Title

Belief Utility as an Explanatory Virtue

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 37(0)

Authors
Johnson, Samuel G.B.
Rajeev-Kumar, Greeshma
Keil, Frank C

Publication Date
2015

Peer reviewed

Belief Utility as an Explanatory Virtue

Samuel G. B. Johnson, Greeshma Rajeev-Kumar, & Frank C. Keil
(samuel.johnson@yale.edu, greeshma.rajeev-kumar@yale.edu, frank.keil@yale.edu)
Department of Psychology, Yale University, 2 Hillhouse Ave., New Haven, CT 06520 USA

Abstract

Our beliefs guide our actions. But do potential actions also guide our beliefs? Three experiments tested whether people use *pragmatist* principles in fixing their beliefs, by examining situations in which the evidence is indeterminate between an innocuous and a dire explanation that necessitate different actions. According to classical decision theory, a person should favor a prudent course of action in such cases, but should nonetheless be agnostic in belief between the two explanations. Contradicting this position, participants believed the dire explanation to be more probable when the evidence was ambiguous. Further, when the evidence favored either an innocuous or a dire explanation, evidence favoring the dire explanation led to stronger beliefs compared to evidence favoring the innocuous explanation. These results challenge classic theories of the relationship between belief and action, suggesting that our system for belief fixation is sensitive to the utility of potential beliefs for taking subsequent action.

Keywords: Explanation; beliefs; causal reasoning; categorization; rationality.

Introduction

We are agents embedded in the world. Our cognitions exist in part to support adaptive behavior (Fiske, 1992; James, 1983/1890). Thus, beliefs allow us to store information that may be useful for taking beneficial actions later on. Here, we examine two ways that beliefs might guide actions—and that actions might guide beliefs.

The classical *decision-theoretic* view asserts that our actions are guided by our beliefs according to a set of decision-making principles. That is, we attempt to ascertain the truth, and on the basis of these beliefs, we take action (Jeffrey, 1965; von Neumann & Morgenstern, 1944). Although most behavioral economists (unlike laypeople; see Johnson & Rips, 2015) do not believe that people are utility maximizers, most modifications to utility-maximization theory retain the underlying assumption that beliefs about outcome probabilities are fixed before the decision-making process occurs (e.g., Kahneman & Tversky, 1979; Shafir & LeBoeuf, 2002).

An alternative, *pragmatist* view holds that not only do our beliefs guide our actions, but our potential actions also guide our beliefs, because some beliefs are more useful to hold than others. (See Evans & Over, 1996 for a related distinction between impersonal, logic-based and personal, utility-based rationality.) To adapt an example from the philosopher Charles Sanders Peirce (1997/1903), consider the plight of a ship captain caught in a storm, who must decide whether to put his wheel to port or to starboard, acting on one or another hypothesis. Even if the probabilistic evidence favors the hypothesis that he should turn the ship to port, he might nonetheless act on the starboard hypothesis, if the consequences of being wrong are graver when the starboard hypothesis is true. On the pragmatist view, the captain might not merely *act* prudently, as though the starboard hypothesis is true, but also *believe* it to be true, despite its lower probability.

More generally, in high-stakes situations where beliefs guide our actions, we might be prudent not only in our actions, but also in our beliefs. The decision-theoretic view can explain the ship captain's prudent action if he assigns a low probability to the dangerous outcome, yet acts to prevent that outcome because its disutility is so high. But on the pragmatist view, this calculation might be facilitated by the belief system itself, which may adjust the probabilities to favor the more prudent course of action, even if the evidence disagrees.

Although pragmatist considerations have long played a role in psychological theories (Fiske, 1992; James, 1983/1890), this kind of radical pragmatism would be a departure from standard approaches to decision-making. Traditionally, biases in decision-making are explained in terms of short-cuts in belief formation (Tversky & Kahneman, 1974) or nonlinear utility functions relative to probability (Kahneman & Tversky, 1979). If people both adjusted their beliefs prudentially in light of the utility of potential actions, and then acted prudentially *given those already-adjusted beliefs*, then people would adjust twice for the greater utility of taking the prudential action, and may act in a way that is too conservative, relative to the principles of rational decision theory.

We conducted three experiments to test whether people are more likely to believe explanations that have greater (prudential) utility. The basic paradigm was the same in all experiments. Participants learned about some evidence, which two potential hypotheses could explain—either an innocuous explanation (e.g., a minor disease that leads to soreness) or a dire explanation (e.g., a severe disease that leads to a fatal tumor). The evidence either favored one of the explanations or was ambiguous. However, because one explanation necessitated action more strongly than the other, participants should take action as though the severe explanation is true, even when the evidence is ambiguous (e.g., a doctor would treat the severe disease even if a minor disease is just as likely). Similarly, when the evidence favors the severe disease, one should be strongly inclined to take the corresponding action, whereas when the evidence favors the minor explanation, one should be comparatively less inclined to take the corresponding action because the consequences of inaction are minor. This result would be consistent with either the decision-theoretic or the pragmatist theory.

However, the decision-theoretic and pragmatist theories diverge in their predictions for beliefs. When the evidence is completely ambiguous, favoring neither explanation, people should be agnostic between the two explanations according to the decision-theoretic view—prudent actions emerge because people take into account the greater disutility of inaction if the severe explanation is true. Further, if the evidence is probabilistically symmetric when it favors either the minor or the severe explanation, the decision-theoretic view would predict that if one has a given degree of confidence in the minor explanation when the evidence favors that explanation, one should have that same degree of confidence in the severe explanation when the evidence favors that explanation.

However, on the pragmatist view, people may favor the severe explanation even when the evidence is ambiguous, because this belief would facilitate prudent action. They also may believe more strongly in the severe explanation when the evidence favors it, compared to how strongly they believe the minor explanation when the evidence favors it. Such results would be in normative tension with probability theory and expected utility theory, as well as dominant theories of decision-making in psychology.

Our experiments varied both the vignette content and the degree of explanatory ambiguity. In Experiment 1, we used a medical diagnosis paradigm to test these hypotheses, in line with previous studies of explanatory reasoning (e.g., Khemlani, Sussman, & Oppenheimer, 2011; Lombrozo, 2007). In Experiment 2, we extended these results to a wider range of stimuli that included both causal explanations and categorizations. To vary explanatory ambiguity, Experiment 3 introduced an additional unverified prediction to one of the explanations, which interferes with normative probabilistic reasoning (Johnson, Rajeev-Kumar, & Keil, 2014; Khemlani et al., 2011).

Experiment 1

In Experiment 1, participants gave diagnoses and treatment recommendations for patients with various combinations of symptoms. We measured both participants' preferred actions (i.e., treatment recommendations) and beliefs (diagnoses), to distinguish between the decision-theoretic and pragmatist theories.

Method

We recruited 200 participants from Amazon Mechanical Turk; 32 participants were excluded from data analysis because they failed a manipulation check (see below).

Participants were told that they would learn about some diseases and "a patient who has one of the diseases." Participants completed three items, each specifying that two diseases had equal base rates. For example:

> *There are two rare diseases, called Prasntosis and Hanriosis. Both affect about 1 in 800 people during their lifetimes.*

Then, participants read about the symptoms of each disease, which differed in one symptom that was either minor or severe:

> *Prasntosis causes itchy skin, spots on the face, and mild soreness.*
>
> *Hanriosis causes itchy skin, spots on the face, and a potentially fatal tumor.*

Next, participants read about treatments for the diseases:

> *There are effective medications for treating both Prasntosis and Hanriosis. In a recent study, the Prantosis medicine was effective for 80 out of 100 people, and the Hanriosis medicine was effective for 80 out of 100 people. There are no known side effects or risks associated with taking either medicine.*

Participants then learned about the patient's symptoms. In the *Minor* condition, the patient had all the symptoms of the minor disease:

> *Laura has itchy skin and spots on her face. She also has mild soreness.*

In the *Severe* condition, the patient had all the symptoms of the severe disease:

> *Laura has itchy skin and spots on her face. She also has a potentially fatal tumor.*

Finally, in the *Ambiguous* condition, information about the distinguishing symptom was unavailable:

> *Laura has itchy skin and spots on her face. We don't know whether she has mild soreness or a potentially fatal tumor.*

Participants then completed an *Action* question and a *Belief* question. For the *Action* question, participants were asked to recommend a treatment ("Suppose you can only give medicine to treat one disease. For which disease would you administer the medicine to Laura?") on a scale from 0 ("Definitely Prasntosis") to 10 ("Definitely Hanriosis"). For the *Belief* question, participants were asked to diagnose the patient's disease ("Which disease do you think Laura has?") on the same scale.

The names and order of listing the two diseases was randomized for each item. The order of mentioning the diseases in the Ambiguous condition and the left/right orientation of the rating scales were adjusted to match. The order of the Action and Belief questions was counterbalanced across participants. The assignment of vignette (i.e., names and symptoms of the diseases) was counterbalanced with condition using a Latin square, and items were presented in a random order.

Two manipulation checks were also included. First, after each item, participants were asked to rate the seriousness of each disease. Any participant was excluded who gave a higher seriousness rating for the minor disease for any of the items. Second, at the end of the experiment, participants completed a memory test for items encountered during the experiment. These check questions were included in order to detect participants who might be responding at random. Any participant answering more than one-third of these questions incorrectly was excluded.

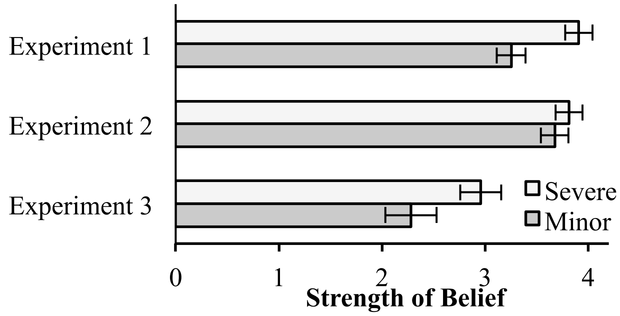

Figure 1: Asymmetry in belief strength between Severe and Minor conditions. Bars represent 1 SE.

Results and Discussion

In reporting results of all experiments, participants' responses were converted to a -5 to 5 scale, where negative scores correspond to the minor explanation and positive scores correspond to the severe explanation.[1]

We first analyzed responses to the Action question, to ensure that our manipulation was successful. In the Minor condition, participants favored the medicine for the minor disease [M = -2.28, SD = 3.43; $t(167)$ = -8.61, p < .001, d = -0.66, BF_{10} > 1000], whereas in the Severe condition, participants strongly favored the medicine for the severe disease [M = 4.48, SD = 1.26; $t(167)$ = 4.48, p < .001, d = 3.56, BF_{10} > 1000]. Finally, in the Ambiguous condition, where the evidence favored neither disease, participants favored treating the serious disease [M = 2.72, SD = 3.43; $t(167)$ = 15.24, p < .001, d = 1.18, BF_{10} > 1000]. Thus, participants chose their actions in accord both with the evidence (favoring actions corresponding to evidence when unambiguous) and with prudence (favoring the safer course of action when the evidence was ambiguous). Further, the inclination to treat the severe disease was much greater when the evidence favored the severe disease, compared to the inclination to treat the minor disease when the evidence favored the minor disease.

Our main interest was in whether these pragmatic considerations might influence participants' beliefs. There are two ways in which this might occur. (Neither effect differed in any experiment as a function of whether the action or belief question was asked first, speaking against the possibility of demand effects or scale biases.)

First, participants could give more extreme belief ratings in the Severe condition than in the Minor condition. This difference occurred: Ratings were more positive in the Severe condition [M = 3.91, SD = 1.73] than they were negative in the Minor condition [M = -3.25, SD = 1.83; $t(167)$ = 4.34, p < .001, d = 0.34, BF_{10} = 436.7], indicating that their belief in the severe disease was stronger when favored by the evidence than was their belief in the minor disease when favored by the evidence. Figure 1 plots this asymmetry for all three experiments, showing mean belief in the Severe condition, and the inverse of the mean in the Minor condition.

Second, participants could favor the severe disease even in the Ambiguous condition, where the evidence was equally consistent with both explanations. Figure 2 plots this effect across all three experiments, showing the mean belief in the Ambiguous condition. This effect was not significant in Experiment 1 [M = 0.14, SD = 1.20; $t(167)$ = 1.47, p = .14, d = 0.11, BF_{01} = 5.6], although the mean was in the predicted direction in all three experiments.

These results support the pragmatist position. Because the base rates of the diseases were equal, evidence favoring the severe disease is no more diagnostic than evidence favoring the minor disease. Yet, participants more strongly believed the severe explanation when favored by the evidence than the minor explanation when favored by the evidence. This follows participants' greater confidence in treating the severe disease in the Severe condition than in treating the minor disease in the Minor condition, and suggests that participants' beliefs were influenced by pragmatic considerations—taking into account the utility of each belief.

If the pragmatist position is correct, then why did participants not reliably favor the serious disease in the Ambiguous condition? Various features of a medical diagnosis task could potentially attenuate this effect. For example, putting oneself in the position of an expert such as a doctor might encourage the use of more deliberate rather than intuitive judgments, which could lead one to rely more on probability and less on belief utility. Further, although the instructions stated that the patient had one of the diseases, diseases are not mutually exclusive, and participants wishing to express a degree of belief that the patient has both symptoms might use the center of the scale to express this belief. In Experiment 2, we used a wider variety of items to address such possibilities.

Experiment 2

Experiment 2 had two primary goals. First, we wished to generalize the effects of belief utility to a wider range of stimuli. If the null effect in the Ambiguous condition of Experiment 1 is due to task features specific to medical diagnosis, then this effect might be detectable in different but conceptually related tasks.

Second, we wished to test whether belief utility is used as an explanatory virtue not only in causal explanation, but also in categorization. Several findings suggest that both categorization and causal explanation may rely in part on the same mechanisms for abductive (data-to-hypothesis) inference (e.g., Johnson, Merchant, & Keil, 2015; Johnson, Rajeev-Kumar, & Keil, 2015). To test

[1] In addition to conventional statistics, we also report Bayes Factors (BFs) for each test (scale factor = 1), because we wished to be able to quantify evidence in favor of the null hypothesis (Rouder, Speckman, Sun, Morey, & Iverson, 2009). For example, if the evidence were three times likelier under the null hypothesis than under the alternative, this would be denoted 'BF_{01} = 3.0'. In contrast, if the evidence were six times likelier under the alternative hypothesis than under the null, this would be denoted 'BF_{10} = 6.0'.

whether belief utility might likewise be an explanatory virtue common to both cause- and category-based explanation, Experiment 2 included both kinds of items.

Method

We recruited 200 participants from Amazon Mechanical Turk; 32 participants were excluded because they failed more than one-third of the check questions.

Participants completed six items, in a format similar to Experiment 1, except a variety of situations were used in place of medical diagnosis. For example, one item read:

> *Imagine you are an airport security personnel in charge of the x-ray machines. You have to determine which bags to open and inspect based on these signals. The x-ray machine gives the following signals to indicate safe and danger.*
>
> *A safe signal results in a square, a ringing tone, and a check mark.*
>
> *A danger signal results in a square, a ringing tone, and an X mark.*
>
> *You see a triangular bag. In your experience, about half of triangular bags are safe and about half are dangerous.*

That is, like the scenarios of Experiment 1, one potential explanation ("the bag is safe") had minor consequences whereas the other ("the bag is dangerous") had severe consequences, and they had equal base rates (since half of triangular bags belong to each category).

Two items (in the *Minor* condition) indicated that all features or effects of the innocuous explanation occurred:

> *The triangular bag gets a square and a ringing tone. It also gets a check mark.*

For two *Severe* items, all consequences of the grave explanation occurred:

> *The triangular bag gets a square and a ringing tone. It also gets an X mark.*

Finally, for two *Ambiguous* items, information about the distinguishing observation was unavailable:

> *The triangular bag gets a square and a ringing tone. You can't tell whether it got a check mark or an X mark.*

The *Action* question asked participants what they would do (e.g., "Would you open and inspect the triangular bag?"), on a scale from 0 ("Definitely No") to 10 ("Definitely Yes"), and the *Belief* question asked participants what they thought the best explanation was (e.g., "Do you think the triangular bag got the safe signal or the danger signal?") on a scale from 0 ("Definitely Safe") to 10 ("Definitely Danger").

Six cover stories were used. In three cases, the explanations were causes that explained effects (airport security, machines at a factory, and automotive repair) and in three cases, the explanations were categories that explained features (animals when hunting, air traffic control signals, and railway signals).

The order of the minor and severe explanations was pseudorandomized across items, and the assignment of the three conditions to the six cover stories was counterbalanced using a Latin square. The 'seriousness' questions from Experiment 1 were omitted to avoid potential demand characteristics, but the memory check was retained at the end of the experiment.

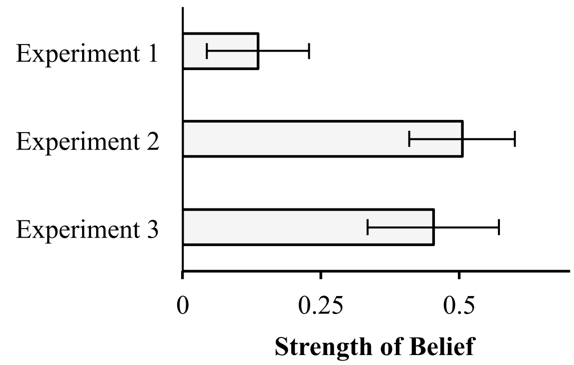

Figure 2: Strength of belief in the severe explanation in the Ambiguous condition. Bars represent 1 SE.

Results and Discussion

As in Experiment 1, participants' action judgments favored the minor explanation in the Minor condition [M = -2.91, SD = 2.43; $t(167)$ = -15.54, p < .001, d = -1.20, BF_{10} > 1000], but more strongly favored the severe explanation in the Severe condition [M = 3.85, SD = 1.81; $t(167)$ = 27.53, p < .001, d = 2.12, BF_{10} > 1000]. They also favored the severe explanation in the Ambiguous condition [M = 3.10, SD = 2.02; $t(167)$ = 19.94, p < .001, d = 1.54, BF_{10} > 1000]. Thus, participants again made judgments in accord with the evidence and with prudence.

As in Experiment 1, participants' beliefs were influenced by prudential considerations. Participants in Experiment 2 favored the severe explanation even in the Ambiguous condition [M = 0.50, SD = 1.24; $t(167)$ = 5.30, p < .001, d = 0.41, BF_{10} > 1000; Figure 2]. That is, when the evidence favored neither explanation, participants favored the explanation corresponding to the prudential course of action. The asymmetry between the strength of belief in the Severe and Minor conditions was not significant in Experiment 2 [M = 3.82, SD = 1.71 and M = -3.68, SD = 1.73; $t(167)$ = 0.91, p = .36, d = 0.07, BF_{01} = 10.9; Figure 1], although it was in the predicted direction in all experiments.

These results once again support the pragmatist view, uncovering an even more flagrant violation of decision-theoretic norms than in Experiment 1. When the evidence is indeterminate between two explanations with equal base rates, the explanations have equal probability. Yet, participants' beliefs favored the severe explanation when the evidence was indeterminate, as predicted by the pragmatist position. These results both generalize effects of belief utility to a broader set of items, and show that belief utility is used as an explanatory virtue both in cause-based and category-based explanations.

Experiment 3

In our previous experiments, the evidence in the Ambiguous condition was indeterminate between the two explanations because a critical piece of diagnostic information was unavailable. In general, people distrust explanations that make unverified or *latent* predictions (Khemlani et al., 2011). Although this bias cannot explain the results of Experiments 1 and 2 because *both* explanations made latent predictions in the Ambiguous condition, we took advantage of this bias to introduce greater perceived ambiguity in Experiment 3. In addition to the latent predictions already made in the Ambiguous condition, we added an additional latent prediction to either the minor or severe explanation in all three conditions. Because explanatory intuitions are less stable when latent predictions are introduced, we anticipated that this added ambiguity could make more room for belief utility to affect explanatory judgments.

Method

We recruited 100 participants from Amazon Mechanical Turk; 10 participants were excluded because they failed more than one-third of the check questions.

Experiment 3 was identical to Experiment 2, except that it incorporated the latent evidence as follows.

For three (*Minor-Latent)* items, the innocuous explanation had an additional consequence (e.g., "a brown dot"), which was unobserved. For example:

> *A safe signal results in a square, a ringing tone, a brown dot, and a check mark.*
>
> *A danger signal results in a square, a ringing tone, and an X mark.*

For the other three (*Severe-Latent*) items, the grave explanation had the additional unobserved consequence:

> *A safe signal results in a square, a ringing tone, and a check mark.*
>
> *A danger signal results in a square, a ringing tone, a brown dot, and an X mark.*

Within each set of three items, there was one item for which there was strong evidence for the *Minor* explanation:

> *The triangular bag gets a square and a ringing tone. It also get a check mark. You can't tell whether it gets a brown dot or not.*

There was one item for which there was strong evidence for the *Severe* explanation:

> *The triangular bag gets a square and a ringing tone. It also gets an X mark. You can't tell whether it gets a brown dot or not.*

Finally, there was one item for which the evidence was ambiguous between the *Minor* and *Severe* explanations:

> *The triangular bag gets a square and a ringing tone. You can't tell whether it got a check mark or an X mark. You also can't tell whether it gets a brown dot or not.*

Which three vignettes were in the *Minor-Latent* or *Severe-Latent* condition was counterbalanced. The other factors were counterbalanced as in Experiment 2. The six items were presented in a random order

Results and Discussion

There were no differences between items for which the latent symptom was diagnostic of the minor or severe explanation, so we collapse across this factor.

Once again, action judgments were as expected, favoring the minor explanation in the Minor condition [M = -1.22, SD = 3.15; $t(90)$ = -3.66, $p < .001$, d = -0.39, BF_{10} = 40.0] and the severe explanation in the Severe condition [M = 3.68, SD = 1.68; $t(90)$ = 20.76, $p < .001$, d = 2.19, $BF_{10} > 1000$] and the Ambiguous condition [M = 2.97, SD = 2.01; $t(90)$ = 14.01, $p < .001$, d = 1.48, $BF_{10} > 1000$].

These prudential considerations again affected belief judgments. First, beliefs favored the severe explanation more in the Severe condition [M = 2.96, SD = 1.90] than they favored the minor explanation in the Minor condition [M = -2.28, SD = 2.36; $t(89)$ = 2.58, p = .011, d = 0.27, BF_{10} = 2.0; Figure 1]. Second, beliefs favored the severe explanation even in the Ambiguous condition, where the evidence was equally consistent with either possibility [M = 0.45, SD = 1.12; $t(89)$ = 3.82, $p < .001$, d = 0.40, BF_{10} = 66.9; Figure 2].

These are the most robust findings in favor of the pragmatist position, since participants' judgments significantly violated decision-theoretic principles in both possible ways. This seems to have occurred because the additional ambiguity introduced by the latent evidence enhanced the effect of belief utility on explanatory judgments. Compared with Experiment 2, the effect in the Ambiguous condition was of similar size [$t(256)$ = 0.33, p = .74, d = 0.04, BF_{01} = 9.2], but the asymmetry between the Minor and Severe conditions was marginally larger [$t(256)$ = 1.92, p = .056, d = 0.25, BF_{01} = 2.6]. Future research should follow up on this result to investigate the role of evidence ambiguity in the use of belief utility.

General Discussion

Our actions are shaped by our beliefs. Here, we showed that our beliefs are also shaped by the potential courses of action they entail—that people take account of *prudential* considerations in their explanatory judgments, in two ways. First, evidence favoring a dire explanation was taken as more diagnostic than evidence favoring an innocuous explanation (Experiments 1 and 3). Second, completely ambiguous evidence was taken to favor a dire explanation (Experiments 2 and 3).

Several alternative explanations should be considered, which could be consistent with the classic decision-theoretic view. First, could the evidence have been seen as more diagnostic when it favored the severe explanation? That is, when a person has a tumor, that might be seen as overwhelming evidence favoring one explanation, whereas when a person has soreness, that may be seen as less convincing evidence favoring the other. Although this could potentially account for the difference between the Minor and Severe conditions, it would not predict any effect in the Ambiguous condition, since the evidence is the same for both explanations. Further, this explanation would not account for Experiments 2 and 3, where the evidence would not seem to differ in diagnosticity (e.g., an X mark or check mark).

Second, could the severe explanations be more salient than the minor explanations, leading them to be more believable? Because imagining something to be true makes it seem more likely to be true (Koehler, 1991), perhaps participants found the more vivid severe explanations (tumors, dangerous bags) to be more believable than the more pallid minor explanations (soreness, safe bags). In one sense, this may be more a mechanism for instantiating prudential considerations, rather than an alternative hypothesis. At the same time, though, this account would seem to predict that making the evidence more ambiguous should make the explanations *less* vivid, and hence would attenuate the effects. Experiment 3 found evidence for the opposite.

Finally, could participants have been interpreting the belief questions ("Which disease do you think Laura has?") as asking about pretense ("Which disease would you act as though Laura has?")? Although this interpretation would indeed lead to the same pattern of results that we found, we think it is unlikely that this is driving our results. These belief questions were asked on the same page as a question asking directly about which course of action the participant would take ("For which disease would you administer the medicine to Laura?"), which should pragmatically discourage participants to encourage the belief question as asking about their actions. Further, the order of asking the belief and action questions did not make any difference, as it should have if the belief question was found to be ambiguous.

These results have broad implications for reasoning, judgment, and decision-making. Although expected utility theory has been widely challenged (Shafir & LeBoeuf, 2002), the underlying assumption that beliefs are computed independently of the utility of actions has remained unchallenged. These findings complicate this picture, showing that the potential courses of actions implied by our beliefs feed back to affect those beliefs.

To the extent that our decision-making capacity might 'double correct' for what is prudent, this could result in overly conservative behavior, such as extreme risk aversion. Further, belief utility seems to exert a stronger effect when people are less able to estimate precise probabilities—a situation that may be all too common in day-to-day life. Yet, interventions might be devised to encourage people to form their beliefs in accordance with the evidence rather than their utility. Such interventions await empirical support.

Acknowledgments

We thank Laurie Santos, Josh Knobe, and the members of the Cognition and Development Lab for discussion.

References

Evans, J.St.B.T., & Over, D.E. (1996). *Rationality and reasoning*. East Sussex, UK: Psychology Press.

Fiske, S.T. (1992). Thinking is for doing: Portraits of social cognition from daguerreotype to laserphoto. *Journal of Personality and Social Psychology*, *63*, 877–889.

James, W. (1983). *The principles of psychology*. Cambridge, MA: Harvard University Press. (Original work published 1890.)

Jeffrey, R. C. (1965). *The logic of decision*. New York, NY: McGraw-Hill.

Johnson, S.G.B., Merchant, T., & Keil, F.C. (2015). Predictions from uncertain beliefs. *Proceedings of the 37th Annual Conference of the Cognitive Science Society*. Austin, TX: Cognitive Science Society.

Johnson, S.G.B., Rajeev-Kumar, G., & Keil, F.C. (2014). Inferred evidence in latent scope explanations. *Proceedings of the 36th Annual Conference of the Cognitive Science Society*. Austin, TX: Cognitive Science Society.

Johnson, S.G.B., Rajeev-Kumar, G., & Keil, F.C. (2015). *Sense-making under ignorance*. Manuscript under review.

Johnson, S.G.B., & Rips, L.J. (2015). Do the right thing: The assumption of optimality in lay decision theory and causal judgment. *Cognitive Psychology*, *77*, 42–76.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, *47*, 263–291.

Khemlani, S. S., Sussman, A. B., & Oppenheimer, D. M. (2011). *Harry Potter* and the sorcerer's scope: Latent scope biases in explanatory reasoning. *Memory & Cognition*, *39*, 527–535.

Koehler, D.J. (1991). Explanation, imagination, and confidence in judgment. *Psychological Bulletin*, *110*, 499–519.

Lombrozo, T. (2007). Simplicity and probability in causal explanation. *Cognitive Psychology*, *55*, 232–257.

Peirce, C.S. (1997). *Pragmatism as a principle and method of right thinking: The 1903 Harvard lectures on pragmatism*. Albany, NY: SUNY Press.

Rouder, J.N., Speckman, P.L., Sun, D., Morey, R.D., & Iverson, G. (2009). Bayesian *t* tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin & Review*, *16*, 225–237.

Shafir, E., & LeBoeuf, R.A. (2002). Rationality. *Annual Review of Psychology*, *53*, 491–517.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, *185*, 1124–1131.

Von Neumann, J., & Morgenstern, O. (1944). *Theory of games and economic behavior*. Princeton, NJ: Princeton University Press.