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ABSTRACT

The purpose of this paper is to articulate the common confusion of correlation for causation. Various articles that have addressed this issue are reviewed, and possible reasons for the misinterpretation of correlation as causation are presented. The differences between correlational and experimental research designs are reviewed, and the implications of their findings are discussed. Discrimination between these two research designs is also highlighted in view of the abilities of the designs to allow the inference of correlation or causality. The dangers of confusing correlation with causality are discussed, and an example of a linear regression analysis is used to illustrate how correlation can be mistaken for causality. (Author/SLD)

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Correlation versus Causation: Another look at a common misinterpretation

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Abstract

The purpose of this paper is to articulate the common misinterpretation of correlation for causation. Various articles that have addressed this issue are overviewed and possible reasons for the misinterpretation of correlation for causation are presented. The differences between correlational and experimental research designs are reviewed and the implications of their findings are discussed. The discrimination that exists between these two research designs is also highlighted in light of their respective abilities to infer correlation or causality. The dangers of confusing correlation with causality are discussed and an example of a linear regression analysis is used to illustrate how correlation can be misinterpreted for causality.

Correlation versus Causation: Another look at a common misinterpretation

One of the fundamental concepts learned in just about any statistics course is that correlation does not imply causality; however, the human mind seems to be programmed to see causal relationships when there are none (Bracy, 1998). The inference of causation from correlation has been an ongoing misinterpretation and one that continues to surface in the literature. Over the years, a number of authors have articulated the differences between the two concepts while others have proposed possible explanations for the misinterpretation of these concepts. The purpose of this paper is to highlight the misinterpretation of correlation for causation by: 1) discussing the implication of the correlation statistic, 2) discussing the differences between correlation and research design and their respective abilities to infer correlation or causality, 3) highlighting the dangers of confusing correlation with causality and, 4) using an example of a linear regression analysis to illustrate how correlation can be misinterpreted for causality.

The Correlation Statistic

Silvestri (1989) suggested that the term "correlation" is a reference to either the correlation statistic or the non-experimental research design. The correlation statistic is a measure of the strength and directionality of a relationship between variables. It does not infer a cause and effect relationship between the variables. Bateson (1995) posited an interesting example, suggesting that it is not justifiable to infer that churches cause crime because there is a high positive correlation between the number of churches and the crime rate in urban centers in the United States. From the correlation statistic it can only be established that a relationship of a specified degree and direction exists between the two variables. One cannot make any inferences concerning causality based upon the result of the correlation statistic (Onwuegbuzie & Daniel, 1999).

Correlation and Research Design

According to Silvestri (1989), the research design determines whether there exists a causal relationship or a mere association. The experimental design is a research protocol that is set up to establish causal inferences between variables. In these types of research designs, variables are strictly controlled and manipulated in order to infer a causal relationship. In addition, alternative causal possibilities must be eliminated before a definite cause is settled upon. The satisfaction of these conditions are not theoretically possible but are approximated to a substantial degree in practice (Harcum, 1988).

Correlational, or non-experimental, designs (commonly referred to as observational studies) do not allow for causal inference. They merely establish relationships that exist between variables and define these relationships in terms of their strength and direction. These relationships are usually determined by a series of observations that are carried out by the researcher. The observations are based upon the "real world" interaction of the variables and not a pre-defined environment in which the variables can be manipulated (Miller, Chaplin, & Coombs, 1990). These studies, which typically employ correlational statistics, comprise the bulk of the studies that currently exist in the literature. However, Silvestri (1990) cautioned that there need not be a predefined relationship between the non-experimental design and the use of the correlation statistic.

The misinterpretation of causation for correlation could possibly be attributed to the difference in status between experimental and correlational studies. Experimental studies tend to be accredited with greater importance by virtue of their sophisticated design, verifiable results, and their ability to infer causality. Correlational studies tend to be viewed as second rate because they are based upon hypotheses that ultimately need to be verified by an experimental design (Miller, Chaplin, & Coombs, 1990). This bias against correlational design is unfounded and should not suggest a hierarchical ranking of the two types of research designs. Both design types are equally important and necessary in order for each other to successfully accomplish their objectives. Neither is superior nor could exist independently. However, in certain research situations it may be necessary to employ the use of a specific type of research design type due to the nature of the variables. This is especially true when it is not possible to manipulate or is unethical to manipulate predictor variables under study. In such a situation, a correlational study may be the only option available to the researcher. Nevertheless, it is important to note that both design types are equally important and necessary in order to explain the existence and interaction of variables within a specific environment (Miller, Chaplin, & Coombs, 1990).

Part of the discrimination between the different research designs can be attributed to research journals which tend to favor studies that have been conducted via the experimental design (Miller, O' Bannon, & Melvin, 1980). Although most journals will publish any material that warrants recognition, there still exists a stigma attached to experimental studies. This is clearly evident from the large number of journals that are specifically dedicated to experimental research as opposed to other research types. A number of authors have tried to address the imbalance that exists between the two, but to no avail. Editors and authors need to make a concerted effort not to elevate any one type of design as being superior but rather to equate all design types on a neutral platform. Experimental and correlational designs are equally effective; they merely differ in their objectives and approach.

Dangers of Confusing Correlation with Causality

The misinterpretation of causation for correlation can have far reaching consequences. Bracy (1998) cited a study in which the College Board established a high positive correlation between students who took algebra in eighth or ninth grade and those who went to college. This finding was misinterpreted by the Secretary of Education who eventually went on to state that courses in mathematics including algebra were the gateway to college and future employment. Hence, a causal relationship was interpreted from the high positive correlation. The consequences for a misinterpretation such as this can be detrimental, in that most lay readers would be deceived into believing the statement made by the Secretary of Education. It could result in an unexpectedly large number of students taking algebra under the pretext that their subject choice will eventually get them into college, an activity that might result in misplacement of many students into courses not suited to their needs, interests, or developmental level (Bracy, 1998).

Data Example

The misinterpretation of correlation for causation occurs fairly frequently by both writers and readers of research especially when linear regression analysis is part of the study. In linear regression, the researcher is primarily concerned with the concept of prediction, which is accomplished in part by establishing correlation between variables. In order to demonstrate just how easy it is to infer causality from correlation, a regression analysis was conducted on data gathered by Holzinger and Swineford (1939). In the Holzinger and Swineford study, the researchers collected data from over 20 tests of ability that were administered to a sample of middle school students. The purpose of their study was to establish how scores from different tests were related to each other in order to determine different groupings of abilities that accounted for overall academic performance.

The present regression analysis conducted on the Holzinger and Swineford data was an attempt that was made to determine whether students' scores on their general comprehension test (variable T6) were related to their scores on the general information verbal test (T5), the sentence completion test (T7), the word classification test (T8) and the word meaning test (T9). Hence, the goal of the analysis was to see if the dependent variable (T6) could be accurately predicted from the predictor variables (T5, T7, T8, and T9). The analysis included the scores of 301, students and the null hypothesis was that there would be no statistically significant (p = .05) correlation between the set of predictor variables and the dependent variable (Ho: $R_{T5, T7, T8, T9 * T6} = 0$).

Insert Table 1 here

As shown in Table 1 results indicate that statistical significance was found at the .001 level thereby rejecting the null hypothesis, the implication being that the predictor variables and the dependent variables were related. The extent of this relationship was evident from the large effect size. The calculated R Square value was .612 thereby suggesting a strong correlation with 61% of the dependent variable variance explained.

Having successfully established a strong relationship between the predictor variables and the dependent variable, an analysis of the regression structure coefficients was conducted. Results as outlined in Table 2 indicate that the correlation between the predictor variables and the dependent variable range from a strong positive correlation (.74) to a high positive correlation (.94).

Insert Table 2 here

From these results we can conclude that not only is there a strong correlation between the predictor variables and the dependent variable, but also that all four of the predictor variables are important in predicting the dependent variable. Hence, it has been established that general verbal information (T5), sentence completion (T7), word classification (T8), and word meaning (T9) abilities are strong predictors of student paragraph comprehension (T6). At this point it would be very easy to infer causality by suggesting that the four-predictor variables cause students to better comprehend paragraphs. However we cannot do this. Our interpretation would have to stop at the point of establishing a positive relationship. We cannot say for certain that these predictor variables cause students to better comprehend paragraphs. An additional variable, which is not a part of this study, could possibly be the cause.

Conclusion

If the cycle of misinterpretation of the meaning of correlation is to be broken, then authors need to be the first to make clear the distinction between correlation and causation. If they are unclear on the implications of their research, can we expect the non-technical reader to make appropriate conclusions? Inconsistencies in interpretation and presentation of results must be corrected before researchers present their work on any type of platform. This will enhance the readers' interpretation of one's work and promote the quest for truth.

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Table 1

Sum of Square Breakdown from Regression Analysis

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2238.452	4	559.613	116.611	.000[a]
	Residual	1420.498	296	4.799		
	Total	3658.950	300			

a. Predictors: (Constant), T9, T8, T5, T7

b. Dependent Variable: T6

Table 2

Regression Structure Coefficients

		Unstandardized Predicted Value
Unstandardized Predicted Value	Pearson Correlation	1.000
	Sig. (2-tailed)	.
	N	301
T5	Pearson Correlation	.840**
	Sig. (2-tailed)	.000
	N	301
T7	Pearson Correlation	.937**
	Sig. (2-tailed)	.000
	N	301
T8	Pearson Correlation	.744**
	Sig. (2-tailed)	.000
	N	301
T9	Pearson Correlation	.901**
	Sig. (2-tailed)	.000
	N	301

**. Correlation is significant at the 0.01 level (2-tailed).

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