Belief bias effect in reasoning of future teachers

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Abstract

Belief bias is the tendency to be influenced by the believability of the conclusion when attempting to solve syllogistic reasoning problem. This type of problems is considered as reflection of major critical thinking skill – i.e. putting aside one’s prior knowledge and reason from new premises. The paper presents results of a study with 597 future teachers, in which we examined their ability to resist belief bias and whether it can be connected to their cognitive abilities (intelligence measured by Vienna Matrix Test) or cognitive dispositions (Master Rationality Motive Scale). Results showed that participants showed highest belief bias with problems that were either valid, but unbelievable, or invalid but believable with cognitive abilities only weakly correlated with resisting to belief bias (only in case of valid but unbelievable problems). Results are discussed in terms of their implication for rationality debate and newly proposed Stanovich’s tripartite model of human mind.

Keywords: belief bias; cognitive ability; formal reasoning task; syllogisms; thinking dispositions; rationality.

1. Rationality and cognitive ability

The association between higher cognitive abilities and rationality is not straightforward. The vast amount of research in heuristic and biases program revealed that despite our intelligence, we often fall prey to many cognitive errors and fallacies. It is due to relying on our intuitive, heuristic type 1 processes, instead of employing more deliberate and accurate type 2 processes. Stanovich (2011) further divides type 2 processes into two parts – algorithmic mind is connected with our cognitive abilities to solve the problems and reflective mind is connected with our disposition to recognize the need for more effortful cognitive processes and our dispositions to engage in them. People are sometimes called “cognitive misers” due to their tendency to employ
the least effortful ways to solve a given problem. Stanovich (2011) also introduced framework for classification of such cognitive errors. Suboptimal reasoning (and thus implications for rational behaviour of people) can be caused either by three general types of errors: (1) dysfunctional autonomous system, (2) tendency to miserly processing, or (3) so called mindware problems.

Stanovich (2011) also asserts that rationality can be divided into fluid and crystallized in analogy with Cattel/Horn/Carroll GfC theory, but acknowledges that in contrast with intelligence, rationality is probably more multifarious. Furthermore, rationality is also related to cognitive abilities (which are necessary but not sufficient for rational thinking) and our thinking dispositions or preferences for more effortful thinking, but both these constructs are measured in different ways. As was mentioned previously, to know one’s intelligence does not predict that s/he will act rationally (for review of relationship between rationality and intelligence see Stanovich, 2009, 2011a, 2011b) and the same applies to self-reported thinking styles (for review of predictive validity of self-reported inventories related to rationality/intuition see Hanák, 2013). Kordačová (1994) studied relationship between irrationality, logical thinking (using syllogisms) and cognitive abilities, but she reports only findings regarding relationships to irrational beliefs. She found that correctness or erroneousness of logical reasoning did not change in dependence on the degree of irrationality. In our previous work (Čavojová & Hanák, 2014) we found only weak correlations between measures of fluid rationality and cognitive styles.

Multifariousness of rationality has important implications to education. If irrationality is caused by lack of knowledge or motivation, it should be addressed more easily than when it is caused by lack of cognitive abilities. Therefore, the aim of this paper is to explore the possibilities to measure one aspect of rational thinking (namely resistance to belief bias) and its connection to cognitive abilities (intelligence) and motivation for rational integration. In the next sections I will briefly introduce belief bias effect and its relation to rational thinking.

1.1. Critical thinking and belief bias

Critical thinking is one of the important aspects of rationality and teaching critical thinking is one of the main proclaimed objectives of almost all educational systems. The issue of critical thinking in teaching psychology in Slovakia was elaborated by Masaryk, Bašnáková and Kostovičová (2013), who pointed out that our curriculum concentrates more on remembering facts than critical appraisal of learned concepts and theories. Critical thinking is often connected with the ability to decouple prior beliefs and opinions from the evaluation of evidence and arguments (Macpherson & Stanovich, 2007) and is closely related to logic, because it requires objective analysis and evaluation of an issue in order to form a judgment, which should adequately reflect the objective reality.

Often the truth of many judgments cannot be determined without rigorous experimentations, but we can infer the correctness of a judgment by comparing the logical structure of the judgment with the structure of rules for correct reasoning (Gahér, 2003). Everyone who reasons correctly applies the logic rules, whether intuitively or consciously. However, there is a lot of evidence that we often fail to adhere to strictly logical rules and fall prey to many cognitive biases, mainly because we fail to decontextualize. Prescriptive logic states that we should apply the same rules regardless the context, but it is often not the case (for review of research done in Slovakia with regard to intuitive/heuristic processing see Ballová Mikušková, 2014).

Belief bias is one of the examples of such cognitive errors. It means that we tend to evaluate the logical validity of deductive arguments mainly on the basis of our personal beliefs regarding the empirical status of the conclusion (Markovits & Nantel, 1989).

Belief bias is studied most often by syllogistic reasoning paradigm where validity and the believability of the conclusion are put in conflict (Macpherson & Stanovich, 2007; Markovits & Nantel, 1989; Morley, Evans, & Handley, 2004). Belief bias is then defined as greater acceptance of believable than unbelievable conclusions and logical competence can be defined as greater acceptance of valid conclusions than invalid conclusions.

Belief bias research uses two main paradigms: production tasks (participants are asked to draw conclusions from the presented premises) and evaluation tasks (participants are presented with some premises and a conclusion to be evaluated – as valid if it necessarily follows from the premises and as invalid if it does not).
The most evidence has been associated with the evaluation tasks (see Morley et al., 2004), but some researchers argued that the requirement to evaluate a conclusion does not necessarily call for deductive thought (Johnson-Laird & Steedman, 1978). Markovits and Nantel (1989) compared evaluation and production paradigm and found significant belief-bias effect in both, although the qualitative analysis indicated that belief-bias effect was more pervasive in production condition.

There are also several kinds of syllogisms that can be used in research. A syllogism usually consists of three statements – the first two statements (premises) each specify the relationship between an end term and the middle term. There are also four possible logical quantifiers (some, all, no, and some ... not) which determine the mood of the statement (A, I, E, O)\(^2\). The order in which the end term and the middle terms are presented can be manipulated to produce one of the four figures of the premises. Traditional label for these four figures is MP-M, PM-S, MP-M, and PM-M, where S is subject, P is predicate and M is a middle term connecting two premises, which does not appear in the conclusion. The order, in which the premises are presented, can also affect the logical performance of participants, which was reported as figural bias by Johnson-Laird and Steedman (1978) and Johnson-Laird and Bara (1984). They demonstrated a clear preference for the direction of the conclusion which interacted with the figure of the syllogism.

In the present study we used the same materials (evaluation task with multiple-model syllogistic problems) as Morley et al. (2004): 1st figure was of two kinds (SiM, MeP, SoP for valid conclusion, SeM, MoP, SoP for invalid conclusion) and 4th figure (PeM, MiS, SoP for valid conclusions, PiM, MiS, SoP for invalid conclusion). Conclusions of the 1st figure type syllogisms were in preferred direction, conclusion of the 4th figure type was in non-preferred direction (Johnson-Laird & Steedman, 1978). Johnson-Laird and Steedman (1978) recommend the each syllogism separately (due to effects of figural bias and preferred direction of conclusion), so the secondary aim of this paper is to examine which kind of syllogism is the most suitable for assessing the belief bias (and resistance to belief bias).

According to Morley et al. (2004) the influence of belief bias interacts with logical status of a problem and is more strongly associated with reasoning on invalid problems. In their study there was only small difference in the acceptance rates of believable (89%) and unbelievable conclusions (59%), but there was a larger difference in acceptance rates for believable (71%) and unbelievable (10%) conclusions for invalid problems.

2. Methods

2.1. Participants and procedure

A total of 597 participants (M\(_{\text{age}}\) = 19.9 years, SD=2.45; 102 men, 470 women, 25 not indicating their gender) took part in the study. The participants were recruited at a pedagogical faculty of large university in Slovakia, so the sample was heterogeneous in their majors, and they were a part of a participant pool who received credit for two different courses for their participation.

Participants completed three different batteries of tasks for the larger study. The intelligence testing (N=501) took place on one session and was collected by author of the paper and her colleagues, formal reasoning tasks (syllogisms) together with thinking dispositions questionnaires and other measures were collected via internet using survio.com online survey software (N=406).

2.2. Measures

Participants completed a syllogistic reasoning task (to measure belief bias), cognitive abilities measure and thinking disposition measure.

\(^2\) (A) universal affirmative (All A are B); (I) particular affirmative (Some A are B); (E) universal negative (No A are B); (O) particular negative (Some A are not B).
2.2.1 Cognitive ability: Vienna matrix test (VMT)

VMT is based on the classical Raven’s test of progressive matrices – two items are from Standard Progressive Matrices and 1 from Advanced Progressive Matrices constructed by Raven. It consists of 24 items in increasing difficulty and is time-limited (25 minutes). Every task contains picture matrix 3x3 with the missing picture in the third row. The task of the participant is to fill in correctly one of the eight possibilities. The essence of the test is to find out the pattern and the test contains several different patterns of rules (distribution of symbols in the task, adding up the symbols, increasing or decreasing the number of symbols or combination of more principles). The VMT shows high correlations with Intelligence Structure Test and the authors conclude that it reflects reliably general cognitive factor. The test is supposed to be culture-fair as it is based on figural content. We used Czech adaptation by Klose, Černochová, Král published by Testcentrum in 2002. The means score for our sample (N=501) was 16.45 (SD=3.9)\(^3\).

2.2.1 Belief bias in syllogistic reasoning

We used eight syllogistic reasoning problems from the Experiment 1 reported by Morley, Evans and Handley (2004). Half of the problems were worded such that the validity judgment was congruent with the believability of the conclusion (these were termed consistent syllogisms), in the other half of problems the validity of judgment was in conflict with believability of conclusion (these were termed inconsistent syllogisms). This resulted in four types of syllogisms: consistent syllogisms could be either valid-believable (e.g. Some healthy people are unhappy. No unhappy people are astronauts. (Therefore) Some healthy people are not astronauts.), or invalid-unbelievable (e.g. No millionaires are hard-workers. Some hard-workers are rich people. (Therefore) Some millionaires are not rich people.). Inconsistent syllogisms could be either valid-unbelievable (e.g. No religious people are healthy. Some healthy people are priests. (Therefore) Some priests are not religious.), or invalid-believable (e.g. No highly trained dogs are vicious. Some vicious dogs are police dogs. (Therefore) Some highly trained dogs are not police dogs.).

To be able to use inferential statistics, we transformed raw data into scores – for each correctly solved syllogism (accepting valid solutions and rejecting invalid solutions regardless their believability and conclusion direction) participant gained 1 point. We also summed scores for combined types of syllogisms – i.e. valid-believable, valid-unbelievable, invalid-believable and invalid-unbelievable; valid-believable and invalid-unbelievable were then added to form consistent syllogism score, valid-unbelievable and invalid-believable were added to form inconsistent syllogism score. Thus, we used all 15 variables (8 individual syllogism scores, 4 subtotals according to validity and believability, 3 totals – consistent, inconsistent and overall).

This type of problems is considered as the reflection of major critical thinking skill – i.e. putting aside one’s prior knowledge and reason from new premises (Toplak et al., 2013). According to Macpherson and Stanovich (2007) belief bias can be expressed as difference between the number of consistent problems answered correctly and the number of inconsistent problems answered correctly. They assert, however, that with adult participants the difference score is less reliable than the raw number of inconsistent problems answered correctly due to a ceiling effect, therefore we analyzed both variables (score for inconsistent problems answered correctly and the difference between the two scores).

2.2.1 Motive for rational integration: Master rationality Motive Scale

Master Rationality Motive Scale (MRMS, Stanovich, 2011) measures the construct of rational motivation (felt need for rational integration). It combines questions from few other scales, mostly measuring cognitive styles or personality. MRMS consists of 15 questions. Five questions are new (items 8 - 13), but all others used from different scales and inventories. We used 6 point Likert scale (1 – completely disagree to 6 – completely agree). Scores could range from 15 (little motive for rational integration) to 90 (high motive for rational integration). Internal consistency of MRMS was examined by Hanák, Čavojová, and Ballová Mikušková (2014) and was quite low (Cronbach’s alpha = 0.638); the means score in our sample was 57.33 (SD=8.25).

\(^3\)Raw score transformed to IQ scores gave these descriptive results: MIQ=106.8 (SD=15.5).
3. Results

First, we analyzed whether there are significant differences between the directions of conclusion within the valid problems. There was no significant difference between Valid-Believable preferred (and Valid-Believable non-preferred problems ($\chi^2=2.488$, p=.072) in accepting problem as valid. However, there was difference in accepting unbelievable solutions as valid depending on the conclusion direction ($\chi^2=23.507$, p<.001). Significantly more participants rejected conclusion as valid when it was unbelievable. In case of invalid problems, there was no difference in accepting invalid conclusions ($\chi^2=1.854$, p=.103) between preferred and non-preferred direction, but again, there was difference in accepting invalid conclusion ($\chi^2=3.469$, p=.041) between preferred and non-preferred direction. The main effect of conclusion direction seem to be for unbelievable conclusions, where preferred direction leads to higher logical competence (accepting valid and rejecting invalid conclusions when the solution is unbelievable).

| Table 1 Descriptive statistics for all problems according to conclusion direction, validity and belief |
|-------------------------------------------------|-------------------------------------------------|---------------------|---------------------|
| believable                                      | unbelievable                                    | preferred           | non-preferred       |
| % of accepted answers                           | % of accepted answers                           | preferred           | non-preferred       |
| mean score (SD)                                 | mean score (SD)                                 | preferred           | non-preferred       |
| valid                                           |                                               | 65.9                | 73.9                | 67.4                | 38.5                |
| % of accepted answers                           |                                               | 0.66                | 0.73                | 0.67                | **0.39**            |
| mean score (SD)                                 |                                               |                     |                     |                     |                     |
| invalid                                         |                                               | 65.7                | 55                  | 17.4                | 44.3                |
| % of accepted answers                           |                                               | **0.33**            | **0.45**            | 0.83                | 0.55                |
| mean score (SD)                                 |                                               |                     |                     |                     |                     |

We also examined difference between believable and unbelievable conclusions after combining preferred and non-preferred direction of conclusion. In general, more people accepted believable (50.2%) rather than unbelievable (31.1%) conclusion, when preferred and non-preferred conclusions were combined. Also more people accepted invalid conclusion when it was believable (37.6%) than when it was unbelievable (9.3%), when preferred and non-preferred conclusions were combined. Logical competence of participants was manifested by the fact, that in general, they accepted more valid than invalid conclusions (50.20% vs. 37.6% in case of believable conclusions and 31.1% vs. 9.3% in case of unbelievable conclusions).

Significant belief bias was displayed; the mean number of consistent syllogism answered correctly (2.77, SD=0.94) was significantly higher than the mean number of inconsistent syllogisms answered correctly (1.84, SD=1.07), t(433)=13.551, p<0.001. Participants did not show consistent logical competence – while they solved correctly more valid (1.39, SD=.67) than invalid syllogisms (.78, SD=.70) when these were believable (t=13.059, p<0.001), they solved correctly more invalid (1.37, SD=.65) than valid syllogisms (1.06, SD=.76) when these were unbelievable (t=−6.284, p<0.001).

Next, we examined the relationship between resistance to belief bias and cognitive ability and thinking dispositions. In agreement with Macpherson and Stanovich (2007) we used number of inconsistent syllogism answered correctly as the best correlational measure of the ability to overcome the belief bias despite the fact that there was no evidence of ceiling effect in our sample. There was no correlation between cognitive ability and resistance to belief bias (r=.094, p=.059) and rational integration (MRMS) and resistance to belief bias (r=−.004, p=.929).

Because of the significant differences between individual syllogism (due to direction of conclusion or their specific type) we performed correlational analysis for all individual syllogisms and their various combinations and these results are presented in Table 2.
### Table 2 Correlation between individual syllogisms and cognitive ability and master rationality motive

<table>
<thead>
<tr>
<th></th>
<th>Cognitive ability (VMT)</th>
<th>MRMS</th>
</tr>
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<tbody>
<tr>
<td>Valid-believable Preferred</td>
<td>-0.015</td>
<td>0.08</td>
</tr>
<tr>
<td>Valid-believable Non-preferred</td>
<td>0.075</td>
<td>0.066</td>
</tr>
<tr>
<td>Invalid-unbelievable Preferred</td>
<td>0.024</td>
<td>0.006</td>
</tr>
<tr>
<td>Invalid-unbelievable Non-preferred</td>
<td>0.064</td>
<td>-0.057</td>
</tr>
<tr>
<td>Valid-unbelievable Preferred</td>
<td>0.112*</td>
<td>-0.066</td>
</tr>
<tr>
<td>Valid-unbelievable Non-preferred</td>
<td>0.118*</td>
<td>0.046</td>
</tr>
<tr>
<td>Invalid-believable Non-preferred</td>
<td>-0.004</td>
<td>0.045</td>
</tr>
<tr>
<td>Invalid-believable Preferred</td>
<td>-0.017</td>
<td>-0.039</td>
</tr>
<tr>
<td>syllogism sum Valid-Believable</td>
<td>0.039</td>
<td>0.101*</td>
</tr>
<tr>
<td>syllogism sum Invalid-Believable</td>
<td>-0.014</td>
<td>0.006</td>
</tr>
<tr>
<td>syllogism sum Invalid-Unbelievable</td>
<td>0.064</td>
<td>-0.041</td>
</tr>
<tr>
<td>syllogism sum Valid-Unbelievable</td>
<td>0.146**</td>
<td>-0.011</td>
</tr>
<tr>
<td>syllogism sum total</td>
<td>0.117*</td>
<td>0.025</td>
</tr>
<tr>
<td>consistent syllogisms</td>
<td>0.071</td>
<td>0.043</td>
</tr>
<tr>
<td>inconsistent syllogisms</td>
<td>0.094</td>
<td>-0.004</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).

It seems that cognitive ability was most related to correct solution in valid-unbelievable syllogisms regardless the direction of the conclusion (preferred or non-preferred), although the relationship is rather weak. Interestingly, master rationality motive was related only to performance in valid and believable syllogisms.

### 4. Discussion

One of the aims of this paper was to examine which kind of syllogisms is the most suitable for assessing resistance to belief bias as one of the major aspects of resistance to miserly processing, which is hypothesised to be major dimension of fluid rationality (Stanovich, 2011). As expected, belief bias was most associated with inconsistent syllogism problems. Direction of conclusion did not have major effect on the solution, with the only exception of valid-unbelievable problems, where formulation of conclusion in the preferred direction lead to average score comparable with scores in solving consistent syllogisms (even higher than for invalid-unbelievable syllogisms with conclusion formulated in non-preferred way).

As expected, the inconsistent syllogisms proved to be most difficult (only 5.5% of the sample solved correctly all 4 inconsistent syllogisms, in contrast with 23.3% who solved correctly all 4 consistent syllogisms). This was true regardless of the direction of conclusion formulation, with the only one exception – valid-unbelievable syllogism with preferred direction of conclusion. We can only speculate, but maybe the reason for this result is the concrete content of the syllogism (judges), with conclusion “Some judges do not have good education”, which in Slovakia due to many scandals connected with judicial sphere has become more believable than unbelievable. (Scandals connected with legal colleges, where people can “buy” education, when their parents are already in legal occupation, dehonestation of lawyers and especially judges due to their political and mafia connections, etc.).

Morley et al. (2004) suggested that belief bias is primarily associated with the rejection of unbelievable conclusion and is hence a negative or “debiasing” effect, because there is significant reduction in the
acceptance rates of unbelievable conclusion especially for invalid problems. They distinguish between negative belief bias (rejection of unbelievable conclusions) and positive belief bias (increased acceptance of believable conclusion). Our results revealed that, in fact, people were more able to solve correctly invalid problems (M=1.54, SD=.24), than valid (M=1.39, SD=.26) problems (t=9.377, p<.001).

The main aim of this paper, however, was to explore resistance to belief bias and its relationship with cognitive ability and motivation to be rational. We found only weak relationship between valid and unbelievable syllogisms and cognitive ability, which means that people with higher cognitive ability were better able to resist belief bias (or maybe they just knew better how to solve syllogisms and de-contextualize them from the content). Markovits and Nantel (1989) found in their study that the belief-bias effect exists independently of the participants’ abstract reasoning abilities (using the task with abstract syllogisms). Stanovich (2011b) explains the lack of mutual relationships between typical cognitive abilities test (algorithmic level) and tests of critical thinking, such as syllogisms (reflective level) by partitioning Type 2 processes into algorithmic and reflective mind. Algorithmic mind (efficiency of cognitive processes) is usually assessed by test measuring optimal performance, while reflective mind (ability to recognize the need for more effortful thinking) is usually assessed by test measuring typical performance. Importance of the instruction that makes the necessity to adhere to strictly logical rules and to de-contextualize salient was shown by many studies (e.g. Čavojová & Hanák, 2014b; Evans, 2003; Jurkovič, Čavojová, & Hanák, 2014) and this effect can also explain our results. While during intelligence testing participants knew exactly that their cognitive abilities were tested and tried to perform at their best (and the test itself is highly abstract and de-contextualized to be culture-fair), the syllogism task was part of a larger battery and although the instruction was to take into account only information from the premises, they were probably not so motivated to show their best performance and the score reflects more typical performance of students (in some cases maybe even to get over with a task necessary for a credit as quickly as possible).

In this study we were able to identify syllogistic problems that created the strongest belief bias (and thus to differentiate between cognitive misers and people resistant to belief bias) and which can be used in further studies to test Stanovich’s proposed framework of cognitive errors. However, some questions still remain. For instance, which is the most predictive for real-life rationality – testing optimal (cognitive abilities) or typical performance (critical thinking skills)? It is obviously important to have some level of cognitive abilities to be able to come to the correct solution, but for real-life performance it is probably more important to be able to detect the need for using one’s abilities properly. However, self-report measures of rational motivation did not prove very telling of one’s actual performance. Another important consideration in Stanovich’s theory is that he places resistance to belief bias (measured by paradigm of syllogism testing) within dimension of resistance to miserly processing, which should be a part of fluid rationality. However, it can be as well part of crystallized rationality and represent the mindware gaps. Solving syllogisms correctly (regardless of their content, figure and direction of conclusion) is just a matter of learning a correct algorithm (e.g. using Venn’s diagrams), which clearly represents a “mindware gap”. This has a huge implication for education of (not only) future teachers. It means that we are able to learn some strategies that would help us to function more rationally and efficiently in modern world and that inclusion of “old-fashioned” disciplines, such as logic, into a modern curriculum should be of high importance.

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