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ABSTRACT

This two-part study began with a replication, statistical validation, and extension of the Karmiloff-Smith and Inhelder study of children's construction of theories about balance. The 128 subjects (ages 4 to 6) were videotaped as they tried to balance blocks on a fulcrum. A scale was developed to assess the degree to which the child's performance indicated a theory-testing orientation to the task. Part 2 of the study used stop-action video in training sessions with 112 of the subjects who were classified as ego oriented or theory oriented. Children were required to either: predict what the block on the fulcrum--stopped in action on the video replay--would do when the tape was reactivated; predict the placement from looking at the replay of the block stopped in midair just before placement on the fulcrum; view the entire footage and summarize what they had just seen in the tape segment; or summarize their most recent attempt to balance a block. Findings indicate that while reflection in general can be conducive to the development of higher understanding, reflection is more powerful in relation to the learner's own questions and when it focuses on contradictions. Five references are listed. (LMM)

Using Video to Study Cognition

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Using Video to Study Cognition

Piaget's (1977) new model of equilibration has engendered a move among cognitive psychologists towards functionalism, incorporating a study of microdevelopment, rather than macrodevelopment, and focusing on problem solving strategies and compensations, rather than stages. Three aspects inherent in the learning process have been expanded from the earlier model and detailed: (1) self-regulation, (2) conflict resolution, and (3) reflexive abstraction.

Aspects Inherent in Learning

Self-regulation

Self-regulation refers to the active processes of assimilation and accommodation. As biological organisms, learners are constantly restructuring and adapting. They make relations and inferences about actions and events and then test out these inferences in an attempt to make meaning out of the world.

According to Kuhn and Ho (1977) the importance of self-regulation has probably been underestimated by educators. These researchers asked children to determine an unknown variable in the basic isolation of chemical task. Some children were allowed to plan their own sequence of steps, in effect to test out their own hypotheses. Others served as yoke controls and were required to do the same steps as their yoke. In other words, the experimental group decided what chemicals to mix in order to determine the correct combination of elements in Beaker x. The control group was told by the researchers which chemicals to mix, the directions determined by whatever actions were performed by the yoke in the experimental group. Hence the subjects in the control group performed the identical actions but they could not test their own hypotheses. Higher level strategies were found to exist on a similar task serving as a posttest for those subjects allowed to test their own hypotheses.

Conflict Resolution

A study by Karmiloff-Smith and Inhelder (1974) illustrates the importance of conflict resolution. These researchers studied children's construction of theories about balance by giving children (ages 3-7 years) symmetrical blocks, asymmetrical blocks, and blocks with hidden weights to balance on a fulcrum. They found that the youngest children's actions were representative of their egocentric schemes. They just "plunked" each block on the fulcrum, with no lateral shifts across the fulcrum to find the balance point. Their compensations, when blocks did not balance, consisted of claiming that the block was an impossible block to balance or of pushing harder on the block above the point of contact with the fulcrum. Since these actions obviously did not produce success, children began to explore the properties of the blocks and to try different positions on the fulcrum. Reflection on these actions brought about a focus on the procedures which worked (lateral shifts) and eventually the construction of a theory about balance which was assumed to work for all blocks. The first theory constructed was a "center" theory (find the middle of the block and it will balance). This theory was over-generalized across all blocks regardless of whether the block was asymmetrically weighted. In testing out their theories, children met with conflict. Eventually, through conflict resolution, more stable theories of balance in relation to weight were constructed.

In a microanalysis of this data, Karmiloff-Smith and Inhelder found that children without a general theory were success-oriented and reflected only on actions and procedures which worked. In contrast, children who began with theories had a theory-testing orientation to the task and thus were led to either confirm or disconfirm their theories in action. This theory testing behavior led to the eventual construction of a new one. Even a wrong theory was more helpful than no theory in the long run. Hence, the title of their article, "If you want to get ahead, get a theory."

Reflexive Abstraction

The third process in learning identified by Piaget and the Genevan School is reflexive abstraction. This process is defined by Gallagher and Reid as:

> ".....the reflection process through which one derives information from one's own actions and from the coordination of actions (putting them into correspondences, linking them, and so forth. It provides the links between and among experiences and can be detected even in the very earliest and most elementary behavior of infants. Reflexive abstraction has two aspects: a projection from a lower to a higher level--for example, from the sensorimotor level to the level of thought--and a reorganization or reconstruction of knowledge at the higher level." (Gallagher and Reid, 1981, p. 235)

Piaget (1977) distinguishes reflexive abstraction from a lower level abstraction which he calls empirical abstraction. He defines empirical abstraction as the reflection occurring in relation to the observables of the objects. In the case of the blocks in the aforementioned study by Karmiloff-Smith and Inhelder, the empirical abstractions would be in relation to the size, shape, weight of the block. In contrast, reflexive abstraction pertains to the reflection which generates theories about balance in general. Of most importance, however, is the fact that empirical abstractions lead to reflexive abstractions. In Piaget's model, reflection is seen as a spiralling process, each reflection bringing the learner to higher levels.

The Problem

While these aspects of learning have been well delineated by Piaget, they have rarely been empirically and/or statistically validated. A microanalysis of the compensations of a few subjects has usually been deemed sufficient.

Current technology allows the researcher the opportunity to record and explore these aspects from a naturalistic paradigm and then to test them in an empirical fashion. For example, video affords the researcher the ability to film individually a large number of subjects of different ages solving a problem. These film clips can then be analyzed microanalytically using stop-action, fast forward, and replay to illuminate the regulations of the subjects. Hypotheses can then be made and tested statistically.

The remainder of this paper is the report of a study using stop-action video of a problem solving task with such an approach. The first part of this study is a replication, statistical validation, and extension of the Karmiloff-Smith and Inhelder study of balance. It's purpose was to provide empirical validation of the ordinal levels as psychologically discrete behaviors and as comprising a heirarchical scale.

Part I: Naturalistic Observations

Validation of Ordinal Scale

Method

Subjects

Sixty-four girls and 64 boys whose ages ranged from 48 to 96 months served as subjects in the study. The mean age of the group was 72 months.

Materials

Materials consisted of a 1/4 inch fulcrum raised along the length of a platform 6" x 10" and a series of blocks to be balanced, modified from the Karmiloff-Smith and Inhelder task. For purposes of scoring placement, the bottom plane of each block had five imaginary points. The blocks were further classified by clusters which were felt to invoke the same theoretical principle of balance (see Figure 1).

A group of "helper blocks" was also provided each subject to use as he/she wished. All helper blocks were painted blue, to contrast with the blocks for balancing which were painted green. There were six helper blocks in all: two 2-3/4 x 2-3/4 x 1-7/8 inches, one 1-3/8 x 1-3/8 x 1-7/8 inches, and two 5-1/2 x 2-3/4 x 1-7/8 inches.

Procedure

Each child was brought individually to a testing room (adjacent to the classroom) by a female experimenter. The child was seated at a low table with the blocks to be balanced placed to his/her right and the "helper blocks" to his/her left. The fulcrum was taped to the table in front of the child. The child was asked by the experimenter to try to balance each of the blocks, one at a time, on the fulcrum. After each block was tried it was removed so that the subject tried each block only once. Subjects were videotaped as they tried each block. Video equipment was obscured from the subject's view.

Measures

Strategy scale. A scale was drafted from an analysis of the Karmiloff-Smith and Inhelder study, assessing the degree to which the child's performance indicated a theory testing orientation to the task. The use of the helper blocks, direction of lateral corrections across the fulcrum, anticipation of the effect of such factors as area or weight, and the degree to which the child tested out his/her theories about balance were all factors taken into account in constructing this scale. The scale was refined through pilot testing and expanded to incorporate five construct levels comprised of 13 operationalized behaviors as follows:

Level 1. Egocentric

1.1 This behavior is characterized by an ego orientation to all the blocks. In other words the child believes that his/her actions should balance the block; blocks are placed at any point erratically on the fulcrum and let go, or pushed hard above the point of contact, or held horizontally in place. No lateral shifts across the fulcrum to find the center of gravity occur. In fact the child at this level frequently describes the block in terms of a seesaw, having an "up" and a "down" side. He/she pushes down on one side or holds the other side up but only one side at a time is the focus.

1.2 This behavior is still characterized by an egocentric orientation although it represents a beginning decentration off a reliance on the self to a focus on the block and its properties. Different dimensions of the block are tried as well as different points of contact with the fulcrum. In place of a hand, helper blocks are used under the block to be balanced in order to "hold the down side up." Even though the properties of the block are beginning to be questioned, no lateral movements, no rotations, occur.

Level 2. Visual Center of the Bottom Plane Theory (VCB)

2.1 Although a child on this level originally places the block on the fulcrum in an egocentric fashion, lateral shifts begin to occur. At first they are towards the midpoint of the bottom plane of the block. The child appears to be beginning to form a theory (general principle) about balance, e.g. all blocks will balance if you shift to the middle of the bottom plane of the blocks. The child does not yet have a stable "theory-in-action" but is beginning to test out variables that might produce success. As the child experiments with lateral movements, he/she discovers that the overhangs of the block are related. A shift can make the "up" side go down and the "down" side go up.

2.2 This behavior is demonstrative of the first real theory. The child believes the midpoint of the bottom plane of the block to be the exact point of balance. He/she in fact struggles through measurement or lateral corrections to find this point. The original placement is a VCB (visual center of the bottom plane) placement, with the expectation that this is the correct placement, rather than an ego oriented, random placement.

2.3 Although the child at this level still originally places the block at its VCB, since this strategy does not work for many of the blocks, the child begins to test out whether the visual center (midpoint) of the whole block (rather than the bottom plane) is a better theory. For example, blocks #1 and #2 have a VCB at point 2. This original placement will not successfully balance the blocks. The child shifts the block towards point 3.

Level 3. Visual Center Theory (VC)

3.1 The distinction between levels two and three is that, whereas the placements in level two were all around or at the VCB, the original placement at this level is a bisection of the whole block in order to find the midpoint. Specifically, at level two, blocks in clusters two and five were placed originally at point 2 and then shifted to point 3. By level three, the child is certain that the whole block must be bisected and thus places these specified blocks at point 3 originally.

3.2 This behavior is characterized by the use of helper blocks. However, this time they are placed on top of the block, rather than underneath for support. Importantly, they are placed on top of the "up" side to make the "down" side come up. This fact suggests that the child is testing whether adding a block to the main block will affect balance. Although helper blocks are used, all blocks are placed and remain at point 3.

3.3 This behavior begins with an original VC placement but the child shifts the block towards the side with the greater area. Since the VC was the original placement this behavior is still classified as representative of a visual center theory. This behavior is most obvious with blocks #7,8,9,13, and 10. Interestingly, this action occurs even in block #10, even though these corrections are away from the obviously more heavily weighted side!

Level 4. Area Center Theory (AC)

4.1 This behavior suggests that the child has given up the insufficient theory about the visual center and now assumes that weight is a factor. However, weight is determined by visual cues; bigger space is assumed to weigh more. Original placements are toward the side with the greater area (e.g., point 2 on blocks #7, 8, 9, 13, 10). Since the child seems sure of this placement as the only "correct" one, all corrections consist of a struggle to find balance around point 2.

4.2 Here the child begins to question whether greater space is really analogous to greater weight. In the face of conflict, he/she reverts back to an earlier theory and uses the visual center as an anchor point. Corrections are made both towards the weighted side and the side with greater space, depending on the block. For example, Cluster 3 blocks are originally placed at point 3 and corrected towards point 2; Cluster 4 blocks, in contrast, are originally placed at point 3 and then corrected towards point 4.

4.3 This behavior is characterized by a reaffirmation about the need to bisect the area of the block. Thus original placements are again at this bisection (point 2 for Cluster 3). Corrections are made, in contrast to 4.1 toward the more heavily weighted side.

Level 5. Weight Theory (WT)

5.1 Here the child has finally constructed a theory about weight and understands that it is the weight that must be bisected by the fulcrum. Thus, the original placement is an estimate of this bisection, point 4 on the weighted blocks. Corrections consist only of a struggle to find this midpoint.

5.2 This last behavior entails production. Because the child has a stable understanding of weight, he/she knows that helper blocks must be added to the impossible blocks (Cluster 5). He/she adds helper blocks and then makes the appropriate lateral shifts to find the balance point, evidence that the reciprocal nature of distance and weight is understood.

This ordinal scale was further operationalized in terms of expected behavior for each of the blocks thus defining an idealized profile for each level. For example, a child at level 2.2 (VCB) should place the length blocks at point 3 originally and struggle with this area searching for the midpoint. The displaced base blocks, in contrast, would be placed originally and corrected around the visual center of the bottom plane, point 2. The same placement would occur with the impossible blocks. With the asymmetrical and weighted blocks, point 3 again becomes the focus even though these attempts at balancing are unsuccessful. The child just deems these as "hard blocks."

Two raters, blind to the age of the child, viewed the video tapes and assigned each child to one of the 13 behavioral profiles. Since there were cases where children did not exhibit a perfect fit to any one of the 13 idealized profiles, the raters double coded 20% of all video tapes. The interrater reliability score was 86% based on the number of perfect matches divided by the number of subjects double coded.

Cluster Score

The blocks were categorized (see Figure 1) into clusters which ostensibly tapped the same level of understanding. For instance, Cluster 1 should be the easiest group of blocks to balance since each block could be balanced successfully with a theory about bisecting the base of the block. Cluster 2 tapped the abstraction of bisecting the whole block rather than just the base. Cluster 3, the asymmetrical blocks, should be passed by subjects holding a theory about area as analogous to weight. The weighted blocks, Cluster 4, should only be passed by subjects having an understanding about weight. Cluster 5, the impossible blocks, should be the most difficult cluster since it required an understanding of the need not only to add counterweight, but also to move the block on the fulcrum to equally balance that weight.

In order to alleviate the possibility that success could occur by chance this measure was made very stringent. Every block in the cluster had to be balanced successfully before the subject was coded as passing that respective cluster. It was assumed that for subjects to pass a cluster they had to make an inference about how the blocks in that cluster were alike and then struggle with them to find the exact balance point. Subjects were given a score of pass or fail on each cluster.

Results

Strategy Scale

The Spearman Correlation Coefficient, appropriate for non-parametric measures, was derived yielding $r=.63$, $p=.001$ for age and level. In order to further assess discreteness between levels the 13 operationalized behaviors were combined into the five construct levels which they tapped. Bonferroni *t* tests assessing mean age differences between levels were significant at .05. Mean ages (in months) for each level were 56,66,76,83,90 respectively.

Cluster Score

A Guttman scalogram analysis was performed to test the hypothesis that a difficulty order existed from one to five and that subjects passing Cluster 2 had also passed Cluster 1; subjects passing Cluster 3 had also passed Cluster 1 and 2, etc. The coefficient of reproducibility was .95 with a coefficient of scalability at .80.

Discussion

The data clearly substantiated the predicted ordinal scale of strategies. The youngest children attempted to balance the blocks by egocentrically placing them at random points on the fulcrum. If the block fell, which happened frequently, they declared that the block could not be balanced. The first corrections observed were towards the middle of the bottom plane of the blocks even when these corrections were obviously in the wrong direction. This VCB theory was eventually transcended to include the whole block. Visual center theories, while successful for some of the blocks, when generalized to all the blocks became insufficient. Thus children eventually determined that area and weight were factors, made corrections towards these factors, and finally understood that weight must be equal on both sides of the balance point.

The Guttman analysis demonstrated that the lower level theories were necessary to the construction of the higher levels. The strategies, although related, were in no way sufficient to produce success on the clusters. In other words, children, in attempting to balance the blocks, frequently were willing to test out other variables than the one they believed to have an effect. For example, children with a VCB theory were willing to test out the middle of the whole block as a balance point. Those with a VC theory were willing to test out the effect of a shift towards the greater area; those with a belief that a bisection of the area was the correct point also tested out the effect of weight. But until they developed "physical necessity" (the understanding that each block was indeed possible), they did not struggle with the new variable enough to be successful with the cluster. To wit, while they were willing to test out variables which contradicted their theory, until they held fast to a new theory they did not struggle enough to be successful with the cluster which tested that theory.

Implications

Piaget's notion of reflexive abstraction suggests that learners need to reflect on the result of their actions in relation to the theory they hold about balance, i.e. contradictions and the resulting reflection bring the learner to produce higher level theories. Although this process seemed apparent in the protocols, there was insufficient data to corroborate such a premise. Thus the second part of this study was designed to test this assumption. It was hypothesized that egocentric children would benefit most from a reflection on the block's action, given their tendency to form assumptions about the role of their own action. According to Piaget, coordinating the action of the object with the self's action should result in the construction of a general physical principle. Thus a reflection, via video replay, on whether the block balanced or fell and to which side of the fulcrum it fell should be profitable. Theory oriented children, on the other hand, were expected to profit more from reflection on the placements that were inconsistent with their theory. For example, a child who thinks the block will balance at point 3, but then sees via video replay that it actually balanced at point 2, might attempt to resolve this contradiction and thus construct a new theory.

Part II: Effect of Stop-action Video

Method

Subjects

One hundred and twelve of the subjects tested in part one of the study were classified as ego oriented or theory oriented. All children who successfully balanced at least one cluster of blocks were assigned to the Theory category, called theory because these children at least had a rule that worked for a subset of all blocks. All children who did not reach criterion on at least one cluster of blocks were assigned to the Ego category, called ego because these children attended more to their desire to have each block balance rather than to general principles about balance.

Materials

The materials used were the same as those in part one of the study.

Procedure

Subjects were randomly distributed into one of four different treatment conditions, given four training sessions, and then posttested. Sex was not controlled since a previous analysis (condition x age x sex) had shown no significant difference (Fosnot, 1983).

A basic factorial design of two orientation groups (ego vs. theory) and four training conditions was used. Children were pretested on the training tasks in session one, later given four training sessions, followed by a posttest session on the training task. Briefly, in Treatment Condition I, called the Predict Block condition, the child was asked to predict what the block on the fulcrum, stopped in action on the video replay, would do when the tape was reactivated. In Treatment Condition II, the Predict Placement condition, the child was asked to predict the placement from looking at the replay of the block stopped in mid-air just before placement on the fulcrum. In Treatment Condition III, called the Summarize Replay condition, the child saw the entire footage from the first grasp of the block to the end of the first clear release of the block and its subsequent balance or fall. The child in this condition was then asked to summarize what he/she had just seen in the tape segment. In Treatment Condition IV, called the Summarize No Video condition, the child was simply asked to summarize his/her most recent attempt to balance a block.

The design tested the null hypotheses that the means of the pre to posttest difference within each condition would be the same for the Ego group and that the means within each condition for the Theory group would be the same. No main effect for condition was expected. A significant interaction effect between orientation and condition was expected with the Ego group performing the best in the Predict Block condition and the Theory group performing the best in the Predict Placement condition.

General directions. The experimenter designated the green blocks and said, "I would like you to balance these blocks one at a time on here (points to the fulcrum). These are helper blocks which you may use to help you if you wish."

Blocks were then presented to the child one at a time by the experimenter. In sessions one and three the blocks were presented in a predetermined order. In sessions two and four that order was reversed.

Predict block condition. The experimenter presented each block, one at a time, with hands on each side of the block so that the bottom length of the block was clear. She said, "Try this one." At the presentation of blocks #2,4,5,6,10,11, and 14 the experimenter pressed the counter on the video recorder to zero. After the completion of the episode (child attempted to balance the block and it balanced or fell) with each of the aforementioned blocks, the experimenter rewound the tape to zero and said, "Let's look at you trying that block on television." The tape was then replayed until the point where the child placed the block on the fulcrum. The experimenter stopped that action by pushing the recorder switch to pause and asked, "What is the block going to do?" If the child did not respond, the experimenter probed with, "Will it balance or fall?" With a response of fall, the child was asked to show on the T.V. which direction the block would fall. The experimenter recorded each prediction on data sheets, then said to the child, "Let's see." The switch was then pushed to play and the remainder of the episode was replayed for the child to observe the correctness of the prediction. Blocks #1,3,6,7,9,12, and 13 were presented to the child for balancing but no video replay was given.

Predict placement condition. The same beginning directions were given as above. During the replay, stop-action occurred just before the child placed the block on the fulcrum. The child was then asked to predict the placement of the block. The experimenter said, "Show me where on the block you are going to place it." If the child did not understand the question, the experimenter said, "Here, or here, or here?" while moving her finger across the bottom of the block from point one to five. Predictions were again written down. The experimenter said, "Let's see." The remainder of the episode was then replayed.

Summarize replay condition. Directions were the same as in conditions I and II except that the tape was rewound to zero in the designated episodes and replayed for the child without stop-action. The experimenter then said, "Tell me what happened." Responses were written down.

No video condition. The child was presented each block to balance as in the other conditions. After the designated episodes, the child was simply asked, "Tell me what happened." Responses were written down by the experimenter.

Thus in all conditions subjects were questioned on seven episodes during a session. The length of each episode was the same across conditions since the replay began with the presentation of the block and ended when the child finished with the block.

Pre and posttest directions. The child was simply asked to try and balance each of the blocks, one at a time, on the fulcrum.

Measures

The dependent variable was a simple assessment (pre to post difference) of the number of blocks successfully balanced.

Results

Planned Comparisons

The mean difference scores between pre and posttests for each of the cells were calculated and planned comparison two-tailed Dunnett d tests were done to compare the performance of the experimental groups with the control groups. No significant difference was found between conditions for children who began with an ego orientation. For children who began with a theory strong enough to pass at least one cluster, this was not the case. As hypothesized, a significant difference (p=.05) was found between the group asked to predict the placement of the blocks and the group receiving no video feedback. As can be seen from Table 1, showing the means of the groups, theory children did best in condition II, although the difference was not statistically significant with groups other than the no video feedback group.

A closer look at which blocks were successfully balanced produced some further insights. When grouped by clusters, thereby eliminating luck as a possible factor, condition II produced more success than every other condition for the Theory group (p=.05) See Table 2.

Analysis of Variance

An analysis of variance with the regression approach for unequal N's was performed. Age was covaried. No main effect was found for the variables Orientation (F=.89, p=.35) or Condition (F=1.34, p=.27). A significant (F=2.6, p=.05) two-way interaction between Orientation and Treatment Condition was found. Post hoc Bonferroni *t* tests showed the interaction to be significant at .05 between the orientation groups in condition II. While this was the most successful training condition for the Theory group, it was the least successful for the Ego group.

Discussion

The data showed conclusively that for children who have already begun to think about a general means of balance, rather than what they themselves do in a specific instance, stop-action video improves performance if the stop-action orients the child to where he/she is about to place the block. This was seen in the Theory category of children in the Predict Placement condition. With this type of video feedback the children had to reflect on their reasons for each placement. Having to predict the placement just prior to the continuation of the feedback tape, combined with the feedback of the consequent success or failure, helped to bring the whole episode into an integrated system of means-end relations. Straight replay was not as potent a training condition, nor was reflection on the action of the block, suggesting that assumptions cannot be made about the content of the child's reflection. Repeated exposure is not necessarily constructive.

Ego children, while being younger than the Theory group, were also characteristically different in their approach to the training task. Response protocols indicated that these children were more often the children who made only brief adjustments with a block if it did not balance. They were more likely to attribute a failure to a "bad block" than to their own placement strategy. They were frequently children who explored the physical attributes of each block independent of how those attributes related to the balancing task.

Children in the Theory group understood, at least in part, that there was some rule that could be applied to several blocks, if not all blocks, that could be discovered if one thought clearly about several blocks at a time. These children would make spontaneous comments such as, "Hey, this one is not like the other one." This was most prevalent when two blocks looked alike but were weighted differently. Thus it is reasonable to conclude that children in the Theory group during training reflected more on the means to establish balance. The rules they constructed were the result of reflecting on means-end relations. The reflection facilitated by Condition I, Predict Block, is not as appropriate a match to the theory-oriented child's assimilatory schemes. The focus of this reflection is not means or theory oriented, but simply object/action oriented. The theory-oriented child is not thinking about "what" happens, but "why" it happens. Evidently reflection on the success and failure of the block, without relating the means by which that success/failure occurred, has no positive effects for problem solving in these situations.

Although the hypothesis about the advantage of the Predict Block condition for the ego-oriented children was not supported, there was a trend for this group to do better in Condition I than in the other conditions. It is possible that had training been longer than four sessions, a significant difference may have been found between conditions for the Ego children. Perhaps Condition I did facilitate a decentration from one's own actions to the action of the block more than the other conditions, but the step from an ego orientation to the first theory is a big one, requiring more time than going from a VC theory to an AC theory.

The reasons for the lack of success of Ego children in Condition II were obvious during the data collection. First, because they had no theory about a necessary placement, the question ascertaining placement made no sense to them and thus probably served as a distractor. Many Ego children during training were observed (in response to the placement question) tracing a vertical line on the monitor from the fulcrum to the point on the block directly above the fulcrum. In other words their responses were based on proximal causes rather than any theory about a "correct" placement. Other Ego children were just simply confused by the question and appeared to be guessing randomly.

Secondly, this condition for Ego children might have served as a negative reinforcer. For Ego children, the question, "Show me the spot on the block where you are going to put it" might have been interpreted with an emphasis on the "you". Thus the ensuing action of the block falling becomes a criticism of their placement. In contrast, Theory children might have emphasized the placement question in relation to a theory about balance, rather than themselves, thus the ensuing action of the block becomes feedback to confirm or disconfirm that theory.

Conclusions and Implications for Further Research

This study is evidence that, while reflection in general can be conducive to the development of higher understanding, when reflection is in relation to the learner's own question and focuses on contradictions it is more powerful. Such a conceptual understanding of reflection is in concert with the notions of learning as a constructed, self-regulated process. In the process of problem solving, the learner has expectations and hypotheses which he/she is testing, dependent on his/her stage of development. Reflection on the result of actions related to these hypotheses is more conducive to learning than simply reflecting on the whole episode. Assumptions cannot be made that because replay is provided the learner is necessarily focusing on the relevant aspects of the episode.

This study also serves as an illustration of how current technology can be used to study cognition. The use of video in part one of this study allowed for a naturalistic filming of the self-regulated behavior of the children as they attempted to balance the blocks. All adjustments, pauses, corrections, and apparent testing of variables could be captured on film and then analyzed later. These data then led to hypotheses about developmental differences in orientation to the task which were consequently tested in part two of the study.

While video technology was sufficient in this experiment in recording behavior, the analysis still had some subjectivity due to human raters making judgements while viewing the tapes. Although interater reliability was high, current computer technology could alleviate any subjectivity. If subjects attempted to solve a similar simulated physics task on a monitor, the computer could record all adjustments made and then determine the variables the subjects were apparently testing.

Computer programming also structures information into a theory testing paradigm. If a child is asked to write a program to simulate the physics of a task, he/she must construct a rule or formula to explain the phenomenom. When the program is run, if it does not work it must be "debugged" or analyzed for errors. This process is analogous to theory testing, a process demonstrated by the video study to be conducive to learning.

The following study has been designed as an extension of the video study using computer technology. Ninety-six boys and girls between the ages of 8 and 10 years will be asked to balance the blocks used in the video study. Two groups will be asked to do this task via a computer simulation (see Figure 2); a third group will serve as a control and will have direct experience with wooden blocks on a fulcrum. The computer groups will differ in that one group will have training in programming the blocks to balance while the other group will simply attempt to balance each block by directly moving the computer graphic. It is hypothesized that the group programming the blocks to balance, since programming requires ~~the~~ generating and testing of a theory, will progress further in an understanding of the physics involved than the groups having only graphic simulation or direct physical experience.

This study should allow educators to capitalize on the more unique features of computer technology in ways that ultimately give students more autonomy in evaluating their own theories about the scientific principles involved in physical knowledge. More importantly, it allows the researcher to be a more efficient, scientific theory tester of theory-testing behavior.

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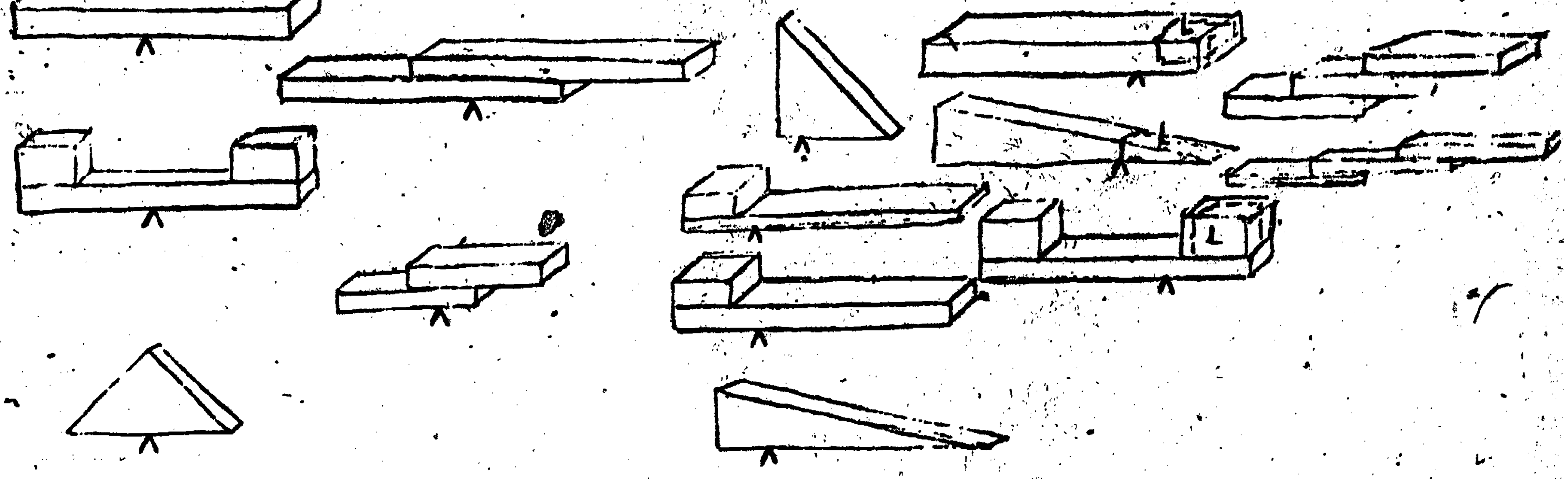
FIGURE 1

Balance task blocks. Blocks drawn to a 1:6 scale. Drawings arranged into 5 clusters.

cluster 1	cluster 2	cluster 3	cluster 4	cluster 5
visually symmetrical blocks		conspicuously weighted blocks	inconspicuously weighted blocks	impossible blocks*



∧ designates balance point

L designates lead

* These blocks can be balanced with the use of helper blocks as counterweights

Helper Blocks:

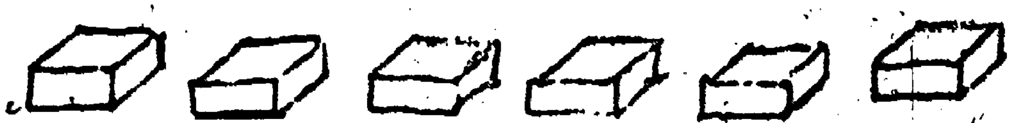
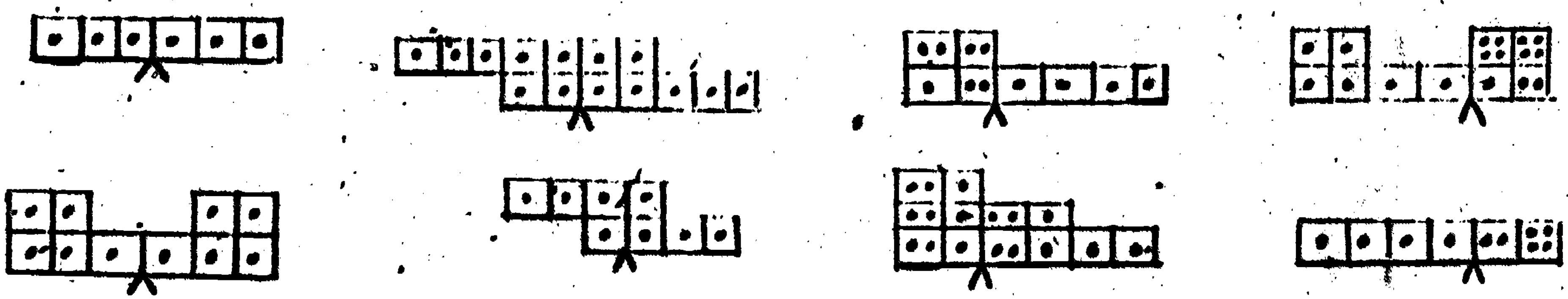


FIGURE 2

Computer Simulations of Blocks in Figure 1



cluster 1 cluster 2 cluster 3 cluster 4

Λ designates balance point (turtle placement)

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TABLE 1

CHANGE IN NUMBER OF BLOCKS SUCCESSFULLY BALANCED BY TREATMENT CONDITION AND PRETEST ABILITY

Pretest Ability	Treatment Condition			
	Block I	Placement II	Replay II	No Video IV
Ego:				
$\bar{x}$ pre test score	1.8(1.5)*	2.5(2.1)	2.1(1.4)	2.2(1.3)
$\bar{x}$ post test score	3.3(2.4)	2.6(3.1)	2.9(3.1)	3.3(1.3)
mean change	1.5	.1	.82	1.17
Theory:				
$\bar{x}$ pre test score	6.7(3.4)	7.1(2.9)	6.4(2.7)	7.8(3.7)
$\bar{x}$ post test score	8.7(4.0)	10.8(3.3)	8.1(4.2)	8.5(4.6)
mean change	1.94	3.76	1.71	.71

*Standard deviations are in parentheses.

TABLE 2

CHANGE IN NUMBER OF CLUSTERS SUCCESSFULLY PASSED BY TREATMENT CONDITION AND PRETEST ABILITY

	Treatment Condition			
Pretest Ability	Block I	Placement II	Replay III	No Video IV
Ego:				
$\bar{x}$ pre test score	0(0)*	0(0)	0(0)	0(0)
$\bar{x}$ post test score	.6(.8)	.4(1)	.5(1)	.5(.9)
mean change	.6	.4	.5	.5
Theory:				
$\bar{x}$ pre test score	2.01(1.1)	1.9(1)	1.7(1)	2.3(1.2)
$\bar{x}$ post test score	2.6(1.7)	3.5(1.3)	2.2(1.6)	2.7(1.8)
mean change	.6	1.6	.5	.4

*standard deviations are in parentheses.