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ABSTRACT
Based on the assumption that inferential statistics can make the operant conditioner more sensitive to possible significant relationships, regressions models were developed to test the statistical significance between slopes and Y intercepts of the experimental and control group subjects. These results were then compared to the traditional operant conditioning eyeball technique analysis. (Author)

THE DEVELOPMENT AND DEMONSTRATION OF MULTIPLE REGRESSION MODELS FOR OPERANT CONDITIONING QUESTIONS

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Summarization of research in operant psychology has relied predominately upon descriptive statistics. Probably the main reason inferential statistics has been given little attention is that early operant research yielded such clear-cut distinctions that it was not necessary to resort to tests of statistical significance. A second reason may be the lack of advice from statisticians regarding limitations of single subject data.

Presently, much research in operant psychology is being done in the natural environment outside the laboratory, as applied behavior modification. In these settings, the control of extraneous variables is more difficult to achieve. As a result, data may fail to exhibit the clear magnitude of effects observed in data from a laboratory manipulation. When this occurs, significant results may not be immediately obvious even though the expected trend seems to be present. When some doubt exists concerning the outcome of an experimental manipulation using behavior modification procedures, consideration should be given to the use of inferential statistics. A number of inferential statistical models are currently available that may assist the operant researcher in analyzing his data. These models are essentially specific applications of the generalized analysis of variance using multiple regression procedures to partial variance.

The purpose of this paper is to develop and demonstrate regression models that may be useful to operant conditioners for statistically analyzing their data. A comparison will be presented between a regression approach to answering operant conditioning questions and traditional operant analysis and interpretations of the same data.

The research questions dealt with here are only examples of the many possible kinds of questions which can be dealt with effectively using multiple regression procedures. Models will be developed to test the following questions:

1. Is there a significant mean difference between Control Group 1 and Control Group 2?

2. Is there a significant difference between the slope of Control Group 1 and Control Group 2 above and beyond individual differences?

3. Is there a significant mean difference between Control Group 1 and Control Group 3?

4. Is there a significant difference between the slope of Control Group 1 and Control Group 3 above and beyond individual differences?

5. Is there a significant mean difference between Control Group 2 and Control Group 3?

6. Is there a significant difference between the slope of Control Group 2 and Control Group 3 above and beyond individual differences?

7. Is there a significant mean difference between Control Group 1 and Experimental Group 1 above and beyond individual differences?

8. Is there a significant second degree curvilinear relationship for Control Group 1 and Experimental Group 1 above and beyond a linear relationship and any individual differences?

9. Is there a significant mean difference between Control Group 2 and Experimental Group 2 above and beyond individual differences?

10. Is there a significant second degree functional relationship for Control Group 2 and Experimental Group 2 above and beyond a linear relationship and any individual differences?

11. Is the mean of Control Group 3 significantly different from the mean of Experimental Group 3 above and beyond any individual differences?

12. Is there a significant second degree functional relationship for Control Group 3 and Experimental Group 3 above and beyond a linear relationship and any individual differences?

13. Is there a significant difference between the slope of Control Group 1 and Experimental Group 1 above and beyond any individual differences?

14. Is there a significant difference between the slope of Control Group 2 and Experimental Group 2 above and beyond any individual differences?

15. Is there a significant difference between the slope of Control Group 3 and Experimental Group 3 above and beyond any individual differences?

METHOD

Subjects. The total subject group consisted of twelve male and female students selected from a pool of names referred for chronic tardiness behavior by the school psychologist, teachers, and counselors at Westland High School, population 1,700, near Columbus, Ohio. Selection was made on the basis of the highest reported frequency of tardiness behavior.

The sample included one male freshman, four male and one female sophomores, two male and one female juniors, and three male seniors. All subjects were white, from approximately middle class socioeconomic background.

Material. The behavioral instruction program used in this design was a modification of Hall's book (1971, Pt. II) describing the basic principles of behavior modification.

The content of the control group instruction for both the teacher's daily lesson plans and the course outline, was taken from the general psychology text (Engle and Snellgrove, 1969), which students were given to use during this instruction.

PROCEDURE

During the initial phase of this design, the control period, the twelve subjects were assigned to three groups, four subjects to each group. Groups 1, 2, and 3 received a control treatment consisting of classroom instruction in general psychology. Immediately following the control period, the four students in Group 1 began receiving behavioral instruction treatment, consisting of classroom instruction in behavioral principles and their application. Group 2 continued receiving classroom instruction in general psychology, and Group 3 received general psychology instruction. When a decelerating trend in Group 1's tardiness behavior was noted, following instruction in behavioral principles, then Group 2 began receiving instruction in behavioral principles, and no longer received instruction in general psychology. When a decelerating trend in Group 2's tardiness behavior was noted, general psychology instruction was terminated with Group 3, and they began receiving instruction in behavioral principles. Group 1 and 2 continued receiving behavioral instruction throughout the remainder of the four week class.

ANALYSIS

The data was analyzed using two techniques:

(1) A multiple baseline design was used to demonstrate the effectiveness of the group instruction in behavioral principles (independent variable) on decelerating tardiness behavior (dependent variable). The multiple baseline design used for analysis of data is illustrated in Figure 1. Further information concerning the use of this type of design can be obtained by reference to Baer, et. al., (1968); Hall, et. al., (1970); and Hall, (1971, Pt. I). Additional data representing the total frequency of tardiness for the 3 groups is illustrated in Table 1.

THE EFFECTS OF BEHAVIORAL INSTRUCTION ON THE MEAN FREQUENCY OF TARDINESS BEHAVIOR OF THREE GROUPS

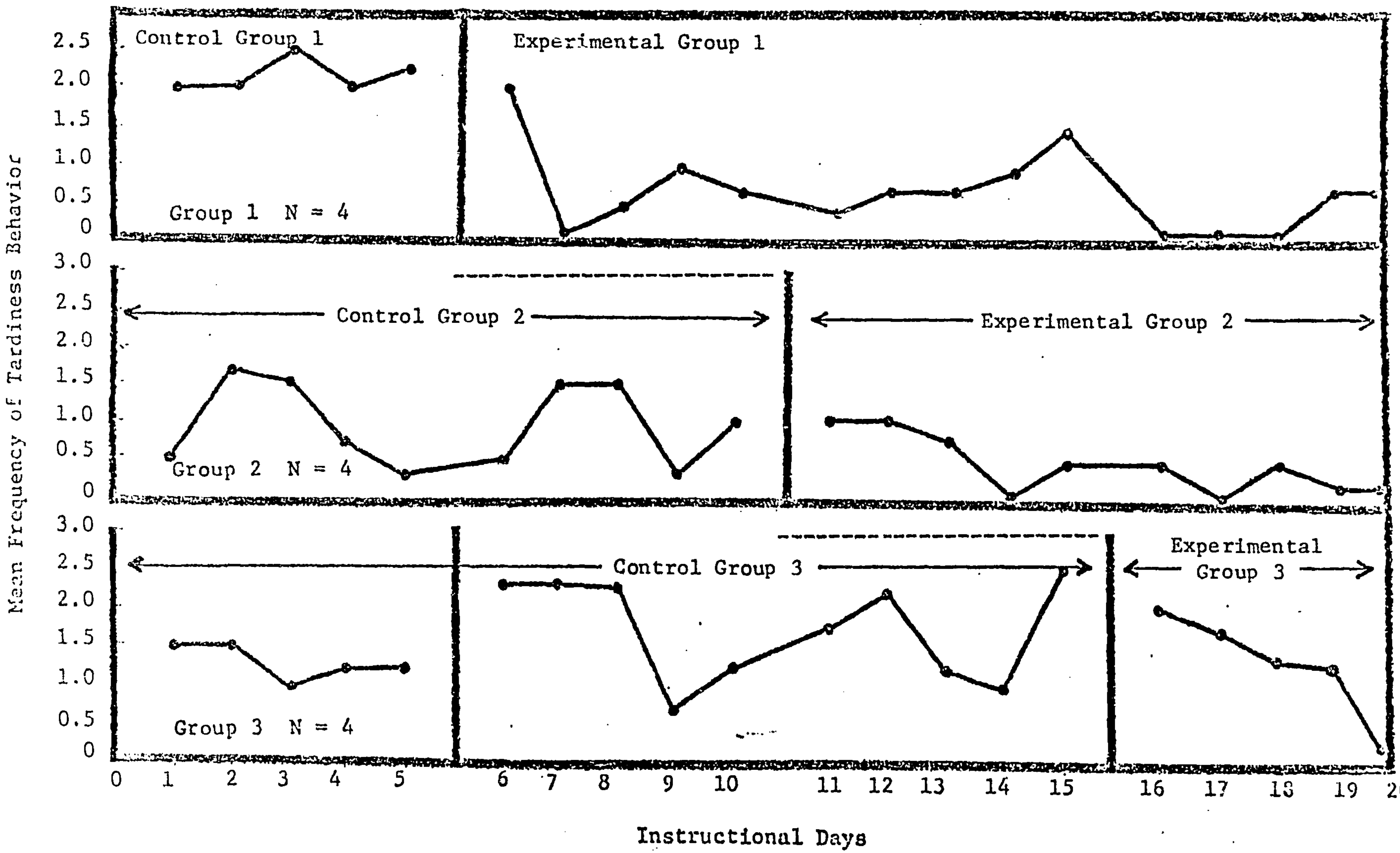

Figure 1 A Multiple Baseline Design indicating the mean frequency of tardiness behavior to school and class for three groups. N = 4 in all groups.

TABLE 1

TOTAL FREQUENCY OF TARDINESS BEHAVIOR TO SCHOOL AND CLASS FOR THREE GROUPS

	Week 1	Week 2	Week 3	Week 4
Group 1	Control 41	Beh. Inst. 17	Beh. Inst. 18	Beh. Inst. 6
Group 2	Control 17	Control 18	Beh. Inst. 13	Beh. Inst. 6
Group 3	Baseline[1] 26	Control 31	Control 35	Beh. Inst. 23

(2) Multiple regression was used to test the same hypothesis as the above traditional method for analyzing the data (see 1 above). For an example of how the data is set up, Figure 2 presents the hypothesis and models used to test them.

EXAMPLE MODELS

Research Hypothesis 1: The control group mean ($\bar{C}_1$) is significantly higher than the experimental group mean ($\bar{E}_1$) above and beyond person differences (P) + E.

Model 1: $Y_1 = a_0U + a_1(C_1) + a_2(E_1) + a_3(P_1) + a_4(P_2) + a_5(P_3) + a_6(P_4) + E$

$$a_1 = a_2$$

Model 2: $Y_1 = a_0U + a_3(P_1) + a_4(P_2) + a_5(P_3) + a_6(P_4) + E$

Research Hypothesis 2: The slopes of the experimental group (D_{e_1}) is significantly different than the slope of the control (D_{c_1}) group above and beyond person differences (P).

Model 3: $Y_1 = a_0U + a_1(C_1) + a_2(E_1) + a_3(D_{c_1}) + a_4(D_{e_1}) + a_5(P_1) + \ldots + a_6(P_4) + \text{Error}$

$$a_3 = a_4$$

Model 4: $Y_1 = a_0U + a_1(C_1) + a_2(E_1) + a_7(\text{Day}) + a_5(P_1) + \ldots + a_6(P_4) + \text{Error}$

In this example there were four persons (P_1, P_2, P_3, and P_4). During the control condition (C_1) each was measured on three consecutive days (D). The same four persons were again measured on three consecutive days during the experimental condition (E_1).

Figure 2

$$Y_1 = a_0 U + a_1(C_1) + a_2(E_1) + a_3(D_{c_1}) + a_4(D_{e_1}) + a_5(P_1) + a_6(P_2) + a_7(P_3) + a_8(P_4) + \text{Error}$$

Group	Person	Y_1	U	C_1	E_1	D_{c_1}	D_{e_1}	P_1	P_2	P_3	P_4	Error
CONTROL GROUP	Person 1	9	1	1	0	1 (1)	0	1	0	0	0	?
	2	6	1	1	0	1 (1)	0	0	1	0	0	.
	3	13	1	1	0	1 (1)	0	0	0	1	0	.
	4	12	1	1	0	1 (1)	0	0	0	0	1	.
	Person 1	12	1	1	0	2 (2)	0	1	0	0	0	.
	2	10	1	1	0	2 (2)	0	0	1	0	0	?
	3	9	1	1	0	2 (2)	0	0	0	1	0	.
	4	7	1	1	0	2 (2)	0	0	0	0	1	.
	Person 1	6	1	1	0	3 (3)	0	1	0	0	0	.
	2	7	1	1	0	3 (3)	0	0	1	0	0	.
	3	8	1	1	0	3 (3)	0	0	0	1	0	?
	4	9	1	1	0	3 (3)	0	0	0	0	1	.
EXPERIMENTAL GROUP	Person 1	7	1	0	1	0	1 (4)	1	0	0	0	.
	2	9	1	0	1	0	1 (4)	0	1	0	0	
	3	8	1	0	1	0	1 (4)	0	0	1	0	?
	4	3	1	0	1	0	1 (4)	0	0	0	1	.
	Person 1	5	1	0	1	0	2 (5)	1	0	0	0	.
	2	7	1	0	1	0	2 (5)	0	1	0	0	.
	3	2	1	0	1	0	2 (5)	0	0	1	0	
	4	1	1	0	1	0	2 (5)	0	0	0	1	.
	Person 1	5	1	0	1	0	3 (6)	1	0	0	0	?
	2	1	1	0	1	0	3 (6)	0	1	0	0	.
	3	2	1	0	1	0	3 (6)	0	0	1	0	.
	4	3	1	0	1	0	3 (6)	0	0	0	1	.

An example of data set up. (N=24) There are four persons. Each is measured 6 times, 3 times for the control condition and 3 times for the experimental condition.

Figure 2 Continued

Where: C_1 = 1 if S_s was in control condition when measured zero otherwise

E_1 = 1 if S_s was in experimental condition when measured zero otherwise

D_{c_1} = day when measured for control group zero otherwise

D_{e_1} = day when measured for experimental group zero otherwise

Error = $Y - \hat{Y}$

U = 1 for each replicate in the study

$a_0 \ldots a_8$ = partial regression weights

RESULTS AND DISCUSSION

Table 2 presents the results of the regression analysis testing each of the fifteen questions. The operant analysis of these questions is presented in Table 3. In comparing these tables one should note that there is only disagreement on question five.

One major advantage of using the regression procedure, rather than the traditional eyeball technique is that probability estimates can be attributed to the accuracy of the statements.

Another advantage of the regressions procedure used is ability to test the curvilinear relationships above and beyond linear ones, which is not feasible with the eyeball technique on multiple baseline analysis. Similarily, one cannot test to see if the slopes of the control group are significantly different statistically.

In addition, as demonstrated in this paper we can also test to see if the functional relationship of one treatment is significantly different from the functional relationship of some other treatment (across some area of interest).

These advantages represent only some of the additional information which can be obtained through statistical analysis of operant data.

Table 2

RESULTS OF REGRESSION ANALYSIS

RESEARCH QUESTION	MODEL	R^2	If n	If d	α	F	P
Is there a significant mean difference between Control Group 1 and Control Group 2?							
$Y_1 = a_0 U + a_1(C_1) + a_2(C_2) + E$	Full	.66	1	58	.05	94.28	.00001
$Y_1 = a_0 U + E$	Restricted	0					
Is there a significant difference between the slope of Control Group 1 and Control Group 2 above and beyond individual differences?							
$Y_1 = a_0 U + a_1(D_{c_1}) + a_2(D_{c_2}) + a_3(P_1) + a_4(P_2) + a_5(P_3) + \ldots + a_{10}(P_8) + E$	Full	.66	1	50	.05	.03	.84
$Y_1 = a_0 U + a_{12}(D_{c_{1+2}}) + a_{13}(P_1) + a_{14}(P_2) + \ldots + a_{20}(P_8) + E$	Restricted	.66					

Table 2 Continued

RESEARCH QUESTION	MODEL	R^2	If n	If d	α	F	P
Is there a significant mean difference between Control Group 1 and Control Group 3?							
$Y_1 = a_0U + a_1(C_1) + a_2(C_3) + E$	Full	.46	1	78	.05	65.71	.00001
$Y_1 = a_0U + E$	Restricted	0					
Is there a significant difference between the slope of Control Group 1 and Control Group 3 above and beyond individual differences?							
$Y_1 = a_0U + a_1(D_{c_1}) + a_2(D_{c_3}) + a_3(P_1) + \ldots + a_6(P_4) + \ldots + a_{11}(P_9) + \ldots + a_{14}(P_{12}) + E$	Full	.46	1	70	.05	.0001	1.0000
$Y_1 = a_0U + a_1(D_{c_1+c_3}) + a_2(P_1) + \ldots + a_5(P_4) + \ldots + a_{10}(P_9) + \ldots + a_{13}(P_{12}) + E$	Restricted	.46					

Table 2 Continued

RESEARCH QUESTION	MODEL	R^2	df n	df d	α	F	P
Is there a significant mean difference between Control Group 2 and Control Group 3?							
$Y_1 = a_0U + a_1(C_2) + a_2(C_3) + E$	Full	.29	1	98	.05	41.42	.00001
$Y_1 = a_0U + E$	Restricted	0					
Is there a significant difference between the slope of Control Group 2 and Control Group 3 above and beyond individual differences?							
$Y_1 = a_0U + a_1(D_{c_2}) + a_2(D_{c_3}) + a_3(P_5) + \ldots + a_{10}(P_{12}) + E$	Full	.49	1	90	.05	.31	.57
$Y_1 = a_0U + a_{11}(D_{c_{2+3}}) + a_{12}(P_{24}) + \ldots + a_{20}(P_{31}) + E$	Restricted	.49					

Table 2 Continued

RESEARCH QUESTION	MODEL	R^2	If n	If d	α	F	P
Is there a significant mean difference between Control Group 1 and Experimental Group 1 above and beyond individual differences?							
$Y_1 = a_0U + a_1(C_1) + a_2(T_1) + a_3(P_1) + \ldots$ $+ a_6(P_4) + E$	Full	.56	1	71	.05	46.31	.00001
$Y_1 = a_0U + a_1(P_1) + \ldots + a_4(P_4) + E$	Restricted	.27					
Is there a significant second degree curvilinear relationship for Control Group 1 and Experimental Group 1 above and beyond a linear relationship and any individual differences?							
$Y_1 = a_0U + a_1(D_{c_1}) + a_2(D_c)^2 + a_3(D_{e_1}) + a_4(D_{T_1})^2$ $+ a_5(P_1) + \ldots + a_8(P_4) + E$	Full	.58	2	68	.05		.258
$Y_1 = a_0U + a_1(D_{c_1}) + a_2(D_{T_1}) + a_3(P_1) + \ldots$ $+ a_6(P_4) + E$	Restricted	.57					

Table 2 Continued

RESEARCH QUESTION	MODEL	R^2	If n	If d	α	F	P
Is there a significant mean difference between Control Group 2 and Experimental Group 2 above and beyond individual differences?							
$Y_1 = a_0U + a_1(C_1) + a_2(T_2) + a_3(P_5) + \ldots$							
$+ a_6(P_8) + E$	Full	.59	1	71	.05	17.17	.0001
$Y_1 = a_0U + a_1(P_5) + \ldots + a_3(P_8) + E$	Restricted	.50					
Is there a significant second degree functional relationship for Control Group 2 and Experimental Group 2 above and beyond a linear relationship and any individual differences?							
$Y_1 = a_0U + a_1(D_{c_2}) + a_2(D_{c_2})^2 + a_3(D_{T_2}) + a_4(D_{T_2})^2$							
$+ a_5(P_5) + \ldots + a_8(P_8) + E$	Full	.63	2	68	.05	.82	.44
$Y_1 = a_0U + a_1(D_{c_2}) + a_2(D_{T_2}) + a_3(P_5) + \ldots$							
$+ a_6(P_8) + E$	Restricted	.62					

Table 2 Continued

RESEARCH QUESTION	MODEL	R^2	If n	If d	α	F	P
Is the mean of Control Group 3 significantly different from the mean of Experimental Group 3 above and beyond any individual differences?							
$Y_1 = a_0U + a_1(C_3) + a_2(T_3) + a_3(P_9) + \ldots + a_7(P_{13}) + E$	Full	.42	1	71	.05	4.67	.03
$Y_1 = a_0U + a_1(P_9) + \ldots + a_4(P_{12}) + E$	Restricted	.39					
Is there a significant second degree functional relationship for Control Group 3 and Experimental Group 3 above and beyond a linear relationship and any individual differences?							
$Y_1 = a_0U + a_1(D_{c_3}) + a_2(D_{c_3})^2 + a_3(D_{T_3}) + a_4(D_{T_3})^2 + a_5(P_9) + \ldots + a_9(P_{13}) + E$	Full	.45	2	68	.05	1.18	.31
$Y_1 = a_0U + a_1(D_{c_3}) + a_2(D_{T_3}) + a_3(P_9) + a_7(P_{12}) + E$	Restricted	.44					

Table 2 Continued

RESEARCH QUESTION	MODEL	R^2	If n.	If d	α	F	P
Is there a significant difference between the slope of Control Group 1 and Experimental Group 1 above and beyond any individual differences?							
$Y_1 = a_0U + a_1(D_{c_1}) + a_2(D_{T_1}) + a_3(P_1) + \ldots$							
$+ a_7(P_5) + E$	Full	.57	1	70	.05	8.19	.005
$Y_1 = a_0U + a_1(D_{c_{1+T_1}}) + a_2(P_1) + \ldots$							
$+ a_6(P_5) + E$	Restricted	.52					
Is there a significant difference between the slope of control Group 2 and Experimental Group 2 above and beyond any individual differences?							
$Y_1 = a_0U + a_1(D_{c_2}) + a_2(D_{T_2}) + a_3(P_5) + \ldots$							
$+ a_7(P_9) + E$	Full	.63	1	70	.05	4	.04
$Y_1 = a_0U + a_1(D_{c_{2+T_2}}) + a_2(P_5) + \ldots$							
$+ a_5(P_8) + E$	Restricted	.61					

Table 2 Continued

RESEARCH QUESTION	MODEL	R^2	If n	If d	α	F	P
Is there a significant difference between the slope of Control Group 3 and Experimental Group 3 above and beyond any individual differences?							
$Y_1 = a_0 U + a_1 (D_{c_3}) + a_2 (D_{T_3}) + a_3 (P_1) + a_7 (P_{12}) + E$	Full	.48	1	70	.05	7.14	.01
$Y_1 = a_0 U + a_1 (D_{c_{3+T_3}}) + a_2 (P_9) + a_6 (P_{12}) + E$	Restricted	.43					

Table 3

THE FIFTEEN TESTED QUESTIONS

Hypothesis Number

1. There appears to be a significant mean difference between Control Group 1 and Control Group 2.

2. There is no apparent slope difference between Control Group 1 and Control Group 2 above and beyond individual differences.

3. There appears to be a significant mean difference between Control Group 1 and Control Group 3.

4. There is no apparent slope difference between Control Group 1 and Control Group 3 above and beyond individual differences.

5. There is no apparent mean difference between Control Group 2 and Control Group 3.

6. There is no apparent slope difference between Control Group 2 and Control Group 3 above and beyond individual differences.

7. There appears to be a significant mean difference between Control Group 1 and Experimental Group 1 above and beyond individual differences.

8. Not applicable.

9. There appears to be a significant mean difference between Control Group 2 and Experimental Group 2 above and beyond individual differences.

10. Not applicable.

11. There appears to be a significant mean difference between Control Group 3 and Experimental Group 3 above and beyond individual differences.

12. Not applicable.

13. There appears to be a significant difference between the slope of Control Group 1 and Experimental Group 1 above and beyond individual differences.

Table 3 Continued

Hypothesis Number	
14.	There appears to be a significant difference between the slope of Control Group 2 and Experimental Group 2 above and beyond individual difference.
15.	There appears to be a significant difference between the slope of Control Group 3 and Experimental Group 3 above and beyond individual differences.

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