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ABSTRACT

This study investigated several levels of internal and external disequilibrium and their interaction. Subjects were 63 fifth graders assigned to three groups according to their degree of internal disequilibrium. Internal disequilibrium was measured by the amount "level mixture" (a tendency to respond to various events at several different reasoning levels) demonstrated on a map drawing pretest. Within each internal disequilibrium group subjects were assigned to low, middle or high external disequilibrium conditions, in which they received training on maps drawn at their own modal level, and one level above, or at two levels above. Post testing was conducted using the map drawing task, two spatial reasoning tasks and a delayed posttest. Findings suggest that: (1) external disequilibrium determines primarily the direction of discrepancy between existing and presented cognitive modes and is therefore an important factor influencing the direction of change; (2) internal disequilibrium relates to instability and may therefore primarily affect the amount of change; and (3) under conditions conducive to progressive change, bias distinguishes between subjects likely to advance in modal level and those likely to undergo further elaboration and consolidation of the current level. (Author/GO)

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An Experimental Test of The Effects of Internal and External Disequilibrium on Spatial Reasoning Development

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Effects of External Disequilibrium on Reasoning Development

PS 008082

An Experimental Test of the Effects of Internal and External Disequilibrium on Spatial Reasoning Development[1]

Piaget's notion of a change mechanism, the equilibration model, has recently been the object of conceptual elaboration (e.g. Flavell & Wohlwill, 1969; Langer, 1969a; Strauss, 1972; Turiel, 1969). The present research attempted empirical test of a recent elaboration by Sidney Strauss (1972) in an effort to delineate several aspects of disequilibrium states which may lead to more precise specification of the mechanisms and conditions underlying developmental advance.

Strauss and others (e.g. Langer, 1969a; Turiel, 1969) have argued that while the course of development can be broadly characterized as movement from less to more stable equilibrium states, it is the child in <u>disequilibrium</u> who is most likely to acquire new information and establish a higher-order equilibrated state which reduces disequilibrium. Just as Piaget (1960, 1967) has emphasized both external and internal aspects of structural stability, so has Strauss (1972) presented an analogous dual analysis of structural instability: (<u>a</u>) <u>external disequilibrium</u> refers to the interplay of current structure with discrepant environmental events and (<u>b</u>) <u>internal disequilibrium</u> refers to contradictions within the existing structure itself. External disequilibrium arises from confrontation with events somewhat in advance of the current cognitive state (e.g. Bruner, 1964; Inhelder & Sinclair, 1969; Kuhn, 1972; Smedslund, 1961, 1963; Turiel, 1969), but motivates attempts at adaptation to the more advanced level only when the discrepancy is recognized (Langer, 1969a). Internal disequilibrium is operationalized as "level mixture" (i.e. a tendency to respond to a variety of events at a range of several different reasoning levels), and is therefore thought to increase the likelihood that discrepancies from the most common or modal level will be recognized (Strauss, 1972; Langer, 1969a,b).

In previous research, both external and internal aspects of disequilibrium have been shown to facilitate developmental advance under certain conditions. Numerous Piagetian training studies (see Brainerd, 1973; Flavell, 1970 for reviews) indicate that experience at a more advanced developmental level can lead to improved performance on the trained problem. Evidence concerning the relative effects of different external disequilibrium levels is found in research examining moral development (Turiel, 1966) and children's object classification styles (Kuhn, 1972). In these studies, a subject's developmental level of moral reasoning or object classification was assessed prior to training. Moral judgments or classification schemes were then modeled at one of several external disequilibrium levels: one level _below_ the subject's (-1), the same level as the subject's (_0_) (Kuhn's study only), and one (+1) or two (+2) levels _above_ the subject's own. The effectiveness of treatments at various levels in facilitating _advance_ differed significantly: +1 was superior to +2, both were superior to -1 (and to _0_ which was similar in effect to -1 in Kuhn's study), and -1 induced only minimal regression. In Kuhn's research, of those subjects exposed to +2 and who advanced, most did so to +1.

Limited evidence concerning the effects of internal disequilibrium and the interaction of internal and external disequilibrium may be derived from _post hoc_ interpretation of several Piagetian training studies in which "transitional" subjects were identified prior to treatment (see Strauss, 1972 for a review). These studies indicate that transitional subjects tend to benefit more from training than do nontransitional subjects. To the extent that transitional reasoning, which must include aspects of at least two different cognitive levels, is indicative of

relatively greater level mixture, this research suggests a differentially facilitative effect of a single external disequilibrium treatment across two broadly-conceived levels of internal disequilibrium.

Despite their joint centrality in attempts to conceptualize mechanisms of change, very little previous research has attempted to examine both internal and external aspects of disequilibrium. The present study therefore attempted to investigate several levels of external disequilibrium and several levels of internal disequilibrium as well as their interaction. Piaget's six-level sequence in the growth of children's map drawing representations was operationalized into a scoring procedure yielding a mixture index as well as the more traditional performance level estimate (Snyder, Feldman & LaRossa, 1975). Subjects were rank ordered according to the extent of level mixture in pretest map drawings, and level mixture was taken as a measure of internal disequilibrium. Subjects were divided into three groups differing in degree of internal disequilibrium. A randomized within strata assignment to three treatments representing different degrees of external disequilibrium produced a 3x3 experimental design. The low external disequilibrium condition (0) provided instruction with map drawing techniques at the subject's preferred level, middle external disequilibrium (+1) utilized map drawing techniques one level above, and high external (+2) involved training with maps two levels above the subject's own. Results from the two-factor, three-level design were intended to bear on three sets of hypotheses:

(1) External disequilibrium has been shown to facilitate developmental advance. Therefore, it was predicted that the 0 condition, which presents a minimum of discrepancy, would result in minimal advance. Both the +1 and +2 conditions provide greater discrepancy and were hypothesized to

induce greater advance, with the +1 condition doing so more effectively than +2. In addition, it was hypothesized that most subjects exposed to +2 and who changed levels would advance to +1. These predictions follow from previous research results (Kuhn, 1972; Turiel, 1966, 1969).

(2) Internal disequilibrium as reflected in level mixture is hypothesized to be an indicator of sensitivity to discrepancy. Because of greater variation ranging across several different levels in the sequence, higher mixture subjects should be more likely to recognize contradictions and more able to resolve them at a more advanced level. It was therefore predicted that within each treatment, subjects with greater internal disequilibrium would show greater developmental advance than would lower internal disequilibrium subjects. This hypothesis follows conceptually from previous studies but has little empirical precedent.

(3) While detailed predictions concerning the interaction of internal with external disequilibrium could not be made, the following questions were raised: (a) Will a minimally discrepant external disequilibrium condition (i.e. 0) induce differential changes in level mixture among higher as compared with lower internal disequilibrium subjects? (b) Will lower internal disequilibrium (i.e. nontransitional) subjects tend to exhibit increased level mixture (i.e. become more transitional) following exposure to a more discrepant external disequilibrium condition (i.e. +1 or +2)? (c) Will higher internal disequilibrium subjects tend to "consolidate" at a higher developmental level following experience +1 or +2 levels from their own mode, thereby inducing decreased level mixture? (d) And finally, what is the optimal combination of internal and external disequilibrium levels, i.e. which combination results in the greatest developmental advance ?

Method

Subjects

Subjects were 96 fifth graders (46 girls and 50 boys) attending standard classes at the public intermediate school in Branford, Connecticut. Sample mean age was 10.70 years with a range from 9.92 to 11.92 years.

Pretesting

The Verbal Meaning subtest of the Primary Mental Abilities Test for grades four through six (Thurstone & Thurstone, 1963b) provided IQ estimates for use in matching subsamples. Parts I and II were group administered ($n \cong 25$) and scored following the procedures outlined in the <u>Examiner's Manual</u> (Thurstone & Thurstone, 1963a).

The principal pretest measure was a Map Drawing Exercise adapted from Piaget and Inhelder (1948).[2] Briefly, the Map Drawing Exercise requires each subject to draw a map of a miniature village landscape. The scoring system is based on Piaget's six-level sequence in the growth of map drawing ability (see Table 1). This procedure was used to evaluate the subject's level of representation (from one to six) of five "feature clusters" through the utilization of four "spatial concepts" (see Table 2). Thus, each map drawing yielded a total of 20 separate scores--(five feature clusters) x (four spatial concepts)=20 "concept/feature" scores—each of which in turn may range from a score of one to six. Objective scoring was facilitated through the use of accurately-scaled transparent plastic overlays and a detailed series of decision rules (see Snyder, Feldman, & LaRossa, 1975).

Insert Tables 1 and 2 about here

The 20 scores were used to compute the following three indicies: (a) a Map Drawing Mean, calculated by summing the concept/feature scores and dividing by the total number of scores (typically 20); (b) a Modal Level, assessed by examining the distribution of concept/feature scores and identifying the most frequent level. In cases where no clear mode existed, Level Mixture was calculated as described below for each possible mode, and the one yielding the highest mix was chosen (after Turiel, 1969). (c) Level Mixture was calculated by multiplying the number of scores at each level by the number of steps separating that level from the Modal Level, and then summing the products (Turiel, 1969). By convention, this sum is multiplied by 100 to remove the decimal point.

Partitioning the Sample

All 96 pretest maps were scored by an assistant. Interjudge agreement on a randomly selected sample of 21 maps (the senior author served as second rater) was 83% across all 21x20 scores. Disagreements--none was greater than one level--were discussed and those scores were adjusted. Only subjects at Modal Level three were assigned to experimental treatments since too few subjects at other modes were represented across the high, medium and low Level Mixture groups. To approximate equal numbers across these conditions, nine low mix subjects at Modal Level three were randomly excluded from the experiment. The remaining 63 subjects, stratified by Level Mixture and sex, were then randomly assigned to the three treatments: high, medium, and low external disequilibrium.

Analysis of variance on the pretest measures indicated no significant differences across external disequilibrium conditions prior to treatment. However, there was a significant difference in Map Drawing Mean among

groups divided according to Level Mixture ($F_{2,54}$=3.34, p <.05) with higher mixture associated with higher Map Drawing Mean (Table 3); a similar difference was reported by Turiel (1969) in his research on moral judgment. Independent group t-tests comparing males with females on all pretest indicies indicated no significant differences associated with sex of subject.

Insert Table 3 about here

Instruction

Instruction was conducted in two separate sessions, approximately ten subjects at a time, under the supervision of the senior author and a female assistant. The treatments were designed to induce low, medium, or high external disequilibrium through experience with "target" maps drawn at the subject's own Modal Level (0 or level three), one level above (+1 or level four), or two levels above (+2 or level five). The general training procedure as described below was followed in all conditions.

During the first training session each subject received a target map drawn at the selected level of a second landscape and an activity booklet. Subjects worked self-paced through the activities which were designed to require comparison of the model to the map with respect to qualities of the target level (Table 4). After completing the activities, subjects drew their own maps of the second landscape.

Insert Table 4 about here

On the following day in the second training session, subjects received the same target map, a photocopy of their own map from the previous day, and a second activity booklet. The activities again encouraged comparisons among the model and the target map, and now the subject's own map as well, again emphasizing the target level map's characteristics.

Posttests and Transfer Measures

Posttest. Immediately following the end of the second instruction session subjects drew a posttest map of the original landscape model; instructions were identical to those in the pretest. The assistant, without knowledge of treatment condition, scored all 63 posttest maps. Interjudge agreement on a randomly selected sample of 20 maps was 92%, and again all discrepancies (none greater than one level) were discussed and adjusted.

Transfer. Two additional posttests examined transfer to related spatial reasoning tasks. Horizontal and vertical systems of reference were assessed with adaptations of the "objects on a slope" and "rotated jars" measures of Piaget and Inhelder (1948). Each of three "horizontal" items (e.g. the plane of liquid in rotated jars) and three "vertical" items (e.g. objects on the slope of a hill, a plumb line in rotated jars) was classified according to the sequence outlined by Piaget, and the mean of the six classifications served as the subject's transfer score on this measure.

An adaptation of the "three mountains" task as described in Laurendeau and Pinard (1970) tested subjects' ability to adopt a series of perspectives other than their own. A video tape display of a three-mountain model, recorded from the "child's eye" view, was the stimulus. A multiple-choice answer booklet contained the following types of schematic drawings as options for each of five different vantage points around the model: (a) the correct view; (b) front/back correspondence correct, but left/right relationships reversed; (c) left/right relationships correct, but front/back correspondence reversed; and (d) the "straight-on" or "egocentric" perspective. The correct representation was scored as two points, the

egocentric view was zero, and each of the "semi-correct" representations received one point. A sum over the five test positions was the subject's Perspectives score.

Delayed posttest. Approximately five weeks after the immediate posttest, subjects drew a third map of the original landscape model. Again, the assistant scored all maps; inter-judge agreement on a randomly selected sample of 20 maps was greater than 90%, and all discrepancies (none more than one level) were discussed and adjusted.

Results and Discussion

Pretest group differences associated with Level Mixture made standard analysis of variance on posttest and delayed posttest Map Drawing Mean scores inappropriate. Since the design of the study and the Map Drawing Mean scores met criteria for covariance analysis (Cronbach & Furby, 1970), results reported for posttest and delayed posttest Map Drawing Mean were calculated by analysis of covariance except as otherwise indicated.

Hypothesis 1--Effects of External Disequilibrium.

The first hypothesis predicted that (a) the 0 treatment would not induce significant change; (b) the +1 and +2 treatments would facilitate greater advance, +1 more effectively than +2 and (c) of those subjects in the +2 condition who advanced in Modal Level, most would advance to +1. Results bearing on Hypothesis 1 are presented below for posttest and delayed posttest maps, then for the transfer measures.

Posttest. Analysis of covariance adjusted scores on the posttest Map Drawing Mean showed a significant main effect in the predicted direction associated with treatment differences ($F_{2,53}$=11.87, $p<.001$). As Table 3 indicates, the rank ordering of raw posttest score means was +2, +1, 0.

Internal analysis of pre- to posttest change in the 0 treatment revealed a mean difference of -.008 which did not approach significance by dependent groups t-test (t_{20}=.177, p >.50). Thus the 0 treatment, as predicted, did fail to produce significant advance. Two orthogonal 1 df contrasts on adjusted posttest Map Drawing Mean scores indicated that while +1 and +2 together were significantly higher than 0 ($F_{1,53}$=23.60, p <.002), the +1 versus +2 comparison revealed an insignificant difference between these two treatments ($F_{1,53}$=.16, p >.50). In sum, while the data supported predictions that 0 would not induce significant advance and that +1 and +2 would facilitate greater advance than the 0 condition, the prediction that +1 would be more effective than +2 was not supported.

An analysis of variance on mean posttest Modal Level (Table 5) failed to indicate a significant main effect of treatment ($F_{2,54}$=1.32, p >.20), but the pattern of advance as shown in Table 6 was in the predicted direction. In 0, three of 21 advanced while in +1 and in +2, seven of 21 advanced in each case. All subjects advancing in Modal Level after treatment did so to level four, i.e. to +1. Assuming the null hypothesis--that among +2 subjects who advanced (n=7), movements to +1 or to +2 were equally probable--it is rejected at the .007 level by binomial theorem. Thus, while the analysis of variance on mean posttest Modal Level did not reveal a significant effect of treatment, the pattern of advances was in the predicted direction. The prediction that most of those subjects exposed to the +2 treatment who advanced in Modal Level would move to +1 was supported.

Insert Tables 5 and 6 about here

Delayed posttest. Analysis of adjusted, delayed posttest Map Drawing Mean showed a significant main effect related to treatment differences ($F_{2,51}$=8.85, p <.001); the rank order of unadjusted posttest scores was

+2, +1, 0 (Table 3). In the 0 condition, the pre- to delayed posttest mean difference of .001 was not significant (t_{18}=.019, p >.50). Internal comparisons by 1 df contrasts on adjusted scores showed that the +1 and +2 treatments together were again associated with significantly more advance than 0 ($F_{1,51}$=17.49, p <.002), but did not differ from each other ($F_{1,51}$=.326, p >.50).

In contrast to the posttest results, analysis of unadjusted delayed posttest Modal Level (Table 5) revealed a significant treatment main effect ($F_{2,52}$=3.62, p <.04). The distribution of advances is shown in Table 6--two of 19 in 0, nine of 21 in +1 and nine of 21 in +2--departed significantly from chance in the predicted direction (X^2_2=6.205, p <.05). A dependent groups t-test demonstrated nonsignificant change in the 0 condition ($\bar{D}$=.105, t_{18}=1.455, p >.50). Two orthogonal 1 df contrasts on raw scores indicated that while the combined +1 and +2 treatments facilitated greater advance in Modal Level than did 0 ($F_{1,52}$=6.95, p <.011), +1 and +2 were again similar in effect ($F_{1,52}$=.014, p >.50). Since all subjects advancing did so to +1, the null hypothesis that movements to +1 or to +2 were equally probable following the +2 treatment was again rejected by binomial theorem, this time at the .002 level.

Transfer. The patterns of scores on the Perspectives and Systems of Reference transfer measures were in the predicted direction (Table 7), but the analysis revealed only nonsignificant contrasts associated with treatment. As prior analyses had suggested that the +1 and +2 treatments were similar in their effects, the sample was collapsed across these two conditions and an analysis of variance was computed on the resulting 3x2 table. While the main effect due to treatment remained nonsignificant on the Perspectives measure (X_0=3.53, $X_{+1,+2}$=4.92; $F_{1,57}$=2.48, p <.12), it

approached significance on the Systems of Reference scores (X_0=3.47, $X_{+1,+2}$=3.78; $F_{1,57}$=3.77, $p<.06$). Both distributions were then standardized, and a second 3x2 analysis of variance was computed with mean z-scores. This analysis revealed a significant treatment effect in the predicted direction on the average of Perspectives and Systems of Reference z-scores (X_0=-.314, $X_{+1,+2}$=.158; $F_{1,57}$=4.46, $p<.04$), thus providing limited evidence of greater transfer from the +1 and +2 treatments than from the 0 condition.

Insert Table 7 about here

Hypothesis 2--Effects of Internal Disequilibrium

The second hypothesis predicted that within each treatment, subjects with higher internal disequilibrium (i.e. higher Level Mixture) would show greater developmental advance than would subjects with lower internal disequilibrium. Results bearing on Hypothesis 2 are discussed below with respect to posttest and delayed posttest maps, then in terms of the transfer measures.

Posttest. Although the pattern of raw posttest Map Drawing Mean scores (Table 3) showed a rank order of high mix, mid mix, low mix as predicted, this same pattern, as noted earlier, was also present on the pretest. Analysis of covariance adjusted posttest Map Drawing Mean scores failed to demonstrate a significant main effect associated with Level Mixture differences ($F_{2,53}$=.374, $p>.45$). Thus, the predicted differential effect was not found with respect to mean performance on the posttest map drawings.

The analysis of variance on posttest Modal Level (Table 5), however, revealed a significant main effect in the predicted direction ($F_{2,54}$=3.09, $p<.053$). The distribution of advances in Modal Level (Table 6)--10 of 22

in high mix, four of 19 in mid mix, three of 22 in low mix--was in the predicted direction and significantly different from chance (X^2_2=6.14, p<.05). Internal comparisons of unadjusted scores by 1 df contrasts indicated that while the mid mix and low mix groups did not differ significantly ($F_{1,54}$=.51, p>.45), high mix subjects advanced in Modal Level significantly more often than did mid mix and low mix subjects combined ($F_{1,54}$=5.68, p<.02). Thus the analysis of posttest Modal Level, as contrasted with Map Drawing Mean, yielded results in support of Hypothesis 2.

Delayed posttest. As with the posttest Map Drawing Mean, examination of unadjusted delayed posttest Map Drawing Mean scores showed a high, mid, low mix rank order as predicted (Table 3). Again, however, analysis of adjusted scores failed to indicate a significant main effect related to differences in Level Mixture ($F_{2,51}$=2.08, p<.14). Analysis of raw delayed posttest Modal Level (Table 5), however, did demonstrate a significant main effect of Level Mixture ($F_{2,52}$=3.26, p<.05) as was the case with the posttest. As presented in Table 6, the distribution of advances in Modal Level--11 of 21 in high mix, five of 19 in mid mix, four of 21 in low mix--was in the predicted direction. When the sample was collapsed to compare high mix (11 of 21 advanced) with mid and low mix combined (nine of 40 advanced), the distribution departed significantly from chance (X^2_1=5.58, p<.02). Internal comparisons of raw scores by orthogonal 1 df contrasts showed no significant difference between mid and low mix subjects ($F_{1,52}$=.635, p>.40) whereas high mix subjects advanced in Modal Level significantly more often than did mid mix and low mix subjects combined ($F_{1,52}$=5.88, p<.02). Thus, results from the delayed posttest parallel those reported above for the posttest. Effects of internal disequilibrium consistent with Hypothesis 2 were demonstrated for Modal Level advances but not for Map Drawing Mean performance.

Transfer. While the patterns of performance on the transfer measures were in the predicted direction (Table 7), analysis of scores on the Perspectives and Systems of Reference tasks failed to indicate significant main effects associated with Level Mixture differences ($F_{2,54}$=.703 and 1.000 respectively, $p > .35$ in both instances).

Negative or regressive changes. In the above results, analysis of posttest and delayed posttest map drawings revealed a significant main effect of internal disequilibrium on Modal Level, with higher mixture associated with more frequent advance as predicted. However, no significant internal disequilibrium effects were demonstrated with respect to mean map drawing performance. In an effort to resolve these apparently contradictory findings, a *post hoc* analysis examined the number and direction of changes in scores from pretest to posttest and from pretest to delayed posttest. This item-by-item examination compared pretest scores for each concept/feature with respective scores on the post and delayed posttests. Items on which the subject improved were designated as "plus," items which remained at the pretest level were recorded as "same," and those items which were classified at a lower level on the later map drawings were scored "minus," in all cases without regard to the size of the change.

Analysis of variance on the ratio of total changes (plus *and* minus) to total number of responses (plus *and* minus *and* same) on the posttest indicated a significant main effect of Level Mixture ($F_{2,54}$=5.17, $p < .01$) as follows: Higher mixture was associated with *more* raw change, i.e. fewer responses remained unchanged from pretest to posttest (Table 8). Two internal comparisons by orthogonal 1 *df* contrasts indicated that while

the mid mix versus low mix difference was suggestive ($\underline{F}_{1,54}=3.34$, $\underline{p}<.07$), high mix subjects made significantly more changes than did mid and low mix subjects combined ($\underline{F}_{1,54}=7.59$, $\underline{p}<.01$).

Insert Table 8 about here

Moreover, while analysis of the ratio of plus changes to total changes (Table 9) failed to demonstrate a main effect of Level Mixture ($\underline{F}_{2,54}=1.23$, $\underline{p}<.30$), there was a significant effect of Level Mixture on the ratio of minus changes to total changes as shown in Table 10 ($\underline{F}_{2,54}=4.98$, $\underline{p}<.01$), with higher internal disequilibrium associated with more minus changes from pre to posttest. Internal comparisons by 1 df contrasts showed that mid mix subjects were similar to low mix subjects ($\underline{F}_{2,54}=2.43$, $\underline{p}=.10$), but that high mix subjects made more minus changes as compared to mid and low mix subjects combined ($\underline{F}_{1,54}=7.59$, $\underline{p}<.01$). Similar analyses on pre to delayed posttest changes showed identical patterns of results but failed to reach statistical significance (Tables 8, 9, and 10).

Insert Tables 9 and 10 about here

The above post hoc analyses begin to clarify the paradoxical results obtained for the effects of internal disequilibrium (i.e. for Level Mixture). For example, changes in concept/feature scores from level three to four as well as those from level five to four both facilitated advance in Modal Level (i.e. movement from level three to four). While Modal Level advances occurred significantly more often among high mix subjects, minus changes also occurred more often in this group, and those from level five to four in effect "cancelled out" plus changes from level three to four, thus reducing the net gain in Map Drawing Mean among these subjects.

Thus, the processes of transition at a given point in development may operate from the "top downward" as well as from the "bottom upward" (Langer, 1969a; Turiel, 1969, 1974). Apparent "regressions" may actually serve a progressive function.

Hypothesis 3—The Interaction of Internal with External Disequilibrium

The third hypothesis made no detailed predictions but rather focused on several general questions regarding (a) differential effects of low external disequilibrium (0) on higher as compared to lower internal disequilibrium, (b) differential effects of higher external disequilibrium (+1 and +2) on higher as compared to lower internal disequilibrium, and (c) the optimal combination of external and internal disequilibrium to facilitate developmental advance.

Effects of external on internal disequilibrium. Table 11 summarizes changes in Level Mixture from pre to posttest and from pretest to delayed posttest for all subjects. Among high internal disequilibrium (high Level Mixture) subjects in the 0 condition, Level Mixture decreased, both from pre to posttest and from pre to delayed posttest as well. This latter decrease was somewhat attenuated by a slight increase in Level Mixture from post to delayed posttest among these subjects. For low internal disequilibrium subjects in the 0 condition, Level Mixture remained essentially unchanged from pre to posttest, but then decreased from posttest to delayed posttest. Changes in Level Mixture among middle internal disequilibrium subjects in the same condition were intermediate between those of high and low mixture groups, showing a decrease from pre to posttest (but less extreme than that in high mix), and a further decrease from post to delayed posttest (but less extreme than in the low mix group).

Insert Table 11 about here

Among middle and high internal disequilibrium subjects in the +1 and +2 conditions taken together, the trend was a decrease in Level Mixture, both from pre to posttest and from pretest to delayed posttest, but the trend was less pronounced in the mid-mix group. For low internal disequilibrium subjects in the +1 and +2 conditions, however, the trend was reversed; there were increases in Level Mixture from pre to posttest and from pre to delayed posttest as well.

To summarize the above trends, the 0 condition did not promote differential changes in Level Mixture among higher as compared with lower internal disequilibrium subjects. By the delayed posttest, all internal disequilibrium groups in the 0 condition showed similar reductions in Level Mixture. The +1 and +2 conditions taken together, however, facilitated increases among low mix subjects and decreases among high mix and mid mix subjects, as had been suggested in Hypothesis 3.

The concept of Bias. The results to this point indicate that both external and internal aspects of disequilibrium contributed to change in map drawing levels and that the effects of external on internal disequilibrium were relatively systematic. In order to begin examination of more complex interactive relationships (and more than a beginning is beyond the scope of this study), it was necessary to include an additional aspect of disequilibrium, the Bias indicator. The Bias indicator is an attempt to add a measure of "directionality" to the simple index of variation around the mode provided by Level Mixture. In the extreme case of "mirror-image" response profiles, where identical patterns of response frequencies occur but on opposite sides of the mode, Modal Level and Level Mixture indicies are identical (see Figure 1). While these two profiles are

therefore indistinguishable with respect to mode and mixture, we believe that they are indicative of quite different developmental states. These states are directly related to the issue of readiness for advance and are distinguishable through the indicator of directionality called Bias.

The operational definition of Bias focuses on the distribution of non-Modal Level responses for each subject: A greater number of responses at levels above the mode than below is designated positive Bias; and conversely, more responses below the mode than above is designated negative Bias (Figure 1). To illustrate the predictive power of the Bias index, 85% of all advances in Modal Level on the delayed posttest occurred among the positive Bias subjects, who themselves comprised but 62% of the sample. Moreover, while 45% (17 of 38) of all positive Bias subjects advanced (irrespective of treatment or mixture), only 13% (3 of 23) of negative Bias subjects did so. This difference in proportions advancing is statistically significant (X_1^2=6.05, $p<.02$).

Optimal conditions for advance. Specification of conditions most conducive to developmental advance (with respect to Modal Level) is enhanced by adding the Bias indicator to the other indicies. For example, 11 of 21 high Level Mixture subjects advanced in Modal Level on the delayed posttest; of these, nine had positive Bias indicies. Similarly, 18 of 42 subjects exposed to the +1 or +2 conditions had advanced in Modal Level by the delayed posttest; 15 of the 18 advancing were positive Bias subjects. Moreover, when higher internal and higher external disequilibrium subjects are considered together, 10 of 15 high mix subjects in +1 and +2 advanced in Modal Level, and eight of those 10 advancing were positive Bias subjects. In terms of Modal Level advances then, changes occurred with greatest frequency among high Level Mixture, positive Bias subjects following the +1 or +2 treatments.

Thus, Bias provides added precision to predictions concerning developmental advances of the kinds that have been investigated in this study. The results therefore suggest that a more fine-grained characterization of internal disequilibrium states requires indicies of directionality as well as measures of dispersion. While the present study was not designed to include analyses based on differential strengths of Bias, and while the number of positive and negative Bias subjects was uneven across mixture and treatment groups, our predictions of shifts in Modal Level are nonetheless enhanced by including the Bias indicator.

Relative Effects of the +1 and +2 Conditions

Results showing that advances of more than one Modal Level or step in the sequence were extremely rare are consistent with our predictions and with prior research on both moral reasoning and object classification. Failure to obtain the predicted differential effect when the +1 treatment was compared with the +2 condition, however, is apparently inconsistent with the same prior research and with Piaget's formulation as well.

The meaning of this mixed patternof treatment effects may be informed by consideration of differences between moral reasoning (the subject of most previous studies) and map drawing. Evidence suggests that moral judgments form a sequence of qualitatively different products which, through the first several levels, are essentially guaranteed by qualitative changes in cognitive capabilities (Kohlberg, 1971; Piaget, 1932). Advance through the more sophisticated moral judgment levels appears to result from sociocultural variables interacting with formally operational cognitive structures (Kohlberg, 1971; Kohlberg & Gilligan, 1974; Turiel, 1969). Differences among judgments at all levels in the moral development sequence, however, are thought to be qualitative in nature (Rest et al., 1969).

In contrast, an examination of the map drawing sequence suggests that while advance through all six levels may be mediated by qualitative changes in cognitive capabilities, changes in the map drawings themselves are qualitative only for levels one through four. At level four a map drawing incorporates with some sophistication all of the essential characteristics of a two-dimensional representation of three-dimensional space. Thus, improvement from a level four to a higher level map may be accomplished by applying qualitatively different conceptual operations to the production of more accurate scaling of sizes and distances, improvements which are themselves quantitative in nature.

This view of the map drawing sequence suggests that while qualitative advances in cognitive ability may be necessary in order to produce a level five map, the quantitatively different maps which served as "target" models in the present study may have posed less difficulty in comprehension than do qualitatively different moral judgments also separated by one level. While the available data do not permit confirmation or rejection of this possibility, it is consistent with informal observation of the training sessions, with our knowledge of subjects' prior experience with maps at level five (+2) or higher, and with the pattern of results obtained.

Subjects had no apparent difficulty understanding the target maps at level five; that is, they were able to complete the activities outlined in the training booklet and were able to do so in approximately the same time as with level four (+1) target maps. In addition, all subjects had had considerable practice working with level five and level six maps in the context of their standard social studies curricula from first grade on. Thus, our analysis of the map drawing sequence suggests that both the level five and level four target maps could be comprehended, but that

improvements in subjects' <u>production</u> of posttest maps were constrained by a lack of requisite changes in conceptual capabilities, capabilities limited to a single level of advance in the sequence. Therefore, while target maps at both level five and level four were similar in their effects on overall performance, changes in Modal Level were always to +1 in both treatments.

Within all three treatments there was a strong tendency for subjects to change responses in the direction of the target map, that is, in the direction from which external disequilibrium was applied. In +1 and +2, where the target level was higher than the subject's mode, the general trend was progressive and is reflected in significant increases in both Map Drawing Mean and Modal Level; there was essentially no change in the means of these variables following the 0 treatment. For subjects in the 0 condition, responses tended to further accumulate at target level three, and this is reflected in a precipitious drop in Level Mixture on the delayed posttest across all three internal disequilibrium groups following the treatment (Table 11).

The above trends are also evident in the *post hoc* analysis of number and direction of changes on the concept/feature scores. The ratio of plus changes to total responses on the delayed posttest (Table 9), for example, showed a significant main effect of external disequilibrium, with subjects in +1 and +2 making higher proportions of plus changes than did subjects in 0 ($F_{2,52}=7.64$, $p<.002$). Similarly, there was a significant treatment effect demonstrated on the ratio of minus changes to total responses ($F_{2,52}=4.16$, $p<.03$) with subjects in 0 making more minus changes than did subjects in the +1 and +2 conditions (Table 10). Moreover, for subjects

in the 0 condition, while pretest Modal Level responses tended to remain at level three (i.e. at the target level) on the delayed posttest (84% did so), 56% of those responses below the mode advanced to the mode, and 52% of the responses above the mode on the pretest regressed to or toward the mode on the delayed posttest.

Instability and consolidation. The patterns of change in the present study may be further informed through more detailed consideration of the concepts of "instability" and "consolidation" (cf. Flavell & Wohwill, 1969; Strauss, 1972) as they relate to the interaction of internal with external disequilibrium. Strauss for example, in summarizing a series of studies, says of internal disequilibrium:

> Children who displayed [level] mixture were more likely than those who displayed no measured [level] mixture to... transform their cognitive structures. One can interpret this to mean that [level] mixture may be an inherently unstable state that is particularly susceptible to change (1972, p.338).

While over the course of normal development this susceptibility is typically described as "readiness" for advance, Strauss (1972) suggests that higher level mixture is also indicative of lower "consolidation" of the emerging abilities, meaning that they may be more likely to regress in favor of a lower, better consolidated level:

> One would imagine that a child who recently learned rules of application to weight problems [or to map drawing] is <u>less likely to reject</u> [lower level] information than a child who has learned the same rules...and who has consolidated them... for a considerable period of time (p. 350, emphasis added).

Our analyses show that higher Level Mixture is associated with more advances in Modal Level (Table 6) and with more total changes in concept/feature scores (Table 8), thus reinforcing the notion that higher internal disequilibrium is indicative of greater susceptibility to change. While the results indicate a general tendency to move from any existing cognitive level toward any level of external disequilibrium that is encountered, this study made no direct attempt to induce regressive change in well-consolidated structures. Very little of such change in fact occurred. None of the subjects showed a downward shift in Modal Level from three to two, and of the 750 concept/feature scores at level three on the pre-test, only 4% (31 responses) regressed to level two on the delayed posttest. The bulk of change from the best consolidated level (i.e. the Modal Level) was progressive--87% of those Modal Level responses changing from pretest to delayed posttest moved to a more advanced level. Most regressive change then, occurred from less well consolidated (i.e. less frequently used) cognitive levels to better consolidated levels as suggested by Strauss (1972).

<u>Demand characteristics</u>. The present study used explicit instructions indicating that the target level map was a "good" model to be copied, and is therefore open to a "demand characteristics" interpretation of its tendency to induce changes in the direction of external disequilibrium. While such a view is not inconsistent with the patterns of change in both the <u>0</u> condition--for which it is the authors' preferred interpretation--and in the +1

treatment, a cognitive developmental view appears necessary to integrate the results from +1 and +2. The patterns of change following the +2 condition suggest that although developmental change was generally toward any more advanced (but comprehensible) model, more fine-grained analysis also revealed change <u>away</u> from the model but <u>toward</u> the emerging cognitive level. Thus, the patterns of regressive changes in +2 were similar to those in +1, with responses at levels five and six tending to move to level four. These movements--toward the model in +1, but away from the model in +2--are in both cases toward the emerging Modal Level and contribute to its elaboration and consolidation. Neither a demand characteristics nor a "developmental" interpretation is alone sufficient to account for the pattern of results obtained, and there is evidence to suggest that both influences affected performance. A naturalistic, longitudinal examination of level-to-level transition is currently in preparation to provide direct evidence on the consolidation phenomenon as it may more typically occur.

<u>Summary of findings</u>

Our findings support the following conclusions about the role of developmentally appropriate interventions:

1. Progressive developmental change is unlikely to occur under conditions of minimal external disequilibrium.

2. Under conditions of sufficient external disequilibrium, <u>all</u> subjects tend to change progressively, regardless of their initial state. Examining the interactions of three variables--internal disequilibrium, external disequilibrium, and Bias--helps to give form to the developmental advances as they occur among groups of subjects exposed to prescribed environmental experiences:

(A) Lower internal disequilibrium (i.e. lower Level Mixture) subjects are unlikely to advance in Modal Level (73% did not) but are likely to show increased Map Drawing Mean and increased Level Mixture when exposed to appropriate instructional experiences (80% did both). In other words, "nontransitional" subjects tend to become more transitional following treatment.

(B) High internal disequilibrium subjects with negative Bias tend to consolidate their current Modal Level and to elaborate more advanced levels so as to shift from negative to positive Bias (80% did so). While these subjects thus show increased Map Drawing Mean scores, they typically retain the same Modal Level (again, 80% did so. Moreover, although Level Mixture generally decreased among high mix subjects following +1 and +2 (Table 11), most of the decrease is accounted for by <u>positive</u> Bias subjects (see below) with high mix, negative Bias subjects showing an average drop of only 2.6 points in Level Mixture. Thus, these already transitional subjects (high mix, negative Bias) become "more" transitional following training, maintaining a relatively high degree of Level Mixture and shifting from negative to positive Bias, but usually retaining the same Modal Level.

(C) High internal disequilibrium, positive Bias subjects are the "most" transitional and are very likely to advance in Modal Level, concomitantly to shift from positive to negative Bias (80% did both). As indicated, most of the decrease in Level Mixture for all high mix subjects in +1 and +2 occurs among the high mix, positive Bias subjects ($\bar{D}$= -15.00). These "most" transitional subjects prior to training are therefore less transitional afterward--showing decreased Level

Mixture and a shift from positive to negative Bias--but less transitional at a higher Modal Level. Because of the contribution of changes in concept/feature scores from both above and below the mode toward the new Modal Level, subjects in this group tend to show somewhat less of an increase in Map Drawing Mean than do high mix negative Bias subjects.

Conclusion. Trends in the data have suggested the following generalizations as guides to future research:

(1) External disequilibrium determines primarily the direction of discrepancy between existing and presented cognitive modes and is therefore an important factor influencing the direction of change.

(2) Internal disequilibrium relates to instability and may therefore be seen to affect primarily the amount of change.

(3) Under conditions conducive to progressive change, Bias distinguishes between those subjects likely to advance in Modal Level and those likely to undergo further elaboration and consolidation of the current level, i.e. to advance in mean performance but not in Modal Level.

The present study was not extended sufficiently to determine if the "most" transitional subjects and the nontransitional subjects would eventually exchange their positions in the course of time as they moved through developmental levels. The conceptual framework stimulated by the results of the present study, however, offers a means to begin the investigation of this and other aspects of developmental change at a level of detail heretofore not possible.

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Footnotes

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2 A detailed description of this instrument, together with discussions of administration and scoring procedures is available in Snyder, Feldman, and LaRossa (1975).

Table 1

Levels of Spatial Reasoning Development as Revealed in Map Drawing

(adapted from Piaget & Inhelder, 1948)

Level 1: No spatial correspondence except for a few elementary proximities.

Characterized by child's inability to distinguish between spatial proximity and logical resemblance or between spatial separation and logical difference. Yields objects on map which do not appear on model and objects on model which are not represented on map. Arrangement appears virtually arbitrary.

Level 2: Partial coordination.

Characterized by recognizable but inconsistent logical and numerical correspondence. Spatial correspondence often confounded with logical resemblance or limited to small groups of proximal objects and isolated left-right relations without an overall spatial plan. Representation limited to one dimension (i.e. uses frontal view) with detail and proportion essentially unrelated to model.

Level 3: Midway between partial and beginning of general coordination.

Characterized by <u>inconsistent</u> coordination, i.e. reasonable logical and numerical correspondence but with a mixture of perspective (e.g. frontal, 45°, 90°) and viewpoints, in poor but recognizable proportion to model. Larger groups of objects now linked together to produce primitive overall representations of model, often with "photograph-like" detail.

Table 1 (continued)

Level 4: Beginning of general projective and Euclidean coordination.

Characterized by items in good logical and numerical correspondence and arranged according to a crude two-way system of reference (i.e. width and depth) with a consistent 45^{o} or 90^{o} perspective. A legitimate two-dimensional representation of the model often with some evidence of abstraction, but with as yet inaccurate scaling--relative sizes of objects often proportional, but distances (especially heights in the 45^{o} perspective) remain distorted.

Level 5: Mastery of distances and proportions.

Characterized by complete coordination of logical and numerical with spatial correspondences. Although not formally scaled with metrics and fractional reduction, an adequate diagrammatic representation of the model. A consistent 90^{o} perspective with clear evidence of abstraction and symbolization.

Level 6: The abstract plan with metric coordinates.

Characterized by complete coordination, totally accurate scaling, a consistent 90^{o} perspective, and use of abstract symbolization.

Table 2

Feature Clusters and Spatial Concepts Used in Scoring Drawings

(after Snyder, Feldman, and LaRossa, 1975)

FEATURE CLUSTERS

1. Buildings--easily identifiable logical class; regularly shaped; obvious third dimension, but relatively easy to represent.

2. Hill, bridge, island, other elevated land--among major features of model; relatively large; irregularly shaped; three dimensional; more difficult to represent.

3. Lake, river, roads, driveways, parking lots--major flat surfaces of model; easily represented.

4. Trees, fence, motor vehicles, flagpole, bushes--relatively small, more "incidental" features of model; obvious third dimension; relatively difficult to represent.

5. All inclusive score--all content combined, the "map as a whole."

SPATIAL CONCEPTS (adapted from Piaget & Inhelder, 1948)

I. Arrangement--emphasizes topological concepts in lower levels and Euclidean concepts, i.e., systems of coordinates, in advanced levels.

II. Proportion--emphasizes Euclidean concepts, i.e. similarity.

III. Perspective--emphasizes projective concepts.

IV. Abstraction/Symbolization--emphasizes pictorial conventions.

Table 3

Pretest, Posttest, and Delayed Posttest Map Drawing Mean

Internal Disequilibrium	External Disequilibrium	Pretest	Map Drawing Mean Posttest	Delayed Posttest	n
High Mix	0	3.26	3.21	3.24	7*
	+1	3.14	3.49	3.40	8
	+2	3.33	3.56	3.66	7
Mid Mix	0	3.20	3.21	3.14	7
	+1	3.12	3.29	3.47	6
	+2	3.07	3.44	3.39	6
Low Mix	0	3.00	3.02	3.06	7*
	+1	3.02	3.30	3.29	7
	+2	3.01	3.28	3.25	8

* Delayed Posttest n=6

Table 4

Summary of Level-Related Characteristics Emphasized by Each of the Instruction Conditions

LEVEL 3--(0) Condition:

A. Arrangement--dual emphasis on logical and mathematical correspondence (i.e. same "kinds" and "number" of items) and on simple topological relations (i.e. left-right, before-behind, etc.).

B. Proportion--emphasis on primitive correspondence in relative size of items (i.e. hill > bridge, lake > any house, etc.).

C. Perspective--no direct emphasis; indirect exposure to mixed perspective and viewpoints via target map.

D. Abstraction/Symbolization--no direct emphasis; indirect exposure to detailed representation via target map.

LEVEL 4--(+1) Condition:

A. Arrangement--emphasis on construction of crude system of two-way reference (i.e. locate items in appropriate quartile of map); indirect incorporation of logical and mathematical correspondence via target map and through numerical comparisons of items in each quartile.

B. Proportion--emphasis on accurate reproduction of small differences in relative size of items; indirect exposure to inaccurate reproduction of distances via target map.

C. Perspective--emphasis on consistent 90° perspective (i.e. "A map is like looking down.").

D. Abstraction/Symbolization--no direct emphasis; indirect exposure to limited abstraction associated with a realistic 90° perspective via target map.

Table 4 (continued)

LEVEL 5 (+2) Condition:

A. Arrangement--emphasis on relatively sophisticated system of two-way reference (i.e. locate items in appropriate sextile of map); indirect incorporation of logical and mathematical correspondence via target map and through numerical comparisons of items in each sextile.

B. Proportion--emphasis on accurate reproduction of small differences in relative size of items and on maintenance of accurate inter-object distances.

C. Perspective--no direct emphasis; indirect exposure to a consistent 90° perspective via target map.

D. Abstraction/Symbolization--emphasis on use of icons and labels to allow the elimination of considerable detail from map and yet permit identification of items.

Table 5

Pretest, Posttest, and Delayed Posttest Modal Level Means

Internal Disequilibrium	External Disequilibrium	Modal Level Pretest	Modal Level Posttest	Modal Level Delayed Posttest	n
High Mix	0	3.00**	3.29	3.17	7*
	+1	3.00	3.62	3.50	8
	+2	3.00	3.43	3.86	7
Mid Mix	0	3.00	3.14	3.14	7
	+1	3.00	3.17	3.50	8
	+2	3.00	3.33	3.17	6
Low Mix	0	3.00	3.00	3.00	7*
	+1	3.00	3.14	3.29	7
	+2	3.00	3.25	3.25	8

* Delayed Posttest n=6

** Pretest Modal Level was 3.00 in all subjects, since this was a criterion for selection into the study.

Table 6

Proportion of Advances in Modal Level on Posttest and Delayed Posttest

Internal Disequilibrium Level	Post/ Delay	External Disequilibrium Level 0	+1	+2	Row Total
High Mix	Posttest	2/7	5/8	3/7	10/22
	Delayed Post	1/6	4/8	6/7	11/21
Mid Mix	Posttest	1/7	1/6	2/6	4/19
	Delayed Post	1/7	3/6	1/6	5/19
Low Mix	Posttest	0/7	1/7	2/8	3/22
	Delayed Post	0/6	2/7	2/8	4/21
Column Totals	Posttest	3/21	7/21	7/21	17/63
	Delayed Post	2/19	9/21	9/21	20/61

Table 7

Scores on the Perspectives and Systems of Reference Transfer Measures

Internal Disequilibrium	Transfer Measures	External Disequilibrium 0	+1	+2	Row Means
High Mix	Perspectives	4.57	5.25	5.43	5.08
	Reference Systems	3.55	3.84	4.10	3.83
Mid Mix	Perspectives	3.00	3.50	6.67	4.40
	Reference Systems	3.41	3.67	3.83	3.64
Low Mix	Perspectives	3.00	4.14	4.50	3.88
	Reference Systems	3.45	3.86	3.41	3.57
Column Means	Perspectives	3.52	4.30	5.53	
	Reference Systems	3.47	3.80	3.78	

Table 8

Ratio of Plus and Minus Changes to Total Responses on the Posttest and Delayed Posttest

Internal Disequilibrium	Post/ Delayed Posttest	External Disequilibrium 0	+1	+2	Row Means
High Mix	Posttest	.47	.51	.47	.48
	Delayed Post	.40	.54	.41	.45
Mid Mix	Posttest	.33	.41	.51	.42
	Delayed Post	.32	.46	.47	.42
Low Mix	Posttest	.24	.40	.36	.34
	Delayed Post	.30	.45	.38	.38
Column Means	Posttest	.35	.44	.45	
	Delayed Post	.34	.48	.42	

Table 9

Ratio of Plus Changes to Total Responses on the Posttest and Delayed Posttest

Internal Disequilibrium	Post/ Delayed Posttest	External Disequilibrium 0	+1	+2	Row Means
High Mix	Posttest	.22	.40	.34	.32
	Delayed Post	.22	.38	.34	.31
Mid Mix	Posttest	.17	.28	.43	.29
	Delayed Post	.14	.37	.39	.30
Low Mix	Posttest	.14	.32	.29	.25
	Delayed Post	.18	.34	.30	.27
Column Means	Posttest	.18	.33	.36	
	Delayed Post	.18	.36	.34	

Table 10

Ratio of Minus Changes to Total Responses on the Posttest and Delayed Posttest

Internal Disequilibrium	Post/ Delayed Posttest	External Disequilibrium 0	+1	+2	Row Means
High Mix	Posttest	.25	.11	.13	.16
	Delayed Post	.18	.16	.08	.14
Mid Mix	Posttest	.15	.13	.08	.12
	Delayed Post	.18	.09	.08	.12
Low Mix	Posttest	.11	.08	.07	.08
	Delayed Post	.13	.11	.08	.11
Column Means	Posttest	.17	.11	.09	
	Delayed Post	.16	.12	.08	

Table 11

Pretest, Posttest, and Delayed Posttest Level Mixture Scores with Pre/Post and Pre/Delayed Post Changes Displayed

Internal Disequilibrium	External Disequilibrium	Pretest Mixture	Posttest Mixture	Delay Mixture	Pre/Post Change	Pre/Delay Change
High Mix	0	62.00	39.43	44.33	−22.57	−18.00
	+1	57.25	41.25	47.25	−16.00	−10.00
	+2	58.57	53.57	40.71	− 5.00	−17.86
Mid Mix	0	43.43	37.14	[illegible]7.86	− 6.29	−15.57
	+1	42.50	37.50	41.67	− 5.00	− .83
	+2	43.67	44.17	34.17	.50	− 9.50
Low Mix	0	30.71	32.43	17.67	1.71	−12.33
	+1	26.43	35.71	45.00	9.29	18.57
	+2	25.00	47.50	40.00	22.50	15.00

Figure Captions

Figure 1. Illustration of positive and negative Bias profiles. The two histograms show two subjects with identical Modal Level and Level Mix scores,[a] but with different valence Biases, one positive and one negative. Positive Bias is thought to reflect the child's "readiness" for advance to the next level, while negative bias is believed to indicate the child's "readiness" for consolidation of the existing Modal Level.

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[a] Modal Level for both subjects is 3
Level mix for Subject 1, positive bias, is calculated below:

$$L\text{-}M = \frac{1(2+5)+2(1+4)+3(0)+4(0)+5(0)}{20} = \frac{7+10}{20} = \frac{17}{20} = .85$$

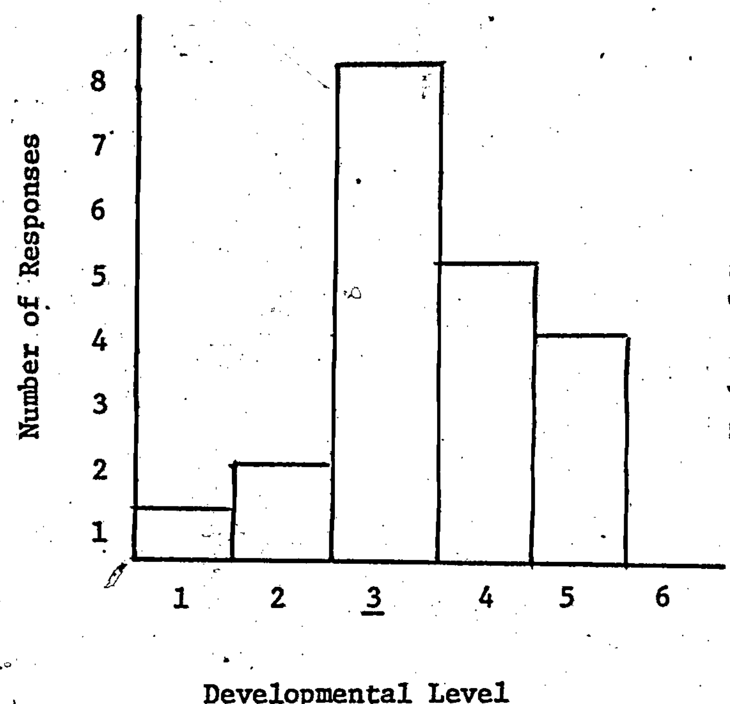
Level Mix for Subject 2, negative bias, is calculated as below:

$$L\text{-}M = \frac{1(5+2)+2(4+1)+3(0)+4(0)+5(0)}{20} = \frac{7+10}{20} = \frac{17}{20} = .85$$

By convention, Level Mix is multiplied by 100 to remove the decimal point, thus yielding identical level mix indicies of <u>85</u> for these subjects.

Subject 1

Positive Bias



Subject 2

Negative Bias