

The Broad Reach of Multivariable Thinking

DEANNA KUHN

*Department of Human Development
Teachers College Columbia
University
525 W. 120th St. New York NY
USA
kuhn@tc.columbia.edu*

ANAHID MODREK

*Department of Psychology
Thomas Jefferson University
Philadelphia PA
USA
anahid.modrek@gmail.com*

Abstract: Simple explanations are very often inadequate and can encourage faulty inferences. We examined college students' explanations regarding illegal immigration to determine the prevalence of single-factor explanations. The form of students' explanations was predicted by their responses on a simple three-item forced-choice multivariable causal reasoning task in which they selected the strongest evidence *against* a causal claim. In a further qualitative investigation of explanations by a sample of community adults, we identified positive features among those who scored high on this multivariable causal reasoning task. We consider limitations of single-factor reasoning and means of encouraging more comprehensive explanations to support claims.

Résumé: Les explications simples sont très souvent inadéquates et peuvent encourager des inférences erronées. Nous avons examiné les explications des étudiants concernant l'immigration illégale afin de déterminer la prévalence des explications fondées sur un seul facteur. La forme des explications des étudiants a été prédite par leurs réponses à une simple tâche de raisonnement causal multivariable à choix forcé de trois éléments dans laquelle ils ont sélectionné la preuve la plus solide contre une affirmation causale. Dans une autre enquête qualitative sur les explications fournies par un échantillon d'adultes de la communauté, nous avons identifié des caractéristiques positives parmi ceux qui ont obtenu une note élevée dans cette tâche de raisonnement causal multivariable. Nous examinons les limites du raisonnement à facteur unique et les moyens d'encourager des explications plus complètes pour étayer les affirmations.

Keywords: causal reasoning, explanation, sociopolitical views, multivariable thinking

1. Introduction

How do people explain themselves? Typically, these days, they aren't inclined to (Grant 2021). When asked for a position on an issue, they may respond with a self-identifying label rather than a robust argument or even an explanation, especially on divisive issues (Lagnado 2021; Barbera et al. 2015; Fisher and Keil 2014). 'Better to play it safe and keep my thinking to myself,' is the position accepted by many as the wise choice. At the extreme, one's personal identity alone is taken as sufficient explanation to others and even to oneself: 'I hold this view because of who I am and who I connect to.' Cognitive factors have been accorded a diminished role by some investigators, who see individuals as 'outsourcing' their views to social groups they feel connected to, have confidence in, and that support their identities (Kahan 2013; Mercier and Sperber 2011; Sloman and Fernbach 2017). When opinions change, Sloman and Rabb (2019) assert, they do not do so one mind at a time. Without denying the powerful roles of social and affective factors, here we highlight cognitive factors on the part of the individual that influence judgments and explanations.

The question of what makes one explanation better than another has been a topic of longstanding philosophical and later psychological debate (Harman 1965; Thagard 1978; Lombrozo 2007). Psychologists have contributed to this debate by asking people to judge the adequacy of different kinds of explanations. Although this line of inquiry has yielded some variable findings and interpretations, two factors have stood out. One is a preference for what are called mechanistic explanations (Ahn and Bailenson 1996). These are explanations that provide an account of the mechanisms that culminate in the outcome event of interest. Such explanations seem more satisfying compared to ones that identify factors thought to be associated with the outcome and shown capable of producing it but without explaining the mechanism involved (Zemla et al. 2017 2022). Mechanistic explanations are thought to be preferred because they provide a sense of understanding (Vasilyeva and Lombrozo 2015; Rozenblit and Keil 2002) whether or not the explanation is correct (Ahn et al. 1995). 'This is how it could happen' overrides evidence that this is what does happen

(Kuhn 1991). Both empirical evidence and mechanistic explanation have justifiable roles to play in explaining events, and it is less than straightforward to prescriptively judge their relative roles (Ahn et al. 1995; Koslowski 1996; Walker et al. 2017; Vasilyeva and Lombrozo 2015).

A second preference identified in both psychological and philosophical study has been the preference for simple explanations over more complex ones that invoke multiple factors (Johnson et al. 2020; Lombrozo 2007; Thagard 1989). Parsimony is valued among experts as well as laypeople, as supported by findings going back as far as a large literature on discounting (Kelley 1973) although recent work has suggested that this preference may be less than universal if multiple factors are seen as providing a superior account of mechanism (Vasilyeva and Lombrozo, 2015; Zemla et al. 2017, 2022). Additionally, there are task factors that influence this preference, such as prediction vs. attribution, with the latter task being more strongly associated with single-factor reasoning (Johnson et al. 2019; Pilditch et al. 2019).

Contemporary findings regarding people's own open-ended explanations nonetheless confirm that people explain a phenomenon by invoking as few factors as possible. Lim and Oppenheimer (2020), for example, asked people to provide explanations for an event (e.g., a college was awarded a top rating) for which either one or three possibilities were suggested. This manipulation had no effect on the number of causes participants provided in their own explanations of the cause—an average of about 1.3 in both conditions, despite the fact that in one condition they had been made aware that there were more available. The authors examined several potential influences affecting this number, but preference for a single-factor explanation remained their most notable result. Similarly, in a more naturalistic setting patrons of a coffee shop were asked, 'Why did Jane Doe, a middle-aged married Midwestern working woman, vote for Donald Trump in 2016?' Of 24 respondents, 17 named just one factor. When asked why they themselves had voted for the candidate they did, 21 named a single factor despite being prompted for anything else they might add (Kuhn and Iordanou 2022).

Most research on explanation has focused on causal explanation—'What caused this phenomenon to occur?' Within this category are the distinctions noted above—whether the explanation offers empirical evidence that cause and effect are related vs. an explanation of the mechanism by which cause leads to effect—as well as the distinction between reasoning from cause to effect (prediction) vs. from effect to cause (attribution or diagnostic reasoning; Fernbach et al. 2010).

Other kinds of explanations are possible, however, and we investigate one such type here, asking individuals to explain why they take a position they do. This request could be interpreted as a request to identify causes that led to their adopting this position, but in everyday conversation, such a request is more likely to elicit a justification for the position than an explanation of its causal origins; findings presented here confirm that such a justification is the kind of explanation participants offered. A justificatory explanation is self-referential, in contrast to a causal explanation, which typically refers to external events. The hypothesis we address here is that individual differences with respect to each of these kinds of explanations exhibit similarities.

With respect to causal explanations, most phenomena are in fact the outcome of multiple contributing causes. Simple single-factor causal explanations are thus very often insufficient ones. If single-factor causal explanations are preferred and hence prevalent, even if usually incomplete, how far-reaching and possibly damaging a problem should we regard this prevalence? This is the question we explore here by comparing causal explanations to another noncausal kind of explanation we have here labeled as a justificatory explanation. Models of causal reasoning are most often proposed to apply universally, but here our focus is on individual differences. Our hypothesis is thus that individuals who exhibit multivariable causal thinking are likely to exhibit multivariable thinking as well in justificatory explanations, while those who exhibit single-factor thinking in one are likely to also do so in the other.

Developmental findings

As developmental psychologists studying causal explanations, in earlier work we first looked at developmental origins. Criteria for inferring causes change during the first decades of life in ways that may seem paradoxical. Young children commonly regard an event as causal simply because it co-occurs with an outcome. They later adhere to more rigorous criteria and begin to distinguish causality from covariation and may become able to eliminate potential causes via controlled comparison. Surprisingly, however, young teens who have mastered this skill are likely to attribute an outcome to a single factor, even when they have themselves just demonstrated that other factors present also affect the outcome (Kuhn et al. 2009; Kuhn 2012). Moreover, the single factor to which they attribute a role shifts across instances examined.

These findings led to a series of studies designed to advance young adolescents' development of multivariable causal reasoning (Kuhn et al., 2015, 2017; Arvidsson and Kuhn, 2021; Lesperance and Kuhn, 2023). Various forms of a multi-session intervention in which adolescents gained practice in coordinating the influences of multiple factors on an outcome showed that this objective was achievable. Of particular interest is a simple three-item multiple-choice causal reasoning instrument on which young adolescents showed a large shift in their choices following intervention. Here we explore this instrument further, focusing attention on multivariable thinking in adults, both college students and community adults, absent intervention. Are there notable individual differences among adults in their reasoning about multiple variables as contributors to an outcome, and are such differences of any great consequence, as would be exemplified by their extending beyond the causal reasoning domain?

Tasks

Our methods span closed-ended assessment, open-ended explanation, and qualitative case study of a selected subgroup of a larger sample.

Causal reasoning task

The simple 3-item causal reasoning task employed in the present work appears in Table 1. At first glance, the task fits most directly into the argumentation literature (Rapanta et al. 2013) since it asks the respondent to evaluate arguments seeking to weaken a claim (hence requesting the more challenging task of disconfirming rather than supporting a claim). The claims, however, are causal claims. A causal reasoning expert is likely to be critical of the task, dismissing all options as wrong (since too little is specified regarding the type of causal claim being made) or all as correct (especially from a probabilistic Bayesian perspective) as all three, to some degree, can be seen as reducing the likelihood of the claim being true.

Table 1. Multivariable Reasoning Assessment Items

<p>1. Some health officials have found cancer rates higher in cities than in outer areas. Dr J. Rawls claimed tanning salons are to blame. Circle ONE piece of evidence that would be best to use if you wanted to argue he was wrong.</p> <p>A. Air pollution is a more likely cause of cancer in the city.</p> <p>B. Many people who don't go to tanning salons also get cancer</p> <p>C. Many people outside the city also go to tanning salons and don't get cancer.</p>
<p>2. People from some countries have longer average life expectancy than people in others. Dr. F. Cole claimed a diet high in fish causes long life. Circle ONE piece of evidence that would be best to use if you wanted to argue he was wrong.</p> <p>A. Exercise is a more important cause of long life.</p> <p>B. People who don't eat fish often live to an old age.</p> <p>C. People who eat a lot of fish often live only to an average age.</p>
<p>3. Venezuela is a country with money trouble, unable to pay its bills. Dr P. Garet claimed the cause was too many social programs to help people. Circle ONE piece of evidence that would be best to use if you wanted to argue he was wrong.</p> <p>A. Poor money management is a more likely cause of a country's money trouble.</p> <p>B. Some countries like Haiti have very few programs to help their people and Haiti has serious money shortages.</p> <p>C. Some countries like Sweden have many social programs and are not in money trouble.</p>
<p><i>(reprinted from Kuhn & Modrek, 2018)</i></p>

The evolving preference for option C as the best choice and the strongest evidence against a causal claim (Kuhn et al. 2017) observed in the developmental studies noted above warrants some explication. The task asks for the strongest evidence to be selected to weaken the claim that X causes Y. Those who appreciate multivariable causality—that is, multiple causal contributors to an outcome—will understand that X failing to cause Y [option C] is solid evidence against a claim of X's causal efficacy (at least as a reliable cause). They will see options A or B (suggesting that other causes are able to produce Y) as not providing direct evidence regarding the efficacy of X. Only option C speaks directly to X's efficacy.

If, in contrast, a respondent sees an outcome as having only one cause, options A and B (suggesting other causes than X) are seen as at least equally as good as, if not better than, C for indicating that the claim that X causes Y must be wrong, because Y can only have one cause. Cast in terms of one of the items in Table 1, to draw on evidence to assess the claim that eating fish is a cause of longevity, investigating fish consumption is the best choice. Identifying additional causes does not discredit it. Yet, across different samples, A (which is devoid of empirical evidence) is the most popular choice followed by B, and then C (Kuhn 2020; Kuhn and Modrek 2018). We use the short 3-item form here, as comparisons found it to be consistent with a parallel 8-item version (Kuhn and Modrek 2018) and other longer measures of the same construct of multivariable causal reasoning (Kuhn, Ramsey and Arvidsson 2015). Arguably most important in validating the task as a measure of multivariable causal reasoning is the shift to preferring option C shown by teen participants following multi-session intervention designed to strengthen multivariable causal reasoning, compared to a non-intervention control group's most often choosing option B (Kuhn et al. 2017).

Sociopolitical explanation task

We deliberately chose a topic that required more than a simple single-factor explanation, entailed a judgment that invoked broader values warranting justification, and, most importantly, called for the coordination of multiple considerations:

What should be done about the problem of young people brought to the US as children and now living in the US illegally—should they be allowed to stay or be sent back?

The respondent was asked to ‘...explain the thinking underlying your choice as fully as possible.’

The issue requires bringing together two competing sets of considerations—those of society and its laws and those of an individual who did not knowingly violate them. Single-factor thinking that ignores one of them does not fully address the issue.

Consistent with the literature noted earlier regarding the tendency toward single-factor explanations, an earlier study posed this question to a community of adults (Kuhn et al. 2020), and the majority cited a single factor or consideration as justification for their position (e.g., ‘They’ve worked hard’ or ‘They broke the law’); moreover, those who identified only a single factor were more likely to express high certainty and strong affect.

The use of the sociopolitical topic of immigration policy in the present study combined with the task of assessing multivariable causal reasoning was intended to explore the extent to which tendencies toward single- vs. multiple-factor causal reasoning extend beyond, and connect to, explanations in the sociopolitical realm that are not explicitly causal in nature—specifically the ones we labeled earlier as justificatory explanations. Do individual differences in tendencies toward single-factor vs. multi-factor explanations extend broadly from a causal to a noncausal domain?

Method

Participants

One sample consisted of 103 college students who were aged mostly 19 and 20 (full range: 18–25), were two thirds female, and were enrolled in a psychology course in a private university in the northeastern United States. Three quarters identified as White, with the remainder identifying as African American, Latinx, and Asian. The college is selective in its admission and serves a largely homogeneous, upper-middle to upper class population who can afford to pay the high fees the institution charges.

A second sample of 123 participants was solicited from Amazon Mechanical Turk to represent a broader sample in terms of age and education range than a college student sample reflects. They were 48% female, mean age 42, SD 11.17 (range 24–71). Roughly half reported having attained college degrees. This sample of 123 completed the same multivariable causal reasoning task and sociopolitical judgment tasks as the college sample.

Procedure

After participants assented to the study, both the sociopolitical explanation task (What should be done about the problem of young people brought to the US as children and now living in the US illegally—should they be allowed to stay or be sent back?) and the causal reasoning task appearing in Table 1 were presented online. Respondents were asked to ‘...explain the thinking underlying your choice as fully as possible’ in their responses to the sociopolitical task. The tasks were untimed, with participants completing them at their own pace and in the order they wished.

Results

Performance of college sample

Multivariable causal reasoning task

Consistent with earlier findings (Kuhn et al., 2015; Kuhn and Modrek 2018; Kuhn 2020), only 21 participants (20%) most often (two of three choices) or always chose option C, which we can

refer to as the multi-cause option. Slightly more, 28 (27%), chose option B, which we can refer to as an evidence-based single-cause option. The remaining 52% preferred the non-evidence-based single-cause option A or, less frequently, showed no preference across the three options (classified as non-dominant).

Sociopolitical explanation task

Responses to the sociopolitical explanation task were found to contain a limited number of different reasons for the position taken. Only statements making a claim accompanied by a reason or justification were coded. The variety of reasons observed appear in Table 2 by category, with categories grouped according to which of the two actions the reason addressed—allowing the undocumented immigrant to stay in the USA (STAY category) or requiring them to leave (GO category). Most participants' responses offered reasons only for their favored position, while others' responses addressed both options.

Participants' explanations were categorized based on their complexity, falling into one of three categories. Of 103 participants, 27 (26%) offered only a single reason (single-reason single-position category) in support of one of the two actions, GO or STAY, that they endorsed; 33 (32%) offered two or more reasons, all of which were in support of one of the actions (multiple-reason single-position category), and 43 (42%) noted one or more reasons with respect to each of the actions (multiple-reason dual-position category). Coding into these categories resulted in an inter-rater agreement of 100%.

Table 2. Reasons Expressed by Participants in Response to the Immigration Probe

<p>Reasons addressed to the <i>STAY</i> option</p> <ol style="list-style-type: none">1. Immigrant deserves charity and compassion2. Immigrant deserves treatment consistent with American values/tradition3. Immigrant deserves an opportunity for a better life, escape adversity4. Immigrants benefit US society5. Immigrant families can be kept intact6. Legal immigration policies are inadequate, faulty <p>Reasons addressed to the <i>GO</i> option</p> <ol style="list-style-type: none">1. Deported immigrant faces danger, hardship on return to own country2. Immigrant families can be kept intact3. Immigrants can be better helped by aid to their own countries4. Deportation may affect further illegal entries5. Illegal immigration violates US law6. Unrestricted immigration harms interests of US citizens

Note. Reasons addressing either option are not necessarily reasons supporting that option but only ones that address it (e.g., citing negative consequences of a forced departure is categorized as addressing the *GO* option, even though the respondent was typically not in favor of this option).

Associations across tasks

To what extent did these categories of response to the closed-ended causal reasoning task predict explanation type on the open-ended sociopolitical explanation task? Explanation types were classified into one of the three categories defined above: single-reason category, multiple-reason single-position category, and multiple-reason dual-position category, referred to hereafter as single, multiple, and dual. Among the group that chose option C (multi-cause option) on the causal reasoning task, 18 of 21 (86%) gave a sociopolitical explanation that included considerations addressing both the GO and STAY alternatives (dual explanation

type). Among the group that chose causal reasoning option B (evidence-based single-cause option), only 8 of 28 (29%) gave a dual sociopolitical explanation (a significant difference, $X^2=15.732$, $p < .001$). In the option-A (non-evidence-based single-cause option) and non-dominant groups, 17 of 54 (31%) performed similarly to the option-B group on the sociopolitical task. These groups also did not differ significantly from one another on the total number of reasons offered in the sociopolitical task.

Hence only a disposition toward multi-cause (option-C) causal reasoning was predictive of the use of the dual (multiple-reason dual-position) form of explanation for the position taken in the sociopolitical task, citing one or more reasons in support of the GO position and one or more in support of the STAY position. The two remaining groups on the causal reasoning task were both unlikely to show the dual (multiple-reason dual-position) category form of justification (29% and 31% respectively). Nor were the 29% that chose the evidence-based single-cause option B on the causal task more likely than the 31% that chose the non-evidence-based single-cause option A to show the multiple-reason single-position form of explanation in the sociopolitical task (43% v. 35%). Neither of these two comparisons was statistically significant.

Performance of community adult sample

Multivariable causal reasoning task

Only 12 of the 123 respondents who responded to the multivariable causal reasoning task chose the multi-cause option C indicative of consolidated multivariable causal reasoning. Five of the 12 were female, and the 12 ranged in age from 26 to 70.

The remaining 111 participants either chose one of the single-cause (A or B) options or showed no preference across the three options (classified as non-dominant). Compared to the college sample, choice of the multi-cause option C among sample 2 participants was thus somewhat less frequent, but otherwise resembled the college sample.

Sociopolitical explanation task

We singled out the 12 high-performing respondents on the causal reasoning task for qualitative examination to further investigate how their strong multivariable causal reasoning performance may have been associated with their reasoning in the noncausal sociopolitical explanation task. What, if anything, characterized the responses of these 12 strong causal reasoners in their explanations in the sociopolitical task, compared to the remainder of sample 2? The majority (10 of 12) of these 12 respondents' open-ended explanations included identification of one or more factors contributing to their decisions, and thus they fell into the multiple-reason category. Contrary to our expectation (and findings from the college sample), however, most fell into the single- rather than dual-position category, that is, they addressed only the position they favored, offering arguments to support it and omitting mention of the opposing position. Among nine of the ten who referred to multiple factors (as they would need to in order to address both positions), the position chosen was STAY, with all identified factors serving to support the STAY position; no mention of positive or negative implications of the opposing GO position were included.

A further characteristic of the explanations given in the sociopolitical task by these 12 strong performers on the causal reasoning task that distinguished them from the remainder of the sample was a high degree of **meta-talk**, that is, talk not focused on the specific decision to be reached but rather a broader reflection on the issue (e.g., 'There are many different facets and perspectives to consider'). Two coders independently examined the open-ended responses of the entire sample (including these 12 participants) and identified only 11 explanations for which both raters reported the presence of meta-talk, with four additional cases in which only one rater found meta-talk (a percentage agreement of 119 of 123, or 97%). Disagreements were resolved by discussion, with only the initial 11 retained in the meta-talk category. Of these, 10 of the 11 occurred in the explanations of the 12 strong causal reasoners.

Meta-talk thus proved rare in the responses of the majority of the sample who were not classified as strong multivariable causal reasoners on our measure, occurring in only one instance. Among

the 12 strong multivariable causal reasoners, in contrast, some made more than just one meta-talk statement, but 10 of the 12 made at least one.

A further characteristic associated with meta-talk among these 10 was talk about potential solutions to the broad issue of immigration (e.g., ‘We should create incentives and disincentives that encourage legal immigration’). Talk of some such steps to take beyond resolution of the particular dilemma posed appeared in the responses of all of the 10 strong causal reasoners who engaged in meta-talk.

Discussion

The findings presented here are consistent with existing ones (Kuhn et al., 2015; Kuhn and Modrek 2018) in showing that no more than a quarter of adults choose (relative to the alternative options posed) the fact that a cause does not reliably produce the outcome as the strongest evidence against its causal power. Instead, the majority are more likely to choose identification of a possible other cause (options A or B) as the strongest evidence against the causal role of the factor under consideration; this choice is presumably influenced by the belief that a single cause explains an outcome.

The present study extends the implication of this finding regarding individual differences in multivariable causal reasoning to reasoning about an issue that is not explicitly causal in nature—namely a sociopolitical issue that, like most such issues, benefits from and even demands thinking that extends beyond invoking a single factor or consideration to provide an explanation that justifies one’s position on the issue. This finding is important in its own right. Yet it also adds to findings noted earlier that interventions intended to enhance multivariable causal reasoning in younger participants show success.

The strong correspondence we show does not, of course, confirm the relation between performance in our causal and sociopolitical tasks as more than correlational. There are certainly additional individual (not to mention social) factors that are strong contenders as contributors to the kinds of reasoning about real-world issues that an individual exhibits and presumably feels

provide sufficient explanation for a position on such issues. Yet, supporting the relevance of performance on the three-item causal reasoning task as a notable predictor of the quality of individuals' explanations of noncausal, value-laden judgments in a sociopolitical domain is not the extent of the association. Also notable is the relative homogeneity of the college sample, which serves to restrict the range and hence the roles of other potential contributors. We purposely selected a sample that was relatively homogeneous in education level, intellectual ability, and family background in order to restrict the variance in these factors known to affect performance on intellectual tasks. Despite common educational level and restricted range in other individual factors, the role of the reasoning types we examined remained strong.

With respect to the specific correspondence observed here, it should be noted we may have incorrectly predicted that multi-cause (option C) reasoning would support the multiple-reason single-position sociopolitical category in which participants identify multiple reasons that support a single position (Table 2). However, consistent with an earlier study of justifications for positions on this topic (Kuhn et al. 2020), it was only the dual category, in which the respondent addressed both GO and STAY positions, that the multi-cause choice was predictive of. Only the dual category clearly requires the coordination of multiple reasons that lead in different, incompatible directions—in essence, that address the two opposing (GO and STAY) alternatives. The dual category may thus be supported by the multivariable proficiency shown in the closed-ended causal reasoning task. The other two (single-position, multiple- or single-reason) explanation types, in contrast, were observed to have more of a narrative quality. In the multiple-reason case, the reasons were joined together into a single account that told a story (for example, that of a young person who has worked hard, fulfilled the American dream, and will contribute to their adopted country), and the reasons were all seen as pointing to a single conclusion.

The quality of the sociopolitical explanation provided by the 12 multivariable causal reasoners that were identified as strong in sample 2 showed that this status did not guarantee that they would go to the trouble of addressing an opposing sociopolitical position

they rejected (thus achieving the dual category), which was something the college students in this category may have been more likely to see as a requirement. Nonetheless, the responses of this small group of 12 were of high quality overall and specifically with respect to the two dimensions identified. Their meta-talk reflected on the issue broadly, recognizing it as complex and multi-faceted, and went on to venture suggestions as to how it might be addressed, going beyond the specific decision that had been presented to them. The following response is a good illustration of these characteristics:

There are many factors to consider... It's important to be able to look up FACTS ...each side can consider the counterarguments raised by the other and do some research. Not necessarily to disprove the other person or validate their thoughts, but take the introduction a step deeper to have another conversation about possible solutions.

Others took their suggestions in more specific directions (“*Many of the issues around immigration are also related to class issues on a broader scale*”), but all addressed the topic on a broader scale and invoked broader objectives (“*We must think about what is fair, what is moral, and what is best for the country*”). These responses reflect rich thinking about a noncausal sociopolitical issue where multiple factors are at play, although the speaker does not directly address the opposing decision.

The fact that the explanations of the 12 strong causal reasoners supported the STAY position nonetheless makes it important to consider whether this conceptually rich but single-sided stance held by adults from a community sample is specific to this topic. They appeared not to consider it necessary to address what, to them, was an unacceptable alternative, even while addressing their own position quite broadly. In any case, the characteristics identified here warrant further investigation involving different topics and different populations.

In current work, we have sought to extend our exploration of single-factor versus multi-factor explanation and address the strengths and downsides of each as well as potential means of enriching them, using samples from diverse adolescent and adult

populations. In one initial study, we drew on a Mechanical-Turk sample to further examine potential reasoning errors that single-factor reasoning may encourage. Participants were presented with a vignette in which two treatments each produce disease remission:

Chris and Pat are a couple who have traveled to Mexico hoping to find a remedy for Chris's long-standing medical condition. A couple of treatments have been tried with some success, with these results:

Treatment A --> Chris's condition improves

Treatment B --> Chris's condition improves

How similar are A and B?

Participants were asked to respond to this question on a scale from 0-100, with 0 representing not at all similar and 100 equaling almost identical.

Is it warranted to conclude that the two treatments are related? A multivariable reasoner should recognize such an inference as unwarranted, whereas a reasoner who thinks in terms of single factors accounting for an outcome may be more likely to see the two treatments as related. Only five participants demonstrated multivariable reasoning on our causal reasoning task—a number too small for statistical comparisons. The performance of the sample as a whole, however, is noteworthy. The percentage who chose a point on the scale of 85 or greater was 80%, with 59% choosing the point of 100, indicating identity or near identity between Treatment A and Treatment B. This finding clearly warrants deeper probing of the thinking underlying these judgments. However, among participants who added justifications, those who chose points of 85 or above provided justifications along the lines of 'They have some relation or are the same because they both lead to the outcome' or simply, 'Both give you the same outcome.'

We tentatively see these statements as reflective of a disposition toward univariable rather than multivariable thinking. Univariable thinkers are content with one explanatory factor accounting for an outcome. If a second factor is introduced that achieves the same outcome, such thinkers may be disposed to equate them, more so than strong multivariable thinkers who operate from a ‘many roads lead to Rome’ mental model. Counterexamples that highlight alternative (as well as additive) paths to the same outcome may prompt the recognition that the similarity between them, in this case between treatment A and treatment B, is entirely unknown. This possibility clearly needs further investigation, yet a long-standing parallel finding from the conditional reasoning literature regarding the introduction of counterexamples (Moshman 2015; Ricco 2015) increases its likelihood. For now, we wish this preliminary finding to suggest only that a large proportion of the broad, non-selective adult population has a tendency to see two unknown causes of the same outcome as having a high degree of similarity rather than being potentially independent until shown otherwise.

At the beginning of this article, we laid the groundwork for understanding the significance of multivariable thinking and its absence. The kinds of issues that people today are commonly asked to make judgments on, such as Brexit, health care, or gun control, can hardly be served by a single-factor mental model. Simple explanations in support of such decisions are thus, by their nature, inadequate, for the simple reason that they lack sufficient power to explain. Today, more than ever, in order for the strength of democracy to be preserved, rich, nuanced, individual (and collaborative) reasoning supported by conceptions of multiple factors contributing additively and interactively to outcomes, is essential. Positions based on only a single factor or consideration are exactly the ones that make it easy for identity politics to attract followers and to thrive.

The findings cited earlier from previous research involving educational interventions that enhanced adolescents’ multivariable reasoning (Arvidsson and Kuhn 2021; Jewett and Kuhn 2016; Kuhn et al. 2015, 2017) hold educational promise but need further development. Enriched thinking may follow even when discourse-

based group sessions are confined to the like-minded (Kuhn et al. 2018), but results are better when opposing views are not only available but personified (Iordanou and Kuhn 2020). Yet few adults participate in such experiments. Ordinary adults are likely to maintain confidence that their views on contemporary issues are well justified. Studies by Keil and Sloman and their colleagues have demonstrated that just asking people to explain the causal function of an object or phenomenon reduces their certainty regarding how it functions (Rozenblit and Keil 2002; Sloman and Fernbach 2017), with reduced certainty regarded as a positive development. Most directly related to the present work, Kuhn and Modrek (2021) have demonstrated that simply framing an issue in a dialogic context enriches explanation.

Situational support, however, cannot replace efforts to enhance reasoning competence and disposition as individual characteristics that are well developed and consolidated enough to operate across a broad range of contexts and levels of support (Zavala and Kuhn 2017), with individuals experiencing both agency and personal responsibility in accounting for their views (Kuhn 2022). For this reason alone, continued effort should be made to better understand the development of these individual reasoning competencies and dispositions so as to make them as broadly achieved and exercised as possible. As has now become widely recognized, both individual attributes and context matter and must be considered jointly.

References

- Ahn, W. and J. Bailenson. 1996. Causal attribution as a search for underlying mechanisms: An explanation of the conjunction fallacy and the discounting principle. *Cognitive Psychology* 31(1): 82-123.
- Ahn, W., C. Kalish, D. Medin and S. Gelman. 1995. The role of covariation versus mechanism information in causal attribution. *Cognition* 54(3): 299-352.
- Arvidsson, T. S. and D. Kuhn. 2021. Realizing the full potential of individualizing learning. *Contemporary Educational Psychology* 65: 1-24. doi.org/10.1016/j.cedpsych.2021.101960
- Barbera, P., J. Jost, J. Nagler, J. Tucker and R. Bonneau. 2015. Tweeting from left to right: Is online political communication more than an echo chamber? *Psychological Science* 26(10): 1531-1542.

- Fernbach, P., A. Darlow and S. Sloman. 2010. Neglect of alternative causes in predictive but not diagnostic reasoning. *Psychological Science* 21(3): 329-336.
- Fisher, M. and F. Keil. 2014. The illusion of argument justification. *Journal of Experimental Psychology: General* 143(1): 425-433.
- Grant, A. 2021. *Think again*. New York: Viking Press.
- Harman, G. 1965. The inference to the best explanation. *The Philosophical Review* 74(1): 88-95.
- Iordanou, K. and D. Kuhn. 2020. Contemplating the opposition: Does a personal touch matter? *Discourse Processes* 57(4): 343-359.
- Jewett, E. and D. Kuhn. 2016. Social science as a tool in developing scientific thinking skills in underserved, low-achieving urban students. *Journal of Experimental Child Psychology* 143: 154-161.
- Johnson, S., J. Valenti and F. Keil. 2019. Simplicity and complexity preferences in causal explanation: An opponent heuristic account. *Cognitive Psychology* 113: 101222.
- Johnson, S., T. Merchant and F. Keil. 2020. Belief digitization: Do we treat uncertainty as probabilities or as bits? *Journal of Experimental Psychology: General* 149(8): 1417-1434.
- Kahan, D. 2013. Ideology, motivated reasoning, and cognitive reflection. *Judgment and Decision Making* 8(4): 407-424.
- Kelley, H. 1973. The processes of causal attribution. *American Psychologist* 28(2): 107-128.
- Koslowski, B. 1996. *Theory and evidence: The development of scientific reasoning*. Cambridge: MIT Press.
- Kuhn, D. 1991. *The skills of argument*. New York, NY: Cambridge University Press.
- Kuhn, D. 2012. The development of causal reasoning. *WIREs Cognitive Science*. DOI:10.1002/wcs.1160.
- Kuhn, D. 2020. Why is reconciling divergent views a challenge? *Current Directions in Psychological Science* 29(1): 27-32.
- Kuhn, D. 2022. Metacognition matters in many ways. *Educational Psychologist* 57(2): 73-86.
- Kuhn, D., T. S. Arvidsson, R. Lesperance and R. Corprew. 2017. Can engaging in science practices promote deep understanding of them? *Science Education* 101: 232-250.
- Kuhn, D., A. Cummings and M. Youmans. 2020. Is reasoning a fruitful path to changing minds? *Discourse Processes* 57: 36-47.
- Kuhn, D., D. Floyd, P. Yaksick, M. Halpern and W. Ricks. 2018. How does discourse among like-minded individuals affect their thinking about a complex issue? *Thinking and Reasoning* 25(3): 365-382.

- Kuhn, D. and K. Jordanou. 2022. Why do people argue past one another rather than with one another? In *Reason, bias, and inquiry: New perspectives from the crossroads of epistemology and psychology*, eds. N. Ballantyne, D. Dunning, 324-338. New York: Oxford University Press.
- Kuhn, D. and A. Modrek. 2018. Do reasoning limitations undermine discourse? *Thinking and Reasoning* 24(1): 97-116.
- Kuhn, D. and A. Modrek. 2021. Mere exposure to dialogic framing enriches argumentative thinking. *Applied Cognitive Psychology* 35(5): 1349-1355.
- Kuhn, D., M. Pease and C. Wirkala. 2009. Coordinating effects of multiple variables: A skill fundamental to causal and scientific reasoning. *Journal of Experimental Child Psychology* 103(3): 268-284.
- Kuhn, D., S. Ramsey and T. S. Arvidsson. 2015. Developing multivariable thinkers. *Cognitive Development* 35: 92-110.
- Lagnado, D. 2021. *Explaining the evidence: How the mind investigates the world*. Cambridge: Cambridge University Press.
- Lesperance, R. and D. Kuhn. 2023. Breadth and relevance of multivariable inquiry supports deep understanding of science practice. *Science Education* 107: 71-88.
- Lim, J. and D. Oppenheimer. 2020. Explanatory preferences for complexity matching. *Plos One* 15(4): doi.org/10.1371/journal.pone.0230929
- Lombrozo, T. 2007. Simplicity and probability in causal explanation. *Cognitive Psychology* 55(3): 232-257.
- Mercier, H. and D. Sperber. 2011. Why do humans reason? Arguments for an argumentative theory. *Behavioral and Brain Sciences* 34(2): 57-111.
- Moshman, D. 2015. *Epistemic cognition and development: The psychology of justification and truth*. New York: Psychology Press.
- Pilditch, T., N. Fenton and D. Lagnado. 2019. The zero-sum fallacy in evidence evaluation. *Psychological Science* 30(2): 250-260.
- Rapanta, C., M. Garcia-Mila and S. Gilabert. 2013. What is meant by argumentative competence? An integrative review of methods of analysis and assessment in education. *Review of Educational Research* 83(4): 483-520.
- Ricco, R. 2015. The development of reasoning. In *Handbook of child psychology and developmental science. Vol. 2* (7th ed.), vol. eds. L. Liben, U. Mueller, series ed. R. Lerner, 519-570. Hoboken NJ: Wiley.

- Rozenblit, L. and F. Keil. 2002. The misunderstood limits of folk science: An illusion of explanatory depth. *Cognitive Science* 26(5): 521-562.
- Sloman, S. and P. Fernbach. 2017. *The knowledge illusion: Why we never think alone*. New York, NY: Riverhead Books (a division of Penguin Publishing Group).
- Sloman, S. and N. Rabb. 2019. Thought as a determinant of political opinion. *Cognition* 188(4): 1-7.
- Thagard, P. 1978. The best explanation: Criteria for theory choice. *The Journal of Philosophy* 75(2): 76-92.
- Thagard, P. 1989. Explanatory coherence. *Behavioral and Brain Sciences* 12(3): 435-502.
- Vasilyeva, N. and T. Lombrozo. 2015. Explanations and causal judgments are differentially sensitive to covariation and mechanism information. In *Proceedings of the 37th Annual Meeting of the Cognitive Science Society*, eds D. C. Noelle, R. Dale, A. S. Warlaumont, J. Yoshimi, T. Matlock, C. D. Jennings, P. P. Maglio, 2475-2480. Austin, TX: Cognitive Science Society.
- Walker, C., T. Lombrozo, J. Williams, A. Rafferty, and A. Gopnik. 2017. Explaining constrains causal learning in childhood. *Child Development* 88(1): 229-246.
- Zavala, J. and D. Kuhn. 2017. Solitary discourse is a productive activity. *Psychological Science* 28(5): 578-586.
- Zemla, J., S. Sloman, C. Bechlivanidis and D. Lagnado. 2017. Evaluating everyday explanations. *Psychonomic Bulletin & Review* 24(5): 1488-1500.
- Zemla, J., S. Sloman, C. Bechlivanidis and D. Lagnado. 2022. Not so simple! Mechanisms increase preference for complex explanations. SSRN. <http://dx.doi.org/10.2139/ssrn.4130789>