Inhibiting beliefs demands attention

Kevin Barton, Jonathan Fugelsang, and Daniel Smilek

University of Waterloo, Ontario, Canada

Research across a variety of domains has found that people fail to evaluate statistical information in an atheoretical manner. Rather, people tend to evaluate statistical information in light of their pre-existing beliefs and experiences. The locus of these biases continues to be hotly debated. In two experiments we evaluate the degree to which reasoning when relevant beliefs are readily accessible (i.e., when reasoning with Belief-Laden content) versus when relevant beliefs are not available (i.e., when reasoning with Non-Belief-Laden content) differentially demands attentional resources. In Experiment 1 we found that reasoning with scenarios that contained Belief-Laden content required fewer attentional resources than reasoning with scenarios that contained Non-Belief-Laden content, as evidenced by smaller costs on a secondary memory load task for the former than the latter. This trend was reversed in Experiment 2 when participants were instructed to ignore their beliefs when reasoning with Belief-Laden and Non-Belief-Laden scenarios. These findings provide evidence that beliefs automatically influence reasoning, and attempting to ignore them comes with an attentional cost.

Keywords: Attention; Beliefs; Causal reasoning; Dual process theory; Inhibition.

One is frequently required to make decisions about causal hypotheses based on information acquired through many sources. Often these decisions involve choosing between two or more competing potential causes for a single observed outcome. For example, consider the case of having nasal congestion. Nasal congestion can be caused by a number of factors, two of

which are seasonal allergies and the common cold. How does one decide which potential cause is the likely candidate in a given situation? One approach is to make the decision based on the available statistical data, such as the current pollen counts for the region and their relation with incidence rates of the common cold. Here, one presumably would rely on "rational" or "logical" reasoning processes to arrive at a conclusion. Another approach is to rely on one's "intuitions" or prior beliefs about likely causes of nasal congestion. Decades of research have clearly established that people use both of these approaches when making decisions and that often these approaches are used simultaneously and interact whereby one's beliefs influence how normative information is interpreted (e.g., Evans, 1989; Evans, Barston & Pollard, 1983; Fugelsang & Dunbar, 2005; Fugelsang & Thompson, 2000, 2001, 2003; Fugelsang, Stein, Green, & Dunbar, 2004; Gigerenzer & Goldstein, 1996; Kahneman & Tversky, 1996; Klahr, Fay, & Dunbar, 1993; Koehler, 1993; Todd & Gigerenzer, 2000; Tversky & Kahneman, 1974).

DUAL-PROCESS THEORIES AND REASONING

Several influential dual-process theories of thinking and reasoning have been proposed to account for the observed interactions between beliefs and logical reasoning processes on a variety of reasoning tasks (e.g., Evans, 2006; Evans & Over, 1996; Kahneman & Frederick, 2002; Sloman, 1996; Stanovich, 1999; Stanovich & West, 2000). Although the specific formulations of the theories differ, they all posit the operation of two "systems" (hereafter denoted System 1 and System 2) that contribute to responses. System 1 processes are characterised as being heuristic, fast, automatic, and unconscious, whereas System 2 processes are characterised as conscious, controlled, slow, and analytic (see Evans, 2008, 2009, for a comprehensive list of the hypothesised attributes of System 1 and System 2). The extent to which the two systems operate sequentially (e.g., Evans, 1989; Kahneman & Frederick, 2002), in parallel (e.g., Sloman, 1996; Stupple & Ball, 2008), or in a sequential/parallel hybrid fashion (Evans, 2009), and how conflicts between the two systems are processed and resolved, are topics of much debate (see Evans, 2007, 2009; De Neys & Glumicic, 2008, for extensive coverage of this debate).

How are *beliefs* applied when reasoning? Perhaps the most extensive formulation of the application and role of beliefs in reasoning is expressed in the heuristic-analytic dual-process theory of reasoning (Evans, 2006). Here, heuristic processing corresponds to System 1, and analytic processing corresponds to System 2. In developing this theory, Evans and his colleagues (e.g., 1984, 1989, 2006; Evans & Over, 1996, 1997) have proposed that most of learning, including the application of prior beliefs, occurs unconsciously

and intuitively. In this respect, much of the behaviour observed in typical reasoning tasks can be attributed to the unconscious application of prior knowledge and beliefs, which are described as being both heuristic and tacit. Conscious processes, on the other hand, are assumed to be applied ad hoc, and are associated with reasoning performance described as being both analytic and logical. Both processes are combined in the two-stage heuristic-analytic theory whereby the heuristic processes (governed by beliefs) determine which aspects of the problem are relevant, and the analytic processes then focus only on those aspects of the problem pre-consciously deemed relevant. Furthermore, Evans (2006) proposes that heuristic (i.e., belief-based) processing provides *default* responses that can control behaviour directly unless analytic processing intervenes. The degree to which these default heuristic responses can be inhibited, and if so, at what attentional cost is the focus of the present experiments.

EVIDENCE FOR DIFFERENTIAL ATTENTIONAL DEMANDS OF SYSTEM 1 AND SYSTEM 2 PROCESSING

The proposed characteristics of the two systems give rise to several predictions regarding the role of working memory and attentional processes in reasoning. For example, if reasoning with beliefs occurs predominantly through unconscious and heuristic means (System 1), and reasoning with the available data (in the form of logical content, or statistical data) requires deliberate conscious processing (System 2), the latter should demand attentional resources while the former should not. Past investigations of the role of attention in reasoning paradigms have found support for the hypothesis that the amount of attentional resources available to the individual at the time of reasoning is related to their performance in a variety of reasoning tasks.

For instance, in studies observing eye-movements of participants during evaluation of information, an asymmetry of attentional selection has been observed whereby people spend significantly more time examining information that confirms their initial hypotheses (see Evans, 1996, for similar findings using mouse-pointing technology). This pattern has been reported for both indicative (factually based) decisions (Ball, Lucas, Miles, & Gale, 2003) and deontic (behaviourally motivated) decisions (Ball, Lucas, & Phillips, 2005). These findings imply that attention might modulate the interplay between prior beliefs and other available data (e.g., logical form) during decision making. However, because attention was not directly manipulated in these studies, the causal role of attention cannot be firmly established.

Stronger support for the causal influence of attention on decision making comes from a recent study reported by Evans and Curtis-Holmes (2005).

They used a syllogistic reasoning task and had participants make decisions either when they were under no time pressure or when they were forced to make speeded responses. The assumption was that fewer attentional resources are available when decision making is speeded than when there is no time constraint on decision making. The results showed a greater reliance on prior beliefs when the task was speeded than when there was no time constraint. This finding was used by the authors to further the argument that constriction of attention through speeded reasoning increases one's reliance on prior beliefs over other consideration factors. They further argued that the secondary analytic processing was not affected by time constraint, as the endorsement of valid over invalid syllogisms was still significantly higher. These findings imply that the relative use of prior beliefs and data during reasoning depends on the amount of attentional resources available. It could be argued, however, that a reduction of the time available for the reasoning process is not a direct manipulation of attentional resources, but rather limits the amount of time for reasoning processes to unfold. As such, these findings only provide indirect support for the idea that the interaction between beliefs and data during reasoning depends on the availability of attentional resources.

Perhaps the most direct evidence for the causal role of attentional processes in reasoning comes from divided attention paradigms. Numerous experiments have been conducted that have examined the role of working memory and attention directly by using divided attention methodologies in a variety of reasoning and decision-making paradigms, such as reasoning about linear relationships (e.g., Baddeley & Hitch, 1974), conditional inference statements (e.g., Evans & Brooks, 1981), categorical syllogisms (e.g., Gilhooly, Logie, & Wynn, 1999, 2002), and probability judgements (e.g., De Neys, 2006a), to name a few. The primary method utilised in these experiments (and the current experiments) is some form of dual-task methodology. Here, participants are typically asked to perform a reasoning task (primary task) while simultaneously performing an attention-demanding task (secondary task) designed to burden attention and working memory resources. The general finding is that divided attention disrupts System 2 processing, as such processing requires attentional resources to operate. This disruption of System 2 processing can then simultaneously permit System 1 (the heuristic system) to dominate responding. Given the association between belief-based processing and System 1, and the relationship between attentional resources and System 2, dual-process theories make another prediction that still remains to be tested directly; namely that the direct suppression of belief-based processing in reasoning will come at an attentional cost.

Relatively few studies have examined the direct role of attention and working memory on belief biases in reasoning using a divided attention

paradigm. A key study examining these issues was conducted by De Neys (2006b). He presented participants with a series of categorical syllogisms that varied in terms of the believability and the logical form of the conclusions. Importantly, participants responded to the syllogisms while performing a secondary task designed to load executive working memory. In addition, participants' working memory span was also assessed via a group-testing version of the operation span task (Le Point & Engle, 1990). De Neys (2006b) found that a secondary memory load disrupted performance on syllogisms in which belief and logic were in conflict, but not when they were congruent. This effect occurred regardless of participants' baseline individual differences in working memory capacity. These data were taken as support for dual-process theories, as they revealed different processing demands for reasoning with problems designed to differentially promote System 1 and System 2 responding.

THE CURRENT EXPERIMENTS

In summary, past research on reasoning with beliefs has found differential attentional requirements of System 1 and System 2 processing, and thus support for dual-process theories of reasoning and decision making. In the current series of experiments we extend this line of research in three important ways. First, we examine the role of attentional processes in reasoning with beliefs and statistical data in a causal reasoning paradigm. To date there has been no research that we are aware of that has directly examined the role of attention in this active field of research. Second, we examine the degree to which beliefs in this paradigm can be *inhibited* to allow analytic processing (System 2) to unfold in an unbiased fashion. Third, we examine an important assumption of dual-process theories, namely that the inhibition of the heuristic system draws on limited attentional and executive working memory resources (Stanovich & West, 2000).

In the current studies we evaluate whether and how the interaction between prior beliefs and statistical data during causal decision making directly depends on the availability of attentional resources. We take a novel approach to this investigation by examining the degree to which allowing beliefs to influence decision making affects performance on a secondary attention-demanding task. In Experiment 1 we evaluate whether reasoning requires fewer attentional resources when relevant beliefs are readily accessible (i.e., when reasoning with Belief-Laden content) than when relevant beliefs are not available (i.e., when reasoning with Non-Belief-Laden content). Since reasoning with beliefs allows System 1 to contribute to responding, we predict that reasoning will be less attention demanding when reasoning with Belief-Laden versus Non-Belief-Laden content (which

presumably would require predominantly System 2). In Experiment 2 we explore the degree to which beliefs in this paradigm can be *inhibited* by an instructional manipulation requiring participants to try to ignore the content of the stimuli. If successful, this presumably will allow analytic processing to dominate responding. Furthermore, we predict that the inhibition of beliefs, which are thought to be the domain of System 1 processing, will come at an attentional cost and thus result in reduced performance on the secondary attention-demanding task.

EXPERIMENT 1

The purpose of Experiment 1 was to evaluate whether reasoning with the aid of beliefs reduces the demands of attention as indexed by increased performance on a concurrent attention-demanding task relative to reasoning without the aid of beliefs. This prediction follows from the prior proposal regarding the heuristic nature, and thus relatively automatic and attentional capacity free, nature of belief-based System 1 processing. The reasoning task consisted of a series of story scenarios requiring the participant to determine which of two competing causal options was responsible for a specific outcome. For example, one scenario contained the following information: "Imagine you are a university professor who is trying to determine the cause of student success on exams. You have two hypotheses: studying or eating cornflakes." As can be clearly seen in this example, participants likely have readily accessible prior beliefs about the efficacy of the possible causes in this scenario. Also, as in this example, each of these Belief-Laden scenarios always included one believable cause (in this case studying) and one unbelievable cause (in this case eating cornflakes). Importantly, we also included scenarios for which participants did not have clear prior beliefs about the possible causes (Non-Belief-Laden stimuli). For example, in these scenarios the candidate cause was a fictitious agent (e.g., eating "endless"). These Non-Belief-Laden scenarios also included two causes, one of which was randomly assigned to be believable and the other to be unbelievable (for direct comparison to the Belief-Laden scenarios). Table 1 presents the mean belief and familiarity ratings for the Belief-Laden and Non-Belief-Laden stimuli collected from an independent sample of 56 participants.

These scenarios were paired with statistical data (presented as the number of cases out of 100) such that (a) the "believable" candidate cause was more prevalent than the non-believable candidate (the believable candidate occurred 70 out of 100 occurrences, whereas the unbelievable candidate occurred 30 out of 100 occurrences), (b) the "believable" and "unbelievable" candidates were equally prevalent (both occurred 50 out of the 100 occurrences), and (c) the believable candidate was less prevalent than the

TABLE 1
Mean belief and familiarity ratings

Stimulus type A priori classification	Belief-Laden		Non-Belief-Laden	
	High Believable Option	Weakly Believable Option	Option 1	Option 2
Average believability (SD)	6.29 (1.04)	1.89 (1.20)	3.61 (1.13)	3.24 (1.21)
Average familiarity (SD)	5.56 (1.49)	3.69 (2.24)	1.55 (1.11)	1.33 (0.83)

Mean belief and familiarity ratings for the Belief-Laden and Non-Belief Laden stimuli collected from an independent sample of 56 participants. Responses for both questions were indicated using a 7-point Likert scale that ranged from 1 (not believable/familiar) to 7 (highly believable/familiar) with a midpoint of 4 (moderately believable/familiar). Standard deviations are in parentheses.

unbelievable candidate. These levels of the accompanying statistical data-independent variable will be referred to as 70% Believable, 50% Believable, and 30% Believable respectively. Furthermore, in order to avoid any bias in reasoning based on spatial location, each of the two options was counterbalanced visually in subsequent trials both vertically and horizontally on the display. Although this data-strength manipulation is secondary for our interests, its inclusion is necessary as a manipulation check to confirm that participants are actually using the statistical data when reasoning. Specifically, participants' responses should increase as a function of the strength of the statistical data.

Critically, participants performed the reasoning task either with a concurrent attention-demanding task (load) or without having to complete the secondary task (no-load). The secondary task involved holding the configuration of four items in memory during the reasoning task. We expected that reasoning with Non-Belief-Laden content would require more attentional resources than reasoning with Belief-Laden content. Accordingly, we expected that the secondary task performance would be impaired more when reasoning with Non-Belief-Laden than Belief-Laden content.

Method

Participants. A total of 24 undergraduate students attending the University of Waterloo completed a computer-based reasoning task in exchange for course credit or pay.

Materials and procedures. The items in the experiment consisted of eight scenarios (complete list of stimuli available on request). Four of the

scenarios contained Belief-Laden content, whereas the remaining four scenarios contained Non-Belief-Laden content as described in the introduction. Each participant completed 96 experimental trials (8 scenarios × 3 evidentiary support pairs [70% Believable, 50% Believable, and 30% Believable] × 4 possible locations on the screen [top/bottom, left/right]). Each experimental trial (containing the four Belief-Laden and four Non-Belief-Laden scenarios) was presented in a different random order for each participant. In addition, to assess the attentional demands of the reasoning task, a dual-task paradigm was used. Specifically, each trial began with a causal reasoning scenario being presented to the participant in the top third of the screen. The participant was instructed to read the scenario and to press any key to continue the experiment. Immediately following the key press, the participant was presented with either a "No memory" instruction or a "Remember" instruction in the centre of the screen, which was followed by the load manipulation. To load attentional and working memory resources, we adapted a visual memory load task previously demonstrated to be highly sensitive to processing demands in a variety of cognitive tasks (e.g., Woodman, Vogel, & Luck, 2001). In this task an array of four left or right open-faced polygons was presented directly beneath the instruction in the "Remember" condition. In the "No memory" condition no visual array was presented. This display remained on screen for 2000 ms, during which time it was expected the participant would focus their attention on remembering the spatial array. Participants were instructed at the beginning of the experiment that the most important aspect of the experiment was remembering the array when it was presented. Following the "memory" display, the initial scenario was returned to the upper third of the screen with an appended statement of "To test these hypotheses you collected the following data:" and the two hypothesised causes were placed below the scenario, one on the left side of the screen, and the other on the right. Accompanying each cause was the level of evidentiary support located adjacent to the cause. Participants were simply instructed to use their best judgement in making the decision about which of these two causes presented with the scenario was the more likely cause and indicate their judgement by pressing "Z" for the left causal option, or "M" for the right causal option on the keyboard. Following this key press, either a "No recall" instruction appeared in the centre of the screen similar to the "No memory" instruction presented earlier in the trial, or a "Recall" instruction accompanied by an array of left and right open-faced polygons. On half the trials the Recall array matched the array previously displayed, and half the trials the array was novel. Participants were required to press "Z" if they thought the array was the same, or "M" if they thought the array was novel.

Results and discussion

The results for this experiment will be presented in two sections. In the first section, we analyse the degree to which participants were influenced by the content (Belief-Laden versus Non-Belief-Laden stimuli) and the data, to serve as a manipulation check that these manipulations were effective. In the second section, we analyse the degree to which reasoning with Belief-Laden versus Non-Belief-Laden content differentially demands attentional resources as measured in terms of performance on the secondary task. Effect size estimates were computed using partial η^2.

A 2 (Content: Belief-Laden versus Non-Belief-Laden) $\times$ 3 (Data: 70% Believable, 50% Believable, versus 30% Believable) repeated-measures ANOVA was performed on the response data. The response data were analysed as the number of responses made towards the specific Content and Data level as a proportion of the total number of responses possible for that trial. Figure 1 presents the effects of Content and statistical Data on causal
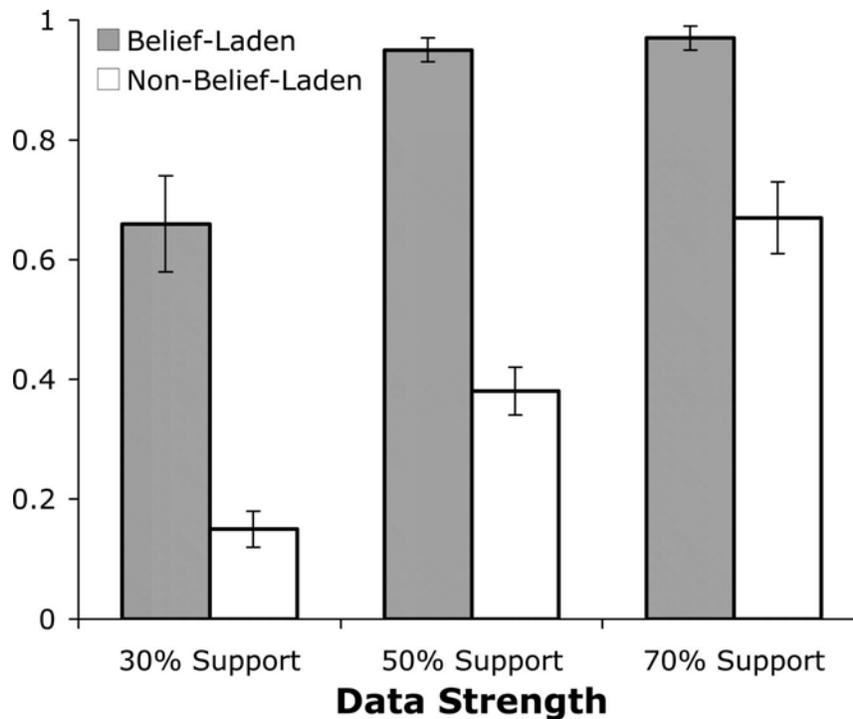
Figure 1. The effects of content and data on causal judgements for Experiment 1. Error bars depict the standard error of the mean.

judgements, and Figure 2 presents the effects of Content and Data on secondary task performance for Experiment 1. As the level of belief (low versus high) in the Belief-Laden content condition was tied to specific statistical Data outcomes, the data in Figure 1 only depict responses to the believable items for these stimuli. The proportion of times the non-believable option was selected represents the remainder of the probability. For example, if the believable option was selected 85% of the time, necessarily the unbelievable option was selected 15% of the time.

A main effect of Content, $F(1, 23) = 94.59$, $MSE = .08$, $p < .01$, $\eta^2 = .80$, was found such that participants endorsed Belief-Laden options significantly more than Non-Belief-Laden options. In addition, there was a main effect of the statistical Data manipulation, $F(2, 46) = 26.27$, $MSE = .08$, $p < .01$, $\eta^2 = .53$, whereby endorsements were more likely when the evidence was strong than when the evidence was weak. Finally, a significant Content × Data interaction was also observed, $F(2, 46) = 11.50$, $MSE = 0.02$, $p < .01$, $\eta^2 = .33$. As can be seen from Figure 1, the locus of
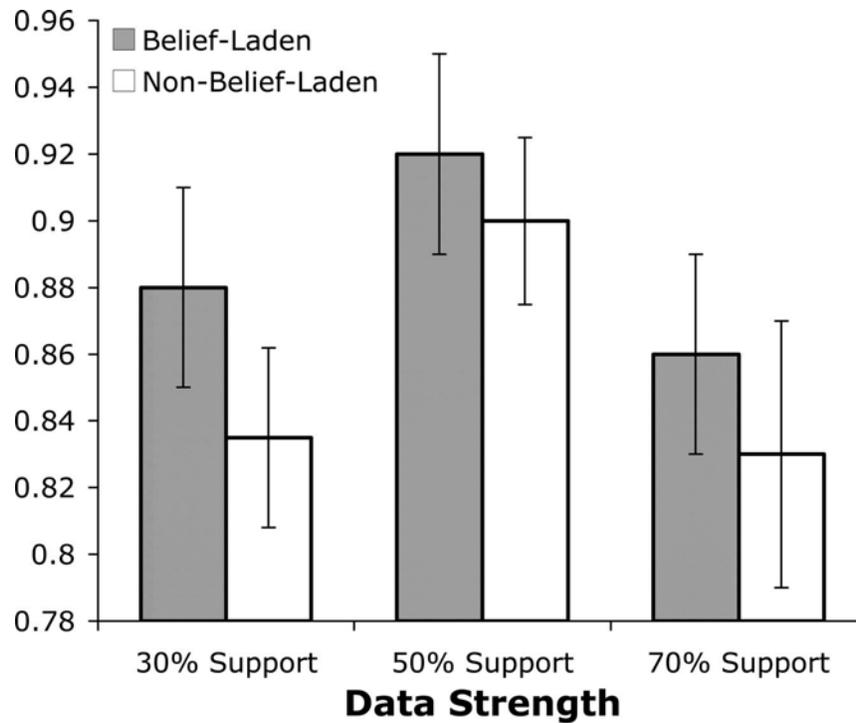
Figure 2. The effects of content and data on secondary task performance for Experiment 1. Error bars depict the standard error of the mean.

this interaction was due to the fact that judgements increased linearly as a function of statistical Data for the Non-Belief-Laden content, but reached ceiling for the scenarios containing Belief-Laden content when they were paired with moderate data (50% Believable) and strong data (70% Believable). These trends were substantiated by statistical analysis that revealed a significant linear, $F(1, 23) = 40.91$, $MSE = 0.08$, $p < .01$, $\eta^2 = .64$, but not quadratic, $F(1, 23) = 1.05$, $MSE = 0.02$, $p > .05$, $\eta^2 = .04$, trend for the Non-Belief-Laden content, and a significant quadratic trend, $F(1, 23) = 11.39$, $MSE = 0.07$, $p < .01$, $\eta^2 = .33$, for the Belief-Laden content.

Our critical analyses pertain to examining the effects of Content and Data on secondary task performance. A 2 (Content: Belief-Laden versus Non-Belief-Laden) × 3 (Data: 70% Believable, 50% Believable, versus 30% Believable) repeated-measures ANOVA was performed on the accuracy data for the secondary "memory" task. A significant main effect of Content on the accuracy of the secondary task judgement was observed, $F(1, 23) = 6.69$, $MSE = 0.06$, $p < .05$, $\eta^2 = .23$. Specifically, accuracy on the secondary memory task was higher when reasoning with Belief-Laden content, than when reasoning with Non-Belief-Laden content. Neither the effects of Data, $F(2, 46) = 2.47$, $MSE = .02$, $p > .05$, $\eta^2 = .10$, nor the Content × Data interaction, $F(2, 46) = .14$, $MSE = .01$, $p > .05$, $\eta^2 < .01$, were significant. Even though the main effect of the statistical Data was not significant, it is interesting to note that there was a significant quadratic trend, $F(1, 23) = 7.86$, $MSE = 0.01$, $p < .01$, $\eta^2 = .26$, whereby performance on the secondary task was highest in the 50% data support condition. This is likely due to the decreased statistical reasoning required when both causal candidates have equal data support. This reduction of statistical reasoning, which presumably results in the reduction of deliberate System 2 processing, thus frees up attentional resources for the secondary task.

In summary, these data clearly show that reasoning with the Belief-Laden scenarios taxed working memory less than reasoning with Non-Belief-Laden scenarios. This finding suggests that reasoning *without* the aid of beliefs requires more attentional resources presumably as this limits the contribution of System 1 to responding.

EXPERIMENT 2

In Experiment 1 we established that reasoning with Belief-Laden content requires fewer attentional resources than reasoning with Non-Belief-Laden content. In Experiment 2 we sought to examine the degree to which beliefs in this paradigm can be inhibited, and if so, at what attentional cost. To address this issue we instructed participants to ignore their beliefs about the content when making judgements for both the Belief-Laden and Non-Belief-Laden scenarios. In addition we simplified the presentation of statistical

data. Specifically, rather than depicting the data in terms of the number of times the potential cause occurred with the outcome out of 100 trials, statistical data was presented in terms of the number of studies (out of 10). We adopted this simplification of the presentation of statistical data (i.e., reduced frequencies while holding actual ratios constant to Experiment 1) in order to presumably simplify the analytic task and thus further promote analytic (System 2) processing. This in effect works against us, and would make any failure to (and attentional cost of) inhibiting beliefs (System 1) even more noteworthy.

We predict that the instructional manipulation to *ignore* beliefs should significantly reduce the effect of Content, and thus potentially equate responses for the Belief-Laden and Non-Belief-Laden material (i.e., promote System 2 to dominate responding). However, it is also expected that this reduction in the use of beliefs will come at a cost. Specifically, it is anticipated that the act of inhibiting one's beliefs will require additional attentional resources. This should reveal itself in terms of reduced performance in the secondary memory task for scenarios with Belief-Laden content when contrasted with those with Non-Belief-Laden content.

Method

Participants.   A total of 24 undergraduate students attending the University of Waterloo completed the experiment in exchange for course credit or pay.

Procedure.   Experiment 2 used the same trial structure and manipulations as Experiment 1 with the following exceptions. First, in place of the instruction to "consider all available information on each trial prior to making your decision", participants were instructed to "avoid using your pre-existing beliefs about each of the options in making your decision". After this initial instruction, the 48 Belief-Laden and 48 Non-Belief-Laden trials were presented in random order for each participant. Second, the statistical data strength for each option was described as "the number of scientific studies found to support the hypothesised cause". In order to facilitate this new description, the statistical data levels were decreased by a factor of 10 from Experiment 1. Specifically, data strength of "70/100" was now "7/10", data strength of "50/100" was now "5/10", and data strength of "30/100" was now "3/10".

Results and discussion

Figure 3 presents the effects of Content and statistical Data on causal judgements, and Figure 4 presents the effects of Content and Data on
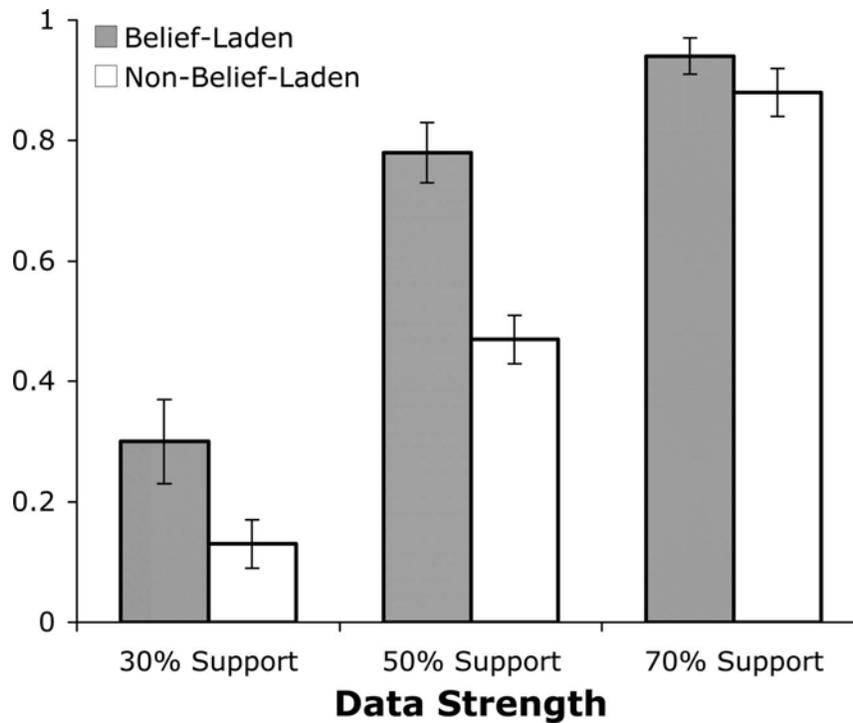
Figure 3. The effects of content and data on causal judgements for Experiment 2. Error bars depict the standard error of the mean.

secondary task performance. As with the prior experiment, a 2 (Content: Belief-Laden versus non Belief-Laden) × 3 (Data: 70% Believable, 50% Believable, versus 30% Believable) repeated-measures ANOVA was performed on the responses. Surprisingly, the instruction for participants *not* to use beliefs did not eliminate the effect of Content, in that a significant main effect of Content was still observed, $F(1, 23) = 15.41$, $MSE = .07$, $p < .01$, $\eta^2 = .40$. Specifically, stimuli with Belief-Laden content were selected as causal significantly more often than Non-Belief-Laden stimuli. In addition, as expected, a main effect of Data was found on responses, $F(2, 46) = 81.60$, $MSE = .07$, $p < .01$, $\eta^2 = .78$, where causal endorsements increased with increasing data support. In addition, similar to Experiment 1, there was a significant Content × Data interaction, $F(2, 46) = 8.169$, $MSE = .02$, $p < .01$, $\eta^2 = .26$, whereby responses to the items with Belief Laden content approached ceiling for the high belief candidates associated with moderate and strong data. As with the previous experiment, judgements for the Non-Belief-Laden stimuli were more linear. These trends were substantiated by an analogous statistical analysis to Experiment 1 revealing a
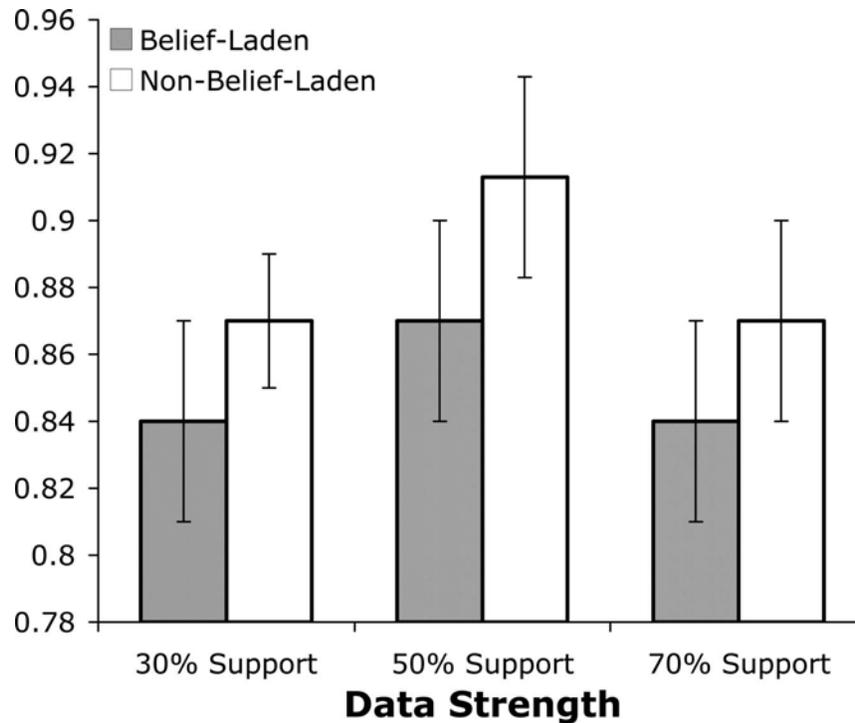
Figure 4. The effects of content and data on secondary task performance for Experiment 2. Error bars depict the standard error of the mean.

significant linear, $F(1, 23) = 96.15$, $MSE = 0.07$, $p < 0.01$, $\eta^2 = .81$), but not quadratic, $F(1, 23) = 1.18$, $MSE = 0.02$, $p > .05$, $\eta^2 = .05$, trend for the Non-Belief-Laden content, and a significant quadratic trend, $F(1, 23) = 12.60$, $MSE = 0.03$, $p < .01$, $\eta^2 = .35$, for the Belief-Laden content.

Analysis of the secondary-task accuracy using a 2 (Content: Belief-Laden versus Non-Belief-Laden) × 3 (Data: 70% Believable, 50% Believable, versus 30% Believable) repeated measures ANOVA revealed a significant main effect of Content on accuracy, $F(1, 23) = 5.87$, $MSE = 0.04$, $p < .05$, $\eta^2 = .20$, with accuracy now being higher on trials in which the reasoning task involved Non-Belief-Laden content as opposed to Belief-Laden content. Note that this main effect of Content in this experiment is the *inverse* of the relation observed in Experiment 1. Importantly, this reversal was also supported by a comparison of the secondary task accuracy scores across the two experiments. Specifically, a 2 (Experiment: Exp 1 versus Exp 2) × 2 (Content: Belief-Laden versus Non-Belief-Laden) interaction was discovered, $F(1, 46) = 12.5$, $MSE = 0.03$, $p < .01$, $\eta^2 = .21$, whereby performance on the secondary task was significantly reduced from Experiment 1 to

Experiment 2 for Belief-Laden content (to an extent where performance was actually lower than the Non-Belief-Laden content) when participants were instructed to avoid using their beliefs. Like Experiment 1, neither the effects of Data, $F(2, 46) = 1.66$, $MSE = .01$, $p > .05$, $\eta^2 = .07$, nor the Content $\times$ Data interaction, $F(2, 46) = .08$, $MSE = .01$, $p > .05$, $\eta^2 < .01$, were significant. Interestingly, as was the case in Experiment 1, there was a significant quadratic trend of the Data manipulation on secondary task performance, $F(1, 23) = 5.11$, $MSE = 0.01$, $p < .01$, $\eta^2 = .18$, whereby performance on the secondary task was highest again in the 50% support condition.

In summary, these findings suggest that although the impact of beliefs can be reduced through instruction manipulations to ignore the content, beliefs still influenced causal judgements. Furthermore, these findings suggest that trying to *inhibit* one's beliefs while reasoning comes with a significant attentional cost.

GENERAL DISCUSSION

The current study investigated the role of attentional resources in the reliance on belief and data in a causal hypothesis-testing paradigm. This was examined by using a novel paradigm wherein the attentional demands of reasoning were assessed by measuring performance on a secondary memory task. Several novel findings emerged. First, under all conditions, prior beliefs influenced decision making, in that Belief-Laden stimuli were given higher causal judgements than Non-Belief-Laden stimuli. Importantly this effect even occurred when participants were given explicit instructions to ignore the content and just concentrate on the data. These findings suggest that under certain circumstances, such as those encountered in the current experiments, ignoring one's beliefs might not be possible. Second, as was evident from Experiment 1, using beliefs (i.e., reasoning with Belief-Laden content) requires fewer attentional resources than when beliefs are un-available (i.e., reasoning with Non-Belief-Laden content). Finally, and per-haps most interestingly, attempting to inhibit using beliefs (Experiment 2) requires more attentional resources than when reasoning while beliefs are simply not available.

These data can be interpreted in terms of contemporary dual-process theories of reasoning outlined in the introduction. One of the key assumptions of this framework is that belief-based processes (governed by System 1) can proceed automatically to aid in reasoning and decision making without causing a burden on limited attentional resources. Consistent with this assumption, reasoning from beliefs in the present paradigm required fewer attentional resources than did reasoning without the aid of beliefs. Decades of research have supported the assumption that

such automatic processes can be executed involuntarily and are less constrained by the capacity limitations of working memory (e.g., Schneider & Shiffrin, 1977). Specifically, when people perform a novel cognitive task, performance on that task is governed by the attentional limitations of working memory. Through repeated practice, however, the once novel task can become automatised and thus free from the attentional limitations of working memory.

Our data take this dichotomy one step further by elucidating the attentional cost of attempting to halt this belief application directly through instructional manipulations. Proponents of dual-process theories have stipulated that the inhibition of a System 1 process through conscious intervention should come at an attentional cost (De Neys, 2006b; Evans, 2008; Stanovich & West, 2000). The present findings, however, reveal that one's ability to overcome System 1 processes may be limited. Specifically, even with specific instructions to ignore the content, the believability of the causal candidates significantly influences responding. This inability to completely inhibit beliefs through instructional manipulations has also been observed in deductive reasoning (Evans, Allen, Newstead, & Pollard, 1994). This difficulty of ignoring the infiltration of beliefs is reminiscent of lower-level cognitive phenomena such as the Stroop effect (Stroop, 1935). Here, it has been proposed that word reading interferes with colour naming due to the preservation of the highly trained and automatic word reading response (MacLeod, 1991). In the current paradigm, the application of beliefs can be thought of in a similar light. Specifically, our data support the hypothesis that the application of causal beliefs (like word reading) is *relatively* automatic, and the preservation of which takes precedent over competing tasks. However, an important difference between the current reasoning task and lower-level attentional tasks (such as the Stroop task) is that the influence of beliefs can be reduced by instructing participants to ignore their beliefs, as evidenced by the smaller effects of beliefs in Experiment 2 relative to Experiment 1.

Finally, we wish to highlight an important practical implication of the present findings. Our findings particularly apply to those situations in which individuals are required to make rapid decisions on the basis of a combination of prior experience (i.e., prior beliefs) and data. Such a case might be very common during medical diagnoses in emergency situations. Our findings suggest that in these situations prior beliefs will likely have an unduly large impact on performance and that trying to mitigate the influence of prior beliefs will have a deleterious influence on the performance of other concurrent tasks.

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