Description of the Potential Outcomes Model

From: Grace, J.B. Call for a paradigm shift from statistical causal inference to multi-evidence causal investigation. (in review)

Rubin (2005) describes his model with the help of a table (Fig. 6.1). He begins by defining causal effects as, "Comparisons of potential outcomes under different treatments on a common set of units." His table presents rows of information for *N* study units involved in a randomized experiment where some property of those units *Y* is determined at a particular point in time. In an agricultural experiment, for example, each unit/plot can potentially be either exposed or not exposed to some treatment application, which Rubin calls the "active treatment" if exposed and "control treatment" if not exposed. For each unit, there is a pair of "Potential outcomes" that represent the expected values for outcome variable *Y* at some later time if it turns out to be exposed or not exposed (in the control) to the active treatment. The notation used to express these potential outcome values are $Y(1)$ if a unit is exposed to the active treatment, and $Y(0)$ if that unit is not exposed to the active treatment. The column "Unit-Level Causal Effects" describes how the individual-level causal effects would be estimated if it were possible to observe both outcomes. The estimand for an *individual causal effect* would be $Yi(1) - Yi(0)$, which is the difference between potential outcomes and the answer to the question, "What would be the future state of an individual if they had received the alternative treatment?" An important implication of the PO conceptualization is the fact that the individual causal effect cannot be estimated because it is not possible to observe both outcomes simultaneously. By shifting focus to computing the *average causal effect* for the set of study units, presented in Fig. 2A as the "Summary Causal effects", this problem can potentially be circumvented. Ultimately, the goal established by the PO conceptualization and now a foundational precept of the SCIP is to approximate *cf* causal effects.

An important but neglected point is that Rubin and Holland (refs) justified an exclusive focus on *cf* causal effects based on the limits of what can be done using statistical data analysis rather than principles of science. Holland and Rubin (1987) acknowledged this by saying, "Scientists are usually concerned with understanding causal mechanisms. Purely statistical discussions of causality are substantially more limited in scope, because the unique contribution of statistics is to measuring causal effects and not to the understanding of causal mechanisms." This limited perspective permeates throughout the persistent criticisms of the SCIP.

It should be noted this is an theoretical statistical model. There is no provision for mechanistic knowledge to be considered in this model – i.e., it is purely statistical (their terminology).

Rubin, D. B. Causal inference using potential outcomes: design, modeling, decisions. *Journal of the American Statistical Association* **100**, 322–331, (2005).