P. Cheeseman
R. W. Oldford (Eds.)

Selecting Models from Data

Artificial Intelligence and Statistics IV

Springer-Verlag
New York Berlin Heidelberg London Paris
Tokyo Hong Kong Barcelona Budapest

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Attitude Formation Models: Insights from TETRAD

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ABSTRACT The goal of this paper is to examine the use of TETRAD to generate attitude formation models from data. We review the controversy regarding models of attitude formation in the psychology literature, and we re-analyze the data using different subroutines from TETRAD to shed further light on this controversy.

23.1 Introduction

The goal of this paper is to examine the use of TETRAD to generate causal models about attitude formation from existing data. TETRAD is a computer program that discovers directed acyclic graph (DAG) probabilistic models by examining conditional independence relations in data [Glymour *et al.* 1987]. Since the directed edges in a DAG are often interpreted in terms of causality, this program is helpful in searching for "causal" models underlying the available data. As structural equation modelers are aware of, the definition and the imputation of causality are highly controversial. These discussions have been regularly activated in most fields of sciences, liberal arts, and humanities. Thus, when we talk about a "causal" model, our statements and inferences about causality are only as strong as those of other researchers facing this dilemma. This is especially true when the data is collected using non-experimental methods.

There are numerous possible explanations for observed patterns in non-experimental data. It is practically impossible to develop and evaluate possible explanations. Generally, a few explanations are expounded upon and tested for their viability. In this process, one hopes that the explanation that appears most viable is the best and "true" explanation of the data. As researchers have shown by fitting alternative models to the same data, this may not always be the case. For example, the one-factor and the two-factor models of attitude formation have been extensively debated in the psychology literature [Moreland and Zajonc 1979,Zajonc 1980,Zajonc 1981,Birnbaum and Mellers 1979,Birnbaum 1981,Mellers 1981,Wilson 1979]. There are other examples of such controversies in the social sciences. If one could do a *systematic* search for alternative causal models using available data in the field, then our faith in the conclusions would be greater. TETRAD offers one such option.

We review the controversy regarding models of attitude formation in the psychology literature and re-analyze the data using TETRAD. We find some support for the two-factor theory that states that people do not always have to cognitively process a stimulus before developing a liking

[0]This work is based upon work supported in part by the National Science Foundation under Grant No. SES-9213558, and in part by the General Research Fund of the University of Kansas under Grant Nos. 3605-XX-0038 and 3077-XX-0038. We are grateful to Peter Spirtes and Richard Scheines for providing the latest version of TETRAD II and for their comments and discussions.

[1]*Selecting Models from Data: AI and Statistics IV.* Edited by P. Cheeseman and R.W. Oldford. ©1994 Springer-Verlag.

for it. However, TETRAD suggests models that are different from either the one-factor or the two-factor model proposed in the psychology literature.

23.2 TETRAD

The TETRAD program is a semi-automated method for finding a DAG model for continuous variables [Glymour *et al.* 1987,Spirtes *et al.* 1992]. TETRAD assumes a normal linear model holds for the data set. The linearity assumption enables the program to check for conditional independencies using partial correlations. This is also referred to as the search for vanishing partial correlations or tetrads. TETRAD has been evaluated and compared to statistical techniques such as LISREL and EQS [Spirtes, Scheines, and Glymour 1990]. Both LISREL and EQS have modification indices or a similar number to aid in model development. However, the method of using modification indices is computationally less efficient and has been found to be less reliable than the method used by TETRAD. In structural equation models, the problem of improper solutions can be particularly severe for complex models with small sample sizes [Boomsma 1985]. A likely cause of improper solutions is a misspecified model. Using the TETRAD approach, improper specification of the model is less likely to occur. Thus, one can infer that the misfits are be due to sampling variation only. In case of improper solutions, researchers have been also investigating other approaches [Bagozzi and Yi 1991].

The TETRAD program uses artificial intelligence techniques—graph algorithms and heuristics—to suggest alternative models in a systematic manner and test for these models. The goal of TETRAD is to discover models that are consistent with the correlational data. Other common techniques like factor analysis and regression analysis are also driven by similar goals, such as factor rotations in factor analysis, and stepwise regression procedures in regression analysis. The question however remains: On what basis should we decide which is the best model? Theoretical justifications and the argument for parsimony have been used for resolving this issue. As suggested earlier, the strength of TETRAD lies in its use of artificial intelligence techniques to systematically explore for the possible configurations that could be a representation of the observed data. The "best" elaborations of the initial models are defined as those that imply patterns or constraints that are judged to hold in the population, that do not imply patterns judged not to hold in the population, and that are as "simple as possible."

To suggest possible modifications of the input model, TETRAD uses the following principles [Glymour *et al.* 1987, pp. 93–95]: (1) *Spearman's principle:* Other things being equal, prefer those models that for values of their free parameters, entails the constraints judged to hold in the population. (2) *Thurstone's principle:* Other things being equal, a model should not imply constraints that are not supported by the sample data. (3) *The Simplicity principle:* Simpler models are those that have less causal connections. Other things being equal, select models that suggest the least number of causal connections.

It is not always that these principles lead to identical suggestions. For example, Spearman's principle is more likely to hold for simple models. Simple models imply most constraints, but seldom are constraints supported by data—Thurstone's principle. Thus, the fewer the model constraints implied, the better Thurstone's principle holds. As we incorporate more and more parameters into a model, the principle of simplicity is less likely to be satisfied. In spite of the apparent conflict between the principles, TETRAD has performed admirably in generating models, identifying "correct" models, and suggesting modifications to existing models [Glymour *et al.* 1987].

Past research with TETRAD. Spirtes *et al.* compare the reliability of the computer aided model specifications using TETRAD [Spirtes, Scheines, and Glymour 1990], and the other commonly available software such as EQS [Bentler and Chou 1990] and LISREL [Joreskog and Sorbom 1990]. On the basis of simulation studies, the authors conclude that the TETRAD software is better than the others in model specification and search. The main difference is that EQS and LISREL suggest a single model, whereas TETRAD suggests a small list of such "models." Whether the models suggested in the small list are interpretable is not considered in TETRAD. Others [Bentler and Chou 1990,Joreskog and Sorbom 1990] raise interesting questions about the brute force search method and the computer aided model search philosophy underlying TETRAD.

Scheines has extended the use of TETRAD in modeling the measurement of latent variables [Scheines 1993]. The emphasis is more on developing the "best" measurement model rather than the structure of latent variables. The MIMBUILD subroutine, in TETRAD, is used to develop a "pure" measurement model—a model where each observed variable is an indicator of a single latent variable.

Notwithstanding the objections of the classical theorists, we think that research in the use of TETRAD for inducing models from data has been inadequate. This is highlighted considering the fact that TETRAD gives us a systematic approach to evaluating a host of alternative representations of the correlational (or covariance) data. Applications of TETRAD in theory development in the applied as well as the basic sciences should be welcomed.

23.3 Models of attitude formation

The purpose of the current study is to demonstrate the use of TETRAD in theory development and conflict resolution in a research area. We will focus on the models of attitude formation in psychology for this demonstration. Do preferences need inferences? Is cognition a necessary precondition for liking to develop?

Two different models of attitude formation have been suggested in the literature [Birnbaum and Mellers 1979,Moreland and Zajonc 1977,Moreland and Zajonc 1979]. The two models are shown in Figures 1 and 2. In these figures, latent variables are shown as elliptic nodes, and observed variables are shown as rectangular nodes. Also, latent variables are given upper-case labels, and observed variables are given lower-case labels. The model in Figure 1 is called the *one-factor* model, and the model in Figure 2 is called the *two-factor* model. The one-factor model supports the traditional view that to prefer or like something, one has to first recognize it (Figure 1). The two-factor model supports Zajonc's claim that recognition of a stimulus does not have to precede liking it (Figure 2).

Cognition and affect controversy. Till the late sixties and the early seventies, practically all research in stimulus processing assumed cognition to be an intervening stage for liking, i.e., subjects responded to a stimulus only after a cognitive processing cycle [Zajonc 1980, p. 153]. It was only later that this paradigm was challenged by Zajonc and his associates [Zajonc 1980,Zajonc and Markus 1982,Moreland and Zajonc 1979]. This resulted in a controversy among cognitive psychologists. This is evidenced by the extensive rebuttals, and re-analysis of these studies [Birnbaum and Mellers 1979,Lazarus 1982,Lazarus 1984]. Experimental evidence suggests that subjects do not appear to recognize certain stimuli but still have positive feelings

Figure 1. Birnbaum and Mellers' one-factor model of attitude formation.

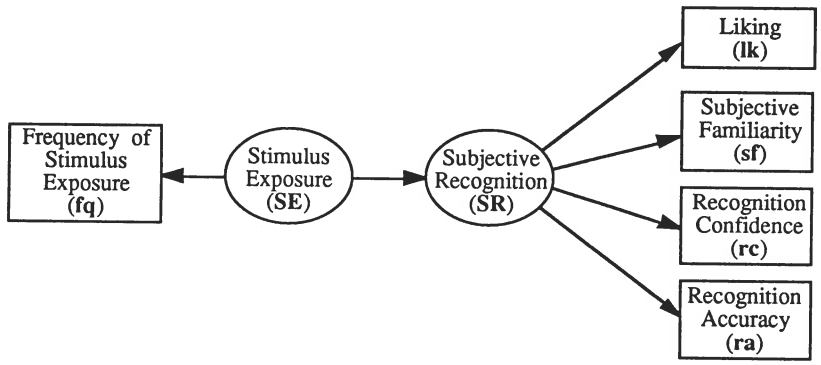


Figure 2. Moreland and Zajonc's two-factor model of attitude formation.

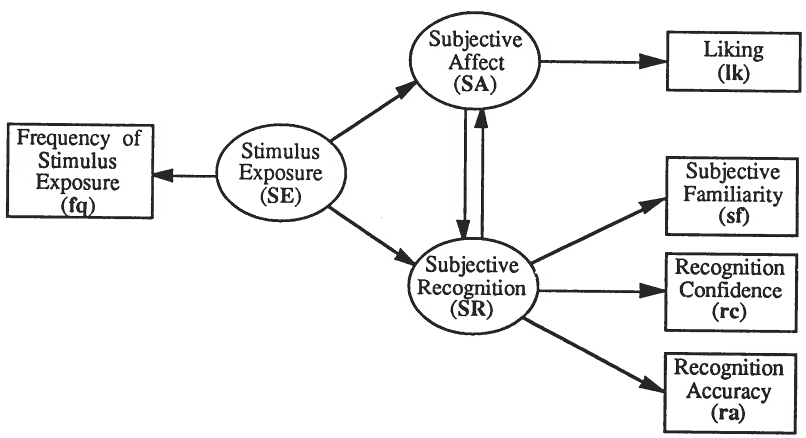


Table 1. The correlation matrix.

	fq	lk	sf	rc	ra
fq	1.000				
lk	0.663	1.000			
sf	0.579	0.533	1.000		
rc	0.340	0.252	0.291	1.000	
ra	0.413	0.302	0.555	0.417	1.000

about them if they have been exposed to them. This led Zajonc to model "feeling without thinking" or "preferences without inferences." The affectists argue that affective reactions to stimuli are often the first reactions and can occur without extensive perceptual and cognitive encoding. These reactions are made with more confidence than cognitive judgments and can be made sooner. This is also referred to as the two-factor theory (Figure 2). The cognitivists believe that "thought is a necessary condition of emotion" and are proponents of the one-factor theory (Figure 1).

Moreland and Zajonc conducted two experiments to investigate the recognition and affect theory [Moreland and Zajonc 1977]. They conclude that subjective recognition is not a necessary condition for the occurrence of the observed exposure effects. This is in contrast to the one-factor theory that considers affect to be post-cognitive. However, a re-analysis of the same data (Table 1) led others to conclude that the data could have been generated from a one-factor model by incorporating correlated errors for the recognition measures [Birnbaum and Mellers 1979].

23.4 Further insights into the controversy

The debate over the data and the re-evaluation of the conclusions of the Moreland and Zajonc study make this an appropriate test of TETRAD's capacity to induce models from data. There are numerous ways in which we can use TETRAD. Most of the differences are determined by how much of the hypothesized model one accepts. As stated earlier, TETRAD has an inherent bias for simpler models hence an edge specified in the model is less likely to be eliminated. The program suggests *elaborations* to a hypothesized model. The deletion of edges can be based on results from EQS.

Assuming properly specified measurement model. We shall first consider the results from TETRAD, assuming that the measurement model as developed by Moreland and Zajonc [Moreland and Zajonc 1977] is appropriate, i.e. stimulus exposure is measured by frequency, subjective affect is measured by liking, and subjective recognition is measured by subjective familiarity, recognition accuracy, and recognition confidence.

The SEARCH subroutine is used to suggest enhancements to the model. The input includes the correlation matrix, a hypothesized graph, significance levels for the tests. (See [Mishra and Shenoy 1993] for details of the various models run and subroutines used.) Extra knowledge about the phenomenon under study is incorporated in the "/Knowledge" section. Since exposure of the individual to the stimulus must occur before any affect or recognition of the stimulus, we set temporal precedence of **fq** over the other variables. We also prevented any observed variables from affecting the latent variables or other observed variables. However, latent variables could cause observed variables and other latent variables. TETRAD suggested three edges be added: **SA→sf, SE→ra**, and **SA→ra**. The tetrad score of 100 implies that every constraint passes the program's statistical tests and none fail. The model, denoted by M1, is presented in Figure 3. The dashed arrows represent hypothesized relations and the solid arrows represent elaborations suggested by TETRAD. We conclude from M1 that stimulus exposure affects recognition accuracy. Also, subjective affect affects recognition accuracy and subjective familiarity. However, M1 says nothing about the relationships between the latent variables.

Figure 4 shows the model suggested by TETRAD, denoted by M2, when only edges between latent variables are permitted. The tetrad score for the added edges is 92.50. The difference from the earlier model, M1, is that relationships between the latent variables and measured variables not included in the graph statement are forbidden. We conclude from M2 that **SE** causes **SR**, and **SR** causes **SA**. M2 is unlike the two-factor model shown in Figure 2 because there is no direct path from **SE** to **SA**. This means that **SE** does not directly influence **SA**. M2 appears to support the one-factor theory. However, M2 is not the one-factor model because **SR** does not directly influence the liking variable even when this is permitted.

Figure 3. Model M1 suggested by the SEARCH subroutine in TETRAD with elaborations from latent variables to observed variables permitted. Dashed arrows were assumed, and solid arrows were suggested by TETRAD.

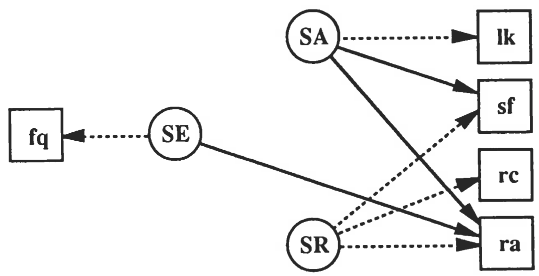
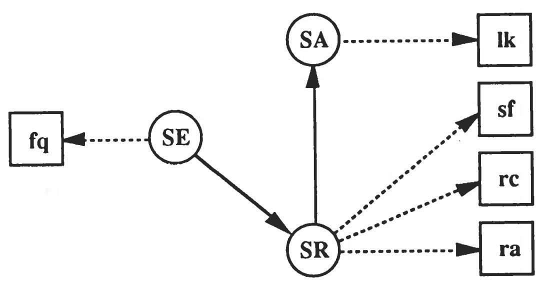


Figure 4. Model M2 suggested by the SEARCH subroutine in TETRAD with elaborations permitted among latent variables only. Dashed arrows were assumed, and solid arrows were suggested by TETRAD.



We conclude that the models suggested by TETRAD are neither the one- nor the two- factor models suggested by past researchers. A major assumption for these sets of models is that the measurement model is appropriate. A closer look at the past results [Birnbaum and Mellers 1979,Moreland and Zajonc 1979] shows that the factor loadings for the recognition accuracy and confidence measures may not be adequate. Normally, loadings should be greater than 0.707 (which means that at least 50% of the variance in measured variables is attributable to the latent variables). The loadings for the recognition accuracy and confidence variables are below this accepted norm. Therefore, we used the MIMBUILD subroutine to check the purity of the measures.

Purity of the measurement model. A measurement model is pure if each indicator variable is directly caused by only one latent variable, and the error terms are uncorrelated [Spirtes *et al.* 1992]. The MIMBUILD routine stopped when there were only two indicators of both **SA** and **SR**. This is likely to happen when a pure model is absent because no further purification of the model is possible. Based on the EQS results and our understanding of the data, we believe that the specified measurement model is not a pure one. In fact, model M1 suggests **SA** as a direct cause of **ra** and **sf** even when these were already being caused by **SR**.

Using the BUILD subroutine. If we are not sure about the validity of the measurement model proposed by the earlier researchers (and there are some reasons to doubt the validity), TETRAD has a subroutine, BUILD, which suggests possible relations among the observed variables. The two major classes are: (1) Models that assume causal sufficiency, i.e. the measured variables do not have any latent causes, and (2) Models that do not make this assumption, i.e. the measurement aspect of the model is also considered.

In the input to BUILD, we fixed exposure to the stimulus to precede everything else. Also, because the debate involves whether liking for a stimulus is always preceded by cognitive action, we made no designation for the temporal order for liking with respect to the other variables.

When causal sufficiency is assumed, the suggested model, M3, includes the following directed edges: **fq→sf**, **fq→rc**, **lk→sf**, **ra→sf**, and **rc→ra** (as shown in Figure 5). The edge **fq—lk** is undirected, but based on the temporal precedence of **fq** over **lk**, we could direct the edge from **fq** to **lk**. This supports the two–factor theory that exposure frequency directly impacts liking. Contrary to the one–factor theory that liking is post-cognitive, we do not have a directed edge from any of the cognitive measures to **lk**. In fact, the only suggested path between the two sets is *from* **lk** *to* **sf**. Liking appears to be causing subjective familiarity.

Critics may argue that we did not consider any latent causes for the measured variables in this model, hence it is a misspecified model. Therefore, we also used the BUILD routine without assuming causal sufficiency. The resultant model, M4, is shown in Figure 6.

The routine directs the edges **fq→sf**, **fq→rc**, **ra→sf**, and **rc→ra**. The routine suggests that there could be a common cause for **fq** and **lk**, or the order of causality is undetermined. The edge o—o indicates that **fq** and **lk** are statistically dependent conditional of every set of measured variables. However, based on temporal precedence we can direct the edge from **fq→lk**. What is more interesting is that the routine does not suggest a common cause for the cognitive measures: **sf**, **rc**, and **ra**. This questions the validity of the measurement model suggested in one–factor and two–factor theory, i.e., **SR→sf**, **SR→rc**, and **SR→ra**. The edge **lko→sf** indicates that **lk** is either a cause of **sf** or there is a common unmeasured (or latent) cause of **lk** and **sf** or both. This means that the only *suggested* common cause is between **sf** and **lk**.

Based on the models suggested by the BUILD subroutine, we conclude that the measurement model for the subjective recognition variable suggested by the one–factor and two–factor models is not valid. Also, we find no evidence for liking being post-cognitive.

23.5 Conclusions

We used TETRAD to shed further light on the controversy between the one-factor and the two-factor models of attitude formation. Based on the BUILD results, we conclude that recognition accuracy, recognition confidence, and subjective familiarity do not appear to be measurements of a common cause, subjective recognition. Models M1 and M2 suggested by TETRAD confirm this conclusion. Also, the only directed edge is not from one of these measures to **lk**, but the other way around (liking to subjective familiarity). This suggests that liking is not post cognitive.

Figure 5. Model M3 suggested by the BUILD subroutine of TETRAD assuming causal sufficiency.

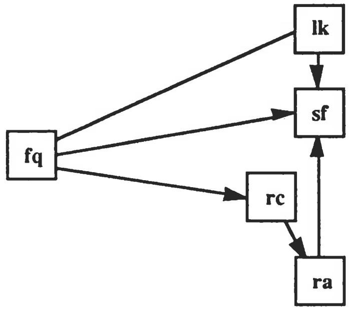
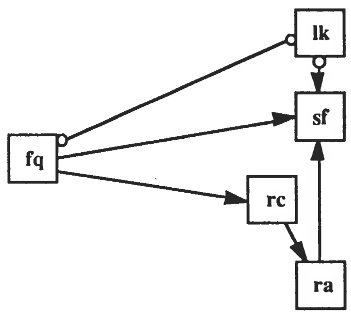


Figure 6. Model M4 suggested by the BUILD subroutine of TETRAD not assuming causal sufficiency.



This supports the two-factor theory that people do not always have to cognitively process the stimulus before developing a liking for it: mere exposure is enough. Thus, although we find some support for the two-factor theory, neither the one-factor nor the two-factor model is supported by TETRAD. Instead, TETRAD suggests several different models. It would be interesting to estimate the fit of these models using LISREL or EQS.

The one-factor and two-factor models are relatively simple models with only five observed variables. Ideally, we would have liked to have multiple measures for the stimulus exposure and subjective affect variables. This would have helped purify the model better. The small sample size (n = 400) could be a problem as well. We did not vary the numerous control parameters of the TETRAD subroutines and for the most part worked with the defaults. Also, the results from EQS suggest very good fits for the models suggested in past research. This reduces the scope for improvement. Coupled with the fact that the data set has very few observed variables, the power of the TETRAD is not fully utilized. Future applications of TETRAD should consider these issues.

23.6 References

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