From: Tony Cox
To: CASAC and Dr. Chris Frey
Re: Selection of Literature on Validation of Modern Causal Analysis and Inference Methods
Date: 10-22-2019

On our call today, Dr. Chris Frey asked for references on empirical validation of methods of modern causal analysis (referred to several times on our call as "emerging" methods). A full review would be time-consuming, as these methods have been extensively developed, applied, and validated in a wide variety of scientific applications over the past century (e.g., Wright, S. (1921). "Correlation and causation," J. Agricultural Research. 20: 557-585; Neyman J (1923), ''Statistical Problems in Agricultural Experiments,'' Journal of the Royal Statistical Society Series B (suppl.) (2):107–80; Yule GU. 1926. "Why do we sometimes get nonsense-correlations between time-series? – A study in sampling and the nature of time series." J R Stat Soc. 89:1–63.Simon HA (1952) "On the definition of the causal relation," Journal of Philosophy 49 (16):517-528; Wiener N. (1956) "The theory of prediction," In E. F. Beckmann, editor, In Modern Mathematics for the Engineer. McGraw-Hill, New York; Blalock HM (1961) "Correlation and causality: The multivariate case." Social Forces, 39(3)March: 246-251; Campbell DT and Stanley JC (1963), *Experimental and Quasi-Experimental Designs for Research*; Granger, CWJ (1969). "Investigating causal relations by econometric models and cross-spectral methods". Econometrica. 37 (3): 424–438; Heckman JJ (2005) "The scientific model of causality," Sociological Methodology, 35(1), 1–97; Pearl J (2009) "Causal inference in statistics: An overview" Statist. Surv. Volume 3 (2009), 96-146.) Since about 2000, these methods have been synthesized and integrated into a largely unified framework (see comments of Drs. Aliferis and North), based largely on the ideas of nonparametric structural equations, directed graph models, conditional independence tests, and invariance of causal relationships, developed since about 1918. Advances and applications in epidemiology and many other scientific fields continue in journals such as the *Journal of Causal Inference* (www.degruyter.com/view/j/jci).

Although a comprehensive review of validation techniques and results for these methods would be lengthy, the following references provide a sample of relevant work, heavily biased toward recent literature. If needed, I will be pleased to provide additional references and/or a more comprehensive discussion. Briefly, validation techniques now in widespread use in a variety of scientific fields that use modern causal inference include

- K-fold cross-validation (i.e., using multiple disjoint training and test sets)
- Competitions (e.g., Kaggle competitions) in which different algorithms seek to infer causal relationships from observational data,
- Empirical tests in which already known causal relationships (e.g., connectivity patterns in neuroscience) are used to assess the validity of the causal relationships inferred from observations.

Selected References

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https://afni.nimh.nih.gov/pathana (See model validation in Section 6)

Bielczyk NZ, Uithol S, van Mourik T, Anderson P, Glennon JC, Buitelaar JK. Disentangling causal webs in the brain using functional magnetic resonance imaging: A review of current approaches. Netw Neurosci. 2019 Feb 1;3(2):237-273. doi: 10.1162/netn_a_00062.

Ellis B, Wong WH. Learning Causal Bayesian Network Structures from Experimental Data. https://web.stanford.edu/group/wonglab/doc/EllisWong-061025.pdf (See especially Section 5.)

Meinshausen N, Hauser A, Mooij JM, Peters J, Versteeg P, Bühlmann P. Methods for causal inference from gene perturbation experiments and validation. Proc Natl Acad Sci U S A. 2016 Jul 5;113(27):7361-8. doi: 10.1073/pnas.1510493113.

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NIPS 2013 Workshop on Causality Large-scale Experiment Design and Inference of Causal Mechanisms Monday December 9, 2013 http://clopinet.com/isabelle/Projects/NIPS2013/ (Multiple papers, including results from Kaggle competition.)

Saito Y, Shota Y. Counterfactual Cross-Validation: Effective Causal Model Selection from Observational Data. https://arxiv.org/abs/1909.05299

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Yehezkel R, Lerner B. Bayesian Network Structure Learning by Recursive Autonomy Identification. JMLR: Workshop and Conference Proceedings 10:1527–1570, 2009 http://www.causality.inf.ethz.ch/ciml/CiML-v8-book.pdf (See discussion of cross-validation.)

Zur, RM et al. A Validation of Piecewise Structural Equation Modelling (SEM) Compared to Traditional Structural Equation Modelling: A Simulation Study et al. Value in Health, Volume 21, S223 - S224. https://www.valueinhealthjournal.com/article/S1098-3015(18)31818-7/fulltext