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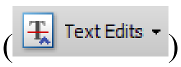
- Use the **Text Edits tool** (

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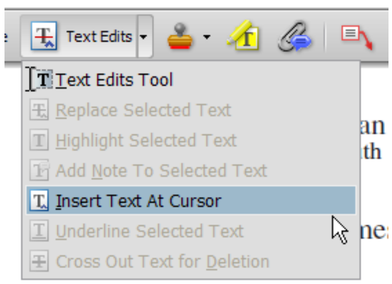

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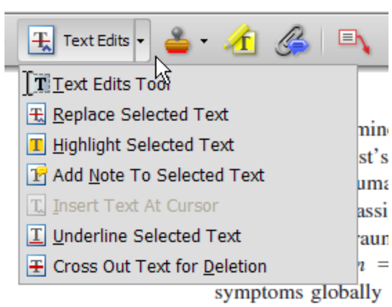

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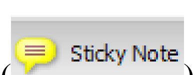
- Use the **Sticky Note tool** (

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Table 5
Experiment 4: Comparative Optimism as a Function of Self-Presentation and Event Valence

	Event					
	Positive		Negative		Total	
Self-presentation	*M*	*SD*	*M*	*SD*	*M*	*SD*
Public/student	3.46	0.13	3.60	0.10	3.53	0.12
Public/expert	2.66	0.12	2.78	0.13	2.73	0.13
Control	2.39	0.11	2.46	0.09	2.43	0.11
Total	2.84	0.47	2.95	0.50		

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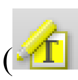
- Use the **Highlight tool** () to indicate font problems, bad breaks, and other textual inconsistencies. Describe the inconsistencies with the callout tool (shown) or a sticky note. One callout (or sticky note) can describe many changes.

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$$du/dt = -\lambda v^{\alpha} = -\lambda u$$
$$du/u = -\lambda dt$$
$$u_t = ue^{-\lambda t}.$$

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Development of Heuristic Bias Detection in Elementary School

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Although human reasoning is often biased by intuitive heuristics, recent studies have shown that adults and adolescents detect the biased nature of their judgments. The present study focused on the development of this critical bias sensitivity by examining the detection skills of young children in elementary school. Third and 6th graders were presented with child-friendly versions of classic base-rate problems in which a cued heuristic response could be inconsistent or consistent with the base rates. After each problem children were asked to indicate their subjective response confidence to assess their bias detection skills. Results indicated that 6th graders showed a clear confidence decrease when they gave a heuristic response that conflicted with the base rates. However, this confidence decrease was not observed for 3rd graders, suggesting that they did not yet acknowledge that their judgment was not fully warranted. Implications for the development of efficient training programs and the debate on human rationality are discussed.

Keywords: reasoning, heuristics, conflict detection, response confidence

Imagine a lawyer friend invites you to a small party he is throwing for his colleagues. There are some two dozen people at the party. All of the attendees are lawyers, but your friend tells you he also invited his new neighbor who is an engineer. When you are heading to the fridge to grab a drink you accidentally bump into someone and start a conversation. This person tells you his name is Ben, he is 37, married, likes to design websites in his free time, and drives a minivan. Upon hearing this information, you'll probably infer that this guy must be the engineer–neighbor. Intuitively, this seems to be making sense. After all, Ben's description fits with our stereotypical image of an engineer. However, from a probabilistic point of view, your conclusion is quite unlikely. Given that there are far more lawyers than engineers in the room (i.e., 1 out of 20+ people), the statistical base rates favor the conclusion that any random person you bump into will most likely be a lawyer. Although Ben's personality description might fit better with an engineer than with a lawyer, taking the base rate into account should push the scale to the lawyer side.

This introductory example is based on Kahneman and Tversky's (1973) famous lawyer–engineer problem. Over the last decades literally hundreds of studies have shown that most educated adults fail to solve this and related reasoning problems. In general, the problem seems to be that people tend to overrely on stereotypical intuitions and so-called heuristic thinking when making decisions (e.g., Evans, 2003, 2008; Kahneman & Frederick, 2005). Although the intuitive heuristics can sometimes be useful, they can also cue responses that conflict with traditional logical or probabilistic normative considerations and bias our decisions (e.g., Evans, 2010; Kahneman, Slovic, & Tversky, 1982).

Recent studies on conflict detection during thinking demonstrate that despite the widespread bias, young adults and adolescents at least detect that their heuristic answer conflicts with normative principles (e.g., Bonner & Newell, 2010; De Neys, Cromheeke, & Osman, 2011; De Neys, Moyens, & Vansteenwegen, 2010). Using a range of methods these studies showed that despite their erroneous answer, people are remarkably sensitive to violations of normative principles in classic reasoning tasks. For example, giving an unwarranted heuristic response in these tasks has been shown to be accompanied by increased autonomic arousal (e.g., De Neys et al., 2010) and increased response times (e.g., Bonner & Newell, 2010; Stupple & Ball, 2008; Thompson, Striemer, Reikoff, Gunter, & Campbell, 2003; Villejoubert, 2009). Neuroimaging work with the lawyer–engineer problem also established that the anterior cingulate cortex (ACC), a medial frontal brain region that is believed to mediate elementary conflict detection processing (e.g., Botvinick, Cohen, & Carter, 2004), showed increased activation when participants gave a heuristic response that conflicted with the base rates (e.g., De Neys, Vartanian, & Goel, 2008). In addition, people's subjective response confidence in the heuristic answer on the lawyer–engineer problem is also significantly lower than their response confidence on control problems where the cued heuristic answer does not conflict with the base rates (e.g., De Neys et al., 2011). Taken together these studies suggest that reasoners are detecting the biased nature of their judgment: Although people are typically tempted to give the heuristic response, they at least sense that it is not fully warranted (e.g., De Neys & Glumicic, 2008; see also Morsanyi & Handley, 2011).

The conflict detection findings have been taken as support for the importance of inhibitory processing in sound reasoning (e.g., De Neys & Franssens, 2009; De Neys & Glumicic, 2008). There is indeed a vast literature in the reasoning field that has stressed the critical role of inhibitory processing skills to override erroneous heuristic responses (e.g., Dempster & Brainerd, 1995; De Neys &

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Everaerts, 2008; De Neys & Van Gelder, 2009; Handley, Capon, Beveridge, Dennis, & Evans, 2004; Houdé, 1997, 2007; Moutier, Plagne-Cayeux, Melot, & Houdé, 2006; Reyna, Lloyd, & Brainerd, 2003; Simoneau & Markovits, 2003; Stanovich & West, 2000). However, it is well established that reasoning is a multicomponent process and that biased responses might have multiple causes (e.g., Brainerd & Reyna, 2001; Jacobs & Klaczynski, 2002; Klaczynski, Byrnes, & Jacobs, 2001; Stanovich & West, 2008). In theory, it is possible that the widespread bias should be primarily attributed to a conflict detection rather than inhibition failure (e.g., Kahneman & Frederick, 2005). Indeed, if reasoners do not detect that the heuristic response is not warranted they will simply see no reason to inhibit it. Obviously, if this is the case, heuristic bias should be characterized as a detection failure. Although some authors favor such a lax bias detection account, the evidence for adults' bias sensitivity in the conflict detection studies argues against it: The problem does not seem to be that people do not realize that they need to inhibit, but rather that people fail to complete the demanding inhibition process (De Neys & Franssens, 2009).

Note, however, that the bias detection studies have focused predominantly on young adults' performance. It cannot be excluded that bias detection failures play a more crucial role earlier on in our reasoning development. Unfortunately, the development of this bias detection or awareness process has received little attention. In one study, De Neys et al. (2011) did present a set of base-rate problems to a sample of adolescents. Bias detection efficiency was measured by asking participants to rate their response confidence after each problem. As is typically the case in the conflict detection studies, the participants were presented with classic, so-called conflict problem versions in which the base rates and personality description cued conflicting responses (e.g., see the introductory example) and newly constructed control versions in which the base rates and personality description cued the same response. Note that such a control problem can be constructed by simply switching the base rates around (e.g., people would be told that there were two dozen engineers and only one lawyer in the room). Results showed that although the effects were more pronounced for the older adolescents, all adolescent participants showed a decreased response confidence after solving the conflict versions, indicating that just like adults, they sensed that their heuristic response was not fully warranted. This suggests that the detection process is successful after the onset of adolescence. However, the detection skills of younger children remain to be explored.

Obviously, from a theoretical point of view it is important to identify possible changes in the nature or locus of heuristic bias throughout our development. At a more applied level, establishing whether heuristic bias results from a bias detection failure is also important to develop efficient intervention programs to de-bias adults and children's thinking. Influential existing intervention programs have focused on training reasoners' inhibitory processing capacities (e.g., Houdé, 2007; Houdé et al., 2000; Moutier, 2000; Moutier, Angeard, & Houdé, 2002; Moutier & Houdé, 2003). However, if younger children do not yet detect that their heuristic response is erroneous, the inhibition training will have less than optimal results. Indeed, any increase in inhibitory processing capacity per se is rather pointless if one is not able to determine whether it is needed to inhibit in the first place. Hence, examining children's detection skills is paramount to determine which component(s) intervention studies need to target.

In sum, both for theoretical and practical reasons it is important to test younger children's bias detection efficiency. In the present study we addressed this issue by focusing on the bias detection skills of children in elementary school. We focused on two grade levels: eight-year-old third graders and 11-year-old sixth graders. Basic neurological evidence suggests that the ACC, the critical brain structure that is supposed to be mediating conflict detection during thinking, is quite slow to mature and would not reach full functionally until the start of adolescence (e.g., Davies, Segalowitz, & Gavin, 2004; Fitzgerald et al., 2010; Santesso & Segalowitz, 2008). We therefore expected that by the end of elementary school, our sixth graders might start to show bias sensitivity but that this sensitivity would be lacking in our sample of third graders. Note that our prediction also receives some support from the literature on metacognition. Metacognition refers to cognitive activities that reflect on, monitor, or regulate first-order cognition (Kuhn, 2000). Conflict detection during thinking clearly exhibits metacognitive aspects (e.g., Thompson, 2009; Thompson, Prowse Turner, & Pennycook, 2011). Interestingly, developmental studies have shown that children's metacognitive skills improve substantially over the elementary school years (e.g., Roderer & Roebers, 2010; Schneider, 2008).

To test our hypotheses we adopted a child-friendly card game version of the classic base-rate task (e.g., De Neys & Vanderputte, 2011). In the task children were familiarized with the base rates in a sample by showing them cards that depicted characters that belonged to one of two groups. For example, nine cards depicted a boy and one card depicted a girl. On the back of the cards we showed a picture of an object that would cue a clear stereotypical association. In this case, for example, children would be told that on the back of the cards they would find a picture of the child's favorite toy (e.g., a toy truck or a doll). Next, children could observe how the experimenter shuffled the cards, put them in a bag, and randomly drew one card from the bag. The experimenter showed children the back side of the drawn card (e.g., a truck) and then asked them whether there would be a boy or girl on the front. This format maintained the crucial characteristics of the original base-rate problems while remaining appropriate for testing children.

We measured bias detection sensitivity by asking the children to rate their response confidence on a simplified rating scale. If elementary school children detect the unwarranted nature of their heuristic judgments, we expected them to give lower confidence ratings after solving conflict than after solving control no-conflict problems.

Method

Participants

Sixty-three third graders (mean age = 8.73 years, *SD* = .29) and 68 sixth graders (mean age = 11.74, *SD* = .38) of a suburban elementary school participated in the study.[1] The study was approved by the local school board and all parents or guardians gave informed consent for the study.

[1] Ethical restrictions set by the school board prevented us from recording detailed gender data. Casual observation suggested both genders were equally balanced in the two age samples.

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Materials

The reasoning task was modeled after the developmental adaptation of the classic base-rate task that was introduced by De Neys and Vanderputte (2011). The children were presented with plastic cards (6 cm × 7.5 cm) that had an image of a cartoon character on the front and an image of an object on the back side. Figure 1 shows an example.

F1

In each problem children were presented with 10 cards. The characters on the front sides belonged to one of two groups (e.g., girl or boy). The base rate in each problem was nine to one. The object on the back side of the card was associated with a stereotypical characteristic of the groups in question (e.g., favorite toy). The selected groups and objects were based on the pretesting of De Neys and Vanderputte (2011) that showed that the selected stereotypical associations were highly familiar to elementary school children. Note that this point is critical for the present study. If children are not familiar with the stereotypical association, the problem will not cue an intuitive heuristic response, and conflict detection will by definition not be possible. Although the absence of a cued intuitive response entails that correct responding no longer requires a demanding inhibition process and has been shown to help children reason more accurately (e.g., see Davidson, 1995; De Neys & Vanderputte, 2011; Jacobs & Potenza, 1991; Reyna & Brainerd, 1994; Stanovich, West, & Toplak, 2011), it is clear that it would confound the assessment of their conflict detection skills.

For each problem the experimenter started by laying out the 10 cards in front of the child with the front sides up. Children were familiarized with the task content and observed how the experimenter shuffled the cards, put them in a bag, and randomly drew one card from the bag. Next, the experimenter showed children the back side of the drawn card with the stereotypical object (e.g., a truck) and then asked them to which one of the two groups the character on the other side would belong.

Children solved a total of three conflict and three no- conflict problems. In the conflict problems the shown object depicted a stereotypical characteristic of the smallest group in the sample. Hence, the probabilistic response, based on the sample size, and the heuristic response, based on the stereotypical association, conflicted. In the three no-conflict problems the object depicted a stereotypical characteristic of the largest group. Hence, both probabilistic sample size considerations and heuristic knowledge cued the same response. Note that in order to manipulate the conflict nature of the problem all 10 cards actually had the same object on the back side.

After children had solved the three conflict and no-conflict problems they were presented with a final abstract control problem. In this problem the cards did not depict a character or object but were simply colored yellow or blue. There were nine yellow cards and one blue card. The back sides of the cards were white. The experimenter showed the white back side after drawing it from the bag and asked children what color the other side would have. This control problem allowed us to check whether our young participants had mastered the basic probabilistic skills to select the base-rate response.

On the conflict and abstract control problems, responses that were in line with the base rates (e.g., "boy" or "yellow") were scored as correct responses. On the no-conflict problems the base rates and stereotypical knowledge cued the same response, and selection of this response was scored as correct. Note that strictly speaking, selection of the non-base-rate response on the conflict problems does not necessarily represent a normative violation. Indeed, the actual normative status of the "correct" response in base-rate problems can be debated (e.g., Gigerenzer, Hell, & Blank, 1988). For example, if reasoners adopt a formal Bayesian approach and combine the base rates with the diagnostic value of the stereotypical association, the non-base-rate response might be warranted in some cases. Note that in the present article we are concerned with the empirical question concerning to what extent children take the base rates into account during decision making while remaining agnostic about how the base rates are used and whether the base rates ultimately turn out to be "normative" or not. Hence, for consistency with previous studies we label the base-rate response as "correct" here, but one can adopt a nominalist stance toward our use of the terms *correct* and *error*.

After children selected a response they were asked to indicate their response confidence on a simplified 4-point rating scale that ranged from 0 (*really not sure*) to 3 (*totally sure*). The scale (see Figure 2) was printed on a large board and was presented to the children after each response. F2 As Figure 2 shows, to help children grasp the nature of the scale, the consecutive numerical markers were accompanied by a line segment that linearly increased in height. The children were familiarized with the scale markers and

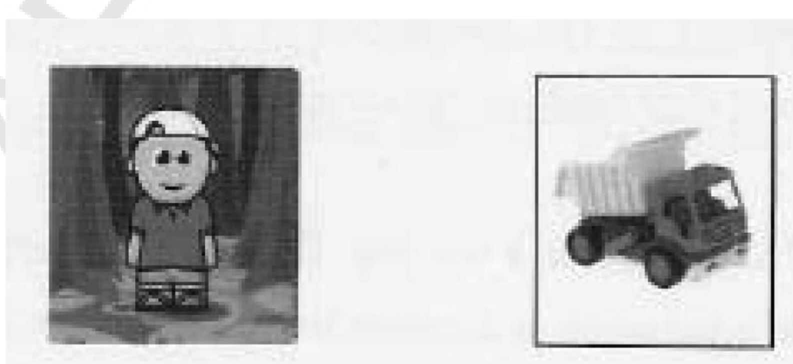


Figure 1. Front and back sides of one of the game cards.

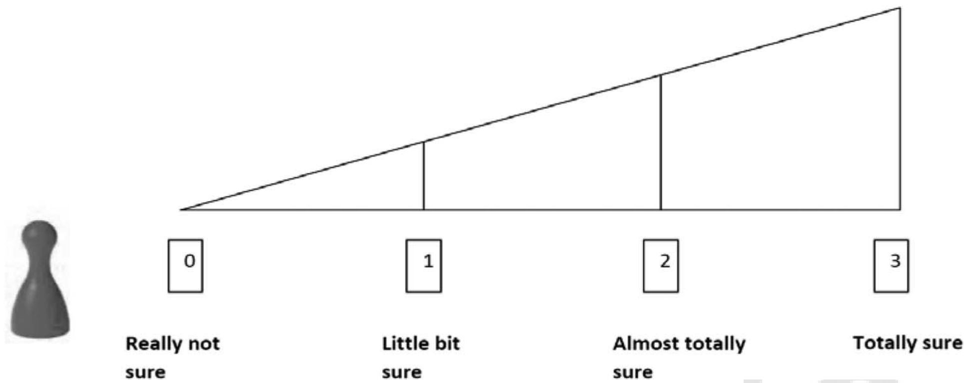


Figure 2. Example of the confidence scale and toy pawn.

were asked to put a board game pawn on the number that best reflected their feeling of confidence.

We would like to stress that the confidence measure was primarily intended to contrast children's response confidence on the conflict and no-conflict problems in the different age groups. We refrain from making any claims based on overall confidence differences across age groups. Obviously, it might be that children in different age groups simply interpret the confidence scale differently, which makes it hard to unequivocally interpret an overall confidence decrease or increase across age. However, such overall age effects should equally affect confidence ratings on the conflict and no-conflict problems within each age group, of course. Hence, by focusing on the confidence contrast for conflict and no-conflict problems across age groups we avoided these possible complications.

F3 Figure 3 presents a schematic overview of the study instructions and procedure. A complete overview of all problem material can be found in the Appendix.

Procedure

All participants were tested individually. They were told that they would be playing a game of cards and that they would need to answer a couple of questions. The complete session lasted about 10 min and was videotaped for subsequent scoring. The problems were presented in one of two randomly determined orders that alternated the conflict nature of the problems. Hence, a conflict problem was always followed by a no-conflict problem (and vice versa). The content of the conflict and no-conflict versions was fully crossed. Problems that were presented in a conflict version to half of the participants were presented as no-conflict problems (i.e., by switching the base rates around) to the other half of the participants in every age group. Finally, the abstract control problem was presented.

Results

Reasoning Accuracy

For each participant we calculated the average performance on the conflict and no-conflict problems and subjected these to a 2 (age, between-subjects) × 2 (conflict, within-subject) mixed model analysis of variance (ANOVA). Figure 4 gives an overview of the results. There was a main effect of conflict, $F(1, 129) = 896.37$, $p < .0001$, $\eta_p^2 = .87$. As expected, accuracy rates were floored on the conflict problems, whereas the no-conflict problems were solved almost perfectly. The main effect of age, $F(1, 129) = 2.13$, $p = .15$, and the interaction with the conflict status, $F(1, 129) < 1$, did not reach significance.

F4

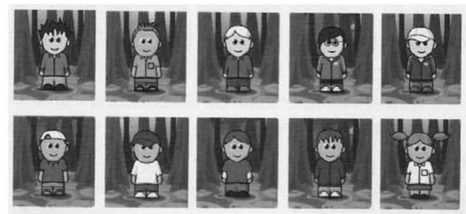
Response Confidence

Our main question concerned elementary school children's response confidence. For each participant we calculated the average confidence rating on the conflict and no-conflict problems and also subjected these to a 2 (age, between-subjects) × 2 (conflict, within-subject) mixed model ANOVA. Figure 5 gives an overview F5 of the results. Although the accuracy findings may have given the impression that there was little age-related development going on, the confidence ratings sketch a more nuanced picture: The main effect of age was not significant, $F(1, 129) < 1$, but as Figure 5 indicates, the age and conflict factors interacted, $F(1, 129) = 6.94$, $p < .01$, $\eta_p^2 = .05$. There was also a main effect of the conflict factor, $F(1, 129) = 20.07$, $p < .001$, $\eta_p^2 = .14$. As expected, planned contrast indicated that sixth graders were significantly less confident about their responses on the conflict than on the no-conflict problems, $F(1, 129) = 26.31$, $p < .001$, $\eta_p^2 = .17$. However, this confidence decrease was not yet significant in the third graders, $F(1, 129) = 1.64$, $p = .203$.[2] Remember that the Fn2 only difference between the conflict and no-conflict problems was the fact that the base rates were switched around and conflicted with the cued heuristic response or not. The decreased confidence shows that sixth graders are sensitive to the presence of this conflict and start doubting their heuristic response.

However, although accuracy rates on the conflict problems were low, some participants did solve them correctly. One might argue that these participants are driving the confidence effect. Clearly, the fact that the few participants who manage to solve the problem correctly know that the base rates matter and are sensitive to the

[2] For completeness, we note that the confidence ratings were stable across our three conflict and no-conflict items. An ANOVA across items confirmed that the confidence decrease was significant for sixth graders, $F(1, 2) = 35.47$, $p < .05$, $\eta_p^2 = .95$, but not for third graders, $F(1, 2) = 2.49$, $p = .26$.

<< The experimenter puts the 10 cards in front of the child >>



"On these cards you can see nine boys and one girl. On the back side of each card there is a picture of each kid's favorite toy."

"OK. As you can see, I'm shuffling the cards really well now and then I put them in this bag. OK. Now, I'm going to draw one card from the bag without looking"

"See, this is the back side of the card that I drew:"

<< The experimenter shows the back side >>

"Now what do you think is most likely; will there be a boy or a girl on the front?"

<<the experimenter asks to turn over the page with the confidence scale image >>

"OK. I would like to know how sure you are that the answer you just gave is the correct answer. You see, we've got four numbers over here (ranging from 0 to four 3. "0" means that you're really not sure that you are right, "1" means you're a little bit sure, "2" means that you're almost totally sure, and "3" means that you're totally sure. Please take this pawn and put it on the number that best indicates how sure you feel about your answer."

Figure 3. Schematic overview of the instructions and task format.

intrinsic conflict between the cued responses is hardly surprising. The key question is whether an 11-year-old who gives a heuristic response detects that his or her answer is not fully warranted. To control for this factor we repeated the above analysis but discarded all conflict trials that were solved correctly. For completeness, we also discarded the few no-conflict trials that were solved erroneously. However, results were not affected. Sixth graders who gave a heuristic response on the conflict problems were still less confident about their conflict answer than about their answer on the no-conflict problems, $F(1, 126) = 32.15$, $p < .001$, $\eta_p^2 = .20$. Once again, third graders did not show the confidence decrease, $F(1, 126) < 1$.

Another way of testing the above point is to examine the correlation between one's performance on the conflict problems and the confidence contrast for conflict and no-conflict problems. Although the floored accuracy on the conflict problems implies that some caution is needed when interpreting these data, we nevertheless present the analysis for exploratory purposes. In the group of sixth graders, the confidence contrast (i.e., average confidence rating conflict problems − average confidence rating no-conflict problems) did not depend on one's accuracy on the conflict problems, $r = .01$, $p = .92$. Since our analyses already indicated that even sixth graders who failed to solve conflict problems show the decreased conflict confidence, this is not surprising. However, for the third graders the correlation did reach significance, $r = -.27$, $p < .05$. Hence, the most gifted third graders, who solved the conflict problems correctly, did tend to show a more pronounced confidence decrease after solving conflict problems. This makes sense since in order to solve a conflict problem correctly one needs successful conflict detection. Although these data need to be interpreted cautiously, they do allow us to underscore the point that despite the observed overall lack of conflict detection, a small minority of third graders do succeed at it. Consistent with our claims, it will be these third graders who will be most likely to solve conflict problems correctly.

Finally, to explore the link between accuracy and confidence further we analyzed the confidence contrast exclusively for conflict problems that were solved correctly in our two age groups. The data are presented in Figure 6 (along with the data for F6
incorrectly solved conflict problems). There was a main effect of

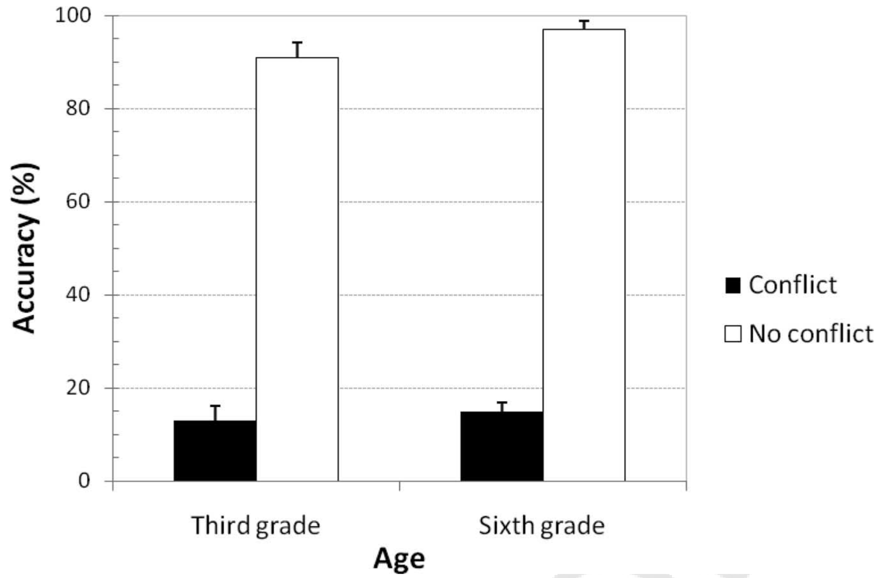


Figure 4. Average response accuracy on conflict and no-conflict problems in the two age groups. Error bars are standard errors.

the conflict factor, $F(1, 34) = 22.43$, $p < .0001$, $\eta_p^2 = .40$, whereas the main effect of age, $F(1, 34) < 1$, and the Age × Conflict interaction, $F(1, 34) < 1$, were not significant. A control planned contrast specifically confirmed that even in the group of third graders confidence ratings were significantly lower for correctly solved conflict problems than for no-conflict problems, $F(1, 34) = 12.68$, $p < .005$, $\eta_p^2 = .27$. This pattern fits with the correlational analysis. We already stressed that given the limited number of data points for correctly solved trials, these findings need to be interpreted with caution. We simply note that in the De Neys et al. (2011) confidence study with adults, reasoners who gave a correct response on the conflict problems did not show a decreased confidence. De Neys et al. attributed this effect to the fact that adult reasoners who solve the problem correctly and inhibit the heuristic response also resolve the initially experienced conflict between the competing responses. One tentative hypothesis is that adults and younger reasoners who manage to inhibit the heuristic response still differ in this respect. That is, adults who give the correct response seem to be confident that it is correct and no longer doubt their response (i.e., in contrast with no-conflict problems), whereas younger reasoners who give the correct response are still affected by the initially experienced conflict. Hence, although some

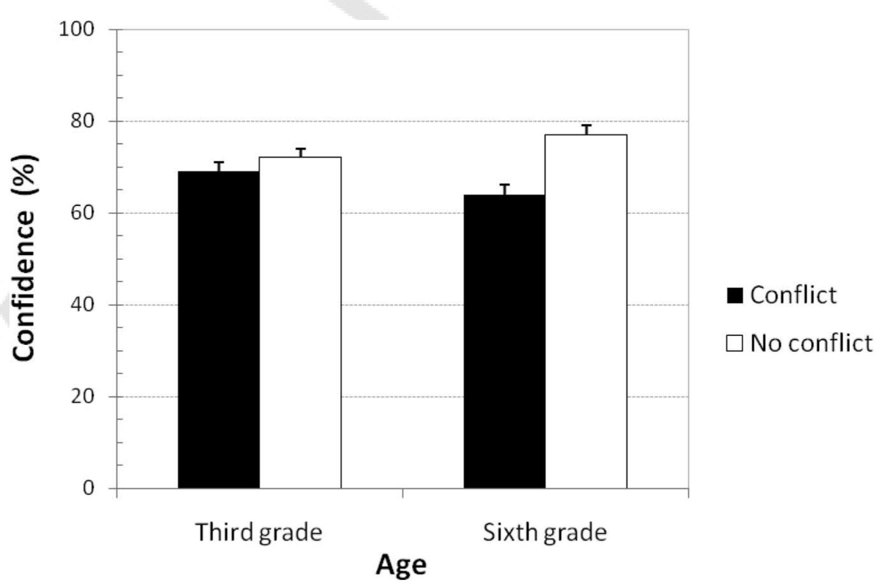


Figure 5. Average response confidence (%) on conflict and no-conflict problems in the two age groups. Four-point confidence ratings were rescaled as percentage scores. Error bars are standard errors.

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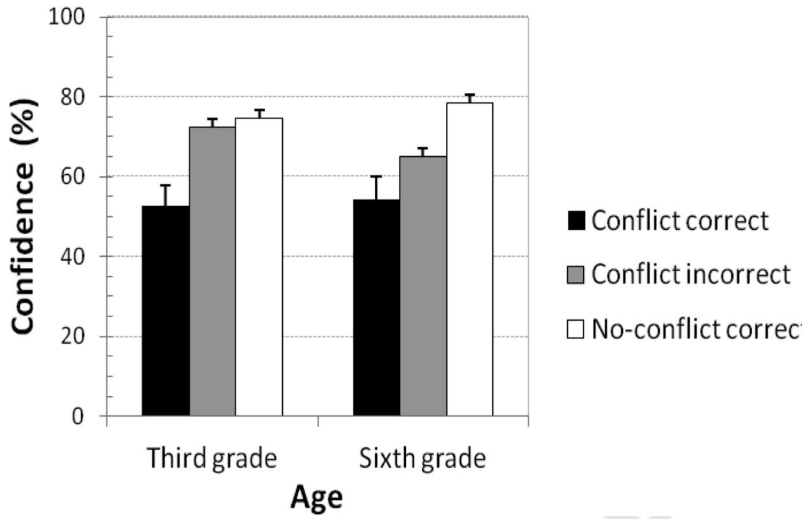

Figure 6. Average response confidence (%) as a function of response accuracy in the two age groups. Four-point confidence ratings were rescaled as percentage scores. Error bars are standard errors.

younger reasoners manage to select the base-rate response and override the heuristic response, this might imply that their inhibitory processing is more superficial or less extensive. Clearly, this hypothesis is tentative and will need proper testing. As we stated, the analyses on the correctly solved conflict problems are presented for exploratory purposes. The present study and methodology were designed to focus on the dominant heuristic responses. With respect to the critical heuristic responses on the conflict problems our results clearly indicate that biased third graders do not yet detect that their answer is not warranted.

Abstract Control Problem

On the abstract control problem heuristic thinking could not interfere with or cue sound reasoning. Solving the problem relies on mere analytic thinking about the group sizes. Thereby the problem allowed us to check whether our youngest reasoners had mastered the necessary knowledge about the impact of group size on probability estimates. Note that this is not a trivial issue. If third graders do not know that base rates matter for their judgment, the lack of bias awareness should not be attributed to a lax conflict detection process but rather to an insufficiently developed probabilistic knowledge base. Indeed, if the base rates do not cue a response there will simply be no conflict to detect. However, consistent with previous findings (e.g., De Neys & Vanderputte, 2011; Téglás, Girotto, Gonzalez, & Bonatti, 2007; Xu & Garcia, 2008), children had little trouble solving the abstract problem. The vast majority of third (M = 82%, SE = 5%) and sixth (M = 92%, SE = 3%) graders gave the correct response. The performance difference between the two groups was not significant, $F(1, 129) = 3.14$, $p = .08$. However, in both the youngest group, $t(62) = 6.75$, $p < .0001$, and the oldest group, $t(67) = 13.37$, $p < .0001$, performance was clearly above chance level.[3] Note that the response confidence on the abstract problem also did not differ between the two groups, $F(1, 129) < 1$.

Although the difference was not significant one might nevertheless note that the accuracy on the control problem tended to be somewhat lower for third graders than for sixth graders. To completely eliminate the possibility that mere knowledge-base differences are driving the critical observed confidence interaction we repeated our 2 (age, between-subjects) × 2 (conflict, within-subject) ANOVA but discarded all participants who failed to solve the abstract control problem correctly. However, results were consistent: The age and conflict factors still interacted, $F(1, 113) = 4.23$, $p < .05$, $\eta_p^2 = .04$. Planned contrast once again confirmed that although sixth graders were significantly less confident about their responses on the conflict than on the no-conflict problems, $F(1, 113) = 23.20$, $p < .0001$, $\eta_p^2 = .17$, this confidence decrease was not significant for third graders, $F(1, 113) = 2.55$, $p = .11$.

Discussion

Studies on conflict detection during thinking have demonstrated that adults and adolescents show a remarkable bias sensitivity. The present study showed that this sensitivity is well developed by the end of elementary school. Just like adults and older adolescents, sixth graders were less confident about their heuristic answer when it conflicted with the base rates than when it was consistent with them. This implies that even sixth graders are sensitive to this conflict and detect that their heuristic answer is not fully warranted.

In sharp contrast with sixth graders, however, our sample of third graders did not show the critical bias sensitivity. Although the few third graders who managed to avoid a heuristic response tended to display a decreased confidence on the conflict problems, biased third graders were equally confident about their answer on

[3] These findings were confirmed with nonparametric tests: A Mann-Whitney U test showed that accuracy was not different for third and sixth graders, U = 1925, $p = .32$, and chi-square tests showed that accuracy for both third graders, $\chi^2(1) = 15.57$, $p < .0001$, and sixth graders, $\chi^2(1) = 30.23$, $p < .00001$, was above chance level.

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conflict and no-conflict problems. At the same time, third graders' performance on the abstract problem showed they were typically familiar with the impact of base rates on probability judgments. This establishes that the absence of a confidence decrease needs to be attributed to a failed monitoring process and not to a knowledge gap per se. That is, the average third grader is familiar with the proportionality principle; the problem is that when faced with salient heuristics he or she does not seem to activate this knowledge and monitor for inconsistencies. Such monitoring has been shown to be effortless and automatic for adults (e.g., Franssens & De Neys, 2009). In line with neurological evidence pointing to the slow maturation of the brain structures that mediate this basic monitoring function (e.g., Fitzgerald et al., 2010; Santesso & Segalowitz, 2008), the present findings suggest that it is still too demanding for most third graders. As a result, third graders will typically not yet detect the unwarranted nature of their heuristic judgments.

Note that although sixth graders were better than third graders at detecting the biased nature of their answers, sixth graders' answers were not more accurate. That is, accuracy rates were not different in the two age groups. At first sight this might seem somewhat contradictory. However, as we noted, here it is important to bear in mind that reasoning is a multicomponent process (e.g., Brainerd & Reyna, 2001; Jacobs & Klaczynski, 2002; Stanovich & West, 2008). Conflict or bias detection is a necessary condition for sound reasoning but by no means sufficient. After successful detection of the unwarranted nature of a heuristic response, selecting the correct base-rate response requires overriding the salient heuristic response. Since this inhibition process is known to be hard for adults (e.g., De Neys & Verschueren, 2006; Newstead, Handley, Harley, Wright, & Farelly, 2004; Stanovich & West, 2000) it is not surprising that 11-year-olds fail to complete it. The point is that although both the majority of third and sixth graders end up being biased, they are biased for different reasons. That is, whereas the typical sixth grader will be biased because he or she presumably fails to inhibit the heuristic response after successful conflict detection, the typical third grader will be biased because he or she does not yet detect the need to inhibit the heuristic response.

In general, the study underscores the claim that reasoning studies need to move away from an exclusive focus on the output of the reasoning process (i.e., the accuracy of the final answer) and take the underlying processing mechanisms into account (e.g., Hoffrage, 2000; Reyna, 2000). Although the accuracy rates may suggest that there is little reasoning development going on between third and sixth grade, our exploration of the bias detection process sketches a different picture. Indeed, it has been argued that the successful nature of reasoners' bias detection has important implications for our view of human rationality (De Neys & Glumicic, 2008). It suggests that people are no mere heuristic thinkers who completely disregard normative logical or probabilistic considerations. For example, the fact that reasoners are sensitive to the conflict between cued base rates and the cued heuristic response implies that although they might not manage to select the base-rate response, the base-rate information is nevertheless taken into account. If this were not the case, the conflict and no-conflict versions should not be processed any differently. Bluntly put, the conflict detection findings establish that reasoners are more normative than their biased answers suggest. The current findings suggest that children make an interesting transition in this respect by the end of elementary school. That is, whereas one could still try to conceive young elementary school reasoners as mere heuristic thinkers,[4] this conceptualization is definitely no longer Fn4
accurate by the end of elementary school. Near the onset of adolescence children will typically start to detect the conflict between cued heuristics and their normative knowledge. In sum, this indicates that by the end of elementary school, heuristic bias can no longer be attributed to a conflict detection failure.

With respect to the conceptualization of sixth graders' bias detection it is important to note that the conflict detection studies with adults already indicated that the detection process is implicit in nature (De Neys, 2012; De Neys & Glumicic, 2008; Franssens & De Neys, 2009). That is, although adults' response confidence, response latencies, and brain activation indicate that they are sensitive to violations of normative principles in classic reasoning tasks, they do not tend to explicitly refer to these normative principles. For example, when De Neys and Glumicic (2008) asked university students to think aloud while solving conflict base-rate problems, they observed that participants hardly ever explicitly mentioned that the base rates were relevant. This lack of explicitation has resulted in the idea that the conflict or "bias" signal should be conceived as an implicit "gut" feeling (e.g., De Neys, 2012; De Neys et al., 2010; Franssens & De Neys, 2009): The signal would inform people that their intuition is not fully warranted, but people would not always manage to verbalize the experience and explicitly label the logical principles that are being violated. In other words, people will be aware *that* there is something fishy about their heuristic response, but they will not be able to put their finger on it and explain *why* their response is questionable (see De Neys, 2012). Although we did not directly test our elementary school children's verbalizations, given the findings with adults, we consider it highly unlikely that sixth graders would demonstrate such explicitation.[5] In sum, just as in the studies with Fn5
adults, we believe that the demonstrated conflict sensitivity is implicit in nature and should be conceived as an elementary warning signal that informs the child that the heuristic response is not warranted.

Our introduction pointed to the practical implications of the present study. We noted that promising intervention programs aimed at improving reasoners' decision making have primarily focused on training participants' inhibitory processing potential (e.g., Houdé et al., 2000; Moutier et al., 2002). The present findings suggest that such programs might have less than optimal results when run with young children. The established lack of bias detection before the end of elementary school implies that young children will not manage to detect whether heuristic intuitions need to be inhibited or not. Hence, even an increased inhibitory processing capacity will have little impact. Indeed, inhibition in the absence of good conflict detection might even have unwanted negative side effects. Note that heuristic thinking is not always wrong. Often, the heuristic response will reside with more delib-

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[4] See also Jacobs and Klaczynski (2002)~~; see~~ Reyna et al. (2003) or De Neys and Vanderputte (2011) for arguments against this idea.

[5] In line with this claim, De Neys and Vanderputte (2011) and Jacobs and Potenza (1991) observed that third and sixth graders' retrospective response justifications rarely referred to the base rates after solving conflict problems.

erate and elaborate logical analysis. Since heuristic thinking is typically fast and effortless (e.g., De Neys, 2006; Stanovich & West, 2000; but see also Morsanyi & Handley, 2008), it can be highly beneficial in these cases. Making optimal use of available inhibitory capacities requires that one monitors for conflict first and shuts down the heuristic route only when it is needed. Training inhibition in the absence of efficient bias detection might therefore result in a general shutdown of the heuristic route. That is, children might simply start to mistrust their heuristic intuitions throughout. In many cases this could deprive children of the advantages of heuristic thinking.

Note that our comments should not be interpreted as a critique on the existing intervention programs per se. To our knowledge, the youngest participants who were trained in these intervention studies so far were late fifth graders (Moutier, 2000). Given the present findings it is reasonable to assume that the conflict detection skills were already sufficiently developed in this age range. In addition, although the intervention programs have focused on inhibitory processing it is possible that they will also stimulate children's monitoring and have an impact on their bias detection skills. Hence, our point is not that running existing programs with young elementary school children necessarily calls for a program revision but rather that the impact of these training programs on children's bias detection should be tested first. We believe that such combined testing and possible training of detection and inhibition skills holds great potential for de-biasing young children's thinking.

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(*Appendix follows*)

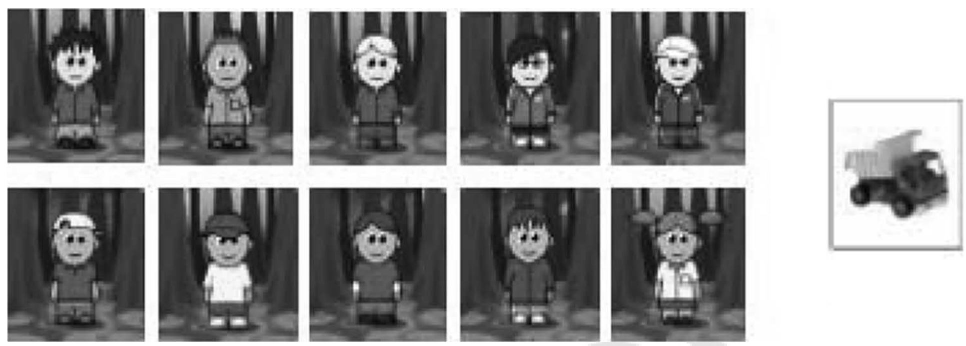
Appendix

Overview of Material Used for Problem Construction

Problem 1:

Front side: Boys/girls

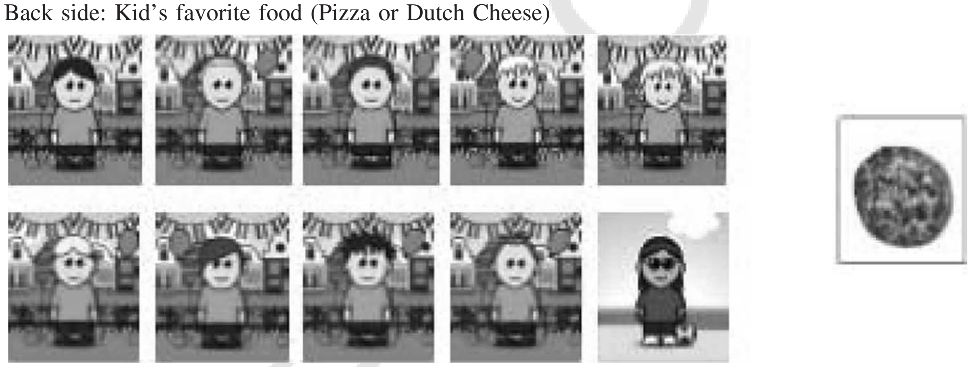
Back side: Kid's favorite toy (Toy truck or doll)



Problem 2:

Front side: Dutch kids/Italian kids

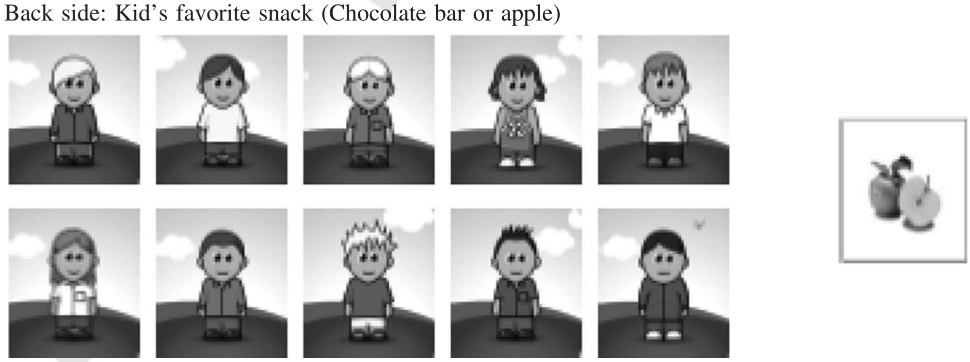
Back side: Kid's favorite food (Pizza or Dutch Cheese)



Problem 3:

Front side: Thin kids/Fat kids

Back side: Kid's favorite snack (Chocolate bar or apple)

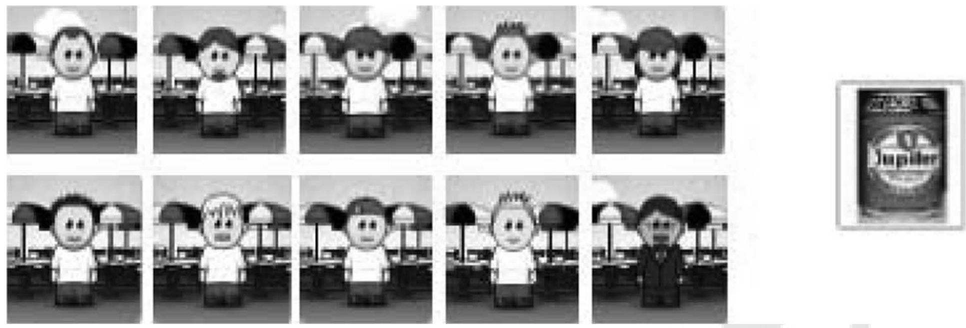


(*Appendix continues*)

Problem 4:

Front side: Brick layers/principals

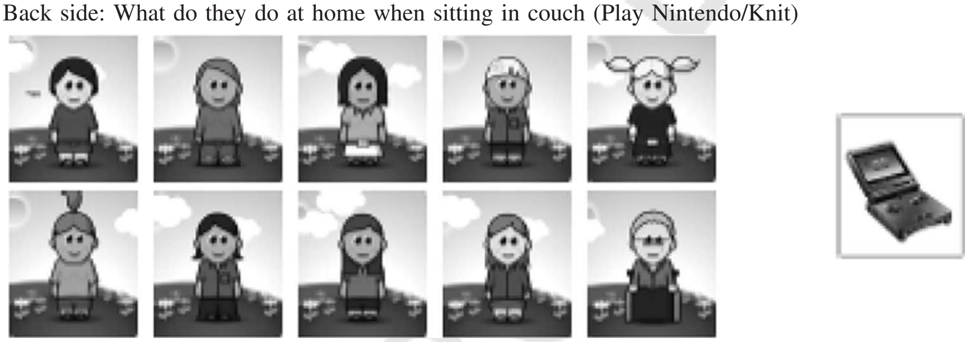
Back side: What do they drink during break at work (Coffee or Beer)



Problem 5:

Front side: Kids/Grannies

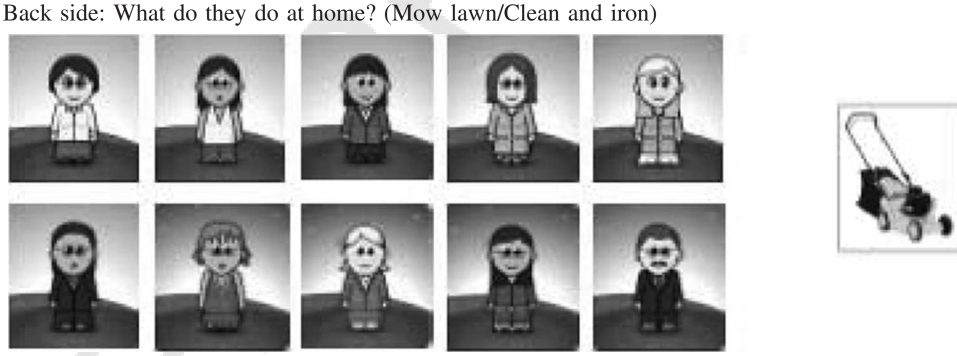
Back side: What do they do at home when sitting in couch (Play Nintendo/Knit)



Problem 6:

Front side: Mommies/Daddies

Back side: What do they do at home? (Mow lawn/Clean and iron)



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AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES **1**