Causal diagrams and matched designs

My first encounter with causal diagrams dates back to the 1990s. It was a long article that seemed to deliver a new and interesting message but was not reader-friendly at all.[1] Subsequent writing hasn't been much better, neither in articles nor in books. When I finally mastered the topic, more or less, I realized that the rules and logic of causal diagrams could be presented concisely and clearly without bombarding the reader with too many terms ("parent", "child", "ancestor", "descendent", "d-separated", "faithful to a DAG", "biasing path", and more.) Sadly, many writers do not follow an old saying, attributed to Einstein: "Everything should be made as simple as possible..."

Although their building blocks are simple—variables, arrows, dashed lines, boxes—causal diagrams are a powerful methodological tool. They cleared up the fog around confounding bias; helped us to replace the misnomer "selection bias"[2] with "colliding bias"; and revealed the antithetical properties of the two. The extension to information bias followed several years later[3,4] and led to the discovery of thought bias[5]—the counterpart of information bias. A third pair of antithetical biases—effect modification bias and causal pathway bias—seems to have completed the story.[6] I dare to claim that every type of bias belongs to one of these six categories. In the department of bias, nothing new is waiting around the corner.

Next in line was the application to study designs, and especially clarifying the widely misunderstood purpose of matching. Sporadic remarks on matching and causal diagrams could be found before 2010, but a methodical analysis was yet to be offered. We examined the topic in a book chapter (published in March 2012),[6] and shortly thereafter (May 2012) offered an elaborated account of matched case-control studies from the perspective of causal diagrams (and variance).[7] You can find the article on PubMed (open access journal).

A year or so later (June 2013)—unaware of our article—Mansournia et al. replicated some of our analysis of matched case-control studies and extended the discussion to a matched cohort,[8] a fairly rare design. Words of praise were probably offered by appointed reviewers (another commentary here), so I will point out only weaknesses.

The writing style of Mansournia reminded me the writing of an affidavit—dense and defensive. The writer seems overly worried to not be caught with a false claim, and the defense mechanism is well known: Inject "generally", "usually", "may be", and the like, so no one can pull out a counter-example to prove you wrong (I wrote "generally"; didn't I?). Here are three examples from the first page (abstract and introduction):

"The matching process *generally* forces certain variables to be independent…" [italics added]

"Matching on variables that are affected…will *ordinarily* produce irremediable bias." [italics added]

"…adjustment for these factors *may be* unnecessary to remove bias." [italics added]

Well, I hate this writing style, because the statements do not claim much. The last quote, for instance, implies that adjustment for these factors (what's wrong with the word "variables"?) *may be necessary* to remove bias. If so, the authors say that it may, or may not, be necessary to adjust for these variables—a powerful lesson indeed. What is the solution? State the conditions under which the claim holds, or make unqualified claims, knowing that exceptions can be found here and there. Trust your readers: they know that not every sentence is a formal theorem.

On a more substantive note, the first page ends with the following:

"For simplicity, we assume throughout that there is no measurement error, and we deal only with expected values, ignoring random error."

That safeguard statement was not needed at all, even under the naïve desire to be perfectly accurate. First, causal diagrams distinguish between notation for original variables of interest (say, *E, D*) and their measured version (E^*, D^*) or imputed version (E_I, D_I).[3-6] No measured variable is shown, so the diagrams depict theories about causal reality, regardless of whether any researcher has ever conducted a matched study, or has measured any confounder. Second, the article deals with unbiased estimation of effects, and bias is defined on expected values. So the comment on expected values is redundant. By the way, where do random errors come from? Are the authors assuming indeterministic causation, or perhaps they still cling to deterministic diagrams, which cannot survive without some dose of "randomness" (i.e., indeterminism)?

I don't know why so many authors draw unappealing causal diagrams, with thin arrows and barely visible arrowheads. And why did the authors impose the horizontal line-up of *L* with *E* and *D*, which forced the drawing of curved arrows? What purpose does it serve? For some reason many authors don't seem to put enough thinking into the drawing.

Despite the focus on causation, both section headings and figures contain sloppy language about association. Numerous figures refer to a variable (*L*) that is associated with some other variable(s), but the diagrams show that *L* is actually a cause of these variables, which is a far more specific condition—as the author surely knows.

A variable in a box denotes conditioning on that variable, a central idea that deserves a separate discussion. Speaking of imprecision, however, throughout the article the authors replaced the variable in the box with a *value* of that variable (*S*=1), redefining the meaning of a box as follows: "The square around S=1 indicates that the analysis is conditional on having been selected…". I am not in favor of this notation. You may present a variable in a box to denote conditioning, or you may present a value of a variable with no box—if you care about effects on that value alone (effects may differ for different values of the outcome variable). But to present both doesn't make sense to me, because a box denotes an altered distribution of its content (that's what conditioning means!). A better notation might be to write "=1" outside the box. Regardless, it was redundant to indicate S=1, because the arguments about colliding bias hold for S=0 as well.

Mansournia et al. ignore the pedagogical and methodological benefit of drawing dashed lines in a causal diagram. We and others draw a dashed line between two variables to denote a new contribution to their association after conditioning on their common effect. Moreover, we distinguish between natural paths (composed of arrows alone) and induced paths (composed of arrows and dashed lines, or of dashed lines alone).[7] After drawing dashed lines, you can easily trace all the paths between any two variables and sort between paths as you wish: natural vs. induced; open vs. blocked; causal vs. non-causal; null summation vs. non-null summation.

The story of causal diagrams starts with the following paragraph:

"The theory of causal directed acyclic graphs (DAGs) can now be found in many reviews and books.[2–5] Briefly, a DAG includes nodes (measured and unmeasured variables) linked by directed edges (arrows). A causal DAG is one in which the absence of an arrow between two variables implies the absence of a direct causal effect, and in which it assumed that all shared causes of any pair of variables are included in the graph."

This paragraph, unfortunately, is far from accurate. First, directed acyclic graphs are indeed a "theory" in the mathematical sense of the word (like "measure theory"). But causal directed acyclic graphs are part of the scientific method. Second, the nodes are variables that are assumed to exist; there is no need to qualify them as "measured and unmeasured" (and there is no third category, anyway.) Third, an arrow ("directed edge") between two variables denotes all causal paths ("directed paths") between them, other than those that are shown. It need not denote "a direct causal effect"—if such an idea even exists.[9] Fourth, the authors are welcome to draw only diagrams in which they assume that "all shared causes of any pair of variables are included in the graph". I never make such a sweeping (and naïve) assumption. But if the authors, or someone else, think that a relevant variable is missing from anyone's diagram, they are welcome to name it. And if they can't name it, they are politely requested to remain silent.[10] Many scientists don't find anything useful in platitudes, such as "there may be another shared cause". We all know that causal inference is conjectural. Let's move on.

I am not sure why the authors decided to incorporate censoring into their article on matched designs, and not some other topic (say, information bias or effect modification bias). Perhaps they saw resemblance to matching because both matching and censoring open the door to colliding bias. But if that was on their mind, they forgot to include analytical colliding bias.[6]

The text on Figure 4 contains a small mistake: "In this setting, although there is no biasing path at the start of the follow-up, a biasing path E-C-L-D is opened due to censoring during the follow-up, necessitating adjustment for L."

Actually, "there is no biasing path at the start of the follow-up"—only if balanced matching was done. Otherwise, inevitable conditioning on S creates an association between L and E, thereby inducing the path E--L→D (E-S-L-D in Mansournia's notation). By the way, all associations post selection (i.e., conditioning on S) are conditional associations, by definition. They are not "unconditional" anymore.

Last but not least, I don't like manuscripts with appendices that are indistinguishable from the main article (here, there are four!). If the content of the appendices is important, put them in the article, or write another article. Lengthy appendices give me the feeling of a breathless author who tried to squeeze in as much as she could. Relax. No article is the last word on anything, so you can leave something to later writing or to another apprentice.

As far as I can tell, this is Mansournia's first publication on the methodology of causal diagrams. Despite the weaknesses and the writing style, I was impressed by the novelty of his thinking and his command of the literature (going back as far as 1959). No wonder I am looking forward to reading more of his original contributions to methodology. Perhaps I may even propose two future topics:
1) Causal diagrams and marginal structural models
2) Causal diagrams and change variables. (Or should it be "change variables and causal diagrams"?)

References

1. Pearl J. Causal diagrams for empirical research. *Biometrika* 1995;82:669-710
2. Hernan MA, Hernandez-Díaz S, Robins JM. A structural approach to selection bias. *Epidemiology* 2004;15:615– 625
3. Shahar E. Causal diagrams for encoding and evaluation of information bias. *J Eval Clin Pract* 2009;15:436-40
4. Hernan MA, Cole SR. Causal diagrams and measurement bias. *Am J Epidemiol* 2009;170:959-62
5. Shahar E, Shahar DJ. Causal diagrams, information bias, and thought bias. *Pragmatic and Observational Research* 2010;1:33–47
6. Shahar E, Shahar DJ. Causal diagrams and three pairs of biases. In: *Epidemiology – Current Perspectives on Research and Practice* (Lunet N, Editor). www.intechopen.com/books/epidemiology-current-perspectives-on-research-and-practice, 2012:pp. 31-62
7. Shahar E, Shahar DJ. Causal diagrams and the logic of matched case-control studies *Clin Epidemiol* 2012;4:137-144
8. Mansournia MA et al. Matched designs and causal diagrams. *Int J Epidemiol* 2013;42:860-869
9. Shahar E, Shahar DJ: Marginal structural models: much ado about (almost) nothing. *J Eval Clin Pract* 2013;19:214-22
10. Shahar E: A method to detect an unknown confounder: something from nothing? *J Eval Clin Pract*, Epub March 13, 2011
11. Shahar E, Shahar DJ: Causal diagrams and change variables. *J Eval Clin Pract* 2012;18:143–148