FIVE EXPERIMENTS IN
THE DEVELOPMENT OF THE EARLY
INFANT OBJECT CONCEPT

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Abstract

A computational model is proposed for the early stages of development of the object concept in infants. Stages in development are represented as a sequence of grammars or rewrite rules parsing a set of perceptual phenomena. The infants' changes between developmental stages can be described by differences between the grammar rules modelling each stage. The program replicates five Bower et al studies on the development of the object concept and reaffirms the primacy of rest and motion parameters as explanatory invariants in early object concept development.

Forty years ago, Piaget first observed and described the problems infants have in understanding the nature of objects (Piaget, 1936, 1937, 1946). Piaget identified six invariant stages of development through which the infant comes to cope with and understand external objects.

One alternative theory of object concept development which has been proposed is the identity theory of Bower and Wishart (Bower, 1967, 1972, 1974; Wishart, 1979). 'Identity theory' believes the infant's problem in understanding the nature of objects to lie in discovering the spatio-temporal relationships which underpin the identity of any object. While Piaget believed the young infant to have no true differentiated awareness of either self or objects in the first year of life, Bower and Wishart believe a basic understanding of the independent existence of both to be present at a very early stage, possibly even at birth. The infant is seen as having difficulty, not in differentiating himself and his actions from other activity in the external world, but rather in understanding the unique nature of objects themselves.

The identity hypothesis can be summarised in the form of a series of three conceptual rules (Bower, 1974, 1981; Wishart, 1979) which can cover all six stages of search behavior found in standard Piagetian object permanence testing situations and can also explain the otherwise puzzling behavior shown by infants in other object-related tasks. (See e.g. Bower & Wishart, 1973, Butterworth, 1977, Wishart & Bower, 1981). While it is the eventual aim of our research to develop a program to cover the entire sequence of object concept development, this paper will report only our initial work on modelling Stages I - II of that development, a period which, according to Bower and Wishart, sees the development of the first two conceptual rules for attributing identity to successive appearances of any object.

These rules can be formulated as a sequence of grammars or rewrite rules that translate perceptual phenomena into sets of behavioral responses. The perceptual phenomena will remain constant throughout the period of testing, i.e., across the running of the sequence of grammars that represents the early stages of development.

This paper hypothesizes that the symbolic output of the featural and motion detection mechanisms is available to the cognizing subject. This model offers no explanation of the physiological origins of such phenomena, but rather emphasizes the descriptive adequacy of the internal symbol structures and the interpretive adequacy of the cognizing subjects' manipulation of such symbol structures. Further, the changes in the computational rules expressing the interpretive adequacy of infants at various stages in development will offer explanation of that development.

Each experiment of this study is composed of a sequence of "snapshots" representing the physical situation according to a time parameter. Snapshots represent objects by themselves, partially or totally obscured by occluders, and replaced by other objects. An example of such a set of snapshots may be seen in Figure 1. This figure represents a subset of the snapshots taken from Experiment 5 of Section II, where S(n) indicates the time parameter.

A set of symbols represents each snapshot and a set of rules characterizes the grammar that interprets each sequence of snapshots Each rule of a grammar represents a different interpretive capacity of the subject such as to locate an object symbol structure within a fixed radius r of a spatial position (x,y,z).

The grammars of this model are designed to implement the rules outlined by Wishart (1979). An implicit assumption is that the infant is motivated to maintain contact throughout the event sequence with the object he/she initially identifies as interesting.

This computational description of the object permanence phenomenon is written in PROLOG (Warren and Periera, 1977; Warren, 1979). The action of PROLOG is of a unification algorithm operating on a set of record structures. These structures are of two general forms: a set of facts and a set of inference rules. The PROLOG facts are used to make-up the object structure for the description of each snapshot. For example the facts loc (OBJN, X, Y, Z, T), color (OBJN, CL T), and size (OBJN, SZ, T) indicate OBJECTN has color CL, size SZ and location (X,Y,Z) at time T. The combination of these and other descriptors make up each snapshot of the experiment. The grammar rules interpret these object structures.

PROLOG rules are of the form "A⊢B,C,D," which may be described procedurally as "to accomplish A attempt to accomplish B and C and D." B, C, and D may be facts (checked to be true) or may themselves be rules that lead to the proof or performance of B, C, and D. For example, Grammar 1 says to test for a permanent* object at a location look for:

1) An object structure within a fixed radius r of the location.
2) Check if previous snapshots would indicate a permanent object should be at this location.
3) Test the object structure for interest (parallax).
4) Check whether the object structure is intact (that is whether it or any of its boundaries are occluded), and finally,
5) Based on this object structure look to an appropriate position for the next object structure.

The grammar of the second developmental stage is similar to the grammar for stage one. The essential difference is a rule called twice by the grammar for the object structure of each snapshot. This rule represents the older infants ability to check different perceptual values such as size and color between snapshots. (Luger et al, 1981).

II. Five Experiments

In this section five experiments will be considered and the action of the computer model in these situations described. The model is in two parts, each representing a stage of development of the infant. The first part, Grammar 1, represents the earliest stage of development modelling Rule 1; Grammar 2 models Rule 2 (Wishart, 1979).

In the conclusion, the results of the computational model run on the experimental situations will be compared with the results of infants tested in the same situations.

*Although this paper does not elaborate on the distinctions between object permanence and object identity interpretations of object concept behaviors, the authors' bias towards identity theory should be made clear. A basic notion of object permanence (i.e. of the continued existence of objects when unperceived) is assumed to be present from very early on (Bower, 1967), according to identity theory, it is the step-like discovery of the precise spatio-temporal nature of that existence which lies behind the sequence of errors found in standard object concept tasks, not the development of a notion of permanence per se.

A. The Experiments

Experiment 1. (Bower, Broughton & Moore, 1971; Bower & Paterson, 1973).

An object, interesting to an infant, is moving on a straight path in full view of the infant. The object then stops in full view.

The young infant (Stages I II) typically pauses with the object for almost half a second and then continues to follow the objects' former path across the field of view (movement error). The older (Stage III) infant pauses with the stopped object, looks onto the path the object no longer follows, and then goes back tothe stopped object.

Experiment 2. (Bower, Broughton & Moore, 1971; Bower & Paterson, 1973).

An object is at rest in full view of the infant. It is displaced and follows a fixed path at constant velocity.

The younger infant follows the displaced object but then looks back to the position of the original stationary object (place error). The older infant pauses and then follows the path of the displaced object.

Experiment 3. (Bower, 1974)

An object moves along a path. It is replaced in mid-path by another object that continues to move along the path.

The young infant is not disturbed by the mid-path substitution. The older infants are confused moving their eyes back and forth between places of different objects.

Experiment 4. (Bower, Broughton & Moore, 1971)

An object moves across the field of view and behind a occluder. A different object reappears on the other side of the occluder.

The young infant follows the path of the object and continues to track the changed object when it appears. The older infant reacts to the new object when it reappears and looks back to the occluder.

Experiment 5. (Bower & Paterson, 1973)

An object moves across the field of view. It stops on one side for a brief period of time and then moves back in the opposite direction stopping in its original position again for a brief time. After repeating this sequence of moves four times it goes off in the opposite direction. See snapshots of Experiment 5 in Figure 1.

The younger infant continues to have movement and place errors as the object moves and stops and moves off again. With repeated exposure to the sequence, she may adopt a place to place strategy of jumping to the object's next stopping point as soon as it begins to move off from its present position. This strategy is only briefly successful since it cannot cope with the final change in direction. The older infant is not disturbed by the movement and stopping in either direction.

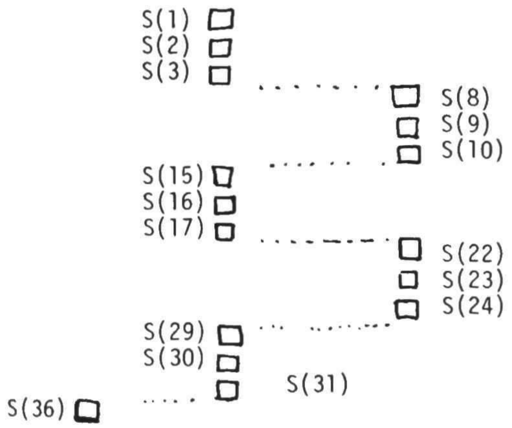

Figure 1. Snapshots from the motion and rest pattern that makes up Experiment 5.

B. The Results

Experiment 1.

Grammar 1 identifies an interesting object, say OBJ1, and associates this object with a path across the field of view. When OBJ1 stops moving Grammar 1 continues to follow the former path, not finding an object it looks back to the now stationary object, calls it OBJ2, and looks back searching again for OBJ1 on its original path. Grammar 2 in this situation identifies OBJ1 as interesting and follows it. When it stops, Grammar 2 continues on path and then looks back to the stopped object, notices its' similarity in size and shape to the original OBJ1 and continues to look at it.

Experiment 2.

Grammar 1 identifies an interesting object, OBJ1, stationary before it. When the object starts to move, Grammar 1 follows it, looks back to its former location and then looks to the new moving object and calls it OBJ2. Grammar 2 does the same as Grammar 1 except that it recognizes the size and shape of the moving object to be the same as that of the original stationary object, and does not create a new object.

Experiment 3.

Grammar 1 identifies OBJ1 and follows its path ignoring the mid-path substitution. Grammar 2 follows OBJ1 as interesting and noting the perceptual changes of the sustituted object calls this new object OBJ2 and continues to follow it.

Experiment 4.

Grammar 1 sees OBJ1 as interesting and follows it along. It continues to follow the path behind the occluder and follows the path as the new object emerges. Grammar 1 sees only one bounded volume of space moving on a path. Grammar 2, noting peceptual changes sees 3 objects; the original, the occluder and the new emerged object.

Experiment 5.

With every movement and pause Grammar 1 sees a different object for each movement and each place. Grammar 2 sees only one object, the perceptual checks at each motion translation allowing transition to new motion sequences without confusion.

III. Summary and Conclusions

Several researchers have recently reported on computational models of preverbal children's problem solving skills (Prazdny, 1980; Young, 1976). The behaviors modelled in these studies are as simple as eye movements, reaching, and gross body movements. Modern research techniques such as video tapes, however, allow researchers to be quite comfortable with the interpretation of such motor behavior. Such data makes up the Bower and Wishart studies, and this is the data our program interprets.

Grammars 1 and 2 follow fairly closely the two rules suggested by Wishart (1979). Grammar 2 with its perceptual checking for size, shape and color factors allows proper detection of changes between the two objects when these change, and proper positing of no change when only the motion and rest factors differ. Thus motion and rest are established in the "identity" model as explanatory invariants of the first stages of infants' acquisition of the object concept.

In both experiments 1 and 2, Grammar 1 identifies 2 objects, one stationary and the second in motion. Grammar 2 with more advanced perceptual checking, notes the similarity of the object in motion and the object at rest and does not posit a second object.

In experiments 3 and 4 Grammar 1 sees only one object following a fixed path. Grammar 2, noting perceptual differences, posits new different objects for each perceptual change in the objects.

In experiment 5, Grammar 1 posits a new object for each path of movement and each stationary object position. Grammar 2 sees only one object.

An important area for continued work is to develop a third grammar capable of interpreting object structures in more complex situations than those dealt with above, in experimental situations, for example, involving partial occlusion of an object or close spatial interaction between a number of objects. Bower and Wishart have posited a third conceptual rule (Rule III) to account for these final stages of the development of object understanding (Piaget's Stage VI). The rule states that two or more objects cannot be in the same place or on the same path of movement at the same time unless they bear a spatial relationship to each other which involves the sharing of common boundaries. The interpretative adequacy of this rule could be evaluated against experimental situations in which such boundary sharing occurs, as, for instance, when an object is placed on top of a platform, inside a cup or behind a screen (Wishart & Bower, 1981). Experiments of this form make up a valuable part of the research to explore the object concept and will be the focus of the next stage of this research.

The ultimate aim of the research will, of course, be to model the rules which produce the change upwards from one conceptual stage to the next. A series of cost-gain acceleration studies with infants is at present in progress in an attempt to produce data which will give us some insight into these mechanisms for change (Bower, 1981).

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