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ABSTRACT

A study of twins was conducted to determine the presence of an hereditary component in short term memory and in three aspects of verbal divergent thinking--flexibility, fluency, and originality. Results showed the existence of a significant genetic component in the trait of short term memory, while none was found in verbal divergent thinking. (AG)

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# THE GENETIC COMPONENTS OF VERBAL DIVERGENT THINKING AND SHORT TERM MEMORY

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In order to determine the existence or extent of genetic determination of the trait, the following hypotheses were tested:

1. The F ratio of within - pair fraternal twin variance to the within - pair identical twin variance on the Short Term Memory will not be significant at the five percent level.

2. The F ratio of within - pair fraternal twin variance to the within - pair identical twin variance on the "Unusual Uses" Test - Flauency will not be significant at the five percent level.

3. The F ratio of within - pair fraternal twin variance to the within - pair identical twin variance on the "Unusual Uses" Test - Flexibility will not be significant at the five percent level.

4. The F ratio of within - pair fraternal twin variance to the within - pair identical twin variance on the "Unusual Uses" Test - Originality will not be significant at the five percent level.

Thirty-seven pairs of identical twins and twenty-eight pairs of fraternal twins were recruited through the Massachusetts Mothers of Twins Association. The trait of short term memory was operationalized using a modified "digit span" as appears in the WAIS. The Torrance Tests of Creative Thinking, Verbal B, "Unusual Uses of Tin Cans" was used for the divergent thinking variable.

The first null hypothesis was rejected, while the second, third, and fourth were not. This was interpreted as the existence of a significant genetic component in the trait of short term memory and a failure to demonstrate a significant genetic component in Verbal Divergent Thinking. The Holzinger Index of Heritability for short term memory was .54. This may be considered the square of correlation between genotype and phenotype, i.e. 54% concomitant variation between genetic make up and the manifested trait.

THE GENETIC COMPONENTS OF VERBAL DIVERGENT THINKING
AND
SHORT TERM MEMORY

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Arthur Jensen's seminal article in the Harvard Educational Review (1969) has rekindled interest in the subject of heritability, that is, the proportion of a manifested trait's variance that is due to genetic variation. Summarizing the literature on the heritability of intelligence, more precisely the heritability of whatever common factor is measured by the conventional IQ tests, Jensen concludes that 80% of the variation in IQ is concomitant with variation in genetic composition. A good deal of the rekindled interest created by the article centers around the vary nature of intelligence. Few scholars today still assert that intelligence is unitary in nature. Instead most researchers have asserted the presence of a number of separate factors in intelligence, and several, e.g. Vandenberg (1965b, 1967), Block (1968), Strandskov (1955), have attempted to isolate those factors to assess separate heritabilities even before the publication of the Jensen article. This interest led to the investigation of two such factors, i.e. verbal divergent thinking and short term memory.

A good deal of data is available on the heritability of the conventional global measure of cognitive ability, the IQ. In "How Much Can We Boost IQ and Scholastic Achievement?" Arthur Jensen (1969) bases much of his argument for the immutability of IQ differences on the high heritability of IQ. He argues that IQ variation is due in great measure to genetic variation.

His thesis, of course, is not without criticism, both philosophical (Cronbach, 1969), (Bereiter, 1969), (Hunt, 1969), and methodological (Kagan, 1969), (Light & Smith, 1969). One of these criticisms regards Jensen's conception of the nature of intelligence. Jensen has focused his review of heritability on the underlying common factor in intelligence tests, Spearman's 'g'. Since factor analysis has shown intelligence is not a unitary trait, there may be other factors of intelligence with heritabilities which differ from Jensen's conclusion concerning the heritability of 'g'.

Considerable evidence is available supporting the existence of separate, somewhat independent factors in intelligence. Guilford (1956) has postulated 120 such separate abilities. Burt (1966, p. 137) points out that "the concept of a motley assortment of cognitive faculties or ' primary abilities" is no longer an acceptable notion of the intellect as a result of the statistical studies using factorial techniques. He asserts that the evidence points to an "organized hierarchy comprising both a 'general cognitive factor' (the subject of Jensen's review) and a number of more specialized 'group factors' of varying extent or breadth" (op. cit., p. 137).

In his review of what has been labeled the "nature-nurture" controversy, Vandenberg (1968, pp. 508) asserts that evidence shows at least six independent intelligence abilities: size of vocabulary, verbal fluency, numerical ability, spatial ability, reasoning ability, and memory, which are coincident with Thurstone's "primary mental abilities."

Jensen himself hypothesizes two levels of Learning ability (Jensen, 1969, pp. 110-111) to explain differences in performance on tests of intelligence, learning and scholastic achievement. The first, Level I, is associative learning, in which there is little transformation of the input. "Level I is tapped mostly by digit memory,..." (op. cit., p. 111). The second level, Level II, involves self-initiated elaboration and transformation of the input, before it becomes an output response. Level II is best measured by "intelligence tests with a low cultural loading and a high loading on 'g' such as Raven's Progressive Matrices" (op. cit., p. 111).

Divergent thinking has been shown to be relatively independent of variously operationalized measures of intelligence. Madaus (1967), (Getzels & Madaus, 1969) has explored and reviewed the relationship between intelligence and divergent thinking and concludes that there is negligible relation between the two. Madaus (1967, p. 232) factor analyzed an array of divergent thinking and intelligence measures and found the first unrotated factor was dominated by the divergent thinking measures with only low to moderate loadings for the intelligence measures.

Some evidence exists which supports the notion that memory, like divergent thinking, is relatively independent among factors in intelligence. Jensen suggested that short term memory, his Level I, is a necessary but not sufficient condition for high intelligence, which connotes some independence between short term memory and intelligence (Jensen, 1970). In reviewing the contorversy over the genetic components of cognitive processes, Vandenberg (1968, p. 7-8) points out that memory is an independent factor among six or more independent factors in intelligence.

Additional evidence supporting the independence of Level I ability comes from Morrison (1967, p. 275) who factor analyzed the eleven WAIS subtests and found that "Digit Span," a short term memory instrument, loaded only moderately on the first factor, 'g', and that the second factor was dominated by "Digit Span."

Table I summarizes the studies of heritability of memory. The two studies using the Primary Mental Abilities Test "Memory," showed no significant heritability. However, of the two studies using "Digit Span," one found a significant heritability component beyond the 5% level; the other did not. Two additional studies conducted in Sweden, using four different instruments, also yielded conflicting results.

Some of the differences in the studies appearing in Table 1 may be attributed in part to the fact that there may be real differences in heritability in the samples, i.e. different nationalities and different age groups tested.

Some of the differences may be attributed in part to the different criterion instruments. A slight variation in the stimulus to be remembered, or variation in the time lapse between presentation and recall or recognition, may mean that the tests are tapping slightly different traits. In particular reference to this possibility of confusing traits, Vandenberg (1968, p. 7) has said "Memory...may not be unitary...Recent work suggests that there are different mechanisms for short-term and long-term memory storage, as well as separate memory abilities for different types of materials."

In addition, there may be differences in the results of Table 1 that are attributable to the unreliability of the tests. None of the studies in Table 1 reported the reliabilities for their criterion instruments on their samples under study and Jensen (1970) has suggested that the usual test of "Digit Span" did not yield sufficiently high reliability for consistent results in heritability studies.

TABLE 1

Summary of Heritability Studies of Memory Using Twins, With Investigators, Instruments, Number of Twin Pairs, and Heritability Significance (F-ratios)

| Investigator, Instrument and Sample | $N_{dz}$* | $N_{mz}$* | Heritability Significance (Fisher's F) |
|---|---|---|---|
| Strandskov et al. (1955)<br>Primary Mental Abilities Test<br>"Memory"<br>American Adolescents | 53 | 45 | F = 1.62<br>N.S. |
| Vandenberg (1965b)<br>Primary Mental Abilities Test<br>"Memory"<br>American Adolescents | 37 | 45 | F = 1.26<br>N.S. |
| Vandenberg (1967)<br>Wechsler Intelligence Scale for Children, "Digit Span"<br>American 15-17 year olds | 10 | 32 | F = 1.37<br>N.S. |
| Block (1968)<br>Wechsler Intelligence Scale for Children, "Digit Span"<br>American Early Adolescents | 60 | 60 | F = 1.53<br>Significant Beyond .05 |
| Wictorin (1952)<br>"Memory for 2 Digits" (recall)<br>"Memory for 3 Digits" (recognition)<br>Swedish 9-15 year olds | 141 | 128 | F = 1.24<br>F = 1.17<br>N.S. |
| Bruun et al. (1966)<br>"Memory for Names | 35 | 69 | F = 2.09<br>Significant Beyond .01 |
| "Memory II"<br>Swedish Adult Males | 29 | 58 | F = 1.98<br>Significant Beyond .01 |

Table adapted from Vandenberg (1966) and (1968).

*$N_{dz}$ = number of fraternal pairs; $N_{mz}$ = number of identical pairs.

In view of these studies and Jensen's remarks on reliability, this research attempted to assess the heritability of short term memory using a modified measure of "Digit Span," such that reliability exceeded .90.

A review of the literature of heritability of divergent thinking produced only one study conducted on high school students, summarized in Table 2. Only one of the nine subtests was found to be significantly heritable.

TABLE 2

F Ratios Between Fraternal and Identical Within-Pair Variances
for Nine of Guilford's Tests of Divergent Thinking
for 24 Pairs of Like-Sex DZ and 67 Pairs of MZ Twins

| Name of Test | F |
|---|---|
| 1. Pertinent Questions | 1.85* |
| 2. Different Uses | 1.53 |
| 3. Social Instutions | 1.39 |
| 4. Seeing Dificiencies | 1.35 |
| 5. Making a Plan | 1.11 |
| 6. Similar Words | 1.10 |
| 7. Associations | 1.08 |
| 8. Figure Production | 1.03 |
| 9. Picture Arrangement | 0.94 |

*p less than .05.

Table from Vandenberg (1968, p. 193).

This research project employed the Torrance Tests of Creative Thinking. This decision was made on three bases: first, the Guilford tests were designed primarily for adult use and the Torrance tests are essentially modified versions of the Guilford tests for specific use with children; secondly, most of the research on divergent thinking has employed the Torrance tests, and we have reliability estimates available in the literature; and thirdly, the Torrance tests have separate factor scores for Fluency, Flexibility, and Originality.

Due to the almost total lack of heritability research in divergent thinking, and the advantages and greater appropriateness of the Torrance tests, this research investigated Verbal Divergent Thinking using Torrance's "Unusual Uses" subtest, scored for Fluency, Flexibility, and Originality. The data from such a study sheds light on the "faciliatation" controversy in divergent thinking (Dacey et al., 1968). The "facilitation" issue is basically the controversy between those who assert that divergent thinking can be "fostered" or "liberated" or even "taught," as opposed to those who believe it is "innate" or "fixed." The presence or absence of a significant genetic component in divergent thinking will add fuel to this controversy.

The object of this investigation, therefore, was the determination of the presence of an hereditary component in short term memory and verbal divergent thinking--fluency, verbal divergent thinking--flexibility, and verbal divergent thinking--originality.

The measures used were as follows: short term memory was measured by the Short Term Memory Test, a modification of the WISC "Digit Span;" divergent thinking was measured by the "Unusual Uses--Tin Cans" subtest of the Torrance Tests of Creative Thinking, Verbal B. scored for fluency, flexibility, and originality.

The hypotheses, stated in null form, are

(1) The F ratio of within-pair fraternal twin variance to the within-pair identical twin variance on the Short Term Memory Test will not be significant at the 5% level.

(2) The F ratio of within-pair fraternal twin variance to the within-pair identical twin variance on the "Unusual Uses" test--Fluency will not be significant at the 5% level.

(3) The F ratio of within-pair fraternal twin variance to the within-pair identical twin variance on the "Unusual Uses" test--Flexibility will not be significant at the 5% level.

(4) The F ratio of within-pair fraternal twin variance to the within-pair identical twin variance on the "Unusual Uses" test--Originality will not be significant at the 5% level.

The method for assessing heritability in this study is the simultaneous comparison twin study. Vandenberg (1966, p. 329) recommends the twin study technique for reasons of economy as well as the fact that it overcomes the difficulties of comparing scores of individuals of vastly different ages, as would be encountered in family and inbreeding studies. The age range of twins does not interfere with the east interpretation of the data, even though the variables have some amount of age-related variation. Since each twin is perfectly matched with his co-twin on age, and comparisons are made only within pairs, the age variation does not enter into the analysis for heritability. This is equivalent to "control" of age.

The twin study technique consists of administering criterion instruments to samples of identical and fraternal twins and calculating the within-pair variance in each set. Since identical twins have exactly the same genes, and fraternal twins share only half their genes on the average, any differences in measures on identical twins will be due to environment alone, while differences in fraternal twins will be due to environment and genetic differences. A substantial difference, then, in the within-pair variance is evidence of an hereditary component in the trait.

The present study employed an adaptation of the method of Clark (1956) as outlined by Vandenberg (1969a, pp. 128-129). This method overcomes the weaknesses of earlier statistical methods and represents the most efficient analysis appropriate to the model of heredity. Sometimes called the "analysis of variance method," the technique calls for one-way ANOVA table where the "group" is a pair of twins; naturally each of the N groups has n = 2 members. The partition of variance for this method and the degrees of freedom are illustrated in Table 3 below.

TABLE 3

Partition of Variance for Twin Studies

| Sources of Variation | SS | df |
|---|---|---|
| Between p pairs | $\frac{1}{2}\Sigma(X_a + X_b)^2 - \frac{1}{2}p\ (\Sigma X)^2$ | p - 1 |
| Within p pairs | $\Sigma X^2 - \frac{1}{2}\Sigma\ (X_a + X_b)^2$ | p |
| Total | $\Sigma X^2 - \frac{1}{2}p\ (\Sigma X)^2$ | 2p - 1 |

If the within-pair variance for fraternal and identical pairs are abbreviated $\sigma^2 W_{dz}$ and $\sigma^2 W_{mz}$ respectively, then the variances may be tested using Fisher's F test:

$$F = \frac{\sigma^2 W_{dz}}{\sigma^2 W_{mz}}$$

The underlying model in this analysis is that used by Vandenberg (1969a) which he refers to as the "classical twin study." In this model, phenotypic variance is viewed as the sum of the genotypic variance, the environmental variance, and the interaction variance. Since monozygotic twins spring from a single egg and sperm, they have precisely the same genetic code. Dizygotic twins, however, come from two different, separately fertilized eggs and, on the average, have only half their genes in common. Dizygotic twins, therefore, are no more alike genetically than any two siblings, except that they are the same age, and are raised at the same time, in the same milieu. It is assumed that environmental influences have as much impact on fraternal twins as on identical twins. In variance terms this means that the environmental variance term in both identical and fraternal twin within-pair variance tend to equality.

If the trait we are interested in has an hereditary component, then the within variance for the dizygotic pairs will be greater than the within variance for the monozygotic pairs, since the added variance will be due to genetic variation. This difference due to an hereditary component reveals itself in the F test and can be converted to Holzinger's $h^2$ by the following formula:

$$h^2 = \frac{\sigma^2 W_{dz} - \sigma^2 W_{mz}}{\sigma^2_{W_{dz}}}$$

The $h^2$ index is generally thought of as a proportion of variance accounted for by a genetic component of variance. A simpler interpretation is that the square root of the index, or simply 'h,' is the correlation between genotype and phenotype. It should be pointed out that the index has fallen out of vogue doe to the careless interpretation of it as a proportion of the trait, rather than as a proportion of the variance of a trait under hereditary influence. That is, the index has powerful meaning for groups in explaining variation, and absolutely <u>no</u> meaning for individuals since an individual represents only one point in a distribution with no variance.

The F value has become more popular because it is probabilistic, i.e. it carries a confidence value and its degrees of freedom give an indication of the strength of the estimate of heritability. Recall that the degrees of freedom associated with the F test in a twin study are the number of fraternal twin pairs and identical twin pairs respectively, hence the larger the sample, the stronger the estimate.

## Disposition of the Null Hypotheses

Within-pair variances for both identical twin pairs and fraternal twin pairs, and F ratios were calculated. In the one case of a significant F ratio, an heritability index was calculated. The conversion of F to $h^2$ is facilitated by observing that since

$$h^2 = \frac{\sigma^2 W_{dz} - \sigma^2 W_{mz}}{\sigma^2 W_{dz}}$$

$$= 1 - \frac{\sigma^2 W_{mz}}{\sigma^2 W_{dz}}$$

and

$$F = \frac{\sigma^2 W_{dz}}{\sigma^2 W_{mz}}$$

then

$$h^2 = 1 - \frac{1}{F}$$

The results of the analysis of variance, i.e. the within-pair variance, F-ratios, and the significant index of heritability, $h^2$, for short term memory, appear in Table . The first null hypothesis, The F-ratio of within-pair variance on the Short Term Memory Test will not be significant at the 5% level, was rejected. Referring to Table , it can be seen that the observed F-ratio was 2.20 and the table value corresponding to 5% level of significance and degrees of freedom of 28 and 37, respectively, was 1.78. This was interpreted to be a rejection of the hypothesis that the memory is under total environmental control, that is, that it has no genetic component.

Turning to the second null hypothesis, The F-ratio of within-pair fraternal twin variance to the within-pair identical twin variance on the "Unusual Uses" test--Fluency will not be significant at the 5% level, was not rejected. Table shows that the calculated F-ratio was 0.66 which is less than the table value of 1.78, the critical value for the 5% level of significance and 28 and 37 degrees of freedom. This failure to reject the null hypothesis was interpreted as a failure to demonstrate the presence of a significant genetic component in Verbal Divergent Thinking--Flexibility, for this sample.

The third null hypothesis, The F-ratio of within-pair fraternal twin variance to the within-pair identical twin variance on the "Unusual Uses" test--Flexibility will not be significant at the 5% level, was not rejected. The observed F-ratio (see Table 4) was .84, which is less than the table value at the 5% level with degrees of freedom 28 and 37, which is 1.78. This was interpreted as a failure to demonstrate a significant heritability component in the measured trait of Verbal Divergent Thinking--Flexibility.

TABLE 4

Within-Pair Variances, F-Ratios, and Heritability Indices*
for the Short Term Memory Test, Unusual Uses Subtest Scores:
Flexibility, Fluency and Originality

| | Within-Pair Variances | | F-Ratio | Holzinger's Index of Heritability |
|---|---|---|---|---|
| | DZ | MZ | | |
| Short Term Memory | 909.85 | 414.49 | 2.20** | .545 |
| Verbal Flexibility | 10.43 | 15.78 | 0.66 | -- |
| Verbal Fluency | 41.68 | 49.70 | 0.84 | -- |
| Verbal Originality | 19.61 | 38.84 | 0.50 | -- |

* Heritability index is calculated only for significant F-ratio at 5% level.

** Significant at the 5% level. $F_{.05,28,37} = 1.78$

The fourth null hypothesis, The F ratio of within-pair fraternal twin variance to the within-pair identical twin variance on the "Unusual Uses" test--Originality will not be significant at the 5% level, was not rejected. The failure to reject was because the observed F-ratio (see Table 4 ) of 0.50 fails to exceed the critical value of 1.78 for the 5% level of significance and 28 and 37 degrees of freedom. The failure to reject this null hypothesis can be interpreted as a failure to demonstrate the presence of a significant genetic component in the measured trait Verbal Divergent Thinking--Originality.

Holzinger's Index of Heritability (Newman, Freeman & Holzinger, 1937) calculated for short term memory, the variable in the first null hypothesis, is .54. This can be interpreted as 54% concomitant variation between genotype and phenotype of short term memory; i.e. there is a significant genetic component in short term memory in the sample investigated. One is cautioned not to oversimplify the interpretations of this index. The index is interpreted as a proportion of the variance of a trait under hereditary influence, not the proportion of the trait itself. This means that the index has meaning in groups and little, in fact no meaning for individuals. It is also fitting to mention again, here, that differences in heritabilities may be found from one sample to another as mentioned earlier. Table 5 summarizes other relevant heritability studies and their indices.

The differences in heritability estimates when other than "digit" memory was used may be explained by the difference in the criterion measures, as well as possible differences in heritability from one population to another.

When the heritability index for short term memory is compared to other mental trait's heritability in Table , one finds that it is substantially lower than the estimates for the general intellective factor, 'g,'

TABLE 5

A Comparison of Holzinger's Index of Heritability Calculated for the Current Investigation and Past Investigations in Memory, Divergent Thinking, and Other Mental Traits

| Investigation | Variable | Holzinger's Index of Heritability |
|---|---|---|
| Current Investigation | Short Term Memory | .54 |
| Strandskov (1955) | Primary Mental Abilities Test "Memory" | .38 |
| Vandenberg (1965b) | Primary Mental Abilities Test "Memory" | .21 |
| Vandenberg (1967) | W.I.S.C. "Digit Span" | .27 |
| Block (1968) | W.I.S.C. "Digit Span" | .35 |
| Wictorin (1952) | Digit Recall | .19 |
| | Digit Recognition | .14 |
| Bruun et al. (1968) | Memory for Names | .52 |
| | Memory II | .49 |
| Vandenberg (1968) | Guilford's "Pertinent Questions" | .46 |
| Jensen (1969) | "Measured Intelligence - 'g' " | .80 (averaged value) |
| Thorsen (1970) | Raven's Progressive Matrices - 'g' | .85 |

from Jensen (1969) and Thorsen (1970). Jensen's estimate for the heritability of 'g' comes from his review of the literature on the heritability of standard intelligence test scores rather than a pure measure of 'g' and represents an "average value." Thorsen's estimate comes from the raw score on the Raven's Progressive Matrices Test, and is based on the same sample of twins as the current investigation.

## Implications of the Findings

As was pointed out earlier, Jensen (1969) feels that high heritability is sufficient to preclude facilitation of intelligence in compensatory education programs. By facilitation is meant the "nurture," "stimulation," or "liberation" of certain traits or attributes. If this assertion of Jensen's is indeed correct, then such compensatory education programs as Head Start are doomed to failure if they attempt to manipulate the environment and experiences of their subjects in order to produce gains in IQ. Yet most heritability data has been generated in the general factor of intelligence, and not for specific factors that have been identified as independent or relatively independent. Thus the pool of mental capacities to be considered for facilitation efforts has not been exhausted.

This research has demonstrated that first, short term memory has a moderate heritability index, .54, as compared to Jensen's .80 for the general intelligence factor 'g,' and the three divergent thinking factors, verbal fluency, verbal flexibility, and verbal originality have no statistically significant genetic components. Second, and consequentially, these mental capacities are identified as candidates for facilitation efforts. If it is a fact that short term memory, Jensen's Level I, does have 54% concomitant variation with genetic makeup, then Level I is a more likely candidate for facilitation than the conventional IQ.

Furthermore, if verbal divergent thinking has no significant genetic component, it is a most likely candidate for facilitation.

A cautionary note is necessary here. To say that a mental trait is not heritable or has low heritability is not to say that it can be facilitated, but merely that is may be facilitated. For example, much controversy centers around the facilitation of divergent thinking (Dacey et al., 1968), with little concensus as to how or when divergent thinking may be facilitated.

A further implication of the findings of a lower heritability for Level I is in the area of training the classroom teacher, since most of the learning in school today is conducted through Level II - 'g.' As Jensen states (1969, p. 116),

> Too often, if a child does not learn the school subject matter when taught in a way that depends largely on being average or above average on 'g,' he does not learn at all, so that we find high school students who have failed to learn basic skills which they could easily have learned many years earlier by means that do not depend much on 'g.' It may well be true that many children today are confronted in our schools with an educational philosophy and methodology which are mainly shaped in the past, entirely without roots in these children's genetic and cultural heritage.

If teachers are made aware of the narrowness of the range through which learning is conducted, and that other learning capacities not only exist but are much less "fixed" than the conventional 'g,' they may be more open to alternative ways of teaching. In this way the schools may learn to utilize the relatively unused strengths of children whose major strength is not of the verbal-cognitive-abstract type. Jensen also points out (1969, p. 117) that Level I may be the basic avenue to learning among the disadvantaged. If this is the case, then it seems mandatory that teachers be made aware of a diversity of approaches to make learning rewarding to children of diverse ability patterns.

The recent work of Dave (1963) and Wolf (1964) indicates that the achievement and intelligence in children can be reasonably well predicted by examining what parents (mothers) <u>do</u> in the home, (process variables), rather than what is <u>found</u> in the home, (status variables). If this is the case and we can identify some mental traits as low in heritability, then, as was the case in compensatory education, those mental traits may be amenable to "facilitation" in the home by guiding parents as to what to do, with respect to the "process variables."

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