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Editorial

Special issue on state-trace analysis

The term, *state-trace analysis* (STA), was coined by Donald Bamber in a paper published in 1979 in which he introduced a new method for testing simple theories of causation. By this he meant that STA could be used to determine if observed changes in two (or more) dependent variables are consistent with the simple causal theory that they each depend on changes in a common latent variable. The inference is also beguilingly simple. First, plot the values of one dependent variable against those of the other across the same set of conditions, forming the observed *state-trace*. Second, determine if this state-trace is consistent with a single monotonically increasing function. If so, conclude that it is consistent with the effects of a single latent variable.

The inferential logic of STA addresses a fundamental question in psychology — whether and under what circumstances is it possible to assert that mental processing can be fractionated into multiple components. As noted by many of the authors in this issue, this question frequently arises in psychology and leads to much debate. That this debate is rarely resolved can be attributed to the lack of well-specified criteria for deciding the issue. Because of its rigorous logic based on a set of explicit assumptions, STA offers just such criteria.

Despite its obvious advantages and its successful application in several different domains, to date *STA* has had only a limited impact on psychological research practice. One of the main reasons for this is that, until recently, there had been no obvious way of testing for the monotonicity of the state-trace in the presence of measurement error. This, it turned out, is a non-trivial problem to which familiar statistical armamenta, such as those involving simple effects or additive models, cannot be directly applied. However, recent developments have successfully addressed this problem and it is now possible to apply at least two different statistical approaches to test for the monotonicity of the state-trace. We do not envisage that these will be the last word in this matter and look forward to further methodological and statistical advances. Indeed, several of the articles in the present issue do just that.

The development of a statistical machinery suited to STA has coincided with an increased interest in how it can be used to address a variety of theoretical questions. Accordingly, we feel it is timely to present a selection of new work based on STA that further develops its underlying logic and range of application. This is the aim of the current special issue of the Journal of Mathematical Psychology. There are nine papers, the first five of which are primarily concerned with the application of STA and illustrate both cases that provide support for one component as well as those that provide support for more than one component.

The first paper by Rachel Stephens, Dora Matzke and Brett Hayes sets the scene for the scope of application of STA. They review evidence from two domains – reasoning and category learning – to highlight the limitations of traditional approaches to inferring the existence of multiple latent variables and demonstrate the application of STA and finding that much of the data support the sufficiency of a single latent variable.

In the second paper by Maria Robinson and David Irwin, the authors apply STA to test the recent proposal that there are two distinct visual short-term memory stores. Again, they demonstrate that this is the inferential method of choice and find data consistent with the simpler model of a single store.

The third paper by Andrew Heathcote, Eleanor Holloway and James Sauer applies STA to determine if two logically distinct forms of bias in decision making can be separated behaviorally. They use STA to provide evidence to support this dichotomy, but also highlight some of the novel statistical issues associated with STA — because it is concerned with *patterns* rather than simple magnitudes of data, caution is required when aggregating over individuals.

In the fourth paper by Yoonhee Jang, Heungchul Lee and David Huber, the authors use STA to analyze the dimensionality of judgments of learning and judgments of recall. They show that conclusions may depend on the nature of the dependent variable — while accuracy of judgments is consistent with a single latent variable, consideration of latency reveals a more complex structure.

The fifth paper by John Dunn and Li-Lin Rao applies STA to test and reject a class of simple models of risky choice. They then extend this analysis by applying *signed difference analysis* – a multivariate generalization of STA – to test more complex models of the data.

The last four papers in the special issue are primarily concerned with methodological and statistical issues in the application of STA.

The sixth paper by Donald Bamber addresses the problem of designing experiments to maximize the possibility of observing a non-monotonic state-trace given the involvement of more than one latent variable. In this case, injudicious selection of conditions may lead to a trivially monotonic state-trace. The paper presents a method to avoid this problem.

The seventh paper by Aaron Benjamin, Michael Griffin, and Jeffrey Douglas introduces a new statistical approach to test the hypothesis of a monotonic state-trace. Because this approach is based on a permutation test, it has the advantage of being fully non-parametric.

The eighth paper by Gregory Cox and Michael Kalish presents an alternative Bayesian method to test for monotonicity given

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minimal assumptions of smoothness in the data generating process. They develop a statistic, $\hat{M}$, that distils the total evidence for and against monotonicity.

The final paper is by Patrick *Sadil*, Rosemary Cowell, and David Huber. It addresses the problem of artificially reduced measurement error caused by aggregation over items, trials, and participants. They propose a hierarchical Bayesian approach that tests for the presence of a monotonic state-trace taking into account these sources of variation.

We would like to thank the past Editor, Phil Smith, for offering space in the Journal for a special issue on STA and for his continuing support for work on this topic. We would also like to thank the contributors who have risen to the challenge to present innovative and original research.

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