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The role of language comprehension in reasoning: How "good-enough" representations induce biases

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ABSTRACT

Research on reasoning and judgment often uses problems where intuition and deliberation are in conflict, suggesting different solutions. In four studies, change detection was used to investigate whether biased responses to these problems are a consequence of faulty problem-solving or whether they can start earlier, from misrepresenting the information in the premises. After participants solved problems, they were presented with the same problems again in different versions, changing conflict problems to no-conflict problems and vice versa. Participants who were more sensitive to these changes showed better reasoning. These results suggest that biases can start before the problem-solving stage, from misrepresenting the conflict between deliberation and intuition.

1. Introduction

Research on verbal comprehension shows that sentences are not subject to careful analysis and consistency checks. Semantic illusions are a powerful demonstration of this. For example, when asked "How many animals of each kind did Moses take in the ark?", most people respond "two", failing to notice that it was not Moses but Noah who took animals in the ark (Erickson & Mattson, 1981). These illusions occur because "the semantic representations that get computed are shallow and incomplete" (Ferreira, Bailey, & Ferraro, 2002, p. 12), merely *good enough representations* (Ferreira et al., 2002). In this paper, we investigate whether errors in reasoning problems may be partly explained by inaccurate representations of the premises that do not preserve all the information that is necessary for successful problem-solving.

According to dual-process theories (e.g., Evans, 2006; Kahneman, 2011; Sloman, 1996; Stanovich & West, 2000), two distinct modes of thought underlie our reasoning: intuition and deliberation. Classic reasoning problems create a conflict between them, such that they produce inconsistent responses. Examples include syllogisms where the believability of the conclusion and its logical necessity are at odds (e.g., De Neys & Franssens, 2009); base-rate (BR) problems where the information about the individual is inconsistent with the majority of the population (e.g., De Neys & Franssens, 2009); the Cognitive Reflection Test (CRT, Frederick, 2005), where there is a compelling but incorrect solution and a correct but thought-demanding solution; etc.

Failures to perform correctly in those tasks are often thought to result from faulty thinking, with intuition prevailing over deliberation. However, considering that people often represent sentences in a shallow and incomplete manner, one reason why people make reasoning errors might be that they misrepresent the problems. Thus, biased responses might not come solely from flaws at the

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problem solving stage. Rather, the bias might start even earlier, when the information in the premises is processed.

Take, for example, the following CRT problem: "A bat and a ball together cost 110 cents. The bat costs 100 cents more than the ball. How much does the ball cost?" Arriving at the correct solution (5 cents) requires deliberating beyond one's initial intuition (10 cents). But it also requires that all the information in the premises (especially the "more than the ball" part, where the intuitive/deliberative conflict lies) is accurately represented when analyzing the problem. Thus, unless an accurate representation of the premises is formed, one is bound to err, for even careful deliberation will produce the incorrect answer if it operates on incorrect premises.

In order to explore problem representation, we used a change detection paradigm (e.g., Sturt, Sanford, Stewart, & Dawydiak, 2004). After solving reasoning problems, participants were shown those problems in different versions and asked whether they detected any change. In the critical trials, the problem changed from a version that poses a conflict between deliberation and intuition (e.g., the bat-and-ball problem) to a no-conflict version where deliberation and intuition concur on the solution (e.g., the bat-and-ball problem without the "more than the ball" part of the second premise; see Appendix A for examples). If part of the reason for responding incorrectly to conflict problems is that these problems are misrepresented and conflict is neglected, then incorrect responders should be worse than correct responders at detecting those critical changes. Conflict-irrelevant changes were also included in order to test whether incorrect responders differ from correct responders specifically in that they misrepresent the conflict, or whether they simply pay less attention to all the information in premises.

2. Study 1

In addition to using change detection, Study 1 included another task that is well established in research on verbal comprehension as a good test of the degree to which people process information in sentences carefully and accurately: the ability to detect semantic illusions (Barton & Sanford, 1993; Erickson & Mattson, 1981). If the ability to reason about conflict problems is related to the ability to represent the information in the premises of those problems correctly, then performance on reasoning problems should be related to performance on verbal comprehension tasks.

2.1. Method

2.1.1. Participants

Sixty participants were recruited at the University of Heidelberg and received either 4 euros or course credit.

2.1.2. Procedure

Participants were asked to solve 6 CRT-type problems (see Appendix A for examples of the materials used in these studies), 6 syllogisms, 6 BR problems (some of the syllogisms and BR problems were adapted from De Neys & Franssens, 2009); and 6 general knowledge questions, some of which contained semantic illusions (adapted from Erickson & Mattson, 1981). Problems were presented one at a time in blocks of the same kind, in the aforementioned order. Within each block, problems were presented in random order. Three problems of each kind were conflict problems and 3 were no-conflict problems. There were 2 versions of the material, counterbalanced between participants, with each problem being presented in either the conflict or the no-conflict version.

There was a final problem containing a semantic anomaly (the survivor problem from Barton & Sanford, 1993). In order to control for memory decay as a cause of poor change detection, the survivor problem was the last to be presented in the problem solving stage and the first to be presented immediately afterwards in the change detection stage, this time in its no-conflict version.

After solving the problems, participants received the following instructions: "Now you will see the same problems again or slightly different versions of these problems. Your task is to indicate whether you detect any change from the original version. If you detect any difference from the original, then indicate what that difference is". Results were analyzed both considering whether participants correctly identified what changed in the problem, and simply considering whether participants indicated that something changed, regardless of whether they were able to correctly identify what changed or not (the latter type of analysis will be referred to as unconditional).

One problem of each kind changed from conflict to no-conflict, another problem changed from no-conflict to conflict, one conflict problem suffered a change that was irrelevant to its conflict status (e.g., in a syllogism, "roses" changed to "tulips"), and the other three problems did not change.

2.2. Results

For all types of problems, participants who correctly detected the critical change from conflict to no-conflict were more likely to solve the problems correctly than those who did not detect it (see Table 1; for the results of the reverse analysis – conditionalizing change detection on performance – see Appendix B).

The number of correct solutions for conflict problems was regressed on the numbers of correct detections for each type of change (conflict to no-conflict, no-conflict to conflict, irrelevant, and no change). Performance in conflict problems was predicted by correct detections of conflict-relevant changes (from conflict to no-conflict, and vice versa), $\beta s \geqslant .33$, $ps \leqslant .009$, but not other changes (irrelevant changes and no changes), $\beta s < .11$, $ps > .315$. In the unconditional analysis, only detections of no-conflict to conflict changes predicted performance, $\beta = .47$, $p = .001$; other $\beta s \leqslant .18$, $ps \geqslant .128$.

In the problem-solving stage, performance (i.e., number of conflict problems correctly solved) on the reasoning problems (CRT, syllogisms and BRs) correlated with performance on the verbal comprehension tasks (i.e., detecting the semantic illusions in the general knowledge questions and in the survivor problem), $r = .32$, $p = .013$. These results