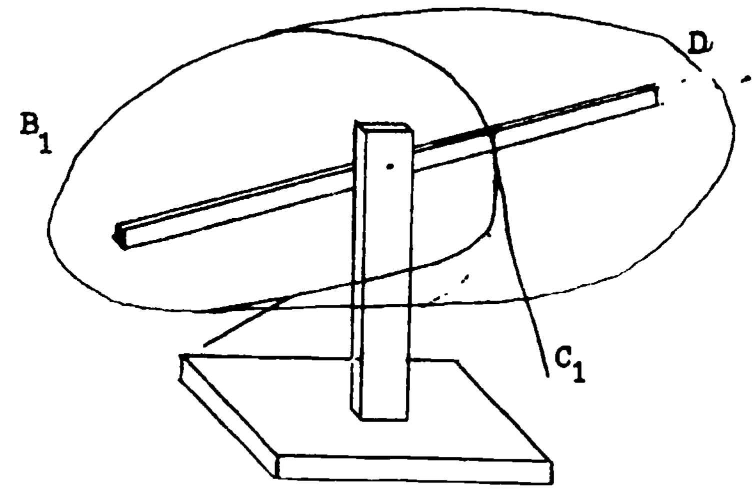
A_1, A_3: ends of beam

A_2, A_1: ends of beam plus relationahip to table top

A_5: pivot area

A_6: stand

B_3: end-end dynamic system aspect



B_1, B_2: pivot and arm aspect

C_1, C_2: pivoted arm and stand aspect

D: pivot and whole beam aspect

APPENDIX 15

A-1 Project

by
Klaus Witz

(Excerpt from (C-15))

A-1 Project

by

Klaus Witz

The aim of the project initiated in the following pages is to create an entity which simulates in real time the internal cognitive processes of a two to four year old child as he interacts with a physical system (a balance beam) and a real experimenter. This entity, the first version of which will be denoted by A-1, operates exclusively in terms of flow of excitation on a system of sensory-motor schemes and activity structures as conceived in (1) - (4); sensory input is supplied in real time directly on appropriate perceptual structures. Sensory-motor and activity structures are specified as a single vast "generalized network" incorporating multiplace relational symbols and nesting (i.e., a configuration in the sense of (4)), with on the order of 500 nodes. Excitation flows between the nodes asynchronously, and in accordance with local rules only. A-1 is currently being programed for simulation on a B 6500 computer.

Considered as an artificial intelligence, A-1 has the following features.

1. A-1 is a true parallel process system. At any moment of time, several subnetworks in different regions of the overall network will be excited, corresponding to the fact that different perceptual ideas, intentions, etc. are going on simultaneously and independently from one another and without overall executive control. Meaningful observable output is guaranteed primarily by the geometry-dynamics of the network.

2. A-1 has "floating computations". This means that coherent subnetworks corresponding to the perception of larger aspects of the apparatus will remain excited and capable of interacting with activity elements. (i.e., of "problem solving") for some period of time after the actual visual input has been shut off. There is no memory storage in the usual sense of the term.

3. A-1 has a primitive but active visual system which focuses on restricted areas of the apparatus and whose movements are coordinated with gross motor activity.

   A-1 has rudimentary capabilities for internally transforming perceptual ideas (e.g., "imagining" that the balance is beginning to move while he sees it at rest).

5. A-1 is spontaneously active and often initiates purposeful activity on his own: he may play with the apparatus, repeat what he has just done, etc.

Detailed blueprinting of A-1 is motivated by and explicitly related to existing studies on prehension, sucking, and the coordination of prehension and sucking with vision in infants, neurophysiological ideas on the organization of movement, and some of the neurophysiological and psychological literature on perception. Observed behavior of A-1 will be compared at varying levels of detail (from gross characteristics like the length of time he is interested in and explores a specific aspect of the apparatus' behavior to minute differences in timing between comparable action sequences) with published descriptions and video tapes of 2 year old visual-motor behavior, and with existing video tapes of 2 to 4 year olds interacting with a beam balance.

A-1 is an attempt to deepen the overall perspective on cognition initiated by Piaget in (1); it opens up a wealth of possibilities of experimentation with new conceptualizations in the study of behavior (see sec. 7). At the same time, however, A-1 is an experiment in abs act parallel process intelligence.

The present document is intended to be a catchall affair for all issues in cognition arising in the design and construction of, and during experimentation with, subsystem of the A-1 system. This indicates the precise networks and network dynamics used, relationships of these to existing conceptualizations and data in behavior theory, and whatever analytical penetration of the overall dynamics we can provide; it excludes all programming problems (these are dealt with elsewhere).

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(1) Piaget, J., The Origins of Intelligence in Children. Orig. Fr. Ed. 1936. Engl. International Universities Press, 1952; Norton Paperback, 1963. All page references are to the paperback edition.

(2) Witz, K. G., Representation of Cognitive Processes and Cognitive Structure in Children I. Arch. Psych. V. 15 (1971), pp. 61-95.

(3) Witz, K. G., Activity Structures in Four Year Olds. To appear in Scandura, J. (ed.) Research in Structural Learning, Gordon and Breach.

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