Research Article

Smarter Than We Think

When Our Brains Detect That We Are Biased

Wim De Neys,[1] Oshin Vartanian,[2] and Vinod Goel[2]

[1]University of Leuven and [2]York University

ABSTRACT—*Human reasoning is often biased by stereotypical intuitions. The nature of such bias is not clear. Some authors claim that people are mere heuristic thinkers and are not aware that cued stereotypes might be inappropriate. Other authors claim that people always detect the conflict between their stereotypical thinking and normative reasoning, but simply fail to inhibit stereotypical thinking. Hence, it is unclear whether heuristic bias should be attributed to a lack of conflict detection or a failure of inhibition. We introduce a neuroscientific approach that bears on this issue. Participants answered a classic decision-making problem (the "lawyer-engineer" problem) while the activation of brain regions believed to be involved in conflict detection (anterior cingulate) and response inhibition (lateral prefrontal cortex) was monitored. Results showed that although the inhibition area was specifically activated when stereotypical responses were avoided, the conflict-detection area was activated even when people reasoned stereotypically. The findings suggest that people detect their bias when they give intuitive responses.*

Half a century of reasoning and decision-making research has sketched a bleak picture of human rationality. Hundreds of studies have shown that when making decisions, people seem to overrely on intuitions and stereotypical beliefs, instead of basing their decisions on more demanding, deliberative reasoning. Although this intuitive, or so-called heuristic, thinking might sometimes be useful, it will often cue responses that are not warranted from a normative point of view. For example, jurors' decisions to sentence a Black defendant to death may be based more on negative stereotypical beliefs about Black people's criminal nature than on objective criteria, such as the number of suspects in the case or previous convictions of the defendant (e.g., Eberhardt, Davies, Purdie-Vaughns, & Johnson, 2006). Likewise, people's risk assessment tends to be based on the operation of simple heuristic associations, rather than on a consideration of the relevant statistics. Despite numerous health-education programs, for example, teenagers tend to ignore the warnings about the dangers of smoking; basing their thinking on the stereotypical idea that only old people get lung cancer (e.g., Peters, McCaul, Stefanek, & Nelson, 2006; Slovic, 2000), they erroneously conclude that smoking is less harmful for younger people (Slovic, 2000).

A classic demonstration of the pervasive impact of intuitive operations on people's decision making is found in Kahneman and Tversky's (1973) studies of base-rate neglect. In these studies, people responded to problems in which a stereotypical description cued a salient but inappropriate response. The problems first provided information about the composition of a sample (e.g., a sample with 995 lawyers and 5 engineers), and then people were told that they would see a short personality description of a randomly selected individual from the sample. The task was to indicate which group the individual most likely belonged to. Statistically speaking, it was likely that a randomly drawn individual would be from the larger, rather than the smaller, group. However, people might be tempted to respond on the basis of stereotypical beliefs cued by the personality description. Indeed, Kahneman and Tversky observed that the vast majority of well-educated university students failed to answer the problem correctly. Even university professors were not immune to the heuristic bias, seeming to neglect the crucial base-rate information.

Although it is clear that people are often biased, the nature of this bias is poorly understood. Some authors claim that people reason heuristically by default and that most of the time they are simply not aware that their intuitions might be wrong. The dominance of intuitive thinking is attributed to a failure to monitor the output of the heuristic reasoning process. In this view, because of lax monitoring, people fail to detect that an intuitive response conflicts with the response favored by probability. The problem is that people do not know that their judgment is biased. This view has been popularized by the work of authors such as Kahneman (2002) and Evans (1984, 2003).

Address correspondence to Wim De Neys, Experimental Psychology Lab, University of Leuven, Tiensestraat 102, 3000 Leuven, Belgium, e-mail: wim.deneys@psy.kuleuven.be.

However, other authors, such as Epstein (1994; Epstein & Pacini, 1999) and Sloman (1996), argue that people always engage in probabilistic thinking and detect when their intuitive response is inappropriate. According to this view, heuristic and probabilistic thinking operate in parallel: People simultaneously engage in both intuitive and more deliberate probabilistic thinking. Consequently, people readily detect a conflict between their stereotypical intuition and the appropriate response. Hence, in this view, there is nothing wrong with the conflict-monitoring process. People know that their intuitive responses are not valid. The problem is that despite this knowledge, they do not always manage to inhibit tempting intuitive beliefs. Thus, people "behave against their better judgment" (Denes-Raj & Epstein, 1994, p. 819) when they give a stereotypical response: They detect that they are biased but fail to block the biased response. In sum, in this view, biased decisions are attributed to an inhibition failure, rather than to a conflict-detection failure per se.

Clarifying the exact nature of the heuristic bias is important for the development of reasoning and decision-making theories. The issue also has far-reaching implications for views of human rationality (e.g., see De Neys, 2006; Stanovich & West, 2000). However, it is hard to decide between the alternative views on the basis of traditional reasoning data (Evans, 2007). The problem is at least in part due to the fact that reasoning and decision-making studies tend to focus on the accuracy of the output (i.e., whether or not people give the correct response), and not on the underlying cognitive processes (e.g., Hoffrage, 2000). Although recently there have been some initial attempts to break the stalemate by developing behavioral processing measures of conflict detection during reasoning (e.g., De Neys & Glumicic, 2008), the rival views persist. The present study addresses this issue by focusing on the neural basis of conflict detection and response inhibition.

In the past decade, numerous imaging studies have established that conflict detection and actual response inhibition are mediated by two distinct regions in the brain. Influential work on cognitive control (e.g., Botvinick, Cohen, & Carter, 2004; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004; van Veen & Carter, 2006) has shown that detection of an elementary conflict between competing responses is among the functions of the medial part of the frontal lobes, more specifically, the anterior cingulate cortex (ACC). Whereas the ACC signals the detection of conflict, responding correctly (i.e., overriding the erroneous, prepotent response) depends on the recruitment of the more lateral part of the frontal lobes. Indeed, there is abundant evidence indicating that the right lateral prefrontal cortex (RLPFC), in particular, plays a key role in response inhibition (e.g., for a review, see Aron, Robbins, & Poldrack, 2004). Recent imaging work in the reasoning and decision-making field also suggests that these same two brain structures, the ACC and RLPFC, mediate the detection of conflict between intuition and probability and the subsequent inhibition of the intuitive response in classic reasoning tasks (e.g., De Martino, Kumaran, Seymour, & Dolan, 2006; Goel & Dolan, 2003; Prado & Noveck, 2007; Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003).

This background suggests how examining the brain might help resolve the dispute about the nature of heuristic bias. Solving a classic decision-making problem that cues a salient but inappropriate intuitive response requires that reasoners first detect that the intuitive response conflicts with the probabilistic response and then successfully inhibit the intuitive response. If the ACC and RLPFC mediate these conflict-detection and inhibition processes, respectively, then correct probabilistic reasoning should be associated with increased activation in both areas (De Martino et al., 2006). It should therefore be possible to clarify the nature of the intuitive bias by contrasting ACC and RLPFC activations observed when participants give probabilistic and stereotypical responses. The bias-as-inhibition-failure and bias-as-detection-failure views make different predictions with respect to the activation of the conflict-detection region. If the former view is right, and people detect that the intuitive response conflicts with more normative probabilistic considerations, the ACC should be activated whether or not people reason stereotypically. However, if the latter view is right, and biased decisions arise because people fail to detect that the intuitive response is inappropriate, people do not experience a conflict when they give a stereotypical response and the ACC should not be activated under these conditions.

To test these predictions, we conducted a functional magnetic resonance imaging (fMRI) study, focusing on participants' ACC and RLPFC activations while they were responding to problems that were modeled after Kahneman and Tversky's (1973) classic base-rate problems, which instigated much of the debate on heuristics and human rationality (Barbey & Sloman, 2007). We also included a number of control problems in which there was no conflict between the cued intuitive response and the probabilistic response. If ACC activation signals the detection of a conflict between probabilistic thinking (cued by consideration of the base rates) and stereotype-based intuition, the ACC would not be expected to be activated in this control condition.

EXPERIMENT

Method

Participants

Thirteen participants (mean age = 27.9 years, $SD = 3.7$; mean education level = 16.1 years, $SD = 1.1$) gave informed consent to participate in the study in return for a monetary reimbursement.

Stimuli

We constructed four types of base-rate problems to test our hypotheses: incongruent, congruent control, neutral control, and heuristic control items. In the crucial incongruent items, the stereotype-based response cued by the description conflicted with the response cued by the base rates, as in the classic, standard problems.[1] In the three kinds of control problems, responses cued by base rates and responses cued by stereotypical thinking did not conflict: In each congruent control item, the description described a typical member of the larger group, so that stereotypical beliefs and base rates cued the same response. In the neutral control items, the descriptions were completely neutral (e.g., "Jack has brown hair and green eyes"); hence, these items did not trigger stereotypical, heuristic responses, and participants were expected to respond by relying on the base rates. Finally, in the heuristic control items, the base rates were neutral (e.g., a sample with 500 lawyers and 500 engineers) and did not cue a response; consequently, responses depended on stereotypical thinking about the descriptions. Table 1 presents examples of the four kinds of items.

Participants answered 24 problems of each type (96 problems in all). The problems were based on a wide range of stereotypes (e.g., involving gender, age, and race) and were selected on the basis of an extensive pilot study.

Instructions

Before going into the scanner, participants were familiarized with the task format. The problems did not explicitly repeat the classic lines about the total sample size and random sampling (e.g., "A total of 1,000 people were tested . . . . The description was drawn at random from the sample . . . ."), in order to avoid repetition and limit the amount of text presented. However, this information was clearly emphasized in the instructions. To make sure that participants grasped the concept of random sampling, we included a training problem in which we demonstrated how 1 description was drawn from an urn containing 10 descriptions (e.g., Gigerenzer, Hell, & Blank, 1988). We also clarified that participants needed to think as statisticians when answering the problems (e.g., Schwartz, Strack, Hilton, & Naderer, 1991). These simple manipulations have been shown to minimize misinterpretation of the task.

Stimulus Presentation

The items were presented in one of two random orders. The beginning of a trial was signaled by a fixation cross that was presented for 500 ms. Next, the problem was presented in three parts. First, the line with the base-rate information was presented for 4,000 ms. Second, the description was presented for 5,000 ms (the base rates remained on the screen). Finally, the question and two response alternatives appeared. Once the question appeared, the entire problem remained on the screen for another 8,500 ms. Hence, each trial lasted exactly 18,000 ms. Participants responded by pressing one of two buttons on a key pad.

fMRI Scanning Technique

Participants were scanned in a 4-T magnet at the Robarts Institute in London, Ontario (Canada). Twenty-three T2*-weighted interleaved multishot, contiguous, echo-planar images, 5 mm thick, were acquired; the voxel size was uniformly 3.44 3.44 5.0 mm. The images were axially positioned to cover the whole brain. A total of 624 volume images was acquired over two sessions (312 volumes per session); the repetition time (TR) was 3 s/volume. The first 6 volumes in each session were discarded (leaving 306 volumes per session). Each session lasted 15.6 min. The scanner was synchronized with the presentation of each trial.

fMRI Data Analysis

Data were analyzed using SPM2 (Friston et al., 1995). Each volume was realigned to the first image of the session. Head movement was less than 2 mm in all cases. The images were smoothed with an isotropic Gaussian kernel with full width at half maximum equal to 12 mm.

Condition effects at each voxel were estimated using a general linear model (GLM), and regionally specific effects were compared using linear contrasts in the GLM. Each contrast produced a parametric map of the t statistic, which was subsequently transformed to a normal Z distribution at each voxel. The blood-oxygenation-level-dependent (BOLD) signal was modeled as a hemodynamic response function during the interval between the presentation of the description and the motor response, on a trial-by-trial, subject-by-subject basis. The presentation of the base rates and the motor response were incorporated into the design but modeled out of the analysis by assigning null weights to their corresponding regressors.

The exact locations of our ACC and RLPFC regions of interest (ROIs) were based on previous work by Klein et al. (2007) and Goel and Dolan (2003), respectively. The ROIs were spheres (12-mm radius) centered on the voxels that showed peak activation in those studies: a right inferior lateral prefrontal ROI (coordinates of the center voxel = 51, 21, 12)[2] and a more medial frontal ACC ROI (coordinates of the center voxel = 1, 15, 43). Figure 1 illustrates where these regions are located in the brain. Reported activations in the ROIs were significant at a voxel-level intensity threshold of $p < .01$ (uncorrected), using a random-effects model.

[1]We assumed that our incongruent problems would elicit the same kind of biases as the classic problems did. Responses in line with the base rates are referred to as "correct." Strictly speaking, however, the stereotype-based responses do not necessarily represent normative violations. In our problems, both categories of responses can be technically consistent with probability theory. Our point is that responses in line with base rates are much more likely to reflect probabilistic consideration of base rates than are responses in line with stereotypes.

[2]SPM2 uses a standard brain from the Montreal Neurological Institute (MNI) as its reference brain. Therefore, all coordinates reported in this article are in standard MNI space.

TABLE 1
Examples of the Four Kinds of Item Types

Incongruent

Study with 5 engineers and 995 lawyers.

Jack is 45 and has four children. He shows no interest in political and social issues and is generally conservative. He likes sailing and mathematical puzzles.

What is most likely?

a. Jack is an engineer+
b. Jack is a lawyer*

Congruent control

Study with 5 Swedish people and 995 Italians.

Marco is 16. He loves to play soccer with his friends, after which they all go out for pizza or to someone's house for homemade pasta.

What is most likely?

a. Marco is Swedish
b. Marco is Italian*+

Neutral control

Study with 5 people who campaigned for Bush and 995 who campaigned for Kerry.

Jim is 5 ft. and 8 in. tall, has black hair, and is the father of two young girls. He drives a yellow van that is completely covered with posters.

What is most likely?

a. Jim campaigned for Bush
b. Jim campaigned for Kerry*

Heuristic control

Study with 500 forty-year-olds and 500 seventeen-year-olds.

Rylan lives in Buffalo. He hangs out with his buddies every day and likes watching MTV. He is a big Korn fan and is saving to buy his own car.

What is most likely?

a. Rylan is forty
b. Rylan is seventeen+

Note. For each item, the table presents the information given to participants (sample composition, individual description), along with the question to be answered and response options. Symbols have been added to identify responses cued by the base-rate information (*) and by stereotypes (+).

Results and Discussion

Behavioral Results

Behavioral scores were in keeping with expectations. As Table 2 shows, participants answered nearly all the control problems correctly. On average, more than 90% of these items were answered correctly.[3] However, participants were much less accurate in responding to the incongruent problems, $F(1, 12) = 30.69$, $p_{\text{rep}} = .99$, η_p^2 ¼ .72. As Kahneman and Tversky (1973) found, participants were biased by their stereotypical beliefs on the majority of the incongruent trails. The base-rate response (i.e., response cued by the base rates) was selected in only 45% of these trials. These findings were mirrored in the response latencies. Overall, control problems were answered more quickly than incongruent problems, $F(1, 12) = 13.93$, $p_{\text{rep}} = .97$, η_p^2 ¼ .54. Stereotype-based responses to the incongruent problems tended to be given more quickly than base-rate responses, $F(1, 12) = 4.6$, $p_{\text{rep}} = .87$, η_p^2 ¼ .28.

[3]The few control problems that were not answered correctly were discarded from the remaining analyses.

fMRI Results

We started by contrasting ACC and RLPFC activations for base-rate and stereotype-based responses to the incongruent problems (i.e., base-rate responses – stereotype-based responses). As expected, RLPFC activation increased when people refrained from stereotypical thinking and selected the base-rate response (coordinates of peak activation: 56, 24, 18; $Z = 2.37$). This finding is consistent with the general idea that this area is typically involved in inhibitory control (e.g., Aron et al., 2004).

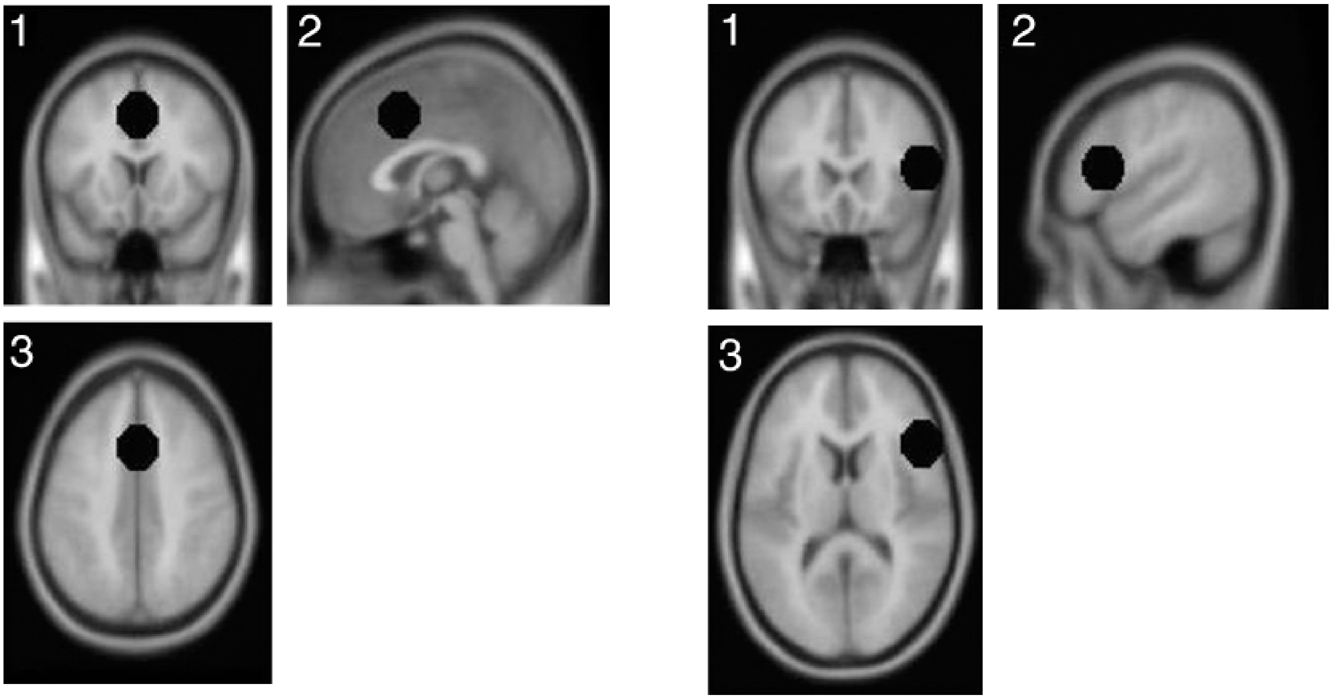

Fig. 1. Brain images showing the regions of interest (ROIs) in anterior cingulate cortex (left panel) and right lateral prefrontal cortex (right panel). The location of each ROI is superimposed on coronal (1), sagittal (2), and transverse (3) sections of a magnetic resonance image, which is in standard space.

With respect to the ACC, the direct contrast between base-rate and stereotype-based responses on the incongruent trials did not show any differential activation, even though we used a very liberal activation threshold and ROI definition. This finding is consistent with the claim that conflict detection is successful even when participants fail to select the appropriate, base-rate response.

However, the lack of differential ACC activation does not suffice to validate this claim. Alternative accounts can be put forward. For example, the ACC might mediate a more general function (e.g., directing attention) that is unrelated to conflict detection but is always engaged when solving decision problems. Alternatively, the ACC might not be involved in decision making and therefore might never be activated in this task. To rule out such explanations of the lack of differential ACC activation for base-rate and stereotype-based responses, we had to establish that the ACC specifically signals the detection of a conflict between base rates and stereotypical thinking. This is where the control problems came into play.

In contrast with the incongruent problems, the control problems did not present a conflict between stereotype-based and base-rate responses: Either probabilistic and stereotypical thinking cued the same response (congruent problems), or the problems cued only a base-rate (neutral control) or a stereotype-based (heuristic control) response. If the ACC signals successful detection of the conflict between the cued responses for incongruent problems (whatever the final response may be), ACC activation should differ between incongruent and control trials. This prediction was confirmed. We observed significant ACC activation in all three contrasts of control trials with incongruent trials: incongruent minus congruent control (2, 24, 42; Z =

TABLE 2
Performance as a Function of Trial Type

Trial type	Score (percentage correct)	Reaction time (ms)
Congruent control	93 (0.11)	2,806 (1,304)
Heuristic control	93 (0.08)	2,894 (1,431)
Neutral control	88 (0.18)	3,056 (1,222)
Incongruent, base-rate response	45 (0.32)	4,044 (1,857)
Incongruent, stereotype-based response	55 (0.32)	3,501 (1,483)

Note. Standard deviations are given in parentheses. On congruent control trials, base rates and stereotypes cued the same response. On heuristic control trials, only the descriptions cued a response. On neutral control trials, only the base rates cued a response. On incongruent trials, base rates and descriptions cued conflicting responses.

2.76), incongruent minus neutral control (0, 26, 44; $Z = 2.4$), and incongruent minus heuristic control (0, 26, 44; $Z = 2.91$). If the ACC mediated a general process that is always engaged in decision making, or if the ACC were simply not involved in decision making, these contrasts should not have yielded significant activations. Furthermore, we never observed activation in the ACC region when we contrasted the activations for different kinds of control problems (i.e., congruent control – neutral control, congruent control – heuristic control, neutral control – heuristic control).[4] These findings establish that the ACC specifically responds to the conflict between the cued responses in the classic, incongruent base-rate problems.

In sum, the crucial finding is that stereotype-based and probabilistic responses to the classic base-rate problems differed only in RLPFC recruitment. Responding to incongruent problems did engage the ACC region, but the activation did not differ between base-rate and stereotype-based responses.

GENERAL DISCUSSION

In the present study, we tried to disentangle two rival views on the nature of the heuristic reasoning bias. Participants solved classic base-rate problems while we monitored the activation of two frontal brain regions believed to be involved in conflict detection (i.e., the ACC) and response inhibition (i.e., the RLPFC). Results showed that although the inhibition area was activated only when people avoided tempting stereotype-based responses, the conflict-detection area was activated even when people reasoned stereotypically. On control problems in which the cued base rates and stereotype did not conflict, the ACC was not engaged. The RLPFC and ACC activation patterns lend credence to the view that biased decision making results from a failure to override intuitive heuristics, and not from a failure to detect the conflict between these heuristics and normative information. If people were mere heuristic thinkers and neglected probabilistic sample-size considerations, our participants should have failed to detect that their intuitive responses conflicted with the base rates, and the ACC should not have been activated.

We noted that there have been some initial attempts to develop behavioral processing measures of conflict detection during reasoning. For example, De Neys and Glumicic (2008) presented participants with an unannounced recall test after they had solved a set of base-rate problems. The authors reasoned that successful conflict detection would result in deeper processing of the base-rate information, and consequently better memorization of that information. Results indicated that participants had no trouble recalling the base-rate information of the incongruent problems they had previously answered (even when they had not answered correctly). Base-rate information of congruent control problems, in which the base rates did not conflict with the intuitive response, was not remembered as well. Hence, this behavioral study is consistent with the present imaging findings in indicating that successful conflict detection is omnipresent, regardless of whether participants answer problems correctly or incorrectly.

Our findings indicate that heuristic bias should be attributed to an inhibition failure. We characterize inhibition as a basic cognitive mechanism whereby participants actively try to withhold a salient, but inappropriate, default response. A failure to inhibit an intuitively cued stereotype-based response after successful conflict detection thus implies that the heuristic response was not overridden. One might wonder whether the inhibition failure also has an affective component (e.g., do people "regret" their stereotype-based response after an inhibition failure?). Our data do not speak to this issue, but as one reviewer noted, possible affective reactions might be linked to cases of "weakness of will." For example, people who are addicted to nicotine might know they are damaging their health and regret this, but because of weakness of will continue to smoke. This example suggests that inhibition failure during decision making and behavior associated with weakness of will (e.g., smoking or other addictions) are related. Although it may be premature to emphasize this similarity at this time, the issue underscores the point that the decision-making field will benefit in the future from a more detailed characterization of the inhibition process per se.

People's probabilistic-thinking failures have been demonstrated in a wide variety of reasoning and decision-making tasks. We focused on base-rate-neglect problems because of the central role they play in the discussions on human rationality. Although our findings will need to be extended and generalized to different decision-making settings in future studies, we want to point to some practical and theoretical implications of our results. At the practical level, one might note that educational programs intended to improve students' decision making in risky situations (e.g., reckless driving, binge drinking, unprotected sex) have been largely ineffective (e.g., Reyna & Farley, 2006; Steinberg, 2007). Likewise, experimental studies in which people received extensive tutoring in logic and probability theory showed only a minimal impact on their performance (e.g., Kahneman, Slovic, & Tversky, 1982). In light of the present study, these results are not surprising. Intervention studies have typically been designed to alter or optimize people's knowledge. Our data indicate, however, that the problem is not a lack of statistical sophistication. People know all too well that base-rate information is relevant to their decisions. Rather, what people seem to struggle with is overriding the temptation of heuristic thinking. This suggests that interventions might be more successful if they were more specifically targeted at improving students' inhibitory capacities (e.g., Houdé, 2007).

At a more theoretical level, the evidence for successful conflict detection helps to sketch a less bleak picture of human rationality. Our findings indicate that people's thinking is more

[4]Likewise, as one might expect given that inhibition was not required for the control problems, the RLPFC did not show significant activation in these control contrasts either. Note that this finding is evidence against the claim that the RLPFC is activated by mere effort per se. Neutral control trials required more effort than congruent control trials (e.g., latencies were slightly longer, and the error rate was higher), but did not require heuristic inhibition. The absence of significant RLPFC activation in the control contrasts indicates that the RLPFC is specifically recruited for inhibitory purposes.

normative than the infamous failure to solve classic decision-making tasks suggests. If people did not know or care about the implications of sample-size considerations, for example, they would not detect conflicts between their intuitive responses and base rates. Although people might not always manage to override the temptation of heuristic thinking, they do seem to recognize when their intuitive answers are not fully warranted. Base rates are not simply neglected, and people are not merely intuitive thinkers. Our findings are in line with Sloman's (1996) and Epstein's (1994) original claims, suggesting that people go against their better judgment when they give heuristic responses. Heuristic bias points to a lack of inhibitory processing. It does not imply that people are irrational beings who lack probabilistic sophistication. In this sense, people are truly smarter than one might think.

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REFERENCES

Aron, A.R., Robbins, T.W., & Poldrack, R.A. (2004). Inhibition and the right inferior frontal cortex. *Trends in Cognitive Sciences*, *8*, 170–177.

Barbey, A.K., & Sloman, S.A. (2007). Base-rate respect: From ecological rationality to dual processes [Target article and commentaries]. *Brain and Behavioral Sciences*, *30*, 241–298.

Botvinick, M.M., Cohen, J.D., & Carter, C.S. (2004). Conflict monitoring and anterior cingulate cortex: An update. *Trends in Cognitive Sciences*, *12*, 539–546.

De Martino, B., Kumaran, D., Seymour, B., & Dolan, R.J. (2006). Frames, biases, and rational decision making in the human brain. *Science*, *313*, 684–687.

De Neys, W. (2006). Dual processing in reasoning: Two systems but one reasoner. *Psychological Science*, *17*, 428–433.

De Neys, W., & Glumicic, T. (2008). Conflict monitoring in dual process theories of thinking. *Cognition*, *106*, 1245–1299.

Denes-Raj, V., & Epstein, S. (1994). Conflict between intuitive and rational processing: When people behave against their better judgement. *Journal of Personality and Social Psychology*, *66*, 819–829.

Eberhardt, J.L., Davies, P.G., Purdie-Vaughns, V.J., & Johnson, S.L. (2006). Looking deathworthy: Perceived stereotypicality of Black defendants predicts capital-sentencing outcomes. *Psychological Science*, *17*, 383–386.

Epstein, S. (1994). Integration of the cognitive and psychodynamic unconscious. *American Psychologist*, *49*, 709–724.

Epstein, S., & Pacini, R. (1999). Some basic issues regarding dual-process theories from the perspective of cognitive-experiential self-theory. In S. Chaiken & Y. Trope (Eds.), *Dual process theories in social psychology* (pp. 462–482). New York: Guilford Press.

Evans, J.St.B.T. (1984). Heuristic and analytic processing in reasoning. *British Journal of Psychology*, *75*, 451–468.

Evans, J.St.B.T. (2003). In two minds: Dual process accounts of reasoning. *Trends in Cognitive Sciences*, *7*, 454–459.

Evans, J.St.B.T. (2007). On the resolution of conflict in dual process theories of reasoning. *Thinking and Reasoning*, *13*, 321–339.

Friston, K., Holmes, A., Worsley, K., Poline, J.-B., Frith, C., & Frackowiak, R. (1995). Statistical parametric maps in functional imaging: A general approach. *Human Brain Mapping*, *2*, 189–210.

Gigerenzer, G., Hell, W., & Blank, H. (1988). Presentation and content: The use of base-rates as a continuous variable. *Journal of Experimental Psychology: Human Perception and Performance*, *14*, 513–525.

Goel, V., & Dolan, R.J. (2003). Explaining modulation of reasoning by belief. *Cognition*, *87*, B11–B22.

Hoffrage, U. (2000). Why the analyses of cognitive processes matter. *Behavioral and Brain Sciences*, *23*, 679–680.

Houdé, O. (2007). First insights on "neuropedagogy of reasoning." *Thinking and Reasoning*, *13*, 81–89.

Kahneman, D. (2002). *Maps of bounded rationality: A perspective on intuitive judgement and choice*. Retrieved January 11, 2006, from http://nobelprize.org/nobel_prizes/economics/laureates/2002/kahnemann-lecture.pdf

Kahneman, D., Slovic, P., & Tversky, A. (1982). *Judgement under uncertainty: Heuristics and biases*. New York: Cambridge University Press.

Kahneman, D., & Tversky, A. (1973). On the psychology of prediction. *Psychological Review*, *80*, 237–251.

Klein, T.A., Endrass, T., Kathman, N., Neumann, J., von Cramon, D.Y., & Ullsperger, M. (2007). Neural correlates of error awareness. *NeuroImage*, *34*, 1174–1781.

Peters, E., McCaul, K.D., Stefanek, M., & Nelson, W. (2006). A heuristic approach to understanding cancer risk perception: Contributions from judgement and decision-making research. *Annals of Behavioral Medicine*, *31*, 45–52.

Prado, J., & Noveck, I.A. (2007). Overcoming perceptual features in logical reasoning: A parametric fMRI study. *Journal of Cognitive Neuroscience*, *19*, 642–657.

Reyna, V.F., & Farley, F. (2006). Risk and rationality in adolescent decision making: Implications for theory, practice, and public policy. *Psychological Science in the Public Interest*, *7*(1).

Ridderinkhof, K.R., Ullsperger, M., Crone, E.A., & Nieuwenhuis, S. (2004). The role of the medial frontal cortex in cognitive control. *Science*, *306*, 443–447.

Sanfey, A.G., Rilling, J.K., Aronson, J.A., Nystrom, L.E., & Cohen, J.D. (2003). The neural basis of economic decision making in the ultimatum game. *Science*, *300*, 1755–1758.

Schwartz, N., Strack, F., Hilton, D., & Naderer, G. (1991). Base-rates, representativeness, and the logic of conversation: The contextual relevance of "irrelevant" information. *Social Cognition*, *9*, 67–84.

Sloman, S.A. (1996). The empirical case for two systems of reasoning. *Psychological Bulletin*, *119*, 3–22.

Slovic, P. (2000). What does it mean to know a cumulative risk?: Adolescents' perceptions of short-term and long-term consequences of smoking. *Journal of Behavioral Decision Making*, *13*, 259–266.

Stanovich, K.E., & West, R.F. (2000). Individual differences in reasoning: Implications for the rationality debate [Target article and commentaries]. *Behavioral and Brain Sciences*, *23*, 645–726.

Steinberg, L. (2007). Risk taking in adolescence: New perspectives from brain and behavior science. *Current Directions in Psychological Science*, *16*, 55–59.

van Veen, V., & Carter, C.S. (2006). Conflict and cognitive control in the brain. *Current Directions in Psychological Science*, *15*, 237–240.

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