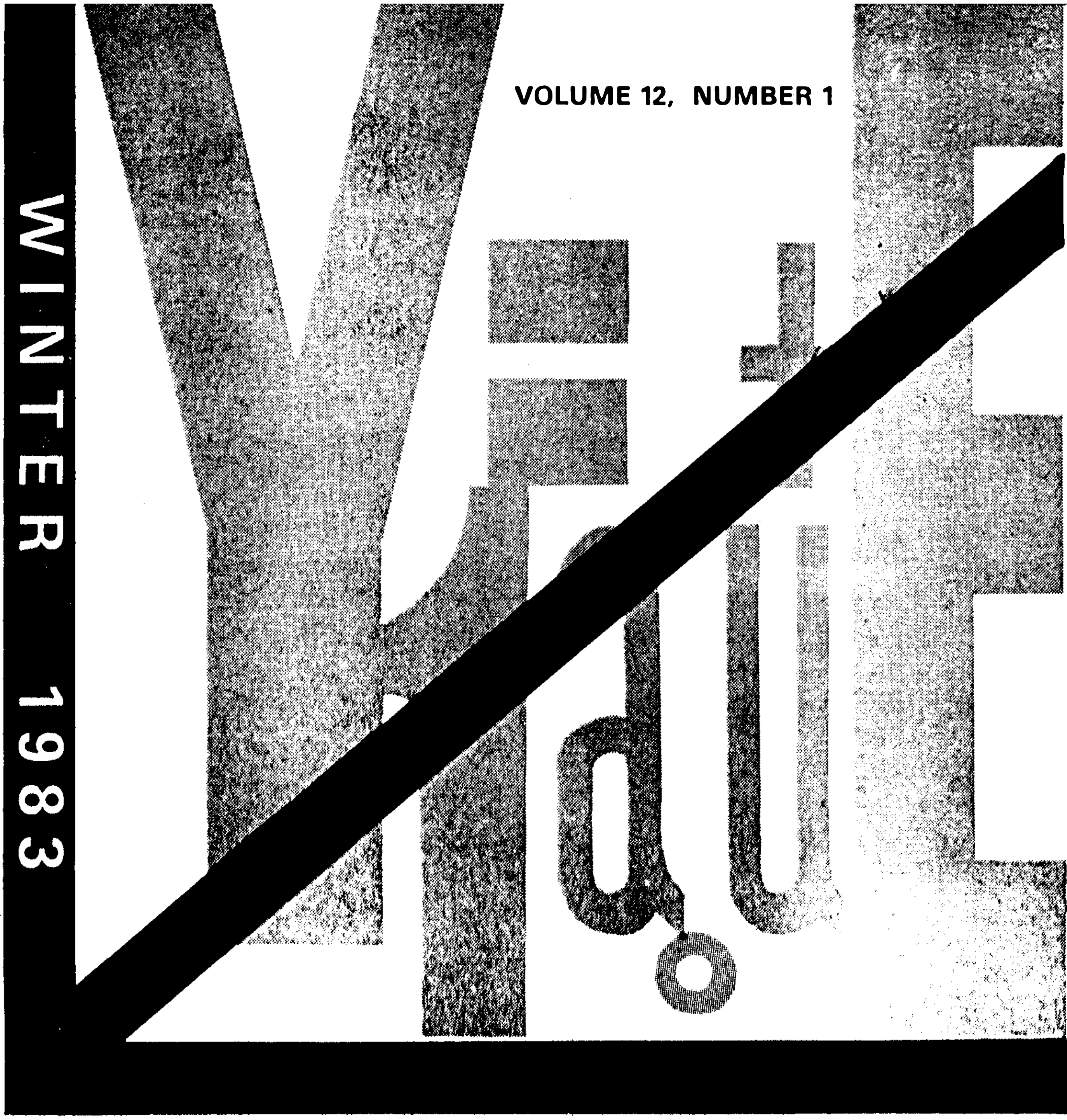

MULTIPLE LINEAR REGRESSION VIEWPOINTS

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MULTIPLE LINEAR REGRESSION VIEWPOINTS

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A METHOD FOR ESTIMATING INDIRECT EFFECTS IN PATH ANALYSIS

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In an earlier paper, Wolfle (1980) considered four kinds of causal models: recursive, block, block-recursive, and nonrecursive. By applying the first law of path analysis, he decomposed zero-order correlations among variables in causal models, and discussed the circumstances under which the components of the decompositions could be interpreted as direct, indirect, and spurious causal effects, plus a component he called joint associations. Since the publication of that paper, a number of people have inquired about the availability of a computer program to compute the components of decompositions explicated in the original paper. There is no computer program to calculate these components, but there is a means by which direct and indirect effects may be calculated with a minimum of effort. (Earlier papers by Griliches and Mason [1972] and Alwin and Hauser [1975] inform this discussion.)

Since joint associations, which involve components of a decomposition that include correlations among exogenous variables, and spurious effects may be considered to be noncausal components of a correlation between variables in a causal model, let us call the sum of direct and indirect effects the "total effect." The purpose of this paper is to demonstrate algebraically that total effects may be obtained through reduced-form regression equations, and the indirect effects may be calculated by taking the difference between the reduced-form regression coefficients and the direct effect. Following the algebraic proof, an empirical illustration will aid in understanding how the method works in practice.

To begin, consider a four-variable, fully recursive path model in which:

$$x_3 = p_{34}x_4 + p_{3u}u \quad (1),$$

$$x_2 = p_{23}x_3 + p_{24}x_4 + p_{2v}v \quad (2),$$

$$x_1 = p_{12}x_2 + p_{13}x_3 + p_{14}x_4 + p_{1w}w \quad (3),$$

in which x_i ($i = 1,2,3,4$) are standardized variables; p_{ij} are standardized regression (path) coefficients from x_j to x_i; and u, v, and w are unmeasured disturbance terms assumed to be independent of the x_i on the same side of the equality. Thus,

$$E(x_4u) = E(x_3v) = E(x_4v) = E(x_2w) = E(x_3w) = E(x_4w) = 0 \quad (4).$$

That the x_i are assumed to be standardized is a convenience which simplifies the algebra to follow. The conclusions to be drawn from the following presentation apply without loss of generalization to metric regression coefficients.

If one multiplies eq. 1 by x_4, and takes expectations, one obtains:

$$E(x_3x_4) = p_{34}E(x_4^2) + p_{3u}E(x_4u) \quad (5),$$

in which $E(x_3x_4) = \rho_{34}$, and $E(x_4^2) = 1$, since these are standardized variables, and $E(x_4u) = 0$ by the assumptions in eq. 4. Thus,

$$E(x_3x_4) = \rho_{34} = p_{34} \quad (6).$$

In analytic terms, eq. 6 indicates that the direct effect, p_{34}, of x_4 on x_3 is measured by the correlation, ρ_{34}.

Now consider eq. 2, but instead of estimating eq. 2 as is, consider:

$$x_2 = p'_{24}x_4 + p'_{2v}v \tag{7}$$

which is merely the regression of x_2 on x_4. If one multiplies eq. 7 by x_4, and takes expectations, one obtains:

$$E(x_2x_4) = p'_{24}E(x_4^2) + p'_{2v}E(x_4v) \tag{8}$$

which reduces to:

$$E(x_2x_4) = p'_{24} \tag{9}$$

Substituting eq. 2 into eq. 9 yields:

$$p'_{24} = E[(p_{23}x_3 + p_{24}x_4 + p_{2v}v)\, x_4] \tag{10}$$

multiplying the parenthetical expression by x_4 yields:

$$p'_{24} = p_{23}E(x_3x_4) + p_{24}E(x_4^2) + p_{2v}E(x_4v) \tag{11}$$

which is equal to:

$$p'_{24} = p_{23}p_{34} + p_{24} \tag{12}$$

because $E(x_3x_4) = p_{34}$, $E(x_4^2) = 1$, and $E(x_4v) = 0$.

Thus, regressing x_2 on x_4 yields a coefficient which is equal to the sum of the direct (p_{24}) and indirect effects ($p_{23}p_{34}$). By using a normal regression routine, one can regress x_2 on x_4, and thereby obtain the total effect from x_4 to x_2. The regression of x_2 on both x_3 and x_4 yields the direct effects of x_3 and x_4 on x_2 (p_{23} and p_{24}, respectively). The difference between p'_{24} and p_{24} ($p'_{24} - p_{24} = p_{23}p_{34}$) therefore gives the indirect effect of x_4 on x_2 through x_3. In other words, while the indirect effect of x_4 on x_2 may not be calculated directly, the product, $p_{23}p_{34}$, is obtainable by first regressing x_2 on x_4, then regressing x_2 on both x_3 and x_4, and calculating the difference between the two coefficients for x_4.

Now consider eq. 3, but instead of estimating eq. 3 as is, one estimates:

$$x_1 = p'_{14}x_4 + p'_{1w}w \qquad (13).$$

Multiplying eq. 13 by x_4, and taking expectations, yields:

$$E(x_1x_4) = p'_{14}E(x_4^2) + p'_{1w}E(x_4w) \qquad (14),$$

which is equal to:

$$E(x_1x_4) = p'_{14} \qquad (15).$$

Substituting eq. 3 into eq. 15 yields:

$$p'_{14} = E[(p_{12}x_2 + p_{13}x_3 + p_{14}x_4 + p_{1w}w)\, x_4] \qquad (16);$$

multiplying the parenthetical expression by x_4 yields:

$$p'_{14} = p_{12}E(x_2x_4) + p_{13}E(x_3x_4) + p_{14}E(x_4^2) + p_{1w}E(x_4w) \qquad (17).$$

Because $E(x_4^2) = 1$, and $E(x_4w) = 0$, one obtains:

$$p'_{14} = p_{12}E(x_2x_4) + p_{13}E(x_3x_4) + p_{14} \qquad (18).$$

By substituting eq. 12 and eq. 6 for $E(x_2x_4)$ and $E(x_3x_4)$, respectively, one obtains:

$$p'_{14} = p_{12}(p_{23}p_{34} + p_{24}) + p_{13}p_{34} + p_{14} \qquad (19).$$

Thus, were one to obtain p'_{14} by regressing x_1 on x_4, and then obtain p_{14} by regressing x_1 on x_2, x_3 and x_4, the difference would equal:

$$p'_{14} - p_{14} = p_{12}p_{23}p_{34} + p_{12}p_{24} + p_{13}p_{34} \qquad (20),$$

which is the sum of all the indirect effects through x_2 and x_3.

Now consider the regression of x_1 on x_3 and x_4:

$$x_1 = p''_{13}x_3 + p''_{14}x_4 + p''_{1w}w \qquad (21).$$

Multiplying eq. 21 by x_4, and taking expectations, yields:

$$E(x_1x_4) = p''_{13}E(x_3x_4) + p''_{14}E(x_4^2) + p''_{1w}E(x_4w) \qquad (22).$$

With a slight rearrangement of terms, eq. 22 reduces to:

$$p''_{14} = E(x_1x_4) - p''_{13}E(x_3x_4) \qquad (23).$$

Substituting eq. 6 for $E(x_3x_4)$, and eq. 3 for x_1, yields:

$$p''_{14} = E[(p_{12}x_2 + p_{13}x_3 + p_{14}x_4 + p_{1w}w)\,x_4] - p''_{13}p_{34} \qquad (24),$$

which becomes:

$$p''_{14} = p_{12}E(x_2x_4) + p_{13}E(x_3x_4) + p_{14}E(x_4^2) + p_{1w}E(x_4w)$$
$$- p''_{13}p_{34} \qquad (25).$$

It can be shown that $p''_{13} = p_{13} + p_{12}p_{23}$; also $E(x_4w) = 0$, and $E(x_4^2) = 1$; substituting these quantities, and eq. 12 for $E(x_2x_4)$, and eq. 6 for $E(x_3x_4)$, yields:

$$p''_{14} = p_{12}(p_{24} + p_{23}p_{34}) + p_{13}p_{34} + p_{14}$$
$$- (p_{13} + p_{12}p_{23})p_{34} \qquad (26),$$

which reduces to:

$$p''_{14} = p_{12}p_{24} + p_{14} \qquad (27).$$

Remember that p'_{14} is obtained by regressing x_1 on the exogenous variable, x_4; p''_{14} is obtained by regressing x_1 on the exogenous variable, x_4, and the first endogenous variable, x_3; p_{14} (the direct effect of x_4 on x_1) is obtained by regressing x_1 on all of its antecedent causes. With estimates of these coefficients, taking the differences among them yields the estimates of the indirect effects. Thus,

$$p'_{14} - p_{14} = p_{12}p_{23}p_{34} + p_{12}p_{24} + p_{13}p_{34} \qquad (28),$$

which is the sum of all the indirect effects from x_4 to x_1 through x_2 and x_3 together, through x_2, and through x_3, respectively;

$$p''_{14} - p_{14} = p_{12}p_{24} \qquad (29),$$

which is the indirect effect from x_4 to x_1 through x_2; and

$$p'_{14} - p''_{14} = p_{13}p_{34} + p_{12}p_{23}p_{34} \qquad (30),$$

which are the indirect effects from x_4 to x_1 through x_3, and through x_3 and x_2 together.

These results are not model specific; they are applicable to any hierarchical causal model. To obtain the total effect of any variable, x_j, in a causal model on any subsequent variable, x_i, in the model, simply regress x_i on x_j and all other variables that precede x_j, or occur causally in the same block with x_j (e.g., the set of exogenous variables). To obtain the direct effect of x_j on x_i, regress x_i on all of its causal antecedents. To obtain the sum of the indirect effects from x_j to x_i, take the difference between the total effect and the direct effect.

AN ILLUSTRATION

To illustrate these algebraic principles in practice, consider the block-recursive path model shown in Figure 1. This is the most general of the hierarchical models considered by Wolfle (1980), and was taken originally from Heyns (1974). She was interested in the degree to which stratification within schools mediates the effect of socioeconomic background on educational outcomes of students. The model shown in Figure 1 indicates that the exogenous variables, PaEduc, PaOcc, and SIBS are correlated for reasons unanalyzed in the present model. A measure of verbal ability is considered to be dependent upon the three exogenous variables, plus an error term assumed to be uncorrelated with the independent variables. Grades and curriculum track membership are thought to be dependent upon the four preceding manifest variables, but no causal nexus is assumed between grades and curriculum. Their disturbance terms, however, are assumed to be correlated with each other, but not with the four preceding manifest variables. Finally, educational aspirations is dependent upon the six causally antecedent variables. In algebraic terms, the regression equations implied by Figure 1 are:

$$x_1 = p_{12}x_2 + p_{13}x_3 + p_{14}x_4 + p_{15}x_5 + p_{16}x_6 + p_{17}x_7 + p_{1w}w \qquad (31),$$

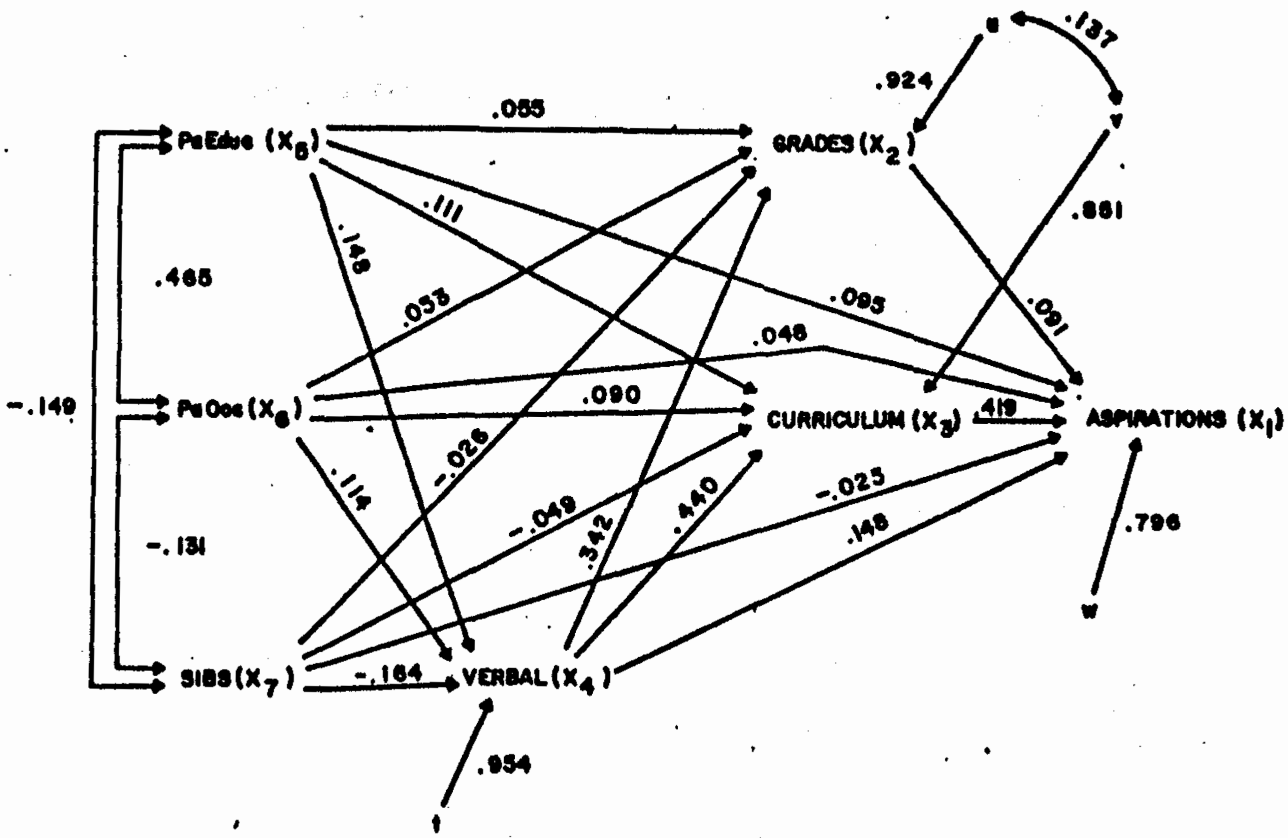

FIGURE 1. BLOCK-RECURSIVE EQUATION MODEL OF EDUCATIONAL ASPIRATIONS (SOURCE: HEYNS, 1974)

$$x_2 = p_{24}x_4 + p_{25}x_5 + p_{26}x_6 + p_{27}x_7 + p_{2u}u \qquad (32),$$

$$x_3 = p_{34}x_4 + p_{35}x_5 + p_{36}x_6 + p_{37}x_7 + p_{3v}v \qquad (33),$$

$$x_4 = p_{45}x_5 + p_{46}x_6 + p_{47}x_7 + p_{4t}t \qquad (34).$$

Estimating eq. 34 yields the total effects of x_5, x_6, and x_7 on x_4. These are equal to the direct effects, because no variables intervene between the exogenous variables and x_4; thus there can be no indirect effects.

The reduced-form regression of x_3 on x_5, x_6, and x_7 would yield the total effects of these exogenous variables on x_3; adding x_4 to the equation (i.e., eq. 33) would yield the direct effects, and the differences between the coefficients for x_5, x_6, and x_7 in the reduced-form equation and the fully specified equation yield the indirect effects of the respective exogenous variables on x_3 through the intervening variable, x_4.

Estimation of the remainder of the model would proceed accordingly; the numeric results for this model are shown in Table 1. The zero-order correlations for these data are available in Heyns (1974, p. 1441).

Table 1. Summary of Regression Analysis for Model of Educational Aspirations

Dependent Variables	Independent Variables							
	Pa Educ (x_5)	Pa Occ (x_6)	SIBS (x_7)	Verbal (x_4)	Grades (x_2)	Curric. (x_3)	α	R^2
			Standardized Coefficients					
Verbal (x_4)	.148	.114	-.164					
Grades (x_2)	.106	.092	-.083					
Grades (x_2)	.055	.053	-.026	.342				
Curric. (x_3)	.176	.140	-.121					
Curric. (x_3)	.111	.090	-.049	.440				
Aspir. (x_1)	.201	.132	-.108					
Aspir. (x_1)	.147	.091	-.048	.363				
Aspir. (x_1)	.095	.048	-.025	.148	.091	.419		
			Regression Coefficients*					
Verbal (x_4)	.561	.078	-.931				28.45	.090
	(.033)	(.006)	(.044)					
Grades (x_2)	.028	.004	-.033				2.94	.040
	(.002)	(.000)	(.003)					
Grades (x_2)	.015	.003	-.011	.024			2.25	.147
	(.002)	(.000)	(.003)	(.001)				
Curric. (x_3)	.026	.004	-.027				.089	.099
	(.001)	(.000)	(.002)					
Curric. (x_3)	.016	.002	-.011	.017			-.398	.275
	(.001)	(.000)	(.002)	(.000)				
Aspir. (x_1)	.131	.016	-.106				12.93	.104
	(.006)	(.001)	(.008)					
Aspir. (x_1)	.095	.011	-.047	.063			11.14	.225
	(.005)	(.001)	(.007)	(.001)				
Aspir. (x_1)	.062	.006	-.025	.026	.223	1.864	11.30	.367
	(.005)	(.001)	(.006)	(.001)	(.017)	(.034)		

* Standard errors are shown in parentheses.

If one happens to be interested in the extent to which two variables are causally related (total effect) in comparison to their total association (zero-order correlation), one compares the zero-order correlation with the reduced-form standardized coefficient. For example, the correlation of verbal ability, x_4, and educational aspirations, x_1, was .425 ; the reduced-form coefficient was .363 ; thus (.425 - .363)/.425 = .15 proportion of the correlation was due to spurious causal effects and joint associations among the exogenous variables.

Indirect effects may be calculated from the coefficients in Table 1. For example, the direct effect of father's education, x_5, on grades, x_2, is .055, and the indirect effect of x_5 on x_2 through verbal ability, x_4, is (.106 - .055) = .051 . Notice that these components could also be calculated from the metric regression coefficients, which enjoy a more substantively pleasing interpretation. Thus, a one-year increase in father's education produces an increase in grades of .028 units, .015 of which is a direct causal effect, and (.028 - .015) = .013 of which is an indirect effect through verbal ability. Notice that the ratios of direct and indirect effects are identical whether one uses standardized or metric coefficients. Thus, .055/.106 = .015/.028, within rounding error (see Wolfle, 1977, p. 47, for proof).

Consider the effects of father's education, x_5, on educational aspirations, x_1. The total effect is .201 ; the direct effect is .095 . The sum of all indirect effects is (.201 - .095) = .106 ; the indirect effects of x_5 on x_1 through verbal ability, x_4, are (.201 - .147) = .054 (note that this component includes <u>all</u> indirect effects through x_4, namely $p_{14}p_{45} + p_{12}p_{24}p_{45} + p_{13}p_{34}p_{45}$); and the indirect effects of x_5 on x_1 through grades, x_2, and curriculum, x_3, are (.147 - .095) = .052 .

CONCLUSION

The decomposition of causal components into direct and indirect effects may be substantively important, because the decomposition allows the consideration of how causal effects occur. For example, when indirect effects overwhelm direct effects, one has in essence described the social mechanism through which the causal relationship operates. For example, father's and son's occupational statuses are moderately correlated in samples of U.S. men. But the indirect effect of father's occupation on son's occupation through son's educational attainment is often greater in magnitude than the direct effect. In substantive terms, the reason father's and son's statuses are correlated is because sons acquire educational levels which lead to their acquiring occupational levels near those of their father's.

Causal models are useful analytic tools because they allow both the author and reader to understand explicitly the assumed order of effects. The interpretations of decompositions calculated as a part of the analysis depend on the assumed causal order of variables. Which associations are to be decomposed depends on the purpose of the analysis and the presentation of results. It would serve little purpose to use the methods explicated in this paper to calculate a wholesale collection of indirect effects; unless, of course, these were required by the research questions which motivated the analysis. The methods explicated herein should ease the burden of of analyzing causal models, but they are not substitutes for reflective analyses of social data.

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ULTIPLE LINEAR REGRESSION VIEWPOINTS

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EVALUATION OF EDUCATIONAL INTERVENTIONS FOR OSTEOARTHRITICS

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Abstract

This experimental field study evaluated educational interventions for osteoarthritics which focused on pain and disease management. One hundred-sixty subjects were obtained from four different settings. Using a factorial design, patients were randomly assigned to one of five treatment groups: (a) an information brochure only; (b) joint preservation teaching plus the brochure; (c) relaxation procedure plus the brochure; (d) relaxation procedure, joint preservation teaching and the brochure; and (e) no treatment. Effectiveness of each inter-

vention was determined by measures of pain and stiffness, amount of medication, mobility problems, changes in perceived level of stress, and knowledge gained about the illness. Both pre- and posttest measures were obtained. Residualized gain scores tested via a two-way ANOVA model demonstrated an overall significant decrease for pain (F [4, 140] = 2.45, p < .05). Post hoc analysis identified the source of the decrease to be the relaxation procedure. Another interesting finding was that pain-related stress increased for rural residents and decreased for urban residents. Significant increases in knowledge were found for subjects from a community center, a rural community and a university clinic. Subjects from a community center and a university hospital reported significantly less joint stiffness than subjects from a private hospital clinic.

Evaluation of Educational Interventions for Osteoarthritics

Due to the growth of the elderly population in the United States, a sharp increase in the incidence of osteoarthritis is occurring (U.S. Department of Health and Human Services, 1980). This increase has intensified interest among health care professionals to find newer treatment approaches for this ancient disease. Because of the increasing number of persons with functional impairment and disability as a result of osteoarthritis, it is now considered to be a significant arthropathy (Huskisson, 1979).

Osteoarthritis is a local disease characterized by narrowing of joints with proliferative degenerative changes at joint margins (Ehrlich, 1979). Originating in joint cartilage, degenerative softening occurs, followed by surface alterations, with eventual cartilage collapse resulting in joint deformity (Sokoloff, 1979).

The symptoms of osteoarthritis, joint pain and stiffness, usually appear after rest but disappear with joint use. However, joint activity may also precipitate pain and discomfort which increases as the day wears on. In addition, pain may be experienced at night because protective splinting of muscles around joints disappears during sleep. Moreover, the degree of pain is not necessarily representative of the amount of disease; making the relationship nonmonotonic (Clark, 1976).

While there is growing refinement regarding the definition, diagnosis, and treatment of osteoarthritis, a factor often overlooked in its management is the provision of educational programs as an adjunct to patient care. Educating the osteoarthritic about the medical aspects of the disease, pain management, joint protection and preservation has implications for preventing premature joint crippling and diminishing the impact of the disease by fostering knowledgeable involvement in a therapeutic program.

The need for educational programs for the osteoarthritic was demonstrated by Dinsmore (1979) who reported that an informational program originally planned for 50 elderly persons with osteoarthritis, drew 150 requests for participation. Furthermore, Stross and Mikkelson (1977) reported that after an educational session related to osteoarthritis, 65 persons over 55 years demonstrated an increase in knowledge. Concomitant with more knowledge, improvement in well-being has been another objective for educating the person with osteoarthritis. Gould (1978) developed an educational series covering aspects of osteoarthritis that included principles of relaxation as a means of decreasing muscle tension and stress. Overall participants reported having more positive feelings about themselves at the end of the series.

Generally, pain, muscle tension and stress are interrelated. Selye (1976) has established that there is a physiological connection between the phenomenon of pain and the stress response. Physical pain increases plasma cortical levels and interferes with normal cortisol circadian rhythms, both indices of physiological responses to stress. Conditioning factors that enhance or inhibit the stress response may be endogenous (genetic predisposition, age, sex) or exogenous (treatment with certain hormones, drugs, or dietary factors). In turn, behavioral responses can be either catatoxic (aggressive actions) or syntoxic (passive actions), the former being more physically harmful than the latter. These actions are under cognitive control, therefore, it is possible to consciously regulate responses encountered in everyday stress (Selye, 1976).

Adjusting to a life of chronic pain certainly may be a source of stress for the arthritic. Moreover, frequent and prolonged elicitation of physiologic changes associated with stress reactions have been implicated in the development of stress-related disease. Benson, Greenwood, and Klemchuk (1977) have demonstrated that prevention and treatment of stress-related disease is possible by evoking the relaxation response. The response can be achieved by various techniques, such as transcendental medication or yoga. The physiologic changes occurring during these procedures consist of decreases in oxygen consumption, respiratory rate, heart rate, and muscle tension--changes directly counteractive to the physiologic stress response (Benson, Beary & Carol, 1974).

Along with physiologic stress reduction, the relaxation response can also affect experienced pain. With relaxation, the anxiety accompanying pain lessens when muscle tension decreases; therefore, pain reduction may also be induced. Furthermore, since thoughts are distracted away from pain as the person concentrates on eliciting relaxation, alterations in pain perception could activate the spinal-gating mechanism to affect pain control (Melzack & Wall, 1965). Grzesiak (1977) demonstrated the usefulness of relaxation techniques for the treatment of chronic pain in spinal cord injured patients. He reported that when four subjects were taught to relax their muscles and refocus their attention onto pleasant images, less pain was experienced. Because of the small sample size, generalization of these findings are quite limited. Nevertheless, Grzesiak has demonstrated that positive outcomes can result when patients are active participants in the care process.

According to Orem (1971) "Ways of determining and meeting one's self-care needs are not inborn" (p. 14). Moreover, her definition of nursing focuses on the design, provision, and management of therapeutic activities aimed at self-care behaviors. The model suggests that self-care can be promoted in specific nursing care situations by way of sharing of knowledge necessary for incorporating therapeutic actions into patterns of daily activities. Therefore, the purpose of this study was to develop and evaluate educational interventions utilizable in a variety of settings, which focused on pain and disease management for osteoarthritics through participation in the care process.

This report will: (a) describe four variations of a teaching approach focused on pain and disease management in osteoarthritis; (b) report the results of validity checks designed to measure the extent to which each intervention was operationalized; and (c) report the effectiveness of the four approaches on outcome measures indicating the extent to which patient education and/or pain control goals were achieved in clinical and community settings.

Method

An educational program for persons with osteoarthritis was tested for potential implementation in clinical and both urban and rural community settings. This required a factorial design in which each intervention was operationalized and manipulated as an independent component. The first intervention focused upon an explanation of osteoarthritis provided via an information brochure; the second utilized a nurse-taught approach focusing on joint management in addition to the information brochure; the third was a nurse-taught relaxation procedure plus information brochure; and the fourth intervention combined the nurse-taught joint management approach with the relaxation procedure and the information brochure. Effectiveness of the interventions were determined by measures of: (a) pain; (b) stiffness; (c) amount of medication; (d) mobility; (e) change in perceived level of pain-related stress; and (f) knowledge gained about osteoarthritis. Validity checks of the interventions included readability analysis of the brochure and analysis of typed transcripts of nurse-taught interactions.

The assignment procedure incorporated random assignment of volunteer subjects to experimental or control groups. In turn, the experimentals were randomly assigned to type of intervention. Except for the rural group, each experimental group for each site was composed of ten subjects; each control, of five subjects. In the rural sample there were five subjects in each experimental group; five subjects in the control. Table 1 summarizes patient assignment to procedures according to research site.

Table 1

Design for Manipulating Approaches: Assignment of 160 Subjects

Intervention		Site: Community Center ($\underline{n}$ = 45)	University Hospital ($\underline{n}$ = 45)	Private Hospital ($\underline{n}$ = 45)	Rural Community ($\underline{n}$ = 25)
Brochure	(I)	10	10	10	5
Teaching + I	(II)	10	10	10	5
Relaxation + I	(III)	10	10	10	5
Combination of I + II + III	(IV)	10	10	10	5
Control	(V)	5	5	5	5

<u>Sample</u>:

The 160 subjects who participated in the educational program were from four different settings: an urban senior center ($\underline{n}$ = 45); outpatient clinics of an urban university hospital ($\underline{n}$ = 45); outpatient clinics of a private inner city hospital ($\underline{n}$ = 45); and a rural group from two small towns with populations less than 3,500 ($\underline{n}$ = 25).

All persons identified by chart review or who affirmed by self report that they had osteoarthritis were eligible for this study.

Table 2

Selected Sample Characteristics of 160 Persons

with Osteoarthritis by Site

Sample Characteristics	Community Center (n = 45)	University Hospital (n = 45)	Private Hospital (n = 45)	Rural Community (n = 25)	Total Sample (n = 160)
	Percentage by Site				
Age (yrs)					
40-59	2	38	11	-	14
60-79	85	60	69	56	69
80-90+	13	2	20	44	17
Sex					
Male	29	22	13	16	21
Female	71	78	87	84	79
Race					
Black	-	49	24	-	21
White	100	51	76	100	79
Marital Status					
Single	4	6	4	16	7
Married	36	31	27	16	29
Sep./Div.	4	16	18	4	11
Widowed	56	47	51	64	53
Living Con.					
Alone	36	38	60	56	46
With others	64	62	40	44	54
Education (yrs)					
13 or more	31	6	11	20	17
9 to 12	38	51	33	40	41
8 or less	31	43	56	40	42
Work Status[a]					
Prof.-Manag.	18	2	2	16	9
Skill.-Tech.	13	6	13	12	11
Clerk-Sec.	29	16	11	8	17
Unskilled	27	56	51	48	45
Never Emp.	13	20	23	16	18
Emp. Status					
Employed	4	4	2	4	4
Homemaker	9	20	24	16	17
Unemployed	-	33	9	-	12
Retired	87	43	65	80	67

[a]Reported "work status" based upon subjects who were in and/or retired from the labor force, and were classified into groups using Hollingshead's (1975) Four Factor Index of Social Status as criteria.

Subjects were told that participation was totally voluntary, decision to participate would in no way effect their care, and confidentiality was assured. Written consent was obtained.

The resulting sample (Table 2) was heterogenous as expected; thus, potentially enhancing the generalizability of the findings. It should be noted, however, that a high proportion of persons were retired (67%). There may have also been over-representation of ethnic groups, caucasian (79%), and sex as evident by the relative high proportion of females (79%).

Measurement

Sixteen items made up the interview schedules. Each item was chosen according to criteria demonstrating documented usefulness from the literature. When possible, triangulation, that is, different measures of the same variable was used to enhance construct validity. Using this approach, items representing constructs such as pain, stiffness, medication-taking behavior, mobility, and pain-related stress were formulated and measured in the following manner:

Pain: Subjects were asked to indicate which word best described their usual arthritic pain (0 = none; 1 = mild, 2 = discomforting; 3 = distressing; 4 = horrible; 5 = excruciating) on the McGill pain intensity scale (Melzack, 1975). Next, information on pain frequency and pain duration was elicited then categorized according to response. Pain frequency was coded utilizing a seven point scale (0 = never; to 6 = all the time); pain duration was coded using a ten-point scale (0 = never; to 9 = all the time).

Stiffness: Quantifiable data were obtained as follows: Degree of stiffness was assessed using a four-point scale (0 = none; 1 =

mild; 2 = moderate; 3 = severe); information related to duration of stiffness was coded using a ten-point scale (0 = never; to 9 = all the time).

Medication-taking behavior: Prescribed medications for treatment of osteoarthritis were coded on a five-point scale (0 = none; 1 = analgesics; 2 = arthritis medication; 3 = codeine derivatives; 4 = combination of analgesics and arthritis medication). In addition, self reports of the amount and frequency of medication use were also obtained.

Mobility: Self-reports of ambulation difficulties, degree of assistive device use and related problems associated with osteoarthritis were also coded using similarly described rating scales. This method provided quantifiable data for mobility problems encountered inside and outside the home.

Pain-related stress: To provide a reference point from which pain-related stress could be evaluated, information on life stress was obtained first using a ten-step ladder scale. After scale end points had been defined in terms of least to most stress (one representing least; ten representing most), subjects were asked to indicate which ladder step represented the amount of perceived stress in their lives at the present time. Repeating this procedure, subjects were then asked to indicate the amount of stress their usual arthritic joint pain caused them.

Knowledge: Four questions were asked. The first two questions were developed for this study and the last two questions were from the McGill Pain Questionnaire (Melzack, 1975). The questions were as follows: (a) "In your own words, tell me what you know about arthritis?" (b) Tell me what you think is the most important thing you can do for your arthritis?" (c) "What kind of things <u>relieve</u> your pain?" and (d) "What kind of things <u>increase</u> your pain? Responses to each question were coded using a five-point scale (0 = no knowledge; 1 = one correct statement; 2 = two correct statements; 3 = three correct statements; 4 = knowledgeable).

Reliability and validity for the McGill Pain Questionnaire has been established (Melzack, 1975; Brena, Chapman, Stegall, & Chyatte, 1979). Therefore, validity for the pain intensity scale and questions related to behavioral responses to pain taken from the McGill Questionnaire for use in this study is assumed.

To establish reliability for the interview items, a pilot sample of eight female nursing home residents (mean age 82.4 years, <u>SD</u> = 6.97) were administered interview schedules. This resulted in a Cronbach's alpha of .80 after a split-half approach for estimating reliability was used.

<u>Procedure</u>

Interviews were conducted before and two weeks after interventions were given. Protocols for interviews and interventions were as follows:

<u>Preintervention interview:</u> Open ended questions from the interview elicited the following: (a) sociodemographic data; (b) information pertaining to perception and knowledge of illness; and (c) information on pain intensity and behavioral responses to pain by the use of selected items from the McGill Pain Questionnaire (Melzack, 1975). In addition, subjects were asked to indicate on a ten-step ladder where they would place their perceived life stress and pain-related stress after end points had been defined in terms of best and worst possible conditions.

After the above data had been collected, the nurse investigator carried out the assigned intervention. At the end of the interaction, a follow-up telephone interview was scheduled with the subject.

Interventions: Patients assigned to Intervention I were given a brochure prepared by the Arthritis Foundation (1979) entitled, "So you have . . . Osteoarthritis". The brochure covered general information related to osteoarthritis, including definition of the illness, symptoms and how pain occurs, medications, physical therapies, and surgical procedures. Because the Arthritis Foundation is a professional organization with experts available to it, credibility and content validity for the information was assumed.

Reliability for implementation was achieved by the following: (a) explaining relevant passages from the brochure to ensure patient understanding; (b) pointing to appropriate pages to elicit comments from patients on the informational content; and (c) analyzing the written material using the formula developed by Flesch (1948) for readability.

Application of the Flesch formula for testing level of abstraction entailed the following: counting numbers of words contained in three randomly selected 100-word sections from the brochure, then counting word syllables, numbers of personal words, and sentence length which after averaging were placed into the appropriate formula: reading ease = 206.833 - .846 x averaged word length - 1.015 x averaged sentence length. This procedure resulted in a readability score of 55.25 which fell in the middle of the 50 to 60 fairly difficult reading range. Since the average number of years of education was at least eight (83.1% of the 160 subjects reported grade school graduation), it was concluded that persons in this study would not have difficulty understanding the brochure.

Patients assigned to Intervention II received the brochure plus a nurse-teaching approach on joint preservation which focused on promoting self care (Orem, 1971).

Joint preservation was taught by demonstration of range of motion methods; joint protection was taught through information on body mechanics. To provide a certain amount of uniformity, diagrams of range of motion exercises and written information on joint protection were given to each person in this group. Although some variability in the approach was inevitable, the content of the information given to each person remained the same.

Validity for content of this teaching approach was obtained from: (a) assessment of the individual's pain, knowledge, and methods of controlling pain; (b) information given to the person in the teaching program; and (c) authorities in the field of arthritis. For the latter, two major sources were used: Toohey and Larson (1977) and Watkins and Robinson (1974). Both works were compiled by experts for use by health care professionals and patients, thus content validity is supported.

Since site of pathological involvement varied between persons given the nurse-teaching approach on joint preservation, validity for implementation of this intervention was obtained by having two independent coders assess 20 typed transcripts randomly selected from a pool of 55. These transcripts were obtained from recordings of this intervention. On a five-point scale (very low to very high), coders were asked to judge to what extent the nurse: (a) assessed patient knowledge; (b) identified the person's needs; (c) did not use a didactic (lecturing type) approach; (d) individualized the intervention;

(e) adjusted material to the person's level of understanding; and (f) explored acceptability of the proposed solution with the person.

The results showed that 82.5% of the ratings fell within the extreme upper end of the scale (very high) and 17.5% within the next level (high), indicating that the teaching approach was adequately operationalized. Using Yates correction factor, a one-sample chi-square test for differences between observed and expected frequencies indicated that the possibility for obtaining a value of high as the X^2 [1] = 55.3 value found for the coders' ratings was less than .001, thereby supporting that the teaching approach was utilized. Furthermore, a significant correlation (r = .74, p < .005) obtained between coder ratings of the scale's coded categories indicated that a certain measure of consistency in nurse-teaching approach for this intervention had also been achieved.

Patients assigned to Intervention III received the brochure and a demonstration of the Benson, et. al., (1977) relaxation technique modified for this study. Each subject in this group was instructed to relax in the following manner: (1) sit comfortably and close your eyes; (2) relax all your muscles; (3) breathe in and out slowly holding your breath to a count of one repeating this procedure five times; and (4) open your eyes and try to imagine something pleasant for yourself.

In order to determine whether the person understood, each technique was demonstrated by the investigator and a return demonstration was given by the subject. In addition, the subject was given written material outlining the technique along with an explanation of the usefulness of a quiet environment in facilitating relaxation. In these ways, validity and reliability for the intervention were enhanced.

Benson, et. al., (1977) do not give specific information regarding the validity of the approach except to note that the relaxation response has its roots in history and is reported as being used in various forms by both ancient and modern cultures. To validate the occurrence of the relaxation response, physiologic criteria related to changes incurred during relaxation have been reported (Benson, Alexander, & Feldman, 1975; Patel, 1973; Stone & DeLeo, 1976).

Persons assigned to Intervention IV received the brochure plus the nurse-taught approach on joint preservation and the relaxation procedure as previously described.

Patients assigned to Intervention V received no direct intervention as they were assigned as controls. However, after posttest data was obtained, the information brochure and materials related to joint management and relaxation, with an accompanying letter explaining the information, were mailed to each control subject.

Posttest Interview: Approximately two weeks after the initial interview, the subject was contacted by telephone. Initial questions asked at pretest were repeated (excluding sociodemographic information). These questions dealt with information on pain intensity, pain-related behaviors, stiffness, mobility, perceived level of pain-related stress and knowledge about osteoarthritic disease.

A total of seven subjects (four male and three females) were unavailable for follow-up interviews for the following reasons: patient hospitalized, spouse objected, phone disconnected, subject uncooperative, and subject unavailable. Analysis of subject attrition showed that the drop out rate conformed to no specific pattern across subgroups or sites. Since no violations in randomness of subject assignment had occurred, missing values were replaced by subgroup means.

Table 3

Summary Table of Adjusted Means for Dependent Measures by Intervention

Variable	Pretest Mean	(I) Brochure (n = 35)	(II) Teaching + I (n = 35)	(III) Relaxation + I (n = 35)	(IV) Combination of I + II + III (n = 35)	(V) Control (n = 20)
Medication-taking behavior	4.63	4.16	5.06	5.18	4.31	4.34
Mobility	4.54	5.16	4.93	4.59	3.99	3.65
Stiffness	4.76	4.82	4.97	4.88	4.73	4.17
Pain	10.63	11.73	11.13	9.65	10.14	10.40
Knowledge	11.84	11.77	10.64	12.64	12.31	11.85
Pain-related stress	0.93	0.57	1.04	0.75	0.95	1.62

Table 4

Summary Table of Adjusted Means for Dependent Measures by Site

Variable	Pretest Mean	Community Center (n = 45)	University Hospital (n = 45)	Private Hospital (n = 45)	Rural Community (n = 45)
Medication-taking behavior	4.63	3.85	4.81	5.38	4.37
Mobility	4.54	4.09	4.45	5.31	4.14
Stiffness	4.76	4.11	4.38	5.82	4.69
Pain	10.63	10.68	10.65	10.74	10.29
Knowledge	11.84	12.34	12.68	10.00	12.73
Pain-related stress	0.93	0.55	0.41	1.08	2.30

Results

Using an International Business Machine (IBM) computer program, pre- and posttest measures were reduced and grouped under the following variables: pain, stiffness, medication-taking behavior, mobility, pain-related stress and knowledge. From these six resultant variables, residualized gain scores were generated and tested using two-way analysis of variance (ANOVA) models that compared interventions with research sites. Adjusted means for type of intervention and research sites as predictors on the six criterion variables are presented in Tables 3 and 4.

Results from the two-way ANOVA models with post hoc analyses are summarized as follows:

Pain: A significant main effect for type of intervention (F [4, 140] = 2.45, $p < .05$) was observed. No main effects for sites or interaction between interventions and sites were found. To isolate type of intervention, t tests for differences among several means were performed (Bruning & Kintz, 1968). The value for critical differences (C. diff.) at the alpha .05 level for group contrasts was C. diff. = 1.51. The results showed that subjects who received the relaxation procedure (Intervention III) reported significantly less pain (C. diff. = 2.08) than subjects who received the brochure (Intervention I). Subjects who received the combined approach (Intervention IV) also reported significantly less pain (C. diff. = 1.59) than subjects assigned the brochure. No significant differences between other intervention group or intervention groups and controls were found.

Stiffness: A significant main effect for sites was found (F [3, 140] = 2.77, $p < .05$) although no main effects for interventions or interaction between site and intervention were evidenced. To isolate these effects, *t* tests for differences among site means were performed. The critical difference at alpha .05 level was C. diff. = 1.33. Subjects at the community center (C. diff. = 1.71) and at the university hospital (C. diff. = 1.44) reported significantly less stiffness than subjects at the private hospital site. No other significant differences were observed.

Medication-taking behavior: No significant main effects or interactions between interventions and sites were found.

Mobility: No statistically significant findings for the two-way ANOVA model comparing interventions with sites were observed.

Pain-related stress: Only a significant main effect for research sites was observed (F [3, 140] = 3.65, $P < .05$). When sites were compared using the *t* test (critical difference = 1.10, at alpha .05 level) subjects at the rural community reported significantly more stress when compared with subjects at the community center (C. diff. = 1.75), university hospital (C. diff. = 1.89), and private hospital (C. diff. = 1.22). Other significant site differences related to pain-related stress were not found.

Knowledge: Although no main effects for interventions or interaction between interventions and sites were evidenced, a main effect for research sites occurred (F [3, 140] = 3.10, $P < .05$). Sites exceeding the critical difference of 2.18 (alpha .05 level) for *t* test multiple group comparisons were community center (C. diff. = 2.34), university hospital (C. diff. = 2.68) and rural community (C. diff. = 2.73) when individually compared with the private hospital site. No further significant site differences were found.

Discussion

Although no single educational intervention for osteoarthritis management demonstrated sufficient patient benefit to rationalize adoption into routine nursing practice, evidence was found to support further development of certain approaches to enhance their impact on outcome measures. For instance, a statistically significant effect of the relaxation intervention was found on the outcome measure for pain when compared with the teaching, brochure only, and control group. Because conscious relaxation results in thought distraction from pain while incurring muscle relaxation, stimulation of the gate control or other biological mechanisms to effect pain was a possible outcome for persons who practiced this technique. According to Stewart (1976), "the combination of conscious relaxation and regular rhythmic breathing is a formidable barrier to pain. The total elimination of pain is not expected; the ability to deal with it is the desired outcome" (p. 958). Therefore, it could be speculated that persons taught the relaxation procedure may have learned an effective method for controlling joint pain. Further support for the utility of the relaxation method can be noted in the fact that, person assigned to the combined approach (which included relaxation), also reported decreased pain.

Even though no specific intervention could be identified, significant decreases in stiffness were also reported by subjects at the university hospital.and the community center when sites were compared. Certain patient characteristics might help account for this finding. The subjects at the university hospital site were younger than subjects at the other three locations; persons at the community center though of comparable age to subjects at the other two sites were a more active group, as was evidenced by participation in recreational activities. It is surprising, though, that improved ambulation was not reported (with decreased stiffness).

A somewhat surprising finding was the significant increase in pain-related stress reported by persons at the rural community. One explanation for this could be that the nurse-patient contact which focused upon pain (a rare event in the rural area) may have effected increased stress levels in these persons. Another explanation may be that the increased stress levels indicated a need for further nurse-patient contact. This contention is supported by the fact that during the initial contact, subjects stood in line waiting to be interviewed.

Nonetheless, persons living in urban areas such as the community center, university hospital and private hospital reported less stress when compared with the rural residents. Even though stress reduction could not be attributed to a specific intervention, it is speculated that persons taught range of motion exercises and relaxation procedures may have experienced less stress since both procedures are effective methods of pain control. As pointed out by Smith and Selye (1979) one way a nurse can help a patient reduce stress is to educate the individual on how to control stressors (such as pain). Further support that exercise and relaxation may have effected stress reduction is gained by the fact that no significant changes in medication-taking practices occurred.

Furthermore, significant increases in knowledge were reported by persons at each research site except the private hospital. Since each person assigned to an educational intervention received the information brochure, the lack of identification of a specific intervention related to knowledge gained about the illness is not unexpected. However, it was unexpected that private hospital subjects reported no change in knowledge related to their illness. Since these persons were at the lower end of the educational continuum (56% reported an educational level of eight years or less) the acquisition of knowledge related to their illness may have been difficult. Another explanation could be that due to reliance on private physicians, they lacked the motivation to learn about their illness and its management. Nevertheless, the majority of subjects in this study were motivated to learn, as reflected by the increased knowledge reported by persons at the community center, university hospital and rural community sites.

In general, approximately, half of the persons given exercise information, slightly less than half of those who received relaxation procedures, and about one-third who received the information brochure reported the information as useful. Since no marked differences were reported in the utility of the various educational approaches, support for any one over the other cannot be promoted. Nevertheless, the fact that a group of elderly persons cooperated with the instructional interventions and were receptive to learning about osteoarthritis demonstrated a need for patient education in this area. According to Hollingsworth (1980), "sometimes a modest gain may represent a major gain in the ability of the older patient to function and to remain independent. No patient is more grateful than the arthritic who lives with constant pain" (p. 228). Therefore, the expressed usefulness of the educational materials along with the minimal dropout suggests that persons participating in this study were generally satisfied with the interventions.

Another indication of patient satisfaction was the significant gain in knowledge about the illness shown by subjects at three of the four settings. With regard to learning in the older person, Schaie (1975) pointed out that the elderly are not less intelligent than younger persons, but may appear so because their educational backgrounds differ; consequently, an older person's ability to learn may be underestimated. The increased knowledge reported in this study reflected the capability of elderly persons to learn about disease management. Therefore, it may be speculated that educational programs related to osteoarthritis and its management need to be developed and implemented since education in this area may also be perceived as helpful by other elderly persons.

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COMPARING MULTIPLE REGRESSION PROCEDURES AND CHI SQUARE IN MMPI ITEM ANALYSIS

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Abstract

Multiple regression procedures and chi square were used to analyze the MMPI items for a group of 110 black and white male college students. Most of the items identified by the multiple regression procedures were also identified by chi square. The added advantage of having R^2 as an estimate of the percentage of variance accounted for by race is discussed in relation to selecting items in empirical scale construction.

The Minnesota Multiphasic Personality Inventory (MMPI) consists of four validity scales and 10 clinical scales. In addition to these 14 scales more than 400 special scales have been developed from the MMPI pool of 550 items (Duckworth & Duckworth, 1975). The method of empirical scale construction has been used in the development of many of the original and special MMPI scales.

In the empirical approach, MMPI items responses of two distinct groups (criterion and control) are contrasted to insure that scale items are selected which are empirically related to the characteristic being assessed. Researchers will usually select items for inclusion in the new scale on the basis of the level of significance, usually .05, from the results of a chi square test. Once the items have been selected, several other steps are carried out which include comparing the means of the criterion and control groups. If the purpose of the new scale is to classify individuals into dichotomous groups, (i.e., black-white, alcoholic - non-alcoholic) cutting scores are also established. The point of this general description of scale construction is to show that little, if any, direct attention is given to assessing the strength of the relationship between the item results and the criterion.

Leitner (1979) has recommended multiple regression procedures in analyzing R x C contingency tables. Chi square is usually applied to these type of data. The multiple regression approach provides the researcher with an estimate of the percentage of variance (R^2) accounted for as a way to better understand the strength of the relationship implied. The purpose of this study was to examine the results from item analyses conducted on a single sample using both chi square and multiple regression procedures.

Method

Subjects

The subjects were 110 black (n = 57) and white (n = 53) male first and seco year college students from a state university in Missouri.

Procedures

The item responses of the sample were analyzed using chi square and multiple regression procedures form the SAS package (Barr, et al., 1979). For the multiple regression analysis the variables were coded as follows:

X = 1 if subject was black; 0 if white

Y = 1 if item response was true; 0 if false

Results

The chi square analysis identified 127 items that differentiated blacks and whites at the .05 level or better and the multiple regression analyeie identified 124. There were 14 items identified by chi square and not identified by multiple regression. There were five items identified by multiple regression and not identified by chi square.

Discussion

Most of the items identified by the chi square analysis were also identified by the multiple regression approach. When the R^2s from the multiple regression approach were examined, the following pattern emerged. In general, for items witl p levels between .01 and .05, race accounted for about 5% (or less) of the varianc for items with p levels between .001 and .009, race accounted for 6 to 8% of the variance; for items with p levels between .0001 and .0008, race accounted for abou 12 to 15% of the variance (one item reached 20%). For about half of the items identified as being significant, race accounted for 5% or less of the variance. The p levels were examined for the 213 race-sensitive items identified by Harrison and Dass (1967) in their study of black and white pregnant women. About half of ne items had p levels between .01 and .05. Making an assumption that the pattern ound by Harrison and Kass, was at least somewhat similar to the results of the urrent study, about half of their items would also have R^2s of 5% or less.

Although Harrison and Kass did not develop a scale from their race-sensitive tems, they have been used, in part, as the basis for selecting items for at least wo MMPI scales (White, 1974; Costello, 1977). The issue to be raised, not only or the two studies cited above, but for item analysis and empirical scales gener-lly is whether researchers can develop better scales (e.g., more highly correlated ith the criterion) by considering the amount of variance accounted for by the item ifferences. If not better scales, perhaps scales just as good with fewer items, y removing items which account for small amounts of variance. It should be ointed out that the Leitner (1979) article also demonstrated how the R^2 statistic ould be generated form the chi square procedure, but it will be observed that most eneral statistical analysis packages do not provide the information directly.

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THE USE OF FULL MLR MODEL TO CONDUCT MULTIPLE COMPARISONS IN A REPEATED MEASURES DESIGN: AN INDUSTRIAL APPLICATION

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Abstract

This paper presents the MLR models used to analyze the impact of the aging process on the ductility of steel tubing. The discussion includes the procedure by which multiple comparisons can be made in a repeated measures design by using only one full MLR model.

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[1]The company's name will not be used as requested by the company.

Introduction

The management of a firm that manufactures steel tubing was faced with the problem of determining what impact the aging processes had on the ductility of the steel tubing.[1] The purpose of this paper is to present the multiple linear regression (MLR) models developed to analyze the impact that the aging process had on the ductility of the steel tubing. Specifically, the discussion centers on the joint utilization of item vectors and multiple comparisons in the MLR models, as discussed by Williams (1980). Included in this discussion, however, is the outline of a procedure through which only one full regression model is required to make multiple comparisons.

Hypothesis

The question being addressed by the company was: Does aging affect the ductility of non-aluminum kilned steel tubing? If this question was answered in the affirmative, the ductility of steel tubing stored for periods of time in inventories could fall below a buyer's minimum standards. Such a result could cause inventory policy to change.

Since the ductility of the tubing was measured by elongation values and management was interested in three specific time periods, the null hypothesis corresponding to the question of interest was as follows:

H_0: There is no difference between the three time periods with respect to the tube elongation values.

The analysis of this hypothesis was best accomplished by the use of MLR models. The MLR models can best be understood after reviewing the sampling procedure and the method by which the aging process was simulated.

Sample and Treatments

Sample items for this project were selected from production lots of tubing of various sizes of non-aluminum kilned steel. Since the tubing had to be exposed to three treatments to reflect the aging process and the collection of the dependent variable readings caused the tubing to be destroyed, three specimens were used from each sample tube. Extreme care was taken to insure that the three specimens machined from each selected tubing sample were alike. All three specimens were cut from the sample tube in the same orientation and from the same side of the tube. Therefore, it was assumed that the three specimens from each sample of tubing were matched prior to the aging process.

The aging process was simulated by exposing the specimens to various heat treatments. One specimen from each tubing sample was not heat treated or allowed to age prior to testing. Those specimens not aged were considered exposed to Treatment A. The second specimen was heated to 300°F for 23 minutes to simulate one year of normal aging. Those specimens aged one year were considered to be exposed to Treatment B. The third specimen from each sample tube was heated at 300°F for 60 minutes to simulate 2 1/2 years of aging. This treatment was labeled Treatment C.

Twenty-seven separate samples of various sizes of both square and rectangular structural tubing were selected for use in the study. As previously mentioned, each sample tubing was divided into three sections and each section was exposed to either Treatment A, B, or C. Thus, the total sample size was 81 with 27 tubing specimens being exposed to each treatment.

Variables and Regression Models

Dependent Variable

Elongation values were used as indicators of the ductility of the tube. The elongation values were obtained by administering a standard strip-tensile test to each tubing specimen after it had been exposed to the appropriate heat treatment. Each specimen of tubing was notched in the middle. Marks were placed two inches apart in the notched section of the tubing and the tubing was stretched until it broke. The pieces were placed back together and the percentage increase in length between the two marks served as the elongation value.

Independent Variables

To insure that the regression models developed to test the null hypothesis were accurate reflections of the situation, i.e., a Type VI error would be avoided (Newman et al., 1976), four independent variables were required. The four independent variables were as follows:

X_1 = Treatment A (no aging). X_1 was equal to 1 if the tubing specimen was exposed to Treatment A; 0 otherwise.

X_2 = Treatment B (aged 1 year). X_2 was equal to 1 if the tubing specimen was exposed to Treatment B; 0 otherwise.

X_3 = Treatment C (2 1/2 years of aging). X_3 was equal to 1 if the tubing specimen was exposed to Treatment C; 0 otherwise.

X_4 = Vector to represent the item vectors. X_4 was equal to the average elongation value (Y) for the three specimens obtained from a given piece of tubing.

The dummy variables X_1, X_2, and X_3 represented the treatments that simulated the aging process. Since the regression models were analyzed through a matrix inversion process, only two of the treatment vectors could be entered into a model at one time.

Variable X_4 was a key variable to include in the model and a variable that required that caution be taken in the interpretation of the computer printouts. Since the three specimens taken from each sample tube were considered matched, it was necessary that the regression models reflect that fact. The matching characteristic would necessitate the use of 26 item vectors, as discussed by McNeil, Kelly, and McNeil (1975). Pedhazur (1977) and Williams (1977), however, outlined a procedure by which the impact of the matching can more easily be represented by one vector. This vector, represented by X_4 in this study, was formed such that the entries for the three specimens for a given tube were equal to the average elongation values (Y) for those three specimens.

To illustrate the data coding procedure for the independent variables consider the data for the first 9 of the 81 specimens as listed in Table 1. The vector values indicate that the first specimen had an elongation value (Y) of 22. It was exposed to Treatment A ($X_1 = 1$, $X_2 = 0$, $X_3 = 0$), i.e., it was not aged. Finally, the value of 20 for X_4 was obtained by averaging the elongation values of 22, 19, and 19 recorded for the three specimens obtained from the same piece of tubing. Thus, the value of 20 recorded for Specimens #1, #2, and #3 indicated that they were obtained from the same piece of tubing.

Table 1

Vectors Used in Full Regression Model

Specimen	Vectors				
	Y	X_1	X_2	X_3	X_4
#1	22.0	1	0	0	20.0
#2	19.0	0	1	0	20.0
#3	19.0	0	0	1	20.0
#4	24.1	1	0	0	22.7
#5	22.0	0	1	0	22.7
#6	22.0	0	0	1	22.7
#7	23.1	1	0	0	20.7
#8	20.0	0	1	0	20.7
#9	19.0	0	0	1	20.7

Regression Models

The full regression model that reflected the research hypotheses used in this study was:

$$Y = a_0U + b_1X_1 + b_2X_2 + b_4X_4 + E_1 \qquad \text{(Model 1)}$$

The restriction placed on Model 1, which was required to test the impact of aging, was $b_1 = b_2 = 0$. The resulting restricted model was:

$$Y = a_0U + b_4X_4 + E_2 \qquad \text{(Model 2)}$$

The results of the computer analysis of the MLR models are contained in Table 2. The R^2 values for the full regression model (Model 1) and the restricted regression model (Model 2) were .9197 and .6789, respectively. To determine whether the decrease in the R^2 value was due to sampling error or the influence of aging, an F test was conducted.

Table 2

Analysis of Model 1 and Model 2

Model 1:

$$Y = a_0U + b_1X_1 + b_2X_2 + b_4X_4 + E$$
$$(-1.55) \quad (4.22) \quad (.148) \quad (1.00)$$
$$R^2 = .9197$$

Model 2:

$$Y = a_0U + b_4X_4 + E_2$$
$$(-.097) \quad (1.00)$$
$$R^2 = .6789$$

Note. The values contained in the parentheses are the regression coefficient values.

The formula for calculating the required F test was as follows:

$$F = \frac{(R_F^2 - R_R^2)/df_n}{(1-R_F^2)df_d}$$

where:

R_F^2 = the R^2 value for Model 1

R_R^2 = the R^2 value for Model 2

df_n = the number of restrictions placed on the full model to obtain the restricted model

df_d = total sample size minus the number of intercepts and independent variables

The F value was calculated as follows:

$$F = \frac{(.9197 - .6789)/2}{(1 - .9197)/52} = 77.97$$

It is important to note that the degrees of freedom for the denominator was equal to 52. Since the sample size was 81 and it appears that there are three independent variables in the full regression model (Model 1), one might think that the df_d should be equal to [81-(3+1)] or 77. One should remember, however, that variable X_4 is a surrogate for 26 item vectors. Therefore, the full regression model "contains" 28 independent variables. The correct df_d would be equal to [81-(28+1)] or 52.

The F value was statistically significant at the predetermined alpha level of .01. Thus, the researchers concluded that aging did have an impact on the elongation values of the tubing. To gain further insight into what impact aging had on the elongation values, the researchers conducted multiple comparison tests.

Multiple Comparisons

The use of multiple comparisons tests would allow the researchers to make specific statements concerning the impact of the aging process on elongation values. Since the regression coefficients for the treatment variables represent the differences between the means of the groups (Treatment A and B) and the group contained in the constant term (Treatment C), the differences between the means of the three treatments could be obtained as follows:

$$\bar{Y}_A - \bar{Y}_C = b_1 = 4.222$$
$$\bar{Y}_B - \bar{Y}_C = b_2 = .148$$
$$\bar{Y}_A - \bar{Y}_B = b_1 - b_2 = 4.222 - .148 = 4.074$$

Williams (1980) outlined a procedure by which the t values of the regression coefficients could be used to test each comparison through Tukey's Honestly Significant Difference (HSD) test. As noted by Williams, the t values had to be adjusted due to the fact that a variable (X_4) was used as a surrogate for the item vectors. That is, the standard error of the coefficient values was calculated based on the "apparent" denominator degrees of freedom of the full model rather than the "correct" number. In this study the standard error of the coefficients wes based on 52 rather than 77.

The procedure discussed by Williams demonstrated that corrected t values can be obtained by multiplying each t value by a constant term. The constant term (C) was defined to be:

$$C = \sqrt{\frac{MS_W \text{ (incorrect df)}}{MS_W \text{ (correct df)}}}$$

where:

MS_W (incorrect df) is equal to the mean square within value obtained from the full regression model (Model 1) that contains the surrogate variable (X_4).

MS_W (correct df) is equal to the mean square within value obtained from the full regression model that does not use the surrogate variable but uses the actual dummy item vectors. Such a model would be based on the correct degrees of freedom.

A closer examination of the computation of the constant term C, however, reveals that it is nothing more than the square root of the ratio of the "correct" degrees of freedom to the "incorrect" degrees of freedom. Thus, the computation of the value of C would be as follows:

$$C = \sqrt{\frac{\text{correct } df_d \text{ for full model}}{\text{incorrect } df_d \text{ for full model}}}$$

where:

correct df_d for full model = (n+1 - # of subjects - # of groups).

incorrect df_d for full model = n - (# of independent variables + # of intercepts). Note: <u>no</u> consideration is given to the fact that one variable represents numerous item vectors.

According to Williams' procedure the t values for b_1 and b_2 could be corrected by multiplying their respective t values by C. This procedure, however, would require that an additional model be analyzed to obtain the t value for the coefficient which represented the comparison between Treatment A and Treatment B. The following model (Model 3) would provide the necessary regression coefficient (b_5) and corresponding t value:

$$Y = a_0U + b_5X_1 + b_3X_3 + b_4X_4 + E \qquad \text{(Model 3)}$$

One Model Procedure

It is possible, however, through the use of a simple calculation to avoid the necessity of analyzing a third regression model when correcting the t values. The corrected t values could be obtained as follows:

$$t_c = \frac{b_i}{\frac{S_{b_i}}{c}}$$

where:

t_c = corrected t value

S_{b_i} = standard error of the coefficient

$$c = \sqrt{\frac{\text{correct } df_d \text{ for full model}}{\text{incorrect } df_d \text{ for full model}}}$$

correct df_d for full model = (n + 1 - # of subjects - # of groups)

incorrect df_d for the full model = n - (# of independent variables + # of intercepts)

The computation of c for this study was

$$c = \sqrt{\frac{52}{77}} = .821$$

Since the standard error of the coefficient values (S_{b_i}) will be the same for all treatment variables, the values for $\frac{S_{b_i}}{c}$ will be the same for all the treatment coefficients. For this study $\frac{S_{b_i}}{c} = \frac{.317}{.821} = .386.$

Dividing the differences between the means by the value obtained for $\frac{S_{b_i}}{c}$ would produce the corrected t values. The differences in the means were obtained from the regression coefficients of the treatment variables found in the only full regression model (Model 1) utilized in the analysis. The differences in the means between Treatment A and Treatment C, between Treatment B and Treatment C, and between Treatment A and Treatment B were equal to b_1, b_2, and b_{1-2}, respectively. See Table 3 for the calculations of the corrected t values.

Table 3

Calculations of the Corrected t Values

Comparison	Regression Coefficient	$\frac{S_{b_i}}{c}$	Corrected t Value
$\bar{Y}_A - \bar{Y}_C$	$b_1 = 4.22$	.386	$4.22/.386 = 10.93$
$\bar{Y}_B - \bar{Y}_C$	$b_2 = .148$	.386	$.148/.386 = .38$
$\bar{Y}_A - \bar{Y}_B$	$b_1 - b_2 = .4074$	.386	$4.074/.386 = 10.55$

The corrected t values were compared to the critical value of $\frac{q}{\sqrt{2}}$ where q was obtained from a table of Studentized Range Values.[2]

The critical value for this study at the .01 was:

$$= \frac{4.33}{\sqrt{2}} = 3.06$$

The df_w and J used to locate the value in the table were:

df_w = the correct number of degrees of freedom for Model 1 ($df_w = 52$)

J = the # of groups (J = 3)

If a corrected t value exceeds the critical value of $\frac{q}{\sqrt{2}}$, the difference between the means was judged to be significant.

Impact of Aging on Ductility

A comparison of the corrected t values to the critical value of 3.06 indicated that the mean for Treatment A was higher than both the means of Treatment B and Treatment C. The difference between the means of Treatment B and Treatment C, however, was not statistically significant. Therefore, the ductility of the steel tubing, as measured by elongation values, decreased as the tubing aged. However, the loss in ductility occurred for the most part during the first year.

The α/N Method

The multiple comparisons could also have been conducted by using the α/N method, where N is equal to the number of comparisons. Since α was set at .01 and three comparisons were made, α/N was equal to .003. The corresponding t value obtained from the t table was approximately equal to 3.36. Thus, if a corrected t value recorded for any comparison exceeded the absolute t value of 3.36, the difference between the groups

[2]Williams (1980) provides tables (pp. 82, 83) in which the Studentized value (q) is already divided by $\sqrt{2}$.

was statistically significant. Such a comparison made for the three comparisons revealed that the mean elongation value for Treatment A was significantly higher than the means of either Treatment B or Treatment C, and there was no difference between the means of Treatment B and Treatment C. It should be noted that these results were the same as the results obtained through the use of Tukey's HSD method.

Conclusion

A question facing an industrial firm could easily be analyzed by utilizing MLR models. The MLR models, however, required the inclusion of two major concepts previously discussed in the literature. First, the MLR models incorporated the use of a variable that served as a surrogate variable to numerous item vectors as outlined by Pedhazur (1977) and Williams (1977). Second, the MLR models were used to make multiple comparisons in a repeated measures design (Williams, 1980). Unlike the procedure outlined by Williams, which requires the use of multiple full models, a procedure that allows multiple comparisons to be conducted by using only one full model was developed and effectively implemented in this study.

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NOTE: SUGGESTED METHOD FOR CORRECTING ALPHA ERROR BUILD-UP ON ORTHOGONAL DEPENDENT VARIABLES

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Quite frequently applied researchers will not correct for alpha error build-up, which is the result of having multiple dependent variables. The most common suggested approach for controling for this problem is to use multivariate analyses. While this method may have advantages and disadvantages, there are many researchers who prefer not working within a multivariate analyses framework.[1]

[1] A discussion of this point is beyond the scope of this note.

The purpose of this paper is to present a simple univariate approach to control for inflated Type I error rates. Given the frequently cited formula

Equation 1: Expected Type I Error Rate $= [1 - (1 - \alpha)^{g-1}]$

Where: α = alpha level desired

g = number of orthogonal contrasts

one can determine the actual Type I error rate for orthogonal dependent variables (variables that are zero correlated with each other).

Newman and McNeil (1972) suggested a regression procedure in which one can make the correlated dependent variables, orthogonal. For example, assume the following dependent variables exist:

G.P.A. (y_1), Reading Achievement (y_2), and Math Achievement (y_3)

and the independent variables are:

Method 1 (x_1), Method 2 (x_2), and Method 3 (x_3)

The following equation can be written to make the criterion variables orthogonal:

Model 1 $y_1 = a_0u + a_1x_1 + a_2x_2 + a_3x_3 + a_4y_2 + a_5y_3 + E_1$

Model 2 $y_1 = a_0u + a_4y_2 + a_5y_3 + E_2$

Model 3 $y_2 = a_0u + a_1x_1 + a_2x_2 + a_3x_3 + a_4y_1 + a_5y_3 + E_3$

Model 4 $y_2 = a_0u + a_4y_1 + a_5y_3 + E_4$

Model 5 $y_3 = a_0u + a_1x_1 + a_2x_2 + a_3x_3 + a_4y_1 + a_5y_2 + E_5$

Model 6 $y_3 = a_0u + a_4y_1 + a_5y_2 + E_6$

Testing Model 1 against Model 2 will determine if treatment differences account for a significant amount of unique variance in y_1, which is independent of y_2 and y_3. Similarly testing Models 3 against 4, will determine if treatment accounts for a significant amount of unique variance in y_2, which is independent of y_1 and y_3, etc.

Since the dependent variables are now orthogonal, Equation 1 allows one to estimate what the actually Type I error rate would be if one was interested in the family wise error rate for all three dependent variable. Setting $\alpha = .05$,

Table 1, which is based upon Equation 1, will give the expected Type 1 error, which = .098, instead of .05.

Table 1

Expected Type 1 Error Rate

N of Orthogonal Contrasts	Chosen Alpha Level			
	.01	.02	.05	.10
2	.010	.020	.050	.100
3	.020	.040	.098	.190
4	.030	.059	.143	.271
5	.039	.078	.185	.344
6	.049	.096	.226	.410
7	.059	.114	.265	.469
8	.068	.132	.302	.522
9	.077	.149	.337	.570
10	.086	.166	.370	.613
11	.096	.183	.401	.651
12	.105	.199	.431	.685

By looking at Table 1, it is obvious that as the number of tests increase the actual Type 1 error rate way exceed the states and desired alpha level. However, if one substitutes a correction for alpha, this problem is eliminated. Using ($\alpha' = \frac{\alpha}{g-1}$) the corrected α' and substituting it for alpha in Equation 1, one can analyitically prove the following by the use of the binomial theorem.

To prove: $1 - (1 - \frac{\alpha}{g-1})^{g-1} \approx \alpha$

Binomial Theorem Yields: $(1 - \frac{\alpha}{g-1})^{g-1} = 1 - (g-1)(\frac{\alpha}{g-1}) + \frac{(g-1)(g-2)}{2!}(\frac{\alpha}{g-1}) - \ldots$

Thus: $1 - (1 - \frac{\alpha}{g-1})^{g-1} \approx 1 - \left[1 - \frac{(g-1)\,\alpha}{g-1}\right]$ for $\frac{\alpha}{g-1}$ small

$= \frac{g-1}{g-1}\alpha = \alpha$

Skeptics of this proof are refered to Table 2 which is based upon Equation 2:

Equation 2: Expected Type 1 error rate (adjusted) =

$$\left[1 - (1 - \frac{\alpha}{g-1})^{g-1}\right]$$

Table 2

Expected Type I Error Rate (corrected by $\frac{\alpha}{g-1}$)

N of Orthogonal Comparisons	Chosen Alpha Level			
	.01	.02	.05	.10
2	.01	.02	.05	.10
3	.01	.02	.05	.10
4	.01	.02	.05	.10
5	.01	.02	.05	.10
6	.01	.02	.05	.10
7	.01	.02	.05	.10
8	.01	.02	.05	.10
9	.01	.02	.05	.10
10	.01	.02	.05	.10
11	.01	.02	.05	.10
12	.01	.02	.05	.10

Please note that we are not suggesting that this correction must be used. Authors such as Games (1971), Cohen & Cohen (1975), McNeil (1972), and Newman and McNeil (1972) state that if the dependent variables are orthogonal and a prior hypotheses have been derived based on some theoretical or logical and rational theory, it may be less critical to correct for the alpha error build-up. However, we are suggesting that Models 1-6 are testing the question about the unique variance for each of the criterions, and if one teated the following Models which measure total variance, then the unique variance can be subtracted from the total variance and an estimate of the common variance can be obtained with this information, one can better evaluate the data and make more logical and rationale decisions about the research questions.

Model 7 $y_1 = a_0u + a_1y_1 + a_2y_2 + a_3y_3 + E_7$

Model 8 $y_2 = a_0u + a_1y_1 + a_2y_2 + a_3y_3 + E_8$

Model 9 $y_3 = a_0u + a_1y_1 + a_2y_2 + a_3y_3 + E_9$

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MULTIPLE LINEAR REGRESSION VIEWPOINTS

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SOFTWARE UPDATE

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Just available is the APPLE microcomputer version of Stoneware's DB Stat Pak, the statistical package designed to accompany their data base package, DB Master. The Stat Pak diskette cannot be booted. It must be reached through the DB Master Main Menu. All of the statistical tests in the package can be run with only one disk drive. Two drives, however, are suggested for DB Master itself. A free backup disk is included in the Stat Pak package which retails for $99.

The Stat Pak can be used for the following procedures:

1. mean, standard deviation, frequency distribution
2. T-tests (paired or unpaired as well as hypothesis tests using the standard normal distribution
3. Mann-Whitney U-test
4. Wilcoxon paired sample test

5. One-way ANOVA with Newman-Keuhls test

6. Chi-square analysis

7. Linear regression and correlation

The manual is written very simply and could be understood by a person with minimal statistics background. The tests are explained well and appropriate use of each test is discussed. Sample data files are available for working through the examples of the manual.

This package is fine for a person with weak statistics background. It is easy to use. Recommend it to friends who want to use statistics occasionally. For yourself, you may want another package for your microcomputer.

Coming: reviews of HSD's Multiple Regression and Micro's Time Series Package. Watch, too, for APPLE's soon to be released factor analysis package, APPLE FACTOR.

If you are submitting a research article other than notes or comments, I would like to suggest that you use the following format if possible:

Title
Author and affiliation
Indented abstract (entire manuscript should be single spaced)
Introduction (purpose—short review of literature, etc.)
Method
Results
Discussion (conclusion)
References

All manuscripts should be sent to the editor at the above address. (All manuscripts should be camera-ready.)

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