What Makes a Good Reasoner?: Brain Potentials and Heuristic Bias Susceptibility

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Abstract

Human reasoning is often biased by intuitive heuristics. A key question is why some people are less susceptible to this bias than others. It is debated whether the bias results from a failure to monitor one's intuitive conclusions for conflict with logical considerations or from a failure to inhibit the tempting intuitions. This results in different views on the role of individual differences in executive monitoring and inhibition capacity for sound reasoning. The present study presents a new approach to address this issue. After an initial reasoning screening a group of the most and least biased reasoners were invited for an EEG study in which neural markers of their executive monitoring (ERN amplitude) and inhibition (N2 amplitude) skills were recorded. Results indicated that biased reasoners were characterized by less developed inhibition but not monitoring capacity. Findings support the view that monitoring one's intuition for conflict during thinking is a flawless and undemanding process suggesting that even the poorest reasoners at least detect that they are biased.

Keywords: Decision-making; Reasoning; EEG

Introduction

Decades of reasoning and decision-making research showed that human thinking is often biased (Evans, 2008; Kahneman, 2002). In general, human reasoners seem to have a strong tendency to base their judgment on fast intuitive impressions rather than on more demanding, deliberative reasoning. Although this intuitive or so-called "heuristic" thinking can be very useful, it will sometimes cue responses that conflict with traditional normative logical or probabilistic considerations and bias our decision-making.

Whereas it is well established that human judgment is often biased, the nature of this bias is far less clear. Some influential authors have argued that the widespread heuristic bias can be attributed to a failure to monitor our intuition (e.g., Kahneman & Frederick, 2002). Because of lax monitoring, people would simply fail to detect that the intuitive response conflicts with normative considerations. However, others have argued that there is nothing wrong with the monitoring process (e.g., Epstein, 1994; Houdé, 2007; Sloman, 1996). According to these authors, people have little trouble in detecting that their intuitive response is biased. The problem, according to this view, is that people's intuitive beliefs are so tempting that they fail to discard them. Thus, people "behave against their better judgment" (Epstein, 1994) when they give an unwarranted heuristic response: They detect that they are biased but simply fail to block the biased response. In sum, according to this flawless detection view, biased decisions are attributed to an inhibition failure rather than a conflict monitoring failure per se.

The debate on the nature of heuristic bias results in opposing views on the interpretation of individual differences in bias susceptibility. Although the vast majority of educated adults are typically biased when solving classic reasoning and decision-making tasks, some people do manage to reason correctly and refrain from giving the tempting but unwarranted heuristic response. Individual differences in executive control capacity (as measured with general working memory or intelligence test) are widely cited as the cause of this reasoning performance variability (e.g., De Neys, 2006; De Neys & Verschueren, 2006; Evans, 2008; Stanovich & West, 2000). However, conflict monitoring and inhibition are both considered key executive processes and the precise contribution of each component as possible mediator of reasoning performance has not been established. Bluntly put, it is not clear what makes a good reasoner: Having a superior monitoring capacity, having a superior inhibition capacity, or a combination of both.

The two views on heuristic bias make differential predictions here. According to the lax monitoring view, people are mainly biased because of inefficient monitoring. Hence, one can expect that good reasoners will be primarily characterized by superior executive monitoring skills. Good reasoners will be better at monitoring their intuitively cued conclusions for conflict with more normative considerations and will be more likely to detect that their initial response is biased. However, the flawless monitoring view conceives monitoring during thinking as a quite undemanding process by entailing that even the most biased reasoners are successful at it (De Neys, Moyens, & Vansteenwegen, 2010; Franssens & De Neys, 2009). Hence, given the postulated minimal demands of the monitoring process during thinking, one can predict that individual differences in executive monitoring skills per se should have little impact on one's reasoning performance: Even people with the least developed monitoring skills should manage to detect the conflict during thinking. According to this view, it will be specifically one's inhibitory capacities that will determine the reasoning performance.

Clarifying the nature of heuristic bias and the individual bias differences is crucial for the study of human thinking. The issue has also far-stretching implications for our view of human rationality and the design of more optimal intervention programs to "debias" human thinking (De Neys & Glumicic, 2008; Evans, 2008). The problem, however, is that it is hard to decide between the alternative views based on traditional reasoning data (Evans, 2007, 2008). Although there have been some recent attempts to break the stalemate by developing processing measures of conflict detection and inhibition during reasoning (e.g., De Neys & Franssens, 2009), the rival views persist. The present study introduces a new approach to address this issue by focusing on neural markers of individual differences of conflict monitoring and response inhibition.

In the study we first invited a large number of participants for an initial screening session in which they were presented with reasoning problems based on two of the most-famous tasks from the judgment and decision-making field: Kahneman and Tversky's (1973) base-rate neglect and conjunction fallacy problems. In these tasks a stereotypical description cues a strong intuitive response that conflicts with more traditional probabilistic normative considerations (see Material for examples). Sound reasoning on these problems requires that people detect the conflict and inhibit the inappropriate heuristic response. Based on the screening, we invited a group of the least and most biased reasoners (i.e., participants with the highest and lowest normative reasoning scores) for a follow-up study in which they were presented with a Go/No-No task while electroencephalography (EEG) was recorded. The Go/No-Go task is a classic task that is widely used to measure people's executive control abilities (e.g., Amodio et al., 2007; Nieuwenhuis et al., 2003). In the task participants must quickly respond to a frequently presented Go stimulus such that the 'Go' response becomes habitual. However, on a small proportion of trials, a No-Go stimulus appears, signaling that one's habitual response should be withheld.

The EEG recording allowed us to test for a possible neurological marker of the differential executive monitoring and/or inhibition capacities of the least and most biased thinkers. Available evidence suggests that the operation of the executive monitoring and inhibition components are reflected in two different event-related potentials (ERP). On one hand, erroneously solved No-Go trials on which participants give the inappropriate dominant 'Go' response are known to give rise to a specific ERP referred to as the Error-Related Negativity or ERN. The ERN is a sharp negative voltage deflection in the EEG that typically peaks about 50 ms after an erroneous response. The ERN is believed to reflect executive control activity associated with the monitoring of conflict and error (Amodio et al., 2004, 2006; Compton et al., 2008; but see Burle et al., 2008). Available evidence suggests that the ERN amplitude is typically larger for people with better monitoring skills (Amodio et al., 2006; Inzlicht et al., 2009).

On the other hand, correctly solved No-Go trials on which participants manage to withhold the dominant 'Go' response are known to give rise to the so-called N2. The N2 is a negative voltage deflection in the EEG that typically peaks about 200 ms after the stimulus onset (i.e., before the response). The N2 is believed to reflect executive control activity associated with the successful inhibition of the prepotent Go response (Nieuwenhuis et al., 2003). Available evidence suggests that the few times that people with less developed inhibitory abilities do manage to withhold the Go response, the N2 amplitude is larger than for people with high abilities (e.g., Johnstone et al., 2007; Kaiser et al., 2003; Prox et al., 2007; Smith, Johnstone, & Barry, 2004; but see also Falkenstein, Hoormann, & Hohnsbein, 1999). This larger N2 amplitude has been interpreted as reflecting the fact that people who have fewer inhibitory control resources will need a much higher activation of the neural control structures for the response inhibition to be successful (Prox et al., 2007; Smith et al., 2004).

In sum, the EEG literature suggests that individual differences in executive inhibition abilities affect the N2 amplitude, whereas individual differences in executive monitoring abilities affect the ERN amplitude. Hence, contrasting these components in a group of biased and unbiased reasoners can help us to clarify the nature of individual differences in heuristic bias susceptibility. If the lax monitoring view is right and good reasoners are characterized by superior monitoring ability, the ERN should be more pronounced for the unbiased than for the biased reasoners. If the flawless monitoring view is right and good reasoners are characterized by superior inhibition rather than monitoring ability, biased and unbiased reasoners should not show a differential ERN and only the N2 should differ in the two groups.

Reasoning Bias Screening

Method

Participants. A total of 399 psychology undergraduates participated in return for course credit.

Material. To screen participants' bias susceptibility during reasoning we presented them with a booklet containing a total of three conjunction fallacy and three base-rate neglect problems. Problems were presented in a fixed, randomly determined order. In all problems a stereotypical description cued a heuristic response that conflicted with the normative response that is traditionally considered correct. Problem content was based on the work of De Neys, Vartanian, and Goel (2008). The exact problem format is illustrated below.

The average number of correct normative responses was taken as an index of people's reasoning performance.

Conjunction fallacy problems. In each problem participants first read a short personality description of a character. Next, they were given two statements about the character and were asked to indicate which one of the two was most probable. One statement always consisted of a conjunction of two characteristics (one characteristic that was likely given the description and one that was unlikely). The other statement contained only one of these characteristics (i.e., the unlikely one). Consider the following example:

> Bill is 34. He is intelligent, punctual but unimaginative and somewhat lifeless. In school, he was strong in mathematics but weak in social studies and humanities.
>
> Which one of the following statements is most likely?
> a. Bill plays in a rock band for a hobby
> b. Bill is an accountant and plays in a rock band for a hobby

Normative considerations based on the conjunction rule always cue selection of the non-conjunctive statement. However, intuitively, people will tend to select the statement that best fits with the stereotypical description (i.e., the most representative statement, see Tversky & Kahneman, 1983). Clearly, the fit will be higher for the conjunctive statement than for the unlikely non-conjunctive statement. Hence, people will be intuitively tempted to pick the erroneous conjunctive statement.

Base-rate neglect problems. In each problem participants first read information about the composition of a sample. People were also informed that short personality descriptions were made of all the individuals in the sample and they would get to see one description that was drawn randomly from the sample. They were asked to indicate to which one of the two groups the randomly drawn individual most likely belonged. Consider the following example:

> A psychologist wrote thumbnail descriptions of a sample of 1000 participants consisting of 995 females and 5 males. The description below was chosen at random from the 1000 available descriptions.
>
> Jo is 23 years old and is finishing a degree in engineering. On Friday nights, Jo likes to go out cruising with friends while listening to music and drinking beer.
>
> Which one of the following two statements is most likely?
> a. Jo is a man
> b. Jo is a woman

Normative considerations based on the group size or base-rate information cue response (b). Given the size of the two groups in the sample, it will be more likely that a randomly drawn individual will belong to the largest group. However, people will be tempted to respond (a) on the basis of stereotypical beliefs cued by the description. Hence, just as in the conjunction problems, normative considerations will conflict with the cued heuristic response.

Descriptions were selected on the basis of an extensive pilot study (Franssens & De Neys, 2009). Selected descriptions moderately but consistently cued one of the two groups. This point is not trivial. We label responses that are in line with the base-rates as correct answers. However, if reasoners adopt a formal Bayesian approach (e.g., Gigerenzer, Hell, & Blank, 1988) and combine the base-rates with the diagnostic value of the description, this can lead to complications when the description is extremely diagnostic. Imagine that we have a sample of males and females and the description would state that the randomly drawn individual "gave birth to two children". Now, by definition, no matter what the base-rates in the sample are, one would always need to conclude that the person is a woman. We limited the impact of this problem by only selecting descriptions that were judged to have a moderate diagnostic value. By combining these with quite extreme base-rates (i.e., 995 and 5) one may generally conclude that the response that is cued by the base-rates should be selected if participants manage to refrain from giving too much weight to the intuitive answer cued by the description.

Results and Discussion

The reasoning performance of our screening sample replicated the typical results in previous studies. Overall, participants were typically biased and gave the cued heuristic responses. The average percentage of correct normative responses on the six problems was only 24% (*SD* = 33%). This pattern was similar for the conjunction (*M* = 21%, *SD* = 32%) and base-rate problems (*M* = 28%, *SD* = 31%).

After the screening we invited a group of the most (i.e., participants who always gave the heuristic response) and least biased reasoners (i.e., participants who gave at least one normative response on both the conjunction and base-rate problems) for the EEG recording session. This cutoff value (at least one response correct) corresponded to the median accuracy for both types of reasoning problems.

EEG Recording

Method

Participants. After the bias screening seven of the least and seven of the most biased reasoners were recruited for the main Go/No-Go EEG study. We refer to these groups as the poor and good reasoners, respectively (see Table 1 for an overview of their reasoning screening performance). Participants were paid €25 for their participation.

Material. *Go/No-Go task*. The Go/No-Go task was based on the procedure introduced by Nieuwenhuis et al. (2003) and Amodio et al. (2007). On each trial, either the letter "M" or "W" was presented in the center of a computer screen. Approximately half of the participants in each group were instructed to make a "Go" response (mouse button press) when they saw "M" but to make no response when they saw “W”; the remaining participants completed a version in which “W” was the Go stimulus and “M” the No-Go stimulus. Each trial began with a fixation point, presented for 500 ms. The target then appeared for 100 ms, followed by a blank screen. Participants were instructed to respond within 500 ms of target onset. A warning message appeared on the screen for 1 s after responses that exceeded this deadline and after erroneous responses. The inter trial interval was 1 s.

The task consisted of 600 trials: 80% Go trials and 20% No-Go trials. The high frequency of Go trials induced a prepotent “Go” response, enhancing the difficulty of successfully overriding a response on the critical No-Go trials. Participants received a short 2-min break after every 150 trials.

Procedure. *EEG recording*. Participants were fitted with a Quickcap, and EEG was collected from 128 equidistantly positioned scalp sites using Ag/AgCl electrodes. The active reference electrode was placed on the vertex between electrodes Cz and Cpz. A ground electrode was placed on the forehead close to AFz. Vertical and horizontal electro-oculogram (EOG) was collected to permit the reduction of the artifact due to eye movements. Impedances were below 5kΩ at each scalp site. EEG was recorded through a 0.15 – 30 Hz bandpass filter and digitized at 1000 Hz using a SynAmps2 amplifier. Data were referenced to the average earlobe. Offline, we used a computerized algorithm to remove eye-blink artifacts. EEG epochs with voltage exceeding +/- 200 µV were rejected as reflecting additional artefact.

ERP processing. *N2*. Our quantification of the N2 and ERN was based on Amodio et al. (2007). For N2 quantification a 1000 ms epoch of EEG signal, beginning 200 ms prior to stimulus onset, was selected for each artifact-free trial. Baseline correction procedures subtracted the average voltage during the 200 ms interval before stimulus onset within each epoch from the entire epoch. Epochs associated with correct responses on Go and No-Go trials were averaged within their respective trial types. The N2 was scored as the peak negative deflection occurring between 200 and 400 ms, relative to target onset, at the vertex site (Cz), where it is typically maximal. The critical N2 component refers to the average N2 amplitude associated with correct “No-Go” responses.

ERP processing. ERN. For quantification of the ERN an 800 ms response-locked epoch of EEG signal, centered on the time of response within each trial, was selected for each artifact-free trial. Baseline correction procedures subtracted the average voltage occurring from 400 ms to 50 ms prior to the response from the entire epoch. Epochs associated with incorrect responses on No-Go trials and correct responses on Go trials were averaged within their respective trial types. The ERN was scored as the peak negative deflection occurring between -50 and 150 ms, relative to response onset, at the frontocentral scalp site (Fcz). The critical ERN component refers to the average amplitude associated with incorrect “Go” responses on “No-Go” trials.

Results and Discussion

Behavioral findings. The behavioral Go/No-Go performance of our two groups of reasoners (see Table 1) was as expected. Accuracy on the No-Go trials is considered an excellent marker of people’s executive control ability. Consistent with the well established finding that good reasoners have superior executive control capacities, we observed that our group of unbiased reasoners outscored the more biased group on the No-Go trials, $F(1, 12) = 11.26$, $p < .01$, $\eta^2 p = .48$. As expected, accuracy on the Go trials, where correct responding did not require monitoring or overriding the intuitive response, was at ceiling and did not differ for the two groups of reasoners, $F(1, 12) < 1$.

Table 1: Average (SD) Reasoning and Go/No-Go Accuracy

	Reasoning			Go/No-Go	
	Base-rate	Con-junction	Total	No-Go	Go
Poor reasoners	0% (-)	0% (-)	0% (-)	67% (11)	99% (1)
Good reasoners	52% (26)	62% (30)	57% (21)	83% (5)	99% (1)

N2 findings. Our ERP data indicated that the average N2 amplitude differed in the group of good and poor reasoners, $F(1, 12) = 4.75$, $p < .05$, $\eta^2 p = .28$. As Figure 1 shows, whenever the poor reasoners did manage to solve No-Go trials correctly this was accompanied by a more pronounced N2 amplitude (i.e., a more negative deflection). Next, we also calculated the correlation between each individuals’ actual reasoning performance on the base-rate and conjunction problems and their N2 amplitude. This analysis showed that in our restricted sample of good and poor reasoners, the N2 amplitude was a good predictor of the tendency to give the standard normative response on these classic reasoning problems, $r = .55$, $p < .05$. Hence, the better participant’s executive inhibition capacity, as indexed by their N2 amplitude, the more they managed to refrain from heuristic responding during reasoning.

ERN findings. As Figure 1 indicates, in contrast with the N2 findings, the average ERN amplitude did not differ for our group of good and poor reasoners, $F(1, 12) < 1$. A correlational analysis also established that the ERN amplitude was not predictive of participant’s reasoning performance, $r = .14$, $p = .63$. Consistent with the flawless monitoring view, this suggest that individual differences in bias susceptibility during reasoning are not driven by differences in executive monitoring skills as indexed by the ERN amplitude.

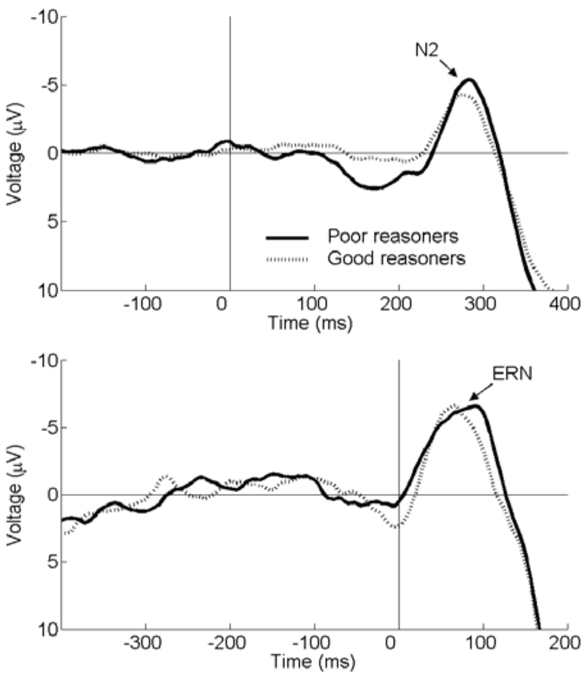

Figure 1. ERP waveforms corresponding to correct No-Go responses (N2 top panel, stimulus onset at 0 ms) and incorrect No-Go responses (ERN bottom panel, response onset at 0 ms), with the waveform for correct Go responses subtracted, for the most (poor) and least (good) biased reasoners.

General Discussion

In the present EEG study we contrasted neural markers of people's executive monitoring (ERN amplitude) and inhibition (N2 amplitude) capacity in two groups who showed differential susceptibility to heuristic bias during reasoning. Results indicated that less biased reasoners showed a smaller N2 amplitude than more biased reasoners while the ERN amplitude of biased and unbiased reasoners did not differ. Consistent with the flawless monitoring view, this suggests that good reasoners are specifically characterized by a superior executive inhibition capacity rather than by a superior monitoring capacity. Hence, what makes a good, unbiased reasoner is not a more developed ability to monitor one's intuitive conclusions for conflict with normative considerations but the ability to inhibit these tempting erroneous intuitions in case such a conflict occurs.

It should be stressed that the present results do not downplay the importance of conflict monitoring during reasoning per se. Both the lax and flawless monitoring views consider the monitoring of one's intuitive inferences as a cornerstone of the reasoning process. Obviously, if people would not monitor their intuitively cued problem solutions, they could simply not detect whether or not it is necessary to override them. Indeed, even the most gifted reasoners do not simply inhibit intuitive inferences throughout and tend to rely on heuristic computations in case it is appropriate (e.g., De Neys & Franssens, 2009; De Neys, Schaeken, & d'Ydewalle, 2005). As suggested previously (e.g., De Neys & Glumicic, 2008), the monitoring process allows reasoners to take advantage of the computational benefits (e.g., speed) of heuristic thinking as long as it does not conflict with normative principles. The key point, however, is that this crucial monitoring process does not seem to be very demanding. According to the flawless monitoring view, monitoring one's intuitions during reasoning is an effortless process that requires only minimal executive monitoring resources. It is this postulated undemanding or automatic nature of the monitoring process during reasoning that can explain why individual differences in executive monitoring capacity do not affect the reasoning performance. The undemanding nature of the monitoring during thinking entails that even for people with minimal executive monitoring resources, the process will be successful.

Our individual differences findings fit with some recent studies that started examining the processing characteristics of the conflict monitoring process during thinking. For example, Franssens and De Neys (2009) tested the postulated effortless nature of the monitoring process in a dual task study. People were asked to solve base-rate problems while their executive resources were burdened with a secondary task. After the reasoning task participants were also presented with a surprise recall test that can be used to measure whether people were monitoring their intuitive inferences and detected the conflict between cued intuitive and normative responses (see De Neys & Glumicic, 2008). Results showed that reasoning accuracy decreased under load (i.e., people gave more heuristic responses). However, the crucial finding was that the conflict monitoring index was not affected by the load. People were equally accurate in detecting the presence of conflict whether or not they were reasoning under load. Combined with the present individual differences findings these studies lend credence to the idea that conflict monitoring during thinking is effortless and flawless.

The present study is the first one to introduce EEG methodology to examine the nature of individual differences in bias susceptibility. Clearly, this implies that our results need to be interpreted with some caution. Although our data fits with recent findings pointing to the effortless nature of the monitoring process during thinking, the results will need to be validated in future studies. Bearing this in mind, our initial findings do suggest that individual differences in executive monitoring are not playing a major role in people's bias susceptibility. A good, unbiased reasoner seems to be primarily characterized by superior inhibitory skills. Although most reasoners might be detecting that their intuitive answer is biased, only people with superior inhibitory capacity manage to discard the tempting intuitive response.

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