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CTA *vs. Not* Chi-Square: Fear and Specific Recommendations *Do* Synergistically Affect Behavior

Paul R. Yarnold, Ph.D.
Optimal Data Analysis, LLC

Classic research tested the *a priori* hypothesis that fear and specificity of recommendation synergistically influence a person's decision to have a tetanus inoculation.[1] Data were inappropriate for analysis by one-way χ^2, and results obtained using χ^2 missed the hypothesized interaction: "…specific plans for action influence behavior while level of fear does not" (p. 27). In contrast, for this design CTA identified a relatively strong, statistically reliable, and cross-generalizable two-strata model that supported the hypothesized interaction. The underlying design was then restructured as a 2 (Fear) x 2 (Recommendation) between-subjects factorial. Data for this design were also inappropriate for analysis by χ^2, but CTA found a relatively strong, statistically reliable, reproducible three-strata model that supported the hypothesis.

Table 1 gives the data for the one-way design.[2] Expected values for all top-row cells (took shot) in the omnibus data table (and for at least one top-row cell in all subtables) are less than the minimum expectation of five, rendering χ^2 an invalid test statistic in this application.[3]

Table 1: Data for One-Way Design

Took Shot	Fear = Y Rec = Y	Fear = Y Rec = N	Fear = N Rec = Y	Fear = N Rec = N
Yes	8	1	0	0
No	21	29	30	60

Using CTA to analyze the data in this design, having the tetanus shot (dummy-coded presently as: yes=1; no=0) is used as the class or "dependent" variable, and "group" [dummy-coded here as: (Fear=Y, Rec=Y)=1; (Fear=Y, Rec=N)=2; (Fear=N, Rec=Y)=3; (Fear=N, Rec=N)=4] is treated as a multicategorical attribute ("independent variable"). While groups 1 and 4 clearly are bipolar opposites on the one-way factor, the relative positions of the intermediate groups 2 and 3 are unspecified. In the absence of complete specification of the putative linear structure underlying a multicategorical measure, a non-directional (exploratory) analysis is used treating the attribute as being categorical.[4,5] The following optimal model emerged: if group=1 (Fear=Y, Rec=Y) then predict tetanus shot was taken; otherwise predict shot was not taken. The resulting confusion matrix is given in Table 2.

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Table 2: Confusion Matrix for CTA Model, One-Way Design

		Predicted Behavior: No Shot	Shot	
Actual Behavior	No Shot	119	21	85.0%
	Shot	1	8	88.9%

For CTA a statistically significant (exact $p<0.0001$), cross-generalizable (the training and jackknife results were identical) and relatively strong effect (ESS=73.9) emerged: 88.9% (8 in 9) of the people who took the shot experienced fear *and* received a specific recommendation, as compared to 100-85.0% or 15.0% (1 in 7) of all other participants in the study.

As seen in Table 3 the problem may be re-conceptualized as reflecting a 2 (Fear) x 2 (Recommendation) between-subjects factorial design. In conventional linear statistical analysis of such designs, analysis of variance is usually used if data are assessed on an ordered measurement scale, and the log-linear model is used if data are assessed on a nominal measurement scale (the case presently).[5-7] As occurred for the one-factor design, violations of the minimum expectation assumption invalidate χ^2 as a test statistic in this application.

Table 3: Data for Factorial Design

	Fear		
Recommend	Yes	No	Took Shot
Yes	8	0	Yes
	21	30	No
No	1	0	Yes
	29	60	No

Using CTA in this design, taking the tetanus shot is used as the class variable, and "Fear" and "Recommend" are used as attributes (all variables are dummy-coded: yes=1, no=0).

The first CTA analysis attempted to replicate the original finding[2] that providing a specific recommendation increased shot-taking behavior. The optimal model was: if Specific Recommendation=No, then predict no shot; otherwise predict a tetanus shot was taken. The resulting confusion matrix is given in Table 4.

Table 4: Confusion Matrix for CTA Model, Factorial Design, Recommendation

		Predicted Behavior: No Shot	Shot	
Actual Behavior	No Shot	89	51	63.6%
	Shot	1	8	88.9%

A statistically significant (exact $p<0.0028$), cross-generalizable, relatively strong effect (ESS=52.5) emerged: 5 in 8 of the people who refused the shot had no specific recommendation, as compared to 1 in 8 people who were given a specific recommendation. This result is consistent with the original finding that a specific recommendation affects behavior.

The second CTA analysis assessed the replicability of the original finding that fear was *unrelated* to shot-taking behavior.[2] The optimal model was: if Fear=No, then predict no shot; otherwise predict a tetanus shot was taken. The resulting confusion matrix is given in Table 5.

Table 5: Confusion Matrix for CTA Model, Factorial Design, Fear

		Predicted Behavior: No Shot	Shot	
Actual Behavior	No Shot	90	50	64.3%
	Shot	0	9	100%

A statistically significant (exact $p<0.0004$), cross-generalizable, relatively strong effect (ESS=64.3) emerged: 5 in 8 people who refused the shot did not experience fear, versus 0 in 9 (i.e., $\leq$1 in 10) people who experienced fear. This result *refutes* the original finding that fear does not affect shot-taking behavior.

The final CTA analysis investigated the initial *a priori* hypothesis that fear and specific recommendations synergistically interact to pre-

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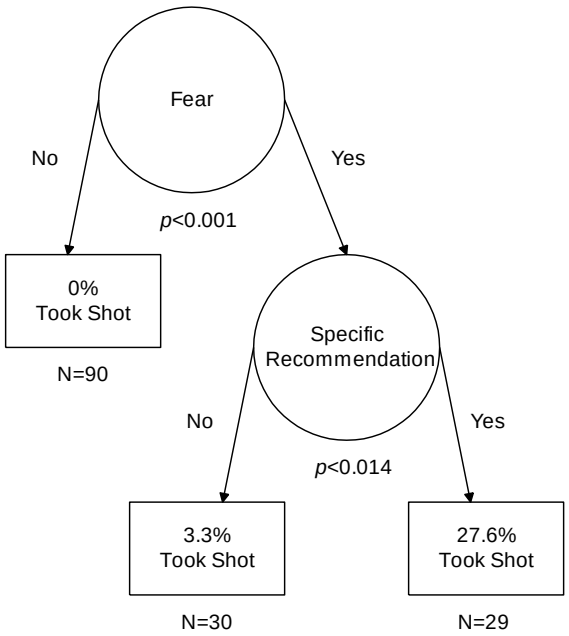
dict shot-taking behavior.[2] Shot taking was thus the class variable, and fear and specific recommendation were attributes. Figure 1 illustrates the three-strata CTA model that emerged.

Figure 1: CTA Model, Factorial Design, Fear and Specific Recommendation



The confusion matrix for this three-strata model is presented in Table 6.

Table 6: Confusion Matrix for CTA Model, Factorial Design, Fear and Specific Recommendation

		Predicted Behavior		
		No Shot	Shot	
Actual	No Shot	119	21	85.0%
Behavior	Shot	1	8	88.9%

A statistically reliable, reproducible, and relatively strong effect (ESS=73.9) emerged: as seen, 7 in 8 of the people who refused the shot were correctly predicted by the model, and 8 in 9 of the people who accepted the shot were correctly predicted by the model (see Table 2).

Consistent with the original hypothesis, fear and specific recommendation interact to affect shot-taking behavior.[1,2] As the root variable, fear plays the dominant role. When there is no fear, 0% of 90 people took the shot. When there is fear, but no specific recommendation is provided, 3.3% of 30 people took the shot. But, when there is both fear and a specific recommendation, 27.6% of 29 people took the shot.

The failure of χ^2 analysis to correctly identify relatively strong, statistically reliable, reproducible support for the *a priori* hypothesis in this seminal study served to direct researchers away from a promising beginning, and scattered theoretical development and empirical research in alternative analytically-misguided directions. How might the field have evolved differently if CTA had been available to support the theory and methods of pioneer researchers in this area, in the beginning? Is this the only example of an important area of research in which flawed, limited, antiquated analytic methods send investigators heading toward darkness?

References

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Author Notes

The study analyzed de-individuated data and was exempt from Institutional Review Board review. No conflict of interest was reported. Happy virtual 89th, Mom!

Mail: Optimal Data Analysis, LLC
6348 N. Milwaukee Ave., #163
Chicago, IL 60646