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Dear Drs. Heather Bortfeld, Michelle de Haan, and Paul Quinn,

I have submitted to the submissions website a manuscript titled, “‘Don’t throw the associative baby out with the Bayesian bathwater: Children are more associative when reasoning retrospectively under information processing demands” for consideration at Developmental Science. The manuscript was written in collaboration with Dr. David M. Sobel, Mr. David Kamper (david\_kamper@brown.edu), and Ms. Rebecca M. Beaton (rebecca.m.beaton@vanderbilt.edu). The manuscript reports two behavioral experiments with 5- and 6-year-old children and two computational models: a simple connectionist (artificial neural network) model and a simple Bayesian model.

Few abilities are more important than the ability to reason about cause and effect in the real world. Despite the fact that researchers have tended to agree about the importance of causal reasoning, there is considerably less consensus about the nature of the cognitive mechanism that subserves this ability. For instance, some posit that causal reasoning is best described by Bayesian inference, in which learners must figure out which hypothesis, among many competing hypotheses, best explains the observed data. In contrast, others posit that associative learning underpins causal reasoning. The crux of this perspective is that causal reasoning involves the formation of “associative links” between candidate causes and effects; the more a candidate cause is associated with an effect, the greater the strength of the connection (i.e., association) between the cause and effect. What remains unresolved is which of these accounts provides the best explanation of causal learning in people.

One way that researchers have tried to resolve this debate is through research on a causal learning phenomenon called "backwards blocking reasoning". This is a form of reasoning that involves reevaluating the causal status of an ambiguous event based on learning more about the status of other unambiguous events. One of the first studies to examine backwards blocking reasoning in children was carried out by Sobel et al. (2004). Three- and 4-year-old children were introduced to the machine and are told that objects that cause the machine to light up and play music are called blickets. During the backwards blocking trial, participants observed that objects A and B together made the machine go. Then participants observed that object A alone makes the machine go. Participants are then asked whether each object was a blicket and then to make the machine go themselves. Compared to participants treatment of object B in a closely related condition in which A failed to make the machine go by itself (this is sometimes called the indirect screening-off condition), participants were much less likely to put object B on the machine. This finding has been taken as evidence of BB reasoning. Moreover, because a simple Bayesian model (but not a simple associative model such as the traditional Rescorla-Wagner model) can predict this finding, some have argued that Bayesian inference, but not associative learning (based on the Rescorla-Wagner, 1983—this is the simplest associative model that has been used to explain certain facets of casual reasoning), explains human causal learning.

An open question—which we address in the manuscript—concerns whether children continue to engage in these various forms of retrospective reevaluation when their information processing abilities are taxed. As we discuss more fully in the paper, there is good (theoretical and empirical) reason to think that when children’s information processing abilities are stretched, their causal inferences resemble more associative processes than those described by Bayesian inference—at present the literature suggest that children’s inferences are best described by Bayesian inference, but this might not always be the case, such as when they are asked to process more than the standard number of objects.

We examine this issue more closely in two experiments and a pair of computational models. Specifically, we examined backwards blocking reasoning in 5- and 6-year-old children in the context of three, four, and five objects in contrast to two objects (which is standard). The idea is that children’s inferences might look less Bayesian-like when asked to reason about more than two causes. In Experiment 1, 5- and 6-year-olds observed three objects (A, B, and C) together cause a machine to activate. They then observed that object A either caused or failed to cause the machine to activate by itself. They were then asked whether each object caused the machine to activate. These trials were compared to control trials in which they observed three different objects (A’, B’ and C’) activate the machine, followed by an event in which a fourth object (D) either caused or failed to cause the machine to activate. Experiment 2 was identical to Experiment 1 except that during the second part of the backwards blocking and indirect screening-off trials, objects A and B (in the experimental trials) and objects D and E (in the control trials) were put on the machine, and the machine either did (backwards blocking) or did not (indirect screening-off) trials. Although children engaged in backwards blocking reasoning across both experiments, there were aspects of their data that were consistent with verbal descriptions of associative learning. The results of subsequent computational models provided quantitative support for this contention: A simple connectionist model—which implemented a version of the Rescorla-Wagner model) provided a better quantitative fit to the behavioral data than did a simple Bayesian model.

We interpret these data as evidence for the operation of *both* an associative learning mechanism and Bayesian inference, although there was a clear tendency for children to process the events associatively. This is a radical departure from how these processes are often presented in the literature—there, the belief is that causal reasoning is either explained by associative learning or Bayesian inference (but not both!). Instead, we conclude that these data suggest that participants may simultaneously be relying on associative processing and Bayesian inference, even when there is a greater tendency to rely on associative learning to reason about more than two causes. We also conclude that these data support the conclusion that children weigh these two cognitive mechanisms differently depending on the number of potential causes about which they are asked to reason. Bayesian inference may be given more weight than associative learning when there are a small number of potential causes (such as in Sobel et al., 2004), but as the number of causes and the information processing demands of the task increase participants give more weight to associative learning (such as in the current study). We believe that this study represents a significant contribution to the causal learning literature and could be of broad interest to the readership of Developmental Science, given an interest by teachers, educators, parents, and clinicians to develop tasks and interventions that improve causal learning (which necessarily requires a detailed understanding of underlying mechanism, which is the contribution our paper makes).

None of the material has been published or is under consideration elsewhere, including the Internet. Potential reviewers for this manuscript include **Vladimir Sloutsky (**[**sloutsky.1@osu.edu**](mailto:sloutsky.1@osu.edu)**), Heidi Kloos (**[**kloosa@ucmail.uc.edu**](mailto:kloosa@ucmail.uc.edu)**), and Teresa McCormack (**[**t.mccormack@qub.ac.uk**](t.mccormack@qub.ac.uk)**).** These potential reviewers are recognized and leading experts on causal reasoning in infants, children, and adults and thus would be excellent reviewers for the present manuscript. I am looking forward to hearing from you.

Sincerely,  
Deon T. Benton