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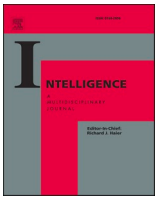

Analytic thinking outruns fluid reasoning in explaining rejection of pseudoscience, paranormal, and conspiracist beliefs

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ABSTRACT

Around one third of people across populations hold beliefs in epistemically unwarranted claims and theories. Why this effect is so strong remains elusive. In three studies (total $N = 827$), we clarified the relationships of fluid reasoning ability, analytic thinking style (indexed by non-intuitiveness and open-mindedness), and unwarranted beliefs in pseudoscience, paranormal phenomena, and conspiracy theories. Fluid reasoning predicted about 11% of variance in rejection of pseudoscience, but only 4% – in paranormal beliefs, and less than 2.5% – in conspiracist beliefs. By contrast, analytic thinking substantially predicted rejection of all the three kinds of beliefs, explaining 37% variance in pseudoscience and around 20% variance in paranormal and conspiracist beliefs. A novel finding indicated that fluid reasoning and analytic thinking predicted rejection of pseudoscience in an over-additive interaction. Fluid reasoning and analytic thinking explained the common variance shared by unwarranted beliefs, but not the belief-specific variance. Their relationships with unwarranted beliefs were stronger for males than for females. Overall, the three studies suggest that analytic thinking is more important than cognitive ability for adopting epistemically supported world-view.

1. Introduction

Epistemically unwarranted beliefs (henceforth, *unwarranted beliefs*) can be dangerous to individuals and society. *Pseudoscientific beliefs* can harm health (vaccine refusal), or at least lead to wasting money (homeopathy). *Paranormal beliefs* may result in unwise life decisions (e.g., following fortune tellers' advice). *Conspiracist beliefs* can motivate to support the radical political movements breaking social rules (e.g., riots against public institutions supposedly controlled by powerful secret groups). Multiple estimates agree that a substantial part of the population holds at least one unwarranted belief – that part is ranging across countries from about one quarter in the relatively sceptic Czech population (Willard & Cingl, 2017), to slightly larger proportion (25%–50%) in Germany (GESIS - Leibniz Institute for the Social Sciences, 2013) and in Spain (FECYT, 2017), up to three quarters in the U.S. (Bader, Mencken, & Baker, 2011).

Substantial interconnections between various types of unwarranted beliefs make them look as a robust world-view. For instance, a strong believer in conspiracy theory on governments spreading viruses and industry concealing (long ago invented) drugs will likely tend to refuse vaccines and turn to alternative medicine. Believing in disproved treatments (bio energy healing) may be grounded in shared ontological misconceptions (special "fields" that elope academic physics). Indeed, vast literature reported moderately positive correlations between pseudoscience, paranormal, and conspiracist beliefs (Bensley, Lilienfeld, Rowan, Masciocchi, & Grain, 2020; Darwin, Neave, & Holmes, 2011; Douglas, Sutton, Callan, Dawtry, & Harvey, 2015; Drinkwater, Dagnall, & Parker, 2012; Lewandowsky, Oberauer, & Gignac, 2013; Lobato, Mendoza, Sims, & Chin, 2014; Ståhl & van Prooijen, 2018).

A key general question pertaining to unwarranted beliefs is: Which people are prone to unwarranted beliefs, and which remain skeptical? More specifically, what cognitive dispositions can lead people to either accept or reject such beliefs? Also, is it possible to reduce the popularity of unwarranted beliefs (when alterable dispositions matter), or not (when built-in dispositions prevail)?

1.1. Thinking style and unwarranted beliefs

Research has identified several cognitive dispositions associated with unwarranted beliefs which, at least in principle, might be subject to positive intervention. In general, these dispositions pertain to formal, analytic, and critical approach to information. For instance,

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disbelievers, as compared to believers, display more valid scientific reasoning, such as logical inference and probability calculation related to hypotheses and observations (Brotherton & French, 2014; Čavojová, Šrol, & Ballová Mikušková, 2020; Rogers, Davis, & Fisk, 2009). They less frequently invoke fallacious lines of argumentation, such as power of authority, group identity, and personal experience (Lobato & Zimmerman, 2019). Also, disbelievers more rarely commit ontological confusions (mixing up the physical, biological, and mental domains; Lindeman, Svedholm-häkkinen, & Lipsanen, 2015; Lobato et al., 2014), and are more resilient to causal illusions (seeing causality in entirely random co-occurrence of events; Torres, Barberia, & Rodríguez-Ferreiro, 2020; see also Blackmore & Troscianko, 1985).

The subjectively assessed individual tendency towards careful processing, critical evaluation, and active validation of information is conceptualized as *analytic thinking style* (as opposed to intuitive style). Typically, it is measured by probing one's reflectiveness (not following immediate intuitions and running rational thinking instead; Cacioppo, Petty, & Kao, 1984; Epstein, Pacini, Denes-Raj, & Heier, 1996) and active open-mindedness (valuing objectivity and acknowledging evidence contradicting one's own beliefs; Pennycook, Cheyne, Koehler, & Fugelsang, 2020; Stanovich & West, 1997). Substantial literature supported at least moderate negative relationships between analytic thinking style and unwarranted beliefs (e.g., Gervais, 2015; Lobato & Zimmerman, 2019; Pennycook et al., 2020; Pennycook, Cheyne, Seli, Koehler, & Fugelsang, 2012; Pennycook, Ross, Koehler, & Fugelsang, 2016; Ståhl & van Prooijen, 2018; Svedholm & Lindeman, 2013; Swami, Voracek, Stieger, Tran, & Furnham, 2014; Toplak, West, & Stanovich, 2011; Trippas, Pennycook, Verde, & Handley, 2015).

On the theoretical level, typical explanations of the above relationships refer to the dual-process approach to thinking (e.g., Evans & Stanovich, 2013; Kahneman, 2011; Stanovich, 2011). It assumes two separate groups of cognitive processes. Type 1 processes are associative and approximate, but fast and effortless. Type 2 processes are analytic and systematic, but slow and effortful, as they depend on the limited working memory capacity (e.g., Evans & Stanovich, 2013). According to this view, accepting unwarranted beliefs results often from intuitive thinking relying on Type 1 processes. The more people tend to engage Type 2 processes, leading to reflective reasoning and skepticism, the less likely they follow the appealing and intuitive but often faulty associations, coincidences, and schemas underlying unwarranted beliefs. Of course, neither Type 1 processes always lead to errors and biases (they may be highly effective in certain situations), nor Type 2 processes are immune to them (insufficient cognitive resources may lead to errors), yet the motivation to engage Type 2 processes during evaluation of one's beliefs has been posed as a crucial factor helping to reject (or unbelieve) unwarranted beliefs (Gervais, 2015; Pennycook et al., 2012). However, the alternative, single-process accounts have also been proposed (Kruglanski & Gigerenzer, 2011; Osman, 2004).

Assuming that unwarranted beliefs result from a, in this case, non-optimal (i.e., intuitive, non-analytic, non-reflective) thinking style (tendency, inclination), and not an irreducible limit in thinking capability, one can try to use psychological interventions targeted at Type II processes in order to improve one's thinking style to become more analytic/reflective. Indeed, either priming (Adam-Troian, Caroti, Arciszewski, & Ståhl, 2019; Swami et al., 2014) or explicitly teaching analytic thinking (Dyer & Hall, 2018; Kane, Core, & Hunt, 2010; McLaughlin & McGill, 2017) resulted in decreased rates of unwarranted beliefs. However, the methodology of such interventions was questioned (Kane et al., 2010), and the effects were reported primarily for paranormal but no other beliefs (McLean, Miller, & a., 2010).

By contrast, other research suggested that unwarranted beliefs are connected with more enduring psychological characteristics, as compared to thinking styles. For instance, schizotypy and paranoid ideation, two facets of personality disorder, unsurprisingly, predicted conspiracist (Bruder, Haffke, Neave, Nouripanah, & Imhoff, 2013; Swami et al., 2014) and paranormal beliefs (Denovan, Dagnall, Drinkwater, & Parker, 2018; Hergovich, Schott, & Arendasy, 2008). Especially conspiracy theories can be durable, because they may constitute by-products of some evolutionary functions (van Prooijen & Van Vugt, 2018) that were adaptive in the past (oversensitive recognition of potentially threatening stimuli and agents), or can be beneficial even nowadays (detection of dangerous coalitions). As such, they might be strongly resistant to any intervention.

1.2. Cognitive ability and unwarranted beliefs

General intelligence (cognitive ability) is a developmentally stable cognitive trait strongly determining performance in virtually all cognitive domains (Carroll, 1993), as well as predicting many academic and socioeconomic variables (Deary, 2012). Especially its reasoning factor (*fluid reasoning*), defined as the ability to draw inferences, form concepts, classify, generate and test hypotheses, identify relations, comprehend implications, solve problems, and the like (see McGrew, 2009, p. 5), can be a prerequisite for rejecting unwarranted beliefs. To reject such a belief, one may need a sufficient level of cognitive ability to understand the meaning of a belief and to contrast it with the body of widely accepted knowledge (e.g., facts and theories adopted by experts), which itself must theretofore be effectively learned and understood. In consequence, a natural prediction emerges that fluid reasoning should be negatively related with acceptance of unwarranted beliefs.

However, reports which examined links between fluid reasoning and unwarranted beliefs are limited in number, and the links found are typically weak. For instance, Toplak et al. (2011) found a weak correlation ($r = -0.12$) between superstitious thinking and WAIS's Matrix Reasoning and Vocabulary scores (Wechsler, 1981). At the same time, Erceg, Galić, and Bubić (2019) reported the null correlation for the same scale and Raven's Advanced Progressive Matrices (*RAPM*, Raven, Raven, & Court, 1998) – a hallmark test of fluid reasoning. A slightly stronger relationship ($r = -0.16$) was reported for paranormal beliefs by Betsch, Aßmann, and Glockner (2020), but they provided no details on how they measured cognitive ability. An even stronger link ($r = -0.21$) was found for a scale probing as many as 34 unwarranted beliefs from various categories and a variant of Raven Matrices (Čavojová et al., 2020).

Importantly, all the relevant studies on unwarranted beliefs used only single measures of cognitive ability (for their recent meta-analyses see Dean et al., 2022; Stasielowicz, 2022), therefore confounding the true variance in ability with test-specific variance, and in consequence attenuating the beliefs-ability link. The gold standard in intelligence research is to use a number of tests as well as the factor analysis to estimate the latent variables representing the (almost) true variance in ability.

Summarizing existing evidence, while the (moderately negative) link between analytic thinking and unwarranted beliefs has been established with a satisfactory level of reliability, the precise relationship between unwarranted beliefs and cognitive ability is still elusive. Moreover, a meta-analysis of 58 data sets (Alaybek, Wang, Dalal, Dubrow, & Boemerman, 2021) yielded a moderate correlation ($\rho = 0.27$) between analytic thinking style and intelligence, suggesting their overlap (at the same time, intuitive style and intelligence were unrelated). It is thus conceivable that both factors may jointly impact unwarranted beliefs in a kind of interaction. Unfortunately, the analysis of a joint contribution of thinking style and fluid reasoning, both reflected at the latent level, to the three primary kinds of unwarranted beliefs (pseudoscience, paranormal, conspiracist), also modelled at the latent level, thus far has been absent in the literature. Consequently, such an analysis was the general aim of the present work.

1.3. Research questions

Specifically, we asked four research questions. First, how strong is the latent-level relationship of fluid reasoning ability with each of the three kinds of unwarranted beliefs (and is this strength comparable or

different across these three kinds)? Second, what is the relative contribution of fluid reasoning to unwarranted beliefs as compared to analytic thinking style? Existing evidence on the role of cognitive ability in acceptance vs. rejection of unwarranted beliefs thus far has been largely inconclusive, so the precise data and analyses are needed to clarify its exact role. Three psychometric studies including multiple measures of fluid reasoning, analytic thinking, and unwarranted beliefs were administered to that end.

Third, using a combined dataset from the three studies, we examined whether fluid reasoning and analytic thinking could predict unwarranted beliefs in an interaction. Specifically, we hypothesized that analytic thinking may be more weakly related with unwarranted beliefs at lower levels of ability, because below a given ability threshold people may be unable to grasp intellectually the typically complex explanations provided by science. As a result, such people may hold unwarranted beliefs quite strongly regardless of their thinking style, because only such intellectually simpler claims may be accessible to them. By contrast, people with higher ability could in principle grasp scientifically supported explanations, but their analytic thinking style might influence whether they either accept these explanations or fail to reject apparent catchiness of alternative unwarranted claims due to inadequate reflection. In other words, strong analytic thinking may facilitate using high ability to reject unwarranted claims, while poor analytic reflection may undermine benefits of high ability. In consequence, an over-additive interaction of fluid reasoning and analytic thinking was expected. No study has examined such an interaction to date.

Fourth, we checked in the combined dataset if the fluid reasoning and analytical thinking relationship with unwarranted beliefs was moderated by sex, as suggested by Betsch et al. (2020).

1.4. Defining pseudoscience, paranormal, and conspiracist beliefs

Before we turn to Study 1, pseudoscience, paranormal, and conspiracist beliefs need to be properly defined for the purpose of this work, because, unlike relatively univocal constructs of fluid reasoning and analytic thinking, their conceptualizations varied across studies. We adopted definitions proposed in the literature that seemed to be most relevant for the current research.

Defining pseudoscience as distinct from antiscience (e.g., religious fundamentalism) and protoscience (e.g., alchemy, early medicine) is a demanding task. Here, we adopted Fasce and Pico (2019) pragmatic definition of pseudoscientific belief as a belief which is presented as scientific knowledge, but assumes existence of entities or phenomena rejected by (real) science, and/or uses deficient (e.g., non-replicable, non-falsifiable) methodology, and/or lacks supporting evidence. Typically, more than one condition applies. In other words, pseudoscientific beliefs pretend to be equally trustworthy as widely accepted scientific facts, but cannot be supported using the same rigorous theories, methods, and data. Pseudoscience does not reject science, but mimics it to reach the same status (funding, influence, prestige) in an effortless way.

Following Lindeman and Aarnio (2006), paranormal beliefs are henceforth understood as supernatural, magical, and superstitious claims that ascribe to a certain phenomenon, belonging to the physical, biological, or psychological category, some core properties belonging to another category (e.g., mental power moving physical objects, planetary conjunction affecting personality). That is, paranormal beliefs violate fundamental ontological assumptions about the nature, so there is no point even to try to validate such beliefs. In this sense, claims such as UFO flying the sky, or crystals protecting against radiation, constitute rather pseudoscientific beliefs, because they pertain to one and the same ontological category, and in principle such claims could be tested empirically, while, obviously, there has been no supporting evidence for them thus far, and their a priori likelihood is low. By contrast, paranormal beliefs can be rejected a priori with even basic knowledge from physics, biology, or psychology.

For conspiracist beliefs, we followed van Prooijen and Van Vugt (2018), who identified the following five necessary components of a conspiracy theory: (i) an anomalous pattern of causal relations between people, objects, or events (e.g., unnatural death), (ii) resulting from deliberate plans (agency), (iii) devised and implemented by a coalition of agents (a single bad character would not count as a conspiracy), (iv) potentially harmful or deceptive, (v) and carried out in deep secrecy. These features seem to distinguish conspiracy theories from both pseudoscientific and paranormal phenomena, because the latter two are assumed to occur naturally and their presumed causes are overt (e.g., a certain field, mental power, effect of pseudo-treatment on an organism, and the like).

2. Study 1

2.1. Participants

A minimum of 200 participants has been recommended for structural equation modeling (SEM) (Kline, 2015). The final sample included 350 people (another two were excluded due to anomalous results suggesting random responding). One part ($N = 170$) of the sample were recruited in Krakow, Poland, using internet advertisements, and were paid the equivalent of 12 euros for participation. The other part ($N = 180$) comprised the first year psychology students from University of Warsaw, Poland, who participated for a course credit. The total sample included 198 women, 149 men, and 3 participants who did not provide information on their sex (mean age = 28.9 years, $SD = 3.8$, range 18–43). All the participants were informed that the participation was anonymous and fully voluntary.

2.2. Measures

Two scales probed analytic thinking (see Appendix for all the questionnaire items). The 12-item *Active Open-mindedness* questionnaire (called *open-mindedness* for short), based on Stanovich and West (1997), assessed how much people value objective evidence, even if it contradicts their beliefs. The 10-item questionnaire, based on the Experientiality scale of Pacini and Epstein (1999), included eight items indicating a larger tendency towards intuitive thinking (later reversed), and two items that probed a tendency for reflective thinking. The final score (*non-intuitiveness*) indicated how strongly one relies on reflection and avoids intuition when making inferences, judgements, and decisions.

Three widely recognized fluid reasoning tests were applied. Cattell's *Culture Fair Intelligence Test* (*CFT-3*; Cattell, 1961) included four sections which required matrix reasoning, pattern series completion, shape categorization, and topological relation understanding, respectively (50 items in total). *Paper folding* test (Ekstrom, French, Harman, & Dermen, 1976) included 16 problems that required visualizing unfolding of a folded paper punctured in specific spots (we removed six easy items from the original test and created another two difficult items). *Number series* test included 18 sequences and arrays of numbers adopted in our laboratory on a basis of existing materials. Each item involved finding out a hidden rule according to which the numbers were constructed, in order to write down the missing number. The time allowed for solving a test was 25, 10 and 20 min, respectively.

On the basis of existing measures (Lobato et al., 2014; Rindermann, Falkenhayn, & Baumeister, 2014), an 18-item Pseudoscience beliefs questionnaire was created in order to measure approval of pseudoscientific claims and theories, such as "Mercury present in vaccines increases the probability of acquiring autism among small children," and "Although the theory of evolution is accepted by most of the scientist, it is only a theory and there is little evidence that it is true." The items covered a wide range of topics (medicine/health, natural science, evolution, psychology, sexuality), and were mixed with nine filler items probing general scientific knowledge. Paranormal beliefs scale was

based on the Revised Paranormal Belief Scale (Tobacyk, 2004). Four items concerning religious belief were removed. Moreover, three items concerning extra-ordinary life forms (e.g. Loch Ness monster), potentially unfamiliar to our participants, were replaced with more appropriate items. The final version contained 20 items such as "In some cases, it is possible to communicate with the dead," and "There are people who possess an ability to move objects using only their mental power." The third measure was the 15-item Generic Conspiracist Beliefs scale (GCB; Brotherton & French, 2014), which covers general and radical conspiratorial beliefs such as belief in prevalent government misconduct, secret groups exerting full control over global events and menacing personal health and liberties, extra-terrestrial cover-up, and the full censorship of information. In each unwarranted belief scale, participants evaluated statement using the 7-point scale (0 = *false for sure*, 3 = *uncertain*, 6 = *true for sure*). The total score on each scale comprised the sum of all the responses.

2.3. Procedure

The participants who were paid for the participation were tested in a psychological laboratory in groups of three to six people. The students were tested during a class. The questionnaires were completed at the beginning of the session, followed by the reasoning tests. The questionnaires were intermixed with various measures of personality and religiosity, which were part of another project.

2.4. Results

First, exploratory factor analysis was run on the Likert scores for all the 53 belief questionnaire items, with normalized varimax rotation. Six meaningful factors were extracted. Following Matsunaga (2010), the criterion for satisfactory loading was set to $\lambda = 0.40$. The first factor, explaining 7.4% of variance in all 53 items, loaded all the fifteen GCB items ($\lambda = 0.50$ to 0.75). The second factor, which explained 5.9% of variance in all items, loaded twelve paranormal items ($\lambda = 0.46$ to 0.75), but excluded seven superstition items (horoscope, tarot, zodiac, breaking a mirror, lucky numbers, lucky days, planets conjunction; $\lambda <$ 0.35), and the item on access to thoughts of former incarnations ($\lambda =$ 0.36). The third factor loaded the six former superstition items ($\lambda = 0.52$ to 0.72), explaining 4.2% of variance in all items. However, the inspection of mean responses to the superstition items showed that they were rarely accepted (mean score < 1). The fourth factor loaded thirteen pseudoscience items ($\lambda = 0.41$ to 0.68), and explained 5.2% of all items variance. The fifth factor loaded the four pseudoscience items not loaded by the fourth factor, and explained 2.6% of all items variance. These items, however, yielded the lowest acceptance rate (< 1). Finally, the sixth factor loaded moderately the remaining pseudoscience item on aliens visiting Earth ($\lambda = 0.59$) and two conspiracist items on governments hiding its criminal activity ($\lambda = 0.59$) and concealing alien contact ($\lambda = 0.51$), seemingly tapping the alien belief specifically. Two remaining paranormal items were loaded by no factor.

Generally, the GCB scale appeared to be highly coherent internally, confirming original data from Brotherton and French (2014). Each of the two remaining scales seemed to include items forming a sub-factor separable from the intended factor. However, the four pseudoscience items forming such a sub-factor constituted the least accepted items, and the correlation of their summary score with the other thirteen pseudoscience items was only moderate ($r = 0.407$). Therefore, these four items, which might have been improperly formulated, together with the alien belief item, were excluded from the Pseudoscience beliefs scale, which finally comprised the thirteen items loading a single factor. Although the correlation of the seven superstition items with the other twelve (supernatural and magical) paranormal items was relatively stronger ($r = 0.639$), as little as one third of variance shared suggested that these two groups of items should not be combined into the single scale. Since superstitions turned out to be rarely accepted, anecdotal claims (at least in the present sample of young adults), only the twelve items (i.e., excluding superstitions as well as the former incarnations item) made the final paranormal beliefs scale. The resulting internal consistency equaled $\alpha = 0.93$ for GCB, $\alpha = 0.85$ for pseudoscience, and $\alpha = 0.92$ for paranormal beliefs.

Reliability of the intelligence tests and analytic thinking scales was also very good ($\alpha > 0.81$). All the measures sufficiently approximated the normal distribution. Table 1 presents descriptive statistics for all the measures. Table 2 reports the correlation matrix for all the measures. Pseudoscience, paranormal, and conspiracist beliefs were moderately intercorrelated ($r \approx 0.52$). Each of them yielded also a significant negative correlation with the two analytic thinking scales ($r \approx -0.30$), while their (also negative) correlations with fluid reasoning tests were much weaker ($r \approx -0.14$).

Before checking with SEM the predictive power of fluid reasoning latent variable with regard to pseudoscience, paranormal, and conspiracist beliefs, we applied confirmatory factor analysis (CFA) in order to test whether the assumed factor structure of the these beliefs was consistent with the data. This measurement model included three latent variables, the first one loading the 13 pseudoscience items, the second one loading the 12 paranormal items, and the last one loading the 15 GCB items, as suggested by the exploratory factor analysis. The three latent variables were allowed to correlate.

The fit of the resulting CFA model was acceptable in terms of the root mean square error of approximation (criterion value <0.08, see Hu & Bentler, 1999), RMSEA = 0.073 [0.069, 0.076], and the standardized root mean squared residual (criterion value <0.08), SRMR = 0.061. The third widely used index, Bentler's Comparative Fit Index (criterion value >0.92) was unacceptable, CFI = 0.819. However, this index was not optimal here, because multiple weak correlations in the data as well as a large number of model's degrees of freedom (there were 40 manifest variables) in relation to the sample size resulted in an overestimated fit of the null model, RMSEA = 0.144, to which CFI compares the proposed model. Therefore, in further analyses we relied solely on the RMSEA and SRMR indices, but omitted CFI. For nested models, the significance of the χ^2 increase was tested.

All the loadings of latent variables on respective items were statistically significant at $p < .001$, and surpassed the criterion of $\lambda = 0.40$, except for the belief that lightning does not strike the same place twice, which yielded $\lambda = 0.37$ on the pseudoscience variable. The mean loading across the 40 items equaled $\lambda = 0.64$. Paranormal and conspiracy beliefs variables explained over 51% of their items variance, pseudoscience beliefs variable explained 38%. The correlation between pseudoscience and paranormal latent variables equaled $r = 0.621$ [546, 696], between pseudoscience and conspiracist variables – $r = 0.560$ [480, 640], and between paranormal and conspiracist variables – $r = 0.556$ [476, 637]. Fixing any of these correlations to one significantly decreased the model fit, $\Delta\chi^2(1) > 483.35$, $p < .001$. Relatedly, the two- and one-factor measurement models yielded unacceptable values of RMSEA and SRMR (> 0.10), so it could be concluded that the three variables constituted separate yet correlated factors. Overall, the structure of the to-be-predicted variables was satisfactory.

In SEM (the Sepath module of Statistica 12.0 was used for estimation), the pseudoscience, paranormal, and conspiracist variables were

Table 1
Descriptive statistics for all measures used in Study 1 (N = 350).

Measure (scale)	*M*	Min	Max	*SD*	Skew	Kurtosis
Pseudoscience beliefs (78)	35.26	2	66	13.57	−0.29	−0.50
Paranormal beliefs (72)	23.23	0	72	16.10	0.53	−0.42
Conspiracist beliefs (90)	41.58	0	90	18.19	−0.21	−0.40
Open-mindedness (48)	33.77	8	48	8.27	−0.54	−0.08
Non-intuitiveness (50)	22.91	8	41	6.43	0.08	−0.25
Cattell's CFT-3 (50)	27.43	8	41	5.10	−0.23	0.38
Paper folding (16)	10.05	0	16	3.52	−0.47	−0.23
Number series (18)	10.92	2	18	3.31	−0.27	−0.28

Table 2
Correlation matrix for all measures used in Study 1 ($N = 350$).

Measure	1.	2.	3.	4.	5.	6.	7.
1. Pseudoscience beliefs	1						
2. Paranormal beliefs	0.537	1					
3. Conspiracist beliefs	0.500	0.529	1				
4. Open-mindedness	−0.406	−0.253	−0.269	1			
5. Non-intuitiveness	−0.377	−0.282	−0.227	0.313	1		
6. Cattell's CFT-3	−0.135	*−0.093*	*−0.046*	0.194	*0.105*	1	
7. Paper folding	−0.249	−0.143	−0.148	0.259	0.154	0.498	1
8. Number series	−0.287	*−0.075*	*−0.076*	0.171	*0.091*	0.426	0.477

Note. Non-significant correlations shown in italics. All other correlations significant at $p < .02$.

defined as endogenous ones, and their disturbance terms were allowed to correlate, as we assumed that not all their shared variance could be explained by the predictors. The exogenous variable, fluid reasoning, loaded the scores on Cattell's CFT-3, Paper folding, and Number series. Fluid reasoning predicted each of the three endogenous variables. The fit of the resulting one-factor model was satisfactory, RMSEA = 0.068 [0.064, 0.071], SRMR = 0.059. The path from fluid reasoning to the pseudoscience variable was moderate, $\beta = -0.36$, $p < .001$, while the respective paths to paranormal, $\beta = -0.17$, $p = .009$, and conspiracist variables, $\beta = -0.15$, $p = .015$, were relatively weak (see the values in round brackets in Fig. 1).

Next, we introduced the second exogenous variable – analytic thinking, which loaded the open-mindedness and non-intuitiveness measures. It was allowed to correlate with the fluid reasoning variable. Both exogenous variables concurrently predicted each of the three endogenous variables. The resulting two-factor model is presented in Fig. 1. Its fit was satisfactory, RMSEA = 0.065 [0.062, 0.068], SRMR = 0.058. Fluid reasoning and analytic thinking correlated moderately, $r = 0.45$. However, only analytic thinking significantly predicted each of the endogenous variables, with the strongest path to the pseudoscience variable, $\beta = -0.72$, and moderate paths to the paranormal, $\beta = -0.49$, and the conspiracist variable, $\beta = -0.50$, each $p < .001$. The respective three paths for fluid reasoning were non-significant, $\beta = 0.07$ or lower, $p > .40$. Fixing all these paths to zero did not decrease the model fit, $\Delta\chi^2(3) = 2.23$, $p = .526$. The disturbance terms of the three endogenous variables shared from 5 to 11% of their variance (as compared to 31 to 38% in the measurement model), suggesting that analytic thinking was able to explain the majority of relationships between unwarranted beliefs. However, disturbance terms indicated that from 45% (pseudoscience) to 78% (paranormal) of variance in unwarranted beliefs remained unexplained by analytic thinking.

An anonymous reviewer suggested that the correlation between fluid reasoning and analytic thinking might have resulted (at least in part) from the fact that high intelligence may lead to the emergence of analytic thinking style (e.g., during development). Although an assumption that the latter style is primarily caused by high cognitive abilities does not seem tenable given the relatively limited correlations between both these constructs in the literature (Alaybek et al., 2021), even when analytic thinking was tested and not only self-reported (Pennycook et al., 2012; Toplak et al., 2011), we attempted to check how well analytic thinking could predict unwarranted beliefs after its variance shared with fluid reasoning had been partialled out. Consequently, we calculated the bifactor SEM model, RMSEA = 0.065 [0.062, 0.068], SRMR = 0.058, in which all the three intelligence tests as well as non-intuitiveness and open-mindedness were loaded by fluid reasoning, while analytic thinking reflected variance shared by non-intuitiveness and open-mindedness that was separate from fluid reasoning. In such a model, the respective paths from fluid reasoning to pseudoscience, paranormal, and conspiracists beliefs were virtually the same as in the one-factor model, $\beta = -0.36$, $\beta = -0.16$, and $\beta = -0.16$, with the loadings for the two analytic thinking scales being significant but relatively low, $\lambda = 0.31$ and $\lambda = 0.18$. The respective paths from analytic thinking were still substantial and not significantly different from the two-factor model, $\beta = -0.64$, $\beta = -0.45$, and $\beta = -0.44$. Therefore, any indirect effects of

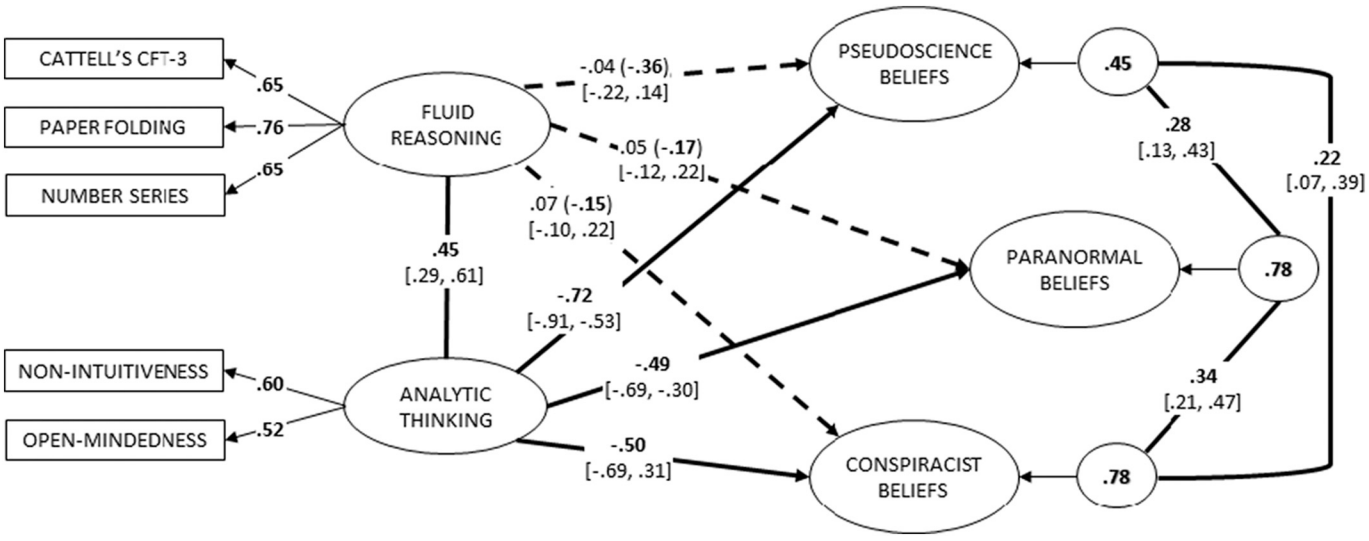

Fig. 1. Structural equation model for Study 1. Ovals represent latent variables, boxes reflect manifest variables for exogenous latent variables, and circles indicate disturbance terms (with the amount of variance printed inside). Lines represent correlations, long/short arrows reflect regression paths/loadings. Numbers by lines/arrows represent correlation/regression/loading point estimates. Numbers in square brackets indicate 95% confidence intervals. Numbers in round brackets indicate coefficients when the analytic reasoning variable is absent in the model. Solid lines/bolded numbers are statistically significant at $p = .05$, dashed lines/regular font indicate non-significant values.

intelligence on analytic thinking seem negligible.

2.5. Discussion

The factorial analysis of the three adopted kinds of unwarranted beliefs: pseudoscience, paranormal, and conspiracist, generally confirmed the theoretical arguments from the literature that these beliefs constitute three separate kinds of unsubstantiated claims. Yet, not surprisingly, they shared around a quarter of variance, implicating some general tendency to accept the questionable world-views, as suggested previously (e.g., Bensley et al., 2020; Darwin et al., 2011; Lobato et al., 2014). One deviation from this literature is that our data did not support the argument (Lindeman & Aarnio, 2006; Lindeman et al., 2015) that superstitions belong to the same category as do magical and supernatural beliefs. Superstitions were generally rejected, and did not load on the factor formed by the two latter beliefs. At least in our sample of young adults living in two large academic cities (most of them being students), anecdotal superstitions such as horoscopes/cards and lucky/unlucky objects/events potentially predicting the future were not accepted as believable claims, in contrast to more "serious" beliefs in supernatural and psychic powers. However, it is possible that in less educated and older samples superstitions possess characteristics more closely resembling the latter beliefs. Finally, there was also some evidence for specificity of beliefs in aliens, but with few items pertaining to such beliefs we did not investigate them more closely.

Regarding our two first research questions, first, the relationships between fluid reasoning (a key marker of cognitive ability) and unwarranted beliefs depended on the kind of belief. Rejection of pseudoscience was moderately related with fluid reasoning, while rejection of paranormal and conspiracist beliefs were only weakly related. Second and most importantly, we found that fluid reasoning predicted these three types of beliefs only due to the variance it shared with analytic thinking, defined as high open-mindedness and non-intuitiveness (reflection). When analytic thinking was entered into the model, fluid reasoning could no longer predict significantly unwarranted beliefs. By contrast, analytic thinking emerged as a reliable and strong predictor of all unwarranted beliefs, even when its variance shared with fluid reasoning had been partialled out.

Overall, the study confirmed at the latent variable level the substantial role of analytic thinking style for unwarranted beliefs observed in previous studies (e.g. Gervais, 2015; Pennycook et al., 2012; Svedholm & Lindeman, 2013; Swami et al., 2014; Toplak et al., 2011). At the same time, the study resolved inconclusive observations regarding the respective role of cognitive ability, suggesting the moderate role of fluid reasoning for rejecting pseudoscience beliefs, but its weak links with paranormal (see Dean et al., 2022) and conspiracist beliefs (see Stasielowicz, 2022).

Before making any firm conclusions, two issues need to be considered. First, we observed that some fluid reasoning tests (Paper folding) more strongly related to unwarranted beliefs than did others (Cattell's CFT-3). It is possible that another choice of fluid reasoning measures might have yielded stronger negative relationships with unwarranted beliefs.

Second, the unwarranted beliefs scales shared method with the analytic thinking scales (both types of measures consisted of self-reports), while the fluid intelligence tests measured objective performance. Although self-reports constitute most widely used method of analytic thinking style assessment, shared method might have been responsible, at least in part, for its strong link with unwarranted beliefs. It is thus important to examine the strength of relationship between unwarranted beliefs and analytic thinking with the latter variable measured using objective, performance-based measures, instead of self-reports.

Study 2 aimed to address these two issues. Cognitive ability was measured using another set of three fluid reasoning tests. One of these tests – RAPM – requires figural matrix reasoning commonly believed to be central to the assessment of intelligence (Snow, Kyllonen, & Marshalek, 1984). The second test required a similar reasoning process (figure series completion). The third test relied on geometric analogies, another assessment method to be central to intelligence (ibidem).

Analytic thinking, apart from open-mindedness and non-intuitiveness, was assessed with *Cognitive Reflection Test* (*CRT*; Frederick, 2005). CRT has been the most widely used performance measure of analytic thinking, shown to relate moderately with unwarranted beliefs (Gervais, 2015; Pennycook et al., 2012, 2016; Shenhav, Rand, & Greene, 2012). CRT is commonly believed to assess how strongly people are resistant to intuitive, schematic lapses to math-like puzzles, that is, how efficiently they can decouple from such lapses and find a solution through reflection. However, after we had collected data in this series of studies, a meta-analysis was published (Otero, Salgado, & Moscoso, 2022) which suggested that CRT may primarily measure general cognitive ability and broad numerical ability, both explaining around two third of the CRT variance in total. That questions whether there is any room for the CRT variance to represent sheer reflectiveness, beyond cognitive abilities. In Study 2, we addressed this question, by partitioning the CRT variance between fluid reasoning and analytic thinking latent variables, to see whether CRT shared any portion of its variance with the latter variable and – if so – in what way such a variance could be related with unwarranted beliefs.

3. Study 2

3.1. Participants

Using internet advertisements in popular publicly accessible websites, 182 volunteers were recruited in Krakow. They were paid the equivalent of 10 euros in local currency for the participation. However, eight participants missed at least one questionnaire. Another eight admitted familiarity of more than one CRT problem (and all of them scored high in this test), and they were also excluded. The final sample counted 166 people (119 women, mean age = 23.3 years, SD = 4.7, range 18–40). All the participants were informed that the participation was anonymous and fully voluntary.

3.2. Measures

The same open-mindedness and non-intuitiveness scales as in Study 1 assessed analytic thinking. We also administered three items (the ball and the bat, widgets, lily pads) of Frederick (2005) original CRT task, as well as three out of four items (barrels, students, pigs) from the later CRT extension (henceforth called CRT4) proposed by Toplak, West, and Stanovich (2014). Their fourth item, which pertained to operations on the stock market (a less popular topic in Poland than in the U.S.), was substituted with the socks problem (Davidson & Sternberg, 1984). For items which were popularized in the media, the content was changed (e.g., lily pads and the lake were exchanged into the fire and the forest), with the problem structure left intact. In each problem, arithmetic calculations were required to find the correct solution. However, the problem's description included value(s) which strongly primed an intuitive but incorrect response. For example, a warm-up item (not included in the CRT scores) asked: "In a family, each of seven sisters has one brother – how many brothers are there in this family"? For most of people, the number "seven" pops out in the mind, before they reflect that one and the same person has to be the brother for all the seven sisters. The CRT3 and CRT4 problems were more difficult than the warm-up problem. The average correct rate per problem equaled 46%. There was no time limit to work with the seven CRT problems, but most of the participants took around 15 min for CRT.

Regarding fluid reasoning, 18 (odd-numbered) RAPM items included a three-by-three matrix of figural patterns which was missing the bottom-right pattern. Eight response options comprised the patterns that could potentially match the missing one. The test required to discover the rules that governed the distribution of patterns in order to choose the

single correct pattern. The Figural Analogies Test (*Analogies*, Chuderski & Necka, 2012) consisted of 18 analogies in the form of "A is to B as C is to X", where A, B, and C were relatively simple patterns of figs. A was related to B according to two, three, four, or five rules (e.g., symmetry, rotation, change in size, color, thickness, number of objects, etc.), and X was an empty space. The task was to choose one figure from a choice of four which related to fig. C, as B related to A. Participants were allowed 40 min to solve each test. The third test – Patterns – included 16 problems with a progressive difficulty that required figural pattern/sequence completion in the total of 20 min.

3.3. Procedure

The participants were tested in a psychological laboratory in groups of 2 to 4 people. The CRT and the reasoning tests were applied at the beginning of the study session, followed by computerized tasks unrelated to the topic of this study (e.g., working memory tests). The unwarranted beliefs scales, followed by analytic thinking questionnaires, were applied at the end of the session. They were intermixed with various personality and religiosity measures, which are not reported here.

3.4. Results

All the measures showed good internal reliability, $\alpha > 0.81$, except for CRT3, $\alpha = 64$, and CRT4, $\alpha = 43$, most likely due to a low number of their items (for the seven items combined, reliability was satisfactory, $\alpha = 71$). Also, the SEM method is known to be robust to variables' inferior psychometric properties. Table 4 presents descriptive statistics. All the measures were normally distributed.

The correlation pattern (Table 5) of unwarranted beliefs, the two analytic thinking scales, and three fluid reasoning tests was analogous to this in Study 1, except that pseudoscience and the three fluid reasoning tests were more strongly linked. At the same time, the latter tests were not related significantly with paranormal and conspiracist beliefs. The CRT measures correlated significantly with pseudoscience, but not with paranormal and conspiracist beliefs. The CRT measures, analytic thinking scales, and fluid reasoning tests yielded moderate positive pairwise correlations.

First, we computed the same measurement model as in Study 1, including 40 unwarranted beliefs items loading the three latent variables in a respective way. The model yielded an acceptable fit, RMSEA = 0.083 [0.078, 0.089], SRMR = 0.077. All the loadings of latent variables on respective items were statistically significant at $p < .001$, and higher than $\lambda = 0.40$ (mean $\lambda = 0.67$), except for the item on lightning, $\lambda = 0.37$, and the item on acupuncture, $\lambda = 0.27$. The pseudoscience and paranormal latent variable correlation equaled $r = 0.495$ [365, 630], for the pseudoscience and conspiracist variable $r = 0.549$ [430, 668], and for the paranormal and conspiracist variable $r = 0.393$ [322, 534]. These correlations were slightly weaker, as compared to those in Study 1.

Next, we calculated the model in which the fluid reasoning latent variable, loading the three reasoning tests, predicted each of the three unwarranted beliefs variables. The model yielded an acceptable fit, RMSEA = 0.079 [0.074, 0.085], SRMR = 0.076. Fluid reasoning predicted significantly pseudoscience, $\beta = -0.42$, $p < .001$, and paranormal beliefs, $\beta = -0.22$, $p = .011$, but was virtually unrelated to the conspiracist beliefs, $\beta = -0.04$, $p = .671$.

Before introducing to the above model the analytic thinking variable, we verified the validity of CRT, using the SEM model in which fluid reasoning and analytic thinking variables predicted the CRT variable, which loaded the CRT3 and CRT4 scores (Fig. 2). The model, RMSEA = 0.083 [0.035, 0.130], SRMR = 0.041, included the strong path from fluid reasoning to CRT, $\beta = 0.75$, $p < .001$, while the path from analytic thinking was not significant, $\beta = 0.11$, $p = .300$. Thus, the CRT measures shared over half of variance with fluid reasoning, in line with Otero et al. (2022), while they failed to work as the performance-based indices of analytic thinking. In consequence, in Study 2 analytic thinking had to be again measured with self-reports, and Study 2 served primarily to replicate Study 1.

Fig. 3 presents the two-factor model, in which fluid reasoning and analytic thinking (intercorrelated), predicted the three endogenous variables representing unwarranted beliefs, with their disturbances allowed to correlate. The model's fit was acceptable, RMSEA = 0.078 [0.073, 0.083], SRMR = 0.076. Fluid reasoning predicted pseudoscience only marginally, $\beta = -0.20$, $p = .058$. Its contribution to paranormal beliefs was virtually null, $\beta = -0.04$, $p = .673$. There was a significant positive path leading to conspiracists beliefs, $\beta = 0.22$, $p = .042$, probably due to a suppression effect imposed by analytic thinking. All the three negative paths from analytic thinking to unwarranted beliefs were significant and substantial: $\beta = -0.50$ (pseudoscience), $\beta = -0.37$ (paranormal), and $\beta = -0.58$ (conspiracist beliefs), each $p < .001$. The correlations between their disturbances were reduced to mean $r = 0.26$, as compared to $r = 0.48$ in the measurement model. The amount of unexplained variance in unwarranted beliefs ranged from 63% (pseudoscience) to 84% (paranormal).

Finally, we also tested the bifactor model analogous to that of Study 1, with all the five predictor measures loaded by fluid reasoning, and analytic thinking representing only the shared variance between non-intuitiveness and open-mindedness that was not shared with fluid reasoning, RMSEA = 0.078 [0.073, 0.083], SRMR = 0.076. As in Study 1, the loadings for the two analytic thinking scales on the fluid reasoning variable were significant but relatively low, $\lambda = 0.39$ and $\lambda = 0.16$, and its respective paths to pseudoscience, paranormal, and conspiracists beliefs closely matched those in the one-factor model, $\beta = -0.42$, $\beta = -0.21$, and $\beta = -0.04$. The substantial paths from the analytic thinking variable to pseudoscience, paranormal, and conspiracist beliefs dropped slightly and non-significantly, $\beta = -0.45$, $\beta = -0.36$, and $\beta = -0.49$, respectively, as compared to the two-factor model.

Table 4
Descriptive statistics for all measures used in Study 2 ($N = 166$).

Measure (scale)	*M*	Min	Max	*SD*	Skew	Kurtosis
Pseudoscience beliefs (78)	36.99	0	68	13.71	−0.52	0.36
Paranormal beliefs (72)	24.81	0	71	16.50	0.42	−0.30
Conspiracist beliefs (90)	41.64	0	88	19.25	−0.18	−0.35
Open-mindedness (48)	32.04	10	48	9.11	−0.42	−0.53
Non-intuitiveness (50)	30.58	15	45	6.21	0.06	−0.60
CRT3 (3)	1.38	0	3	1.14	0.06	−1.43
CRT4 (4)	1.84	0	4	1.19	0.07	−0.87
RAPM (18)	12.09	2	18	3.04	−0.42	0.11
Analogies (18)	12.57	3	18	3.07	−0.46	−0.15
Patterns (16)	9.02	1	16	2.93	0.11	0.01

3.5. Discussion

Study 2 replicated the main findings of Study 1 using another three fluid reasoning tests, including the hallmark RAPM. Fluid reasoning was moderately related to rejection of pseudoscience, but this relationship did substantially drop when analytic thinking was accounted for. The interim conclusion can be made that there exists a systematical moderate link between cognitive ability, as measured with fluid reasoning tests, and rejecting pseudoscience claims. By contrast, an analogous correlation with paranormal beliefs was weaker and completely disappeared when analytic thinking was taken into account. Conspiracists beliefs were unrelated to cognitive ability.

Substantial common variance in the three types of beliefs was explained by analytic thinking, however in Study 2 these beliefs were relatively more independent mutually, as compared to Study 1, probably in part due to a less homogenous sample in Study 2 (no psychology students examined).

Finally, we failed to measure analytic thinking using CRT. In contrast to the view frequently adopted in literature (e.g., Stagnaro, Pennycook,

Table 5
Correlation matrix for all measures used in Study 2 (N = 166).

Measure	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. Pseudoscience beliefs	1								
2. Paranormal beliefs	0.403	1							
3. Conspiracist beliefs	0.490	0.376	1						
4. Open-mindedness	−0.381	−0.217	−0.278	1					
5. Non-intuitiveness	−0.355	−0.310	−0.330	0.313	1				
6. CRT3	−0.353	*−0.076*	*−0.068*	0.416	0.230	1			
7. CRT4	−0.282	*−0.103*	*−0.055*	0.257	0.284	0.599	1		
8. RAPM	−0.360	*−0.141*	*−0.066*	0.306	0.167	0.535	0.567	1	
9. Analogies	−0.344	−0.163	*−0.041*	0.308	*0.068*	0.429	0.394	0.612	1
10. Patterns	−0.308	*−0.107*	*0.022*	0.312	0.167	0.465	0.488	0.584	0.640

Note. Non-significant correlations shown in italics. All other correlations significant at $p < .04$.

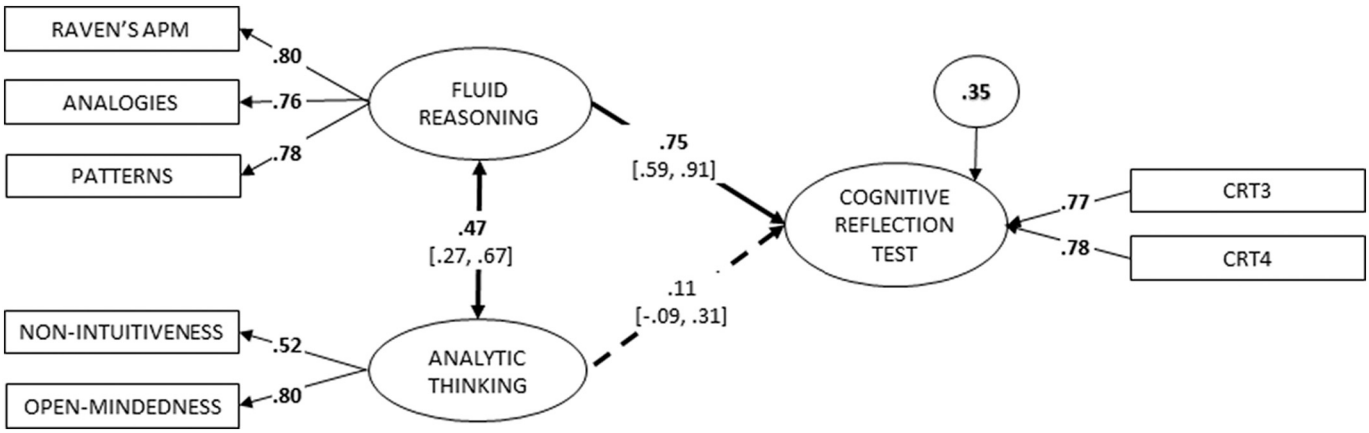

Fig. 2. Two-factor structural equation model explaining Cognitive Reflection Test (CRT) in Study 2. See Fig. 1 for the model elements description.

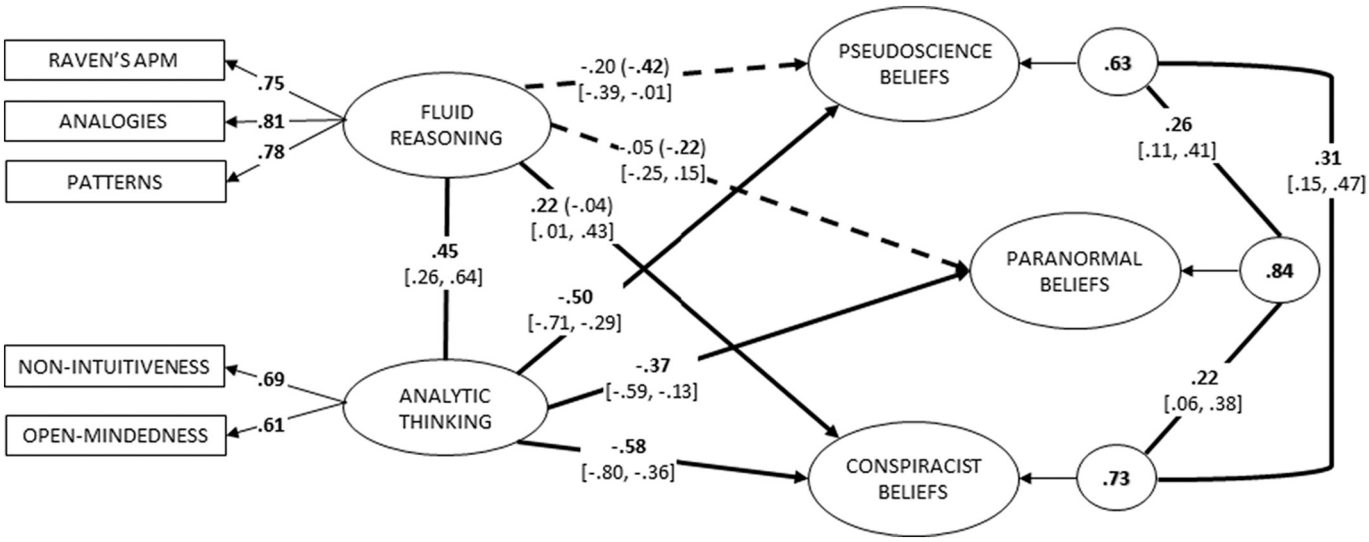

Fig. 3. Two-factor structural equation model in Study 2. See Fig. 1 for the model elements description.

& Rand, 2018; Toplak et al., 2014), it appeared that CRT shared no common latent variance with two self-report measures of analytic thinking. At the same time, CRT shared most of its variance with fluid reasoning, in line with a recent meta-analysis (Otero et al., 2022). Therefore, CRT unlikely captures tendency for reflectiveness and can independently predict variables related to rationality (Pennycook et al., 2020; Pennycook & Ross, 2016; Sinayev & Peters, 2015). By contrast, it seems to primarily depend on reasoning ability and numerical skills (see Campitelli & Gerrans, 2014; Otero et al., 2022; Szaszi, Szollosi, Palfi, & Aczel, 2017; Weller et al., 2013).

To address the above limitation of CRT, in Study 3 we introduced two other widely adopted objective measures of analytic thinking. One is proneness to belief bias, that is, the tendency to violate the formal rules of logical reasoning either by accepting conclusions which are familiar and/or agree with common knowledge (are believable) but do not necessarily follow the premises (are logically invalid) or by rejecting logically valid conclusions which are unbelievable (Evans, 2003). The other measure is the tendency to rely on fast but invalid intuitions

during probability estimation (Čavojová et al., 2020; Musch & Ehrenberg, 2002; Stanovich, 2011; Tversky & Kahneman, 1974).

Moreover, in looking for potential emotional predictors of unwarranted beliefs, beyond the cognitive realm, we probed anxiety. To account for motivational factors, we probed need for cognition (motivation towards complex, effortful thinking). We also asked participants about their education level and political orientation. These analyses were purely exploratory.

4. Study 3

4.1. Participants

We recruited 318 volunteers from Krakow using internet advertisements. Each participant received the equivalent of 20 euros in local currency for the participation. Seven participants missed at least one test or questionnaire from those listed in Section 4.2, resulting in the final sample of 311 (211 women, mean age = 24.3 years, $SD = 5.7$, range 18–45). All the participants were informed that the participation was anonymous and fully voluntary.

4.2. Measures

In order to minimize the overlap between analytic thinking and unwarranted beliefs scales, potentially driving some part of their substantial correlation (e.g., active open-mindedness item no. 5 may resemble a conspiracist claim, intuitive thinking item no. 8 may resemble a paranormal claim, etc.), for intuitive thinking we used only two items: "intuition is the best guide in making decisions" and "I tend to follow my heart rather than reason," which in previous studies correlated with the factor loading the remaining items at $r = 1.0$. For active open-mindedness we used only three items: "changing your mind is a sign of weakness," "it is important to persevere in your beliefs even when evidence is brought to bear against them," and"there are basically two kinds of people in this world, good and bad," which correlated with the factor that loaded the remaining items at $r = 0.95$ [0.89, 1.0]. None of these statements seemed to refer to pseudoscience, paranormal, or conspiracy in any way.

Proneness to belief bias was probed with ten verbal problems designed in our lab, based on existing literature. Four items comprised syllogisms in which no valid conclusion could be drawn, but at least one logically invalid conclusion was believable. For instance, for item "all fish breathe with gills and all herrings breathe with gills; from these it follows necessarily that: (a) all fish are herrings, (b) some fish are herrings, (c) some herrings are fish, (d) nothing follows necessarily," choosing the responses (b) and (c) instead of the valid (d) was interpreted as falling into the belief bias. There was also one item per another six logical task types: the conjunction-disjunction, predicate, set, analogy, transitive, and material conditional items. For each item, at least one invalid response option was definitely more believable than the valid option. For instance, for item "knowing that in country X there is an absolute rule (with no exceptions) that if one has a car, one has to pay tax, indicate what would be necessarily true," choosing response "one pays tax therefore one has a car" instead of the valid response "one does not pay tax, therefore one does not have a car" indicated falling into the belief bias. The ten "biased" items were followed by ten logically isomorphic "unbiased" items, in which all the response options were neutral or the invalid options were unbelievable. For instance, for a respective syllogism "all Tarnow citizens breathe; all Mongols breathe" (Tarnow is a small town nearby Krakow), it was quite unbelievable that "all Tarnow citizens are Mongols", "all Mongols are Tarnow citizens", and even "some Tarnow citizens are Mongols", so we expected the participants to select that "nothing follows necessarily". For item "knowing that in country Y there is an absolute rule (with no exceptions) that if one is over 18 then one can drink alcohol, indicate who breaks this rule", we expected that participants would no longer respond "a person below 18 who is not drinking alcohol" instead of both the valid and believable "a person below 18 who is drinking alcohol (a reformulation priming a permission schema; Cheng & Holyoak, 1985). By comparing both test variants, we could see whether our priming of the belief bias was effective. The score used in the analyses was the number of correct responses in the biased test variant (*logic under belief-bias*). The difference between the variants was not used as a score, as in principle the difference scores display low reliability, inflating error variance and diminishing true variance (Cronbach & Furby, 1970)

Proneness to probability bias was probed using twelve test items, also designed in our lab, two per the representativeness heuristics, the availability heuristics, the conjunction fallacy, the gambler fallacy, the sample-size fallacy, and the base-rate neglect (Stanovich, 2011; Tversky & Kahneman, 1974). These biased items were followed by twelve structurally isomorphic unbiased items, analogously as in the logic test. For instance, using the representativeness heuristic in item "ten children were born in a hospital, five girls (G) and five boys (B); indicate the least likely sequence of these births" should lead to selecting responses "GBGBGBGBGB," "GGGGGBBBBB," and perhaps "GBBGBBGGBG," instead of the valid response "all the three sequences are equally likely," as people typically represent such random events as yielding unsystematic outcome sequences. Lesser bias was expected in item "a factory is manufacturing two kinds of toys, bears and cars, but it is not known whether it does so in an arbitrary or fixed way," as there is no representative way of manufacturing toys. Some items required to calculate probabilities directly, for instance in item "the probability to have a mutated gene in a population equals 1%, unfortunately the genetic test is not entirely reliable and detects this gene in only 90% of people who actually have the gene, while the test falsely detects the gene in 5% of people who do not have the gene; indicate the probability that a random member of the population has the mutated gene when a single application of the test signaled the gene presence in this person." Base-rate neglect should result in selecting "about 90%" instead of the valid "about 15%". In the less biased variant of this item, all the probability values were substituted with respective set sizes: "in 100.000 citizens of city X, 1000 people carry a virus; the test can detect 900 people out of these 1000 people, but it also detects the virus in 50 people out of each 1000 people tested who actually do not carry the virus"). Selecting "about 15%" in this item should be easier, as using natural frequencies typically reduces base-rate neglect (Gigerenzer & Hoffrage, 1995). Analogously as in the logic test, we expected a lower accuracy in the biased vs. unbiased test variant.

Fluid reasoning was assessed with Number Series as in Study 1, and RAPM and Analogies as in Study 2. CRT3 and CRT4 were also applied to validate the CRT results observed in Study 2.

The same three scales of epistemically unwarranted beliefs were used as in Studies 1 and 2.

State anxiety was assessed with ten items selected from the X-1 part of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970) in the Polish adaptation (Sosnowski & Wrześniewski, 1983). The scale probes the current emotional state with such questions as "I am relaxed" (reversed scoring), "I am nervous", "I am tensed", and "I am worried".

Need for cognition was assessed with 12 translated items selected from the Cacioppo et al. (1984) Need for Cognition Scale. It included such items as "I find satisfaction in deliberating hard and for long hours" and "I like to have the responsibility of handling a situation that requires a lot of thinking" and the like, as well as items with the opposite meaning (reverse scored).

Participants declared their level of education on the 1–5 scale, where "1" stood for secondary school pupils (3 people), "2" – for the high school pupils (14), "3" – for the high school graduates (55), "4" – for the college students (163), and "5" – for the BA and MA graduates (76). For political conservatism, "1" coded the leftists (45 people), "2" – the centrists (222), and "3" – the rightists (44).

4.3. Procedure

Participants were tested in a psychological laboratory in groups of six people on average. The fluid reasoning tests were applied along with a number of insight problems, working memory tasks, and personality questionnaires, all reported in detail elsewhere (*reference removed for the blind review*). Unwarranted belief scales and analytic thinking questionnaires were administered at the end of the procedure (they were followed by measures of religiosity, belonging to another project).

4.4. Results

All the measures but one showed good internal reliability (note that reliability could not be calculated for education level and political orientation), with the lowest $\alpha = 0.72$ for the logic under belief-bias (note that reliability of the two-item and three-item analytic thinking measures was discussed above). Only the reliability of the probability under bias measure was unacceptable, $\alpha = 0.30$. The difference in scores between the unbiased and biased variants of the probability estimation test yielded a small effect, $\Delta M = 1.29$ (out of 12), $t(310) = 10.82$, $p < .001$, meaning that accuracy increased only 28% without the bias. As the unbiased test variant was still difficult to solve for our participants (48.5% correct), we interpreted these results as indicating that even the latter variant primed biased responses to some extent. Given that fact, and in order to obtain a more reliable measure, we combined both variants of the probability test. Such a *probability estimation* variable yielded $\alpha = 0.51$ (note that others also reported problems with internal consistency of biases and heuristics, e.g., Teovanović, Knežević, & Stankov, 2015). By contrast, the difference in scores between the unbiased and biased variants of the logic test equaled $\Delta M = 4.41$ (out of 10), $t(310) = 45.08$, $p < .001$, indicating that eliminating the belief-bias manipulation increased accuracy by as much as 141%. Table 6 presents descriptive statistics for all the measures, which were approximately normally distributed.

The correlation matrix is presented in Table 7. The pattern of correlations of unwarranted beliefs, the two analytic thinking scales, and three fluid reasoning tests were analogous to those in Study 1 and 2. The CRT scores were only weakly related with unwarranted beliefs, but quite strongly with the fluid reasoning tests. The SEM model analogous to the model in Fig. 2, in which fluid reasoning and analytic thinking (intercorrelated) predicted the CRT latent variable, yielded similar results as in Study 2: CRT was strongly predicted by fluid reasoning, $\beta = 0.76$, while the contribution of analytic thinking was not significant, $\beta = 0.08$. After being loaded by fluid reasoning, the CRT3 and CRT4 residuals did not converge to a factor. Thus, we no longer considered CRT in our SEM models.

Next, in order to examine the validity of logic under belief-bias and

Table 6
Descriptive statistics for all measures used in Study 3 ($N = 311$).

Measure (scale)	*M*	Min	Max	*SD*	Skew	Kurtosis
Pseudoscience beliefs (78)	40.28	1	77	13.29	−0.41	0.04
Paranormal beliefs (72)	25.61	0	71	15.69	0.09	−0.87
Conspiracist beliefs (90)	43.20	0	84	17.08	−0.58	0.24
Open-mindedness (12)	8.35	0	12	2.85	−0.53	−0.47
Non-intuitiveness (8)	3.80	0	8	1.67	0.10	−0.34
Logic under belief-bias (10)	3.12	0	9	1.94	0.76	−0.05
Probability estimation (24)	10.39	3	20	2.92	0.36	0.27
CRT3 (3)	0.84	0	3	1.00	0.89	−0.42
CRT4 (4)	1.27	0	4	1.11	0.67	−0.26
RAPM (18)	11.14	2	18	3.13	−0.37	−0.04
Analogies (18)	12.09	1	18	3.25	−0.49	−0.19
Number series (18)	9.27	1	18	3.71	−0.09	−0.56
Anxiety (40)	23.47	10	40	6.00	0.21	−0.14
Need for cognition (48)	30.86	4	44	6.94	−0.22	−0.09

Table 7
Correlation matrix for all measures used in Study 3 ($N = 311$).

Measure	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1. Pseudoscience beliefs	1														
2. Paranormal beliefs	0.562	1													
3. Conspiracist beliefs	0.470	0.496	1												
4. Open-mindedness	−0.344	−0.247	−0.265	1											
5. Non-intuitiveness	−0.382	−0.294	−0.125	0.260	1										
6. Logic under belief-bias	−0.253	−0.194	*−0.066*	0.438	0.252	1									
7. Probability estimation	−0.283	−0.156	*−0.086*	0.315	0.224	0.462	1								
8. CRT3	−0.211	*−0.087*	*−0.075*	0.305	0.208	0.490	0.490	1							
9. CRT4	−0.184	−0.130	*−0.103*	172	0.118	0.389	0.435	0.537	1						
10. RAPM	−0.198	−0.154	*−0.078*	0.362	0.203	0.437	0.469	0.514	0.463	1					
11. Analogies	−0.187	−0.188	*−0.093*	0.276	0.187	0.391	0.417	0.446	0.443	0.650	1				
12. Number series	−0.114	*−0.081*	*−0.014*	0.202	0.229	0.386	0.403	0.471	0.391	0.551	0.527	1			
13. Anxiety	−0.117	*−0.005*	*−0.024*	*−0.076*	*−0.055*	*0.060*	*0.099*	*−0.001*	*0.013*	*−0.067*	*−0.053*	−0.044	1		
14. Need for cognition	*−0.081*	*−0.006*	*0.089*	0.212	*0.092*	0.268	0.257	0.270	0.224	0.329	0.332	0.275	−0.123	1	
15. Education	*−0.034*	*−0.089*	*−0.043*	0.171	*−0.019*	0.197	0.141	0.114	*0.085*	0.201	0.253	0.236	*−0.012*	*0.036*	1
16. Conservatism	0.152	0.161	0.270	−0.147	*−0.004*	*−0.012*	*−0.013*	*−0.049*	*−0.020*	*−0.072*	*−0.044*	*0.064*	*−0.090*	*0.094*	−0.116

Note. Non-significant correlations shown in italics. All other correlations significant at $p < .045$.

probability estimation as measures of analytic thinking style, we calculated a model with fluid reasoning and analytic thinking as two intercorrelated predictors, and the endogenous variable loading logic under belief-bias and probability estimation, with $\lambda = 0.70$ and $\lambda = 0.66$, respectively. The results substantially differed, as compared to the CRT model, because now the endogenous variable was primarily predicted by analytic thinking, $\beta = 0.62$, and less by fluid reasoning, $\beta = 0.42$. Thus, the two measures could be considered as objective, performance-based measures of analytic style. The fluid intelligence and analytic thinking variables correlated more strongly than in Studies 1 and 2, $r = 0.62$.

We again started from the one-factor model, in which solely fluid reasoning predicted the pseudoscience, paranormal, and conspiracist beliefs latent variables (note that their loadings on the respective items were highly comparable with those observed in Studies 1 and 2). In this model, fitting the data acceptably, RMSEA = 0.076 [0.072, 0.080], SRMR = 0.072, fluid reasoning predicted significantly pseudoscience, $\beta = -0.21$, $p = .001$, and paranormal beliefs, $\beta = -0.23$, $p < .001$, but was not significantly related with conspiracist beliefs, $\beta = -0.10$, $p = .116$.

Because of the substantial correlation between fluid reasoning and analytic thinking, as well as the fact that the two-factor and the bifactor models in Study 2 showed compatible patterns of the analytic thinking contribution to unwarranted beliefs, in Study 3 we no longer tested the two-factor model, but directly moved to the bifactor model, in which fluid reasoning loaded all seven predictor measures, while analytic thinking loaded the two analytic thinking scales as well as logic under belief-bias and probability estimation. The resulting model, RMSEA = 0.071 [0.068, 0.075], SRMR = 0.071, is presented in Fig. 4. Fluid reasoning weakly predicted pseudoscience beliefs, $\beta = -0.20$, $p = .002$, and paranormal beliefs, $\beta = -0.21$, $p = .001$, but not the conspiracist beliefs, $\beta = -0.09$, $p = .167$. By contrast, analytic thinking contribution to pseudoscience beliefs was strong, $\beta = -0.61$, $p < .001$, and it was moderate with regard to paranormal, $\beta = -0.41$, $p < .001$, and conspiracist beliefs, $\beta = -0.32$, $p < .001$. Both predictors did not explain the mutual correlations between the three types of unwarranted beliefs, which were all significant, mean $r = 0.33$, each $p < .001$.

To test whether unwarranted beliefs could be predicted by performance-based measures of analytic thinking, we eliminated from the bifactor model the open-mindedness and non-intuitiveness variables, leaving all the other elements intact. The paths from fluid reasoning to unwarranted beliefs were not affected (each $\Delta\beta < 0.02$), but the respective paths from analytic thinking considerably weakened. The path to pseudoscience beliefs changed from a strong to a moderate one, $\beta = -0.35$, $p < .001$, however it still was significantly higher than the respective path from fluid reasoning. The path to paranormal beliefs, $\beta = -0.14$, was no longer significant, $p = .145$, but it did not differ significantly from the respective path from fluid reasoning, similarly as the path to conspiracist beliefs, $\beta = -0.08$, $p = .412$. When the two performance based measures were substituted with open-mindedness and non-intuitiveness, then the contributions of analytic thinking increased, as compared to the initial model, with the paths equaling $\beta = -0.74$, $\beta = -0.52$, and $\beta = -0.42$, each $p < .001$, for the pseudoscience, paranormal, and conspiracist beliefs, respectively.

Finally, we looked at non-cognitive correlates of unwarranted beliefs. Anxiety very weakly correlated with pseudoscience beliefs, but with no other measure. Need for cognition shared several percent of variance with each cognitive test and open-mindedness, but was unrelated to unwarranted beliefs. Education level positively correlated with open-mindedness and some of the cognitive tests, but was unrelated to unwarranted beliefs. Only conservatism positively correlated with all unwarranted beliefs, primarily with conspiracist beliefs, sharing over 7% of variance.

4.5. Discussion

The main finding of Study 3 was that analytic thinking could be to some extent captured by measuring the avoidance of belief-bias during logical reasoning and intuitive but invalid heuristics and fallacies during probability estimation. However, these performance-based measures yielded a lesser predictive power than did self-reports, explaining only pseudoscience beliefs. Nevertheless, they demonstrated that substantial associations between analytic thinking and at least pseudoscience cannot be explained away solely in terms of shared method variance (self-report).

The second important finding was that self-report measures of analytic thinking constituted a powerful predictor of all the three types of unwarranted beliefs even when they were reduced to just five straightforward statements, semantically disjoint from the statements included in the unwarranted beliefs scales.

The third finding, consistent with the existing literature, suggested that only conservatism is associated with unwarranted beliefs, primarily with the tendency for supporting conspiracy theories (Pennycook et al., 2020; Ståhl & van Prooijen, 2018). Three other variables frequently considered in the literature (see Betsch et al., 2020): anxiety, motivation towards thinking (need for cognition), and education, yielded negligible links (only anxiety and pseudoscience shared 1% of variance).

Overall, Study 3 replicated Studies 1 and 2, showing that fluid reasoning weakly predicted pseudoscience and paranormal beliefs, but

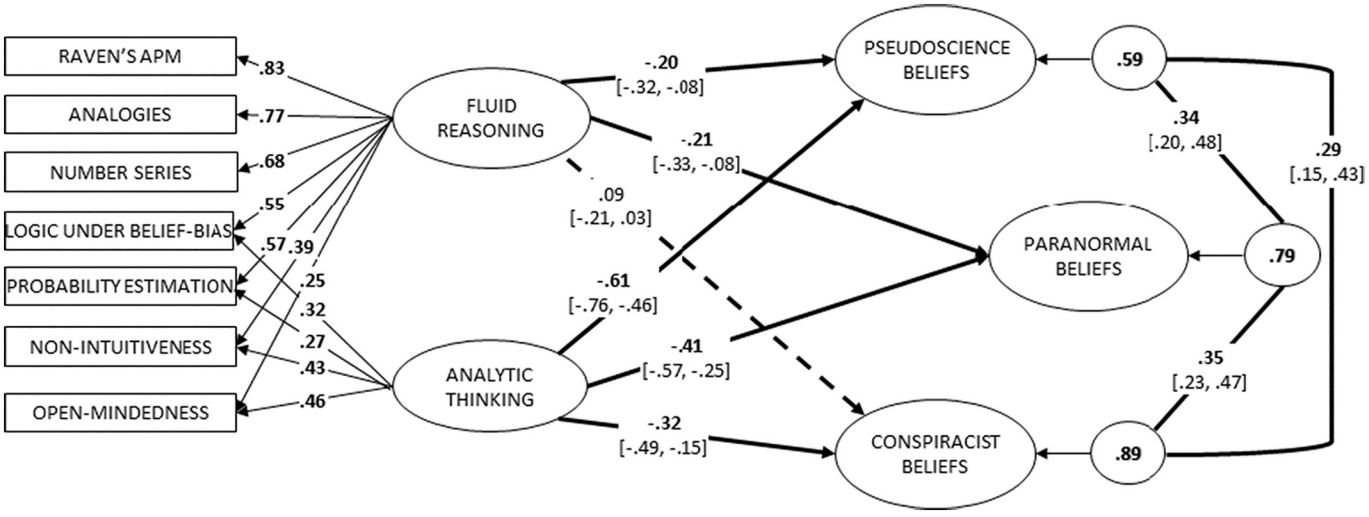

Fig. 4. Bifactor structural equation model in Study 3. See Fig. 1 for the model elements description.

not conspiracist beliefs. At the same time, endorsement of five simple statements, representing one's faith in intuition and value of opinion persistence, after filtering out potential indirect effects of fluid intelligence, explained from 17.6% of conspiracist, through 27.0% of paranormal, up to 54.7% of pseudoscience beliefs variance.

5. Combined dataset

We combined data across Studies 1–3 in the following way: In each study, the total scores on the two non-intuitiveness, the three open-mindedness, the thirteen pseudoscience, the twelve paranormal, and the fifteen conspiracist items were converted into respective *z* scores. The mean of non-intuitiveness and open-mindedness z-score served as the analytic thinking factor. The principal component calculated for the three fluid reasoning test scores served as the fluid reasoning factor. The pseudoscience, paranormal, and conspiracist z-scores as well as the analytic thinking and the fluid reasoning factors from Studies 1–3 were combined into a single dataset, which included 827 participants. This dataset was used to examine a potential interaction of analytic thinking and fluid reasoning in explaining each kind of unwarranted beliefs. Finally, we examined moderation by sex.

An interaction between the fluid reasoning factor and the analytic thinking factor in predicting pseudoscience, paranormal, and conspiracist beliefs was assessed using regression models with the fluid reasoning factor, the analytic thinking factor, and their product as independent variables. The models included also the square of analytic thinking factor, as initial analysis showed that such a quadratic component, even though weak, was significant for each of unwarranted beliefs, $\beta = -0.11$, $\beta = -0.13$, $\beta = -0.12$, respectively. No such component was identified for their relationship with fluid reasoning, each $\beta < 0.03$. Table 8 presents the results of the regression models. Fluid reasoning was a significant predictor only for pseudoscience beliefs, as well as it entered a significant interaction with analytical thinking. For paranormal and conspiracist beliefs, neither fluid reasoning nor its interaction with analytic thinking was significant. Analytic thinking was a significant and substantial predictor of each of unwarranted beliefs. For paranormal and pseudoscience beliefs, also its quadratic component was significant, although its effect was relatively small.

Fig. 5 shows the pattern of interaction between fluid reasoning and analytic thinking in predicting pseudoscience beliefs. In line with our expectations, the interaction was over-additive, that is, the lowest values of pseudoscience beliefs were reported by participants with the highest scores on both fluid reasoning and analytic thinking. For participants below median on the analytic thinking factor, the fluid intelligence factor and pseudoscience beliefs correlated at $r = -0.15$, while for those above median the respective correlation equaled $r = -0.25$, each $p < .01$. For participants below median on the fluid reasoning factor, the analytic thinking factor and pseudoscience beliefs yielded $r = -0.34$, while above median this correlation increased in size to $r = -0.47$, each $p < .001$.

One explanation of stronger links of analytic thinking with pseudoscience in high ability participants may be related with a more precise self-assessment of cognitive abilities and thinking styles in more intelligent participants. Fortunately, in Study 3 the participants marked on the 20-point Likert scale how their assessed their own intelligence level. We standardized this variable and then subtracted from the respective z

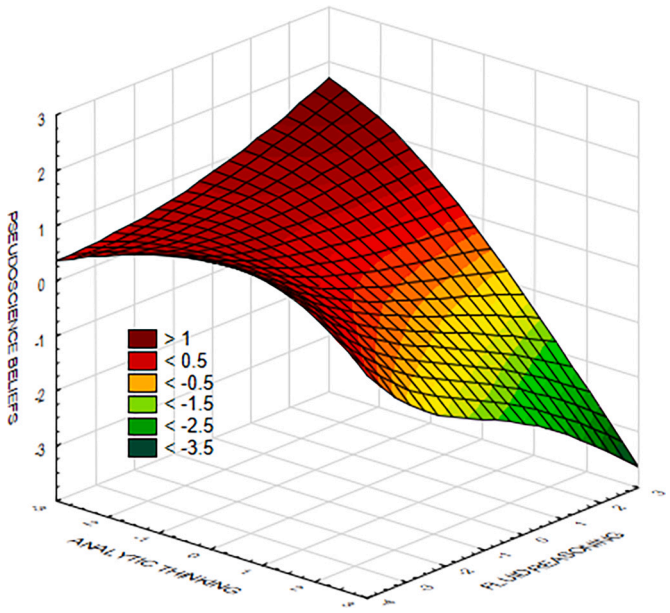

Fig. 5. The 3-D plot of pseudoscience beliefs z-score (ranging green to red) as a function of the fluid reasoning and analytic thinking factors. Data smoothed using distance weighted least squares. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

score the actual values of the fluid reasoning factor. This difference correlated strongly and negatively with the actual fluid reasoning factor, $r = -0.59$, meaning that the low-ability participants highly overestimated their ability level, while the high-ability participants slightly underestimated it. The difference also predicted negatively the variance shared between logic under belief-bias and probability estimation, $r = -0.31$, as well as the variance shared between non-intuitiveness and open-mindedness, $r = -0.21$, each $p < .001$, suggesting that low cognitive ability could be associated also with lower precision of thinking style self-assessment, which could weaken its actual relationships with unwarranted beliefs in the low-ability group. However, a weaker link of fluid reasoning with pseudoscience in people low in analytic thinking cannot be explained by self-assessment (in)precision, because fluid reasoning was assessed using performance measures. Low analytic thinking might attenuate the benefits of effective fluid reasoning: High-ability participants who failed to reflect on a pseudoscience claim might not use their reasoning power in order to evaluate it validly, what they would succeed if only they ran the proper reasoning process.

No significant interaction of fluid reasoning and analytic thinking was observed for paranormal and conspiracist beliefs. A weak quadratic effect for analytic thinking indicated that its relationship with both beliefs changed from virtually null for very low values of analytic thinking, through a moderate relationship for its medium values, up to a strong relationship for its high values.

Finally, we tested for differences in relations of unwarranted beliefs with fluid reasoning and analytic thinking between 528 females and 296 males. Table 9 shows that the link of fluid reasoning with each of the three beliefs was significantly stronger in males than in females. Also the

Table 8
Regression models for the three unwarranted beliefs in the combined dataset ($N = 827$).

Dependent variable	β fluid reasoning	β analytic thinking	β analytic thinking^2	β analytic th. × fluid reasoning	Model's adj. R^2	Model's *F*
Pseudoscience	−0.160	−0.514	*−0.074*	−0.117	0.22	46.41
Paranormal	*−0.059*	−0.427	−0.138	*0.003*	0.12	23.04
Conspiracist	*−0.017*	−0.323	−0.107	*−0.057*	0.07	11.84

Note. Non-significant parameters shown in italics. All other parameters significant at $p < .005$.

Table 9
Path coefficients for the predictors in group SEM analysis in the combined dataset ($N = 824$).

Path	Females	Males	Difference (Z)	Difference (p)
Fluid reasoning- > Pseudoscience	**−0.206**	**−0.372**	**3.45**	**<0.001**
Fluid reasoning- > Paranormal	**−0.104**	**−0.226**	**2.49**	**0.006**
Fluid reasoning- > Conspiracist	***−0.014***	**−0.186**	**3.48**	**<0.001**
Analytic thinking- > Pseudoscience	−0.408	−0.459	1.41	0.079
Analytic thinking- > Paranormal	−0.309	−0.369	1.62	0.052
Analytic thinking- > Conspiracist	**−0.203**	**−0.311**	**2.92**	**0.002**

Note. A non-significant path shown in italics. All other paths significant at $p <$ .002.

link of analytic thinking and conspiracist beliefs was significantly stronger for males, while the sex differences for its relationships with pseudoscience and paranormal beliefs were only marginal.

6. General discussion

Three studies (total $N = 827$) which administered measures of fluid reasoning, analytic thinking style, and epistemically unwarranted beliefs (pseudoscience, paranormal, conspiracist) were conducted in order to assess the strength of the latent-level relationship of fluid reasoning with each kind of these beliefs. Second, we aimed to compare the predictive power of fluid reasoning relative to analytic thinking. Third, we tested for any interactions of both these variables in predicting unwarranted beliefs. Finally, we checked for potential sex differences in the relationships examined.

6.1. Main findings

First, the three studies altogether suggest that fluid reasoning alone can explain about 11% of variance in pseudoscience beliefs (mean $r = -0.33$), 4% – in paranormal beliefs (mean $r = -0.20$), and less than 2.5% – in conspiracist beliefs (mean $r = -0.16$). The former result indicates that rejecting a pseudoscience claim might require some cognitive capacity, that is, it may be easier for an individual to reject such a claim (e.g., creationism) when the scientific theory describing this fragment of nature (i.e., the theory of evolution) is properly understood, and valid inferences can be drawn from it. At the same time, fluid reasoning barely mattered for rejecting paranormal and conspiracist claims.

However, fluid reasoning predicted unwarranted beliefs primarily because of variance it shared with analytic thinking. When the latter variable was entered into the model, it reliably explained substantial variance in each of the three kinds of unwarranted beliefs, while the fluid reasoning contribution was no longer statistically significant. Nonetheless, it is not possible to identify whether either fluid reasoning or analytic thinking drove their shared variance, or perhaps it reflected multiple other factors present during development. Therefore, to avoid interpreting the analytic thinking variable as reflecting (also) fluid reasoning, and to reduce any indirect effects of cognitive ability on it, each our bifactor model represented the analytic thinking latent variable after partialling out the variance shared with the fluid reasoning latent variable. Anyway, analytic thinking remained a substantial predictor of unwarranted beliefs, considerably stronger than fluid reasoning. These results held even when in Study 3 analytic thinking was captured using a minimum number of self-report statements, which reduced possible semantic overlaps with unwarranted beliefs items.

In the case of pseudoscience beliefs, fluid reasoning and analytic thinking contributed in the over-additive interaction. Specifically, participants with high reasoning ability and highly analytic style declared an extraordinary strong rejection of pseudoscience. One potential explanation of this interaction is that low-ability people can less accurately assess their own level of analytic thinking vs. intuitive processing (see Pennycook, Ross, Koehler, & Fugelsang, 2017), similarly as they overestimated their intelligence level in Study 3. Therefore, in low-ability people the reliability of the analytic thinking variable might be lower, and thus its effect – weaker. Alternatively, some level of cognitive capacity may be needed for the critical, reflective evaluation of data, so analytic thinking style may help low-ability people to a lesser extent than it helps high-ability ones, because the former people might fail in representing and integrating the data to be (critically) evaluated. The interplay between cognitive ability and style in the context of unwarranted beliefs is a novel finding that should attract future research.

Finally, the negative links of unwarranted beliefs with fluid reasoning and analytic thinking were overall stronger in males than in females. This exploratory finding is also novel. It does not seem to result from males' vs. females' stronger overall proneness to unwarranted beliefs, because while females scored higher on the pseudoscience scale by 0.33 *SD*, males scored higher on the conspiracist scale by 0.17 *SD*, and there was no reliable difference for the paranormal scale, 0.09 *SD*.

In line with existing literature (e.g., Lobato et al., 2014), pseudoscience, paranormal, and conspiracists beliefs correlated moderately. Analytic thinking explained most of their shared variance, as the amount of commonality for the disturbance terms dropped substantially when analytic thinking was added to the models, with consecutive pairs of beliefs sharing only about 5% of their variance. This result suggests that the common basis of three kinds of unwarranted beliefs is primarily grounded in participants' inclination to analytic thinking. However, still from over half (pseudoscience) to the majority of variance (conspiracy) remained unexplained by analytic thinking and fluid reasoning. Emotional, motivational, and social factors did not help to explain this part of variance (see also Betsch et al., 2020; Čavojová et al., 2020; Lobato et al., 2014), except for conservatism, which accounted for 7% of variance in conspiracist beliefs. Possibly, a substantial part of individual differences in endorsement of unwarranted claims may be idiosyncratic.

In order to overcome a potential problem that the unwarranted belief scales and the analytic thinking scales shared method (self-report), in Study 2 we introduced an objective measure widely used to capture non-reflectiveness – an expanded Cognitive Reflection Test (Toplak et al., 2014). We found, in line with a recent CRT meta-analysis (Otero et al., 2022), that CRT shared the majority of its variance with fluid reasoning, while it was unrelated to analytic thinking. Similarly as fluid reasoning, CRT did not contribute substantially to explaining unwarranted beliefs (for analogous results see Toplak et al., 2011; for contrasting results see Pennycook et al., 2012; Shenhav et al., 2012). In Study 3, logical reasoning under belief-bias as well as avoiding invalid heuristics and fallacies during probability estimation served as objective measures of analytic thinking. Unlike CRT, these measures successfully converged into a latent variable that was able to partially substitute analytic thinking style measured subjectively. This variable still contributed to pseudoscience beliefs more strongly than did the fluid reasoning latent variable, contributed comparably as the latter variable to the paranormal beliefs, while both variables failed to explain significant variance in conspiracist beliefs. Even though self-report measures (even our very short ones) seem to capture analytic thinking more precisely than do the belief-bias and probability estimation tests, at least we demonstrated that such tests are still able to outrun fluid reasoning in predicting pseudoscience. As using performance-based tests of thinking styles has been problematic to date, with the scores on various such tests frequently not converging to a single factor (e.g., Aczel, Bago, Szollosi, Foldes, & Lukacs, 2015; Berthet, 2021; De Baets & Vanderheyden, 2021; Teovanović et al., 2015), more work is needed to develop valid tests of analytical thinking, in order to avoid relying solely on self-report measures.

6.2. Limitations and future directions

One limitation is related to the choice of items in the unwarranted beliefs scales. There are hundreds of unsubstantiated claims, while the nature of the experimental study limits us to probe the participants only on a few tens of them. Although our selection of items was based on existing, widely used scales, we are aware of the possibility of missing some key beliefs. At least, by inspecting carefully the factor validity of our items, we tried to eliminate inessential items (e.g., items loading other factors, instead of the target factor). Definitely, work on validation of the large pool of unwarranted belief items is needed, which would generate the universal and commonly accepted inventories, helping to advance this relatively recent area of research.

Second, we examined only relatively young urban adults from a Central European country, in which Catholicism is a dominating religion. Data from other samples and cultures are necessary for a richer picture of the relationships between cognitive ability, thinking styles, and unwarranted beliefs. Anyway, our main results are compatible with existing evidence on weak links between intelligence and unwarranted beliefs (Čavojová et al., 2020; Toplak et al., 2011), moderate correlation between intelligence and analytic thinking style (Alaybek et al., 2021), substantial links between the latter and unwarranted beliefs (Gervais, 2015; Lobato & Zimmerman, 2019; Svedholm & Lindeman, 2013; Swami et al., 2014), even after controlling for intelligence (Pennycook et al., 2012, 2016; Shenhav et al., 2012), and intercorrelations between different kinds of such beliefs (Bensley et al., 2020; Darwin et al., 2011; Lobato et al., 2014). Our path analyses applied to latent variables representing the above psychological constructs allowed a more comprehensive and precise estimation of the strength of relationships in question, as compared to previous single-measure studies.

Theoretically, given highly heritable (Deary, Penke, & Johnson, 2010) and barely malleable (Melby-Lervåg, Redick, & Hulme, 2016; Sala & Gobet, 2019) nature of intelligence, weak contributions of fluid reasoning to unwarranted beliefs represents an "optimistic" result. As the attempts at enhancing reflectiveness and critical thinking – the skills which seem to translate onto the common sense and scientific grounding of beliefs one holds – yielded moderate success (Abrami et al., 2008; Dyer & Hall, 2018; Kane et al., 2010; McLaughlin & McGill, 2017; Stanovich & Stanovich, 2010), there is a chance for the future educational and training programmes to effectively reduce unwarranted beliefs, with potentially benefits for public health, safety, economy, and political life.

6.3. Concluding remarks

Summing up, the present work clarifies the mutual relationships of fluid reasoning (a key marker of general intelligence), analytic thinking (a key cognitive style linked to non-intuitiveness and open-mindedness), and three major kinds of epistemically unwarranted beliefs. Fluid reasoning contributed moderately to pseudoscience rejection, weakly to paranormal rejection, and negligibly to conspiracist beliefs. By contrast, analytic thinking substantially explained all the three kinds of beliefs. It contributed primarily to their shared variance, while a large part of belief-specific variance remained unexplained, even when additional non-cognitive variables were taken into account. A novel finding consisted of the over-additive interaction of fluid reasoning and analytic thinking in explaining pseudoscience, with their high values leading to exceptionally strong rejection of pseudoscience claims. No such interaction was observed for paranormal and conspiracist claims. Finally, fluid reasoning and analytic thinking were overall more strongly related with rejection of unwarranted beliefs in males than in females – a novel finding that requires additional research.

Concluding, this work helped to delineate the effects of fluid reasoning and analytic thinking on unwarranted beliefs. While the analytic thinking contribution to their rejection was comparable across their three kinds, the respective effects of fluid reasoning differed. Fluid reasoning mattered for rejection of pseudoscience beliefs, and it also boosted the respective effect of analytic thinking (and vice versa) – an interaction yet to be better understood in future studies. By contrast, fluid reasoning did not seem to be important for rejection of paranormal and conspiracist claims. As it had been a reasonable expectation that effective reasoning should help in understanding such claims' ontological (e.g., mental events by themselves cannot affect distant physical events) and probabilistic foundations (e.g., having kept secret alien contacts or mind-control experiments for so long is highly unlikely), resulting in their stronger rejection, which was not supported, our work helps to define the boundaries of the predictive power of intelligence construct, leading to its better understanding. Regarding pseudoscience, paranormal, and conspiracist beliefs, our findings showing that various kinds of beliefs differently relate with cognitive ability, as well as ability and style explain their shared but not separate variance, indicate that various kinds of unwarranted beliefs may be mutually more independent than was previously suggested (e.g., Bensley et al., 2020; Lobato et al., 2014). Such beliefs might not form a particularly integrated and coherent alternative world-view, but rather they might constitute a combination of specific idiosyncratic fractures on world-views of individuals with their generally low reflectiveness in evaluating claims pertaining to those world-views.

Data availability

Raw data for Studies 1-3 can be downloaded from https://osf.io/5r3ay/?view_only=70bbf5b424e34edcb3c5d9c007bf6268

Acknowledgements

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Appendix A. Appendix

Questionnaire items administered in Study 1 and Study 2. Italicized items in the Pseudoscience and the Paranormal scale were excluded from a latent variable due to low loading ($\lambda < 0.40$) in Exploratory Factor Analysis. General Conspiracist Beliefs scale items can be found in Brotherton, French, and Pickering (2013).

Pseudoscience belief scale

1. You can find some energetic points in the human body on which the proper flow of energy in an organism depends.
2. *Consuming genetically modified organisms (GMO) may increase the likelihood of getting cancer* via *inducing certain changes in the DNA structure of the consumer's body cells.*
3. Underground water veins emit energy which may negatively affect the health of people staying nearby.
4. Acupuncture may have some relaxing effects, but it is not an effective way of treating serious diseases. (*Reverse scoring*)
5. Mercury in vaccines may increase the probability of getting autism by small children.
6. Magnetic straps have some healing properties, as they stimulate the diseased body parts with a magnetic field.
7. Bioenergy therapy may be an effective method of healing, as it consists of recovering the energetic balance of an organism.
8. Children conceived by the in-vitro method may often be revealed by their faces, what is connected with more frequent genetic disorders among such children.
9. Regular masturbation leads to sexual disorders.
10. Although it is not always effective, treatment of homosexuality by means of a special therapy is possible.
11. It was proven that criminals and very aggressive people are often characterised by a specific shape of their scull.

12. *Schizophrenia is usually connected with such symptoms as multiple personalities, aggression, and behaviour that is dangerous for other people.*
13. Average people use only about 10% of their brain capacity during daily activities since the effectiveness of neurons is limited.
14. *Crystals possess qualities which protect against the negative influence of electromagnetic radiation.*
15. *Detecting underground water sources using a pendulum is possible due to magneto-energetic forces.*
16. Although the theory of evolution is accepted by most of the scientist, it is only a theory and there is little evidence that it is true.
17. Lightning strikes do not hit twice the same place, because a lightning strike causes a permanent change in the nearby electric field.
18. *Although the official science does not confirm this, there is a lot of convincing evidence that Earth was visited by aliens in the past.*

Paranormal belief scale

1. There are people who possess the ability to move objects using only their mental power.
2. You can't rule out that magic really exists.
3. Under some conditions, the mind or the soul can leave the human body and return afterwards.
4. *Configuration of planets can have a real effect on our lives.*
5. Psychokinesis, which is an ability to move objects using only the power of will, really exists.
6. There are people who possess abilities that can never be explained by science.
7. *Breaking a mirror may bring you bad luck.*
8. It is possible to leave your body when being asleep or in the state of trance.
9. *It is possible to foretell someone's future using horoscopes.*
10. In some cases, thoughts can directly affect material objects.
11. It is possible to put a curse on a person.
12. *There is some evidence that some numbers are lucky and some are unlucky.*
13. *Sometimes we may have access to thoughts from our former incarnations.*
14. *You may often accurately predict the future using the tarot cards.*
15. Reading other people's minds is sometimes possible.
16. Real miracles happen and they can never be explained by science.
17. In some cases, it is possible to communicate with the dead.
18. There are people who have a scientifically unexplainable ability to predict the future.
19. *Signs of zodiac affects personality.*
20. *Certain days of the week are more unlucky than the others.*

Open-mindedness questionnaire

1. Certain beliefs are just too important to abandon no matter how good a case can be made against them.
2. I don't like to be too objective when considering various issues.
3. I don't think that my actions have to be grounded in any rationale.
4. If an opinion suits me and seems right, it doesn't really matter whether it's true for sure.
5. I tend to classify people as either for me or against me.
6. There are two kinds of people in this world: those who are for the truth and those who are against the truth.
7. Changing your mind is a sign of weakness.
8. It is important to persevere in your beliefs even when evidence is brought to bear against them.
9. Considering too many different opinions often leads to bad decisions.
10. There are basically two kinds of people in this world, good and bad.
11. I believe that loyalty to one's ideals and principles is more important than "open-mindedness."
12. Evidence against well established and socially beneficial beliefs should be rejected.

Intuitive thinking questionnaire

1. Of course, it is important to base opinions on facts, but in the end, the most important is what intuition tells us.
2. Intuition is the best guide in making decisions.
3. I tend to follow my heart rather than reason.
4. I don't think it is a good idea to rely on one's intuition for important decisions. (*Reverse scoring*)
5. I can instinctively sense another person character.
6. I trust my initial instinctive judgements in new situations.
7. I prefer to think about something carefully rather than acting spontaneously and instinctively. (*Reverse scoring*)
8. I can accurately sense what other person is feeling, even if that person is silent.
9. Feelings are better at guiding a course of action than reason.
10. Often, it's best to just let go "reasonable arguments" and go by one's instincts.

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