The contingency illusion bias as a potential driver of science denial

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Abstract

Science denial is a pressing social problem, contributing to inactivity in the face of climate change, or to a resurgence in outbreaks of preventable diseases. Cognitive factors are a significant driver of science denial, in addition to social factors such as political ideology. Biases pertaining to judgments of contingency (i.e., inferring causal relationships where none exist) have been associated with misbeliefs, such as belief in the paranormal and conspiracy theories. Here, we examine whether contingency biases likewise predict science denial. We show that (a) various tasks used to study relevant biases do in fact load on a single latent 'contingency illusion' factor; (b) this contingency illusion bias is associated with increased science denial; (c) the contingency illusion bias mediates the relationship between intuitive (vs. analytic) cognitive style and science denial; and (d) this holds even when accounting for political ideology.

Keywords: science denial; individual differences; causal illusion; misbelief; analytic style

Science denial — the failure to believe the scientific consensus, even when this is supported by considerable empirical evidence — has considerable negative outcomes. Science deniers are less likely to vaccinate (Jolley & Douglas, 2014a) or reduce their carbon footprint (Jolley & Douglas, 2014b), potentially contributing to large-scale social harm. Much research on science denial has focused on social factors, such as religious or political ideology (Barone, Petto, & Campbell, 2014; Drummond & Fischhoff, 2017; Kahan et al., 2012; Rutjens, Sutton, & van der Lee, 2017). However, there is evidence that cognitive factors may also play a role. For instance, having an intuitive cognitive style — a tendency to engage in intuitive rather than analytic or reflective thinking — predicts higher levels of science denial (Gervais, 2015; Lobato & Zimmerman, 2019; McPhetres & Pennycook, 2019; Wagner-Egger, Delouvée, Gauvrit, & Dieguez, 2018). But apart from cognitive *style*, are cognitive *biases* related to science denial? If so, how do these cognitive factors interact?

We answer these questions by considering science denial as an example of 'misbelief' — a persistent false belief that is resistant to disconfirming evidence. Misbeliefs encompass a wide range of phenomena, such as conspiracy theorising (e.g., the moon landings were faked; Douglas & Sutton, 2011); belief in the paranormal (e.g., psychic powers; Orenstein, 2002); belief in fake news (falling for fabricated propaganda stories; Bronstein, Pennycook, Bear, Rand, & Cannon, 2019), and, in the clinical realm, delusions (e.g., that one is being persecuted; Peters, Joseph, Day, & Garety, 2004).

The aforementioned intuitive cognitive style predicts misbeliefs (Bronstein et al., 2019; Pennycook & Rand, 2019), but so do specific cognitive biases, such as the Jumping to Conclusions bias (Huq, Garety, & Hemsley, 1988; Ross, McKay, Coltheart, & Langdon, 2015), the Bias Against Disconfirmatory Evidence (McLean, Mattiske, & Balzan, 2017; Prike, Arnold, & Williamson, 2018), a teleology bias (Wagner-Egger et al., 2018), and a causal illusion bias (Blanco, Barberia, & Matute, 2015; Griffiths, Shehabi, Murphy, & Le Pelley, 2018; Torres, Barberia, & Rodríguez-Ferreiro, in press).

If science denial is meaningfully like these other misbeliefs (Lewandowsky, Gignac, & Oberauer, 2013; Lobato & Zimmerman, 2019; Shtulman, 2013; Wagner-Egger et al., 2018), then some of these biases might also correlate with science denial. In that case, demonstrating a relationship between such biases and science denial — as we aim to do here — would be an important step towards combating these widespread, harmful misbeliefs. Specifically, it will help us understand how the process of belief-formation leads people to reject both scientific consensus and the evidence that supports it. This understanding may make for better interventions in the fight against science denial.

First, however, a methodological issue must be cleared up. Several biases relevant to misbelief seem quite similar. Apophenia is the tendency to perceive patterns or meaning where in fact there is just randomness, and it is implicated in aspects of positive schizotypy, such as delusional ideation and magical thinking (Bell, Halligan, & Ellis, 2006; Fyfe, Williams, Mason, & Pickup, 2008). This has also been called a 'Type I error' bias (Brugger & Graves, 1997). The similar-sounding 'illusory pattern perception' bias predicts belief in conspiracies and the supernatural (van Prooijen, Douglas, & De Inocencio, 2018). The 'illusion of causality' is a tendency to infer a causal relationship where there is none, and it predicts belief in the paranormal (Blanco et al., 2015), superstition (Griffiths et al., 2018), and pseudoscience (such as homeopathy, Torres et al., in press).

Plausibly, these similar terms may refer to the same underlying bias. Indeed, apophenia is sometimes explicitly described as incorporating a causal illusion (e.g., Bainbridge, Quinlan, Mar, & Smillie, 2019). However, this conceptual similarity does not avert a concomitant methodological problem: the above phenomeona are studied with a wide range of disparate tasks, and it has not been demonstrated that these tasks do in fact tap an underlying cognitive factor, which we call a 'contingency illusion bias' (since 'causal illusion' is too specific, 'apophenia' has clinical connotations, and 'false-positive bias' might cause confusion with the distinct 'confirmation bias').

Here, we ask whether the contingency illusion bias predicts science denial. We aim to make advances on multiple fronts. Firstly, we explore a range of tasks currently employed in studying misbelief, and check whether these tasks tap a common cognitive factor. Secondly, we test whether this factor predicts science denial. Thirdly, we analyse whether the contingency illusion bias mediates the effect of intuitive cognitive style on science denial. Finally, we check whether the contingency illusion bias still explains variance in science denial when political ideology is included as a covariate.

Methods

Participants

We recruited participants via Amazon's Mechanical Turk platform, using Turkprime (L. Litman, Robinson, & Abberbock, 2017) to manage participation. Participants were recruited in two stages as part of our broader project on science denial. Here, we report data for people that participated in both stage 1 (measuring science knowledge, science denial, and attitudes to science) and stage 2 recruitment (measuring several contingency biases). 415 participants participated in both these stages, of which 51 failed attention or data-quality checks in at least one stage, leaving 364 participants for analysis (mean age 38.8 years, 201 male, 159 female, 4 self-described or skipped the question on gender).

Participants provided informed consent at the beginning of each stage. The study passed the Psychology Department internal ethics procedure at Royal Holloway, University of London. Participants received \$2.00 for completing stage 1 (median duration: 12 minutes) and \$3.00 for completing stage 2 (median duration: 16.4 minutes).

Materials

To measure science denial, we used the following 4 items (with 'true', 'false', and 'don't know' responses): 'Human carbon dioxide (CO_2) emissions cause climate change' (Lewandowsky, Oberauer, & Gignac, 2013); 'Genetic modification of foods is a safe and reliable technology' (Rutjens et al., 2017); 'Vaccines are a safe and reliable way to help avert the spread of preventable diseases' (Rutjens et al., 2017); 'Human beings developed from earlier species of animals' (Smith, Hout, & Marsden, 2016). To avoid revealing our interest in science denial, we randomly interspersed these items among 12 questions on general science knowledge (National Science Board, 2018; Shtulman & Valcarcel, 2012).

We employed a revised version of the Cardiff Anomalous Perception Scale (Bell et al., 2006) to measure people's preferences for unscientific explanations of anomalous events. This revision is intended to tease apart the experience of anomalous events, and one's preferred mode of explaining those events (Ross, Hartig, & McKay, 2017). The original scale presents 32 items describing unusual experiences (e.g., 'Do you ever hear noises or sounds when there is nothing about to explain them?'). Our revised version (R-CAPS) uses the same items, but — following Ross et al. (2017) — changes the response options to the following three choices: (a) 'Yes, and there is sometimes a supernatural or paranormal explanation.' (b) 'Yes, and there is always a naturalistic or scientific explanation.' (c) 'No'. The count of (a) options endorsed serves as an index of preference for unscientific explanation.

We built our own implementations of four tasks that involve contingency illusions. For each task, we describe the measure indicating that the participant mistakenly believes there is some contingency (a pattern, a rule, a causal link) when there is none.

Coin toss (van Prooijen et al., 2018): We generated a sequence consisting of 50 heads and 50 tails in a random order. These 100 tosses were split into 10 trials of 10 tosses each. In each trial, the participant is shown a sequence of 10 heads and tails, and rates whether they think it seems random or determined (6-point Likert scale from 'Definitely random' to 'Definitely determined'). If they think it looks determined, then they are perceiving an illusory pattern. Our contingency measure is mean rating across trials.

Mouse trap (Brugger & Graves, 1997): The participant plays a game where they navigate a cartoon mouse around a 5x5 grid, aiming to get some cheese lying in a corner of the grid. When they land on the square with the cheese, a rule determines whether the mouse gets the cheese (success), or is caught in the trap (failure). The rule is: if the participant takes longer than 4 seconds to land on that square, they succeed, otherwise they fail. The goal is to work out what the rule is. Frequently, people develop superstitious beliefs, such as believing that they must avoid a certain square to succeed. After 10 attempts, the participants are given a list of plausible hypotheses, and select which ones they believe to be true. Brugger and Graves found that those prone to misbelief selected more hypotheses. Thus, our contingency measure is the number of false hypotheses endorsed.

Spurious correlations (Van der Wal, Sutton, Lange, & Braga, 2018): The participant sees 6 statements describing spurious correlations (e.g., 'It has been shown that an increase in chocolate consumption is associated with an increase in Nobel prize winners in a country.'). The participant rates each statement on three separate scales: whether it is explained by a causal relationship, a random coincidence, or some third factor. If they believe there is a causal relationship, they are perceiving an illusory contingency. Thus, our contingency measure is the mean endorsement of causal relationships across items.

Contingency-detection (Blanco et al., 2015): The participant plays as a doctor who is trying to discover whether a novel medication cures an unusual disease. The participant sees 20 patients, and for each patient, decides whether to administer the medication or not. They observe whether the patient is cured. Ultimately, the participant decides whether they think the medication has any effect (5-point Likert scale ranging from ‘Extremely ineffective’ to ‘Extremely effective’). There is a uniform 70% chance that the patient will be cured, regardless of whether any medication is administered. Thus, the medicine has no effect. If the participant believes it does, they are perceiving an illusory contingency. Our contingency measure is just the rating of effectiveness.

Apart from the contingency-illusion tasks, analytic vs. intuitive cognitive style was measured with revised versions (Shenhav, Rand, & Greene, 2012) of the 3-item Cognitive Reflection Test (CRT Frederick, 2005), along with the 4-item CRT-2 (Thomson & Oppenheimer, 2016). These are essentially trick questions, with an intuitively appealing (but incorrect) response. To avoid participants becoming aware of this, the 7 items were interspersed with 4 similar-looking verbal reasoning items (Condon & Revelle, 2014). The measure of analytic style is the sum of correct responses. Lower scores (indicating a more intuitive or less reflective style) indicate an increase in science denial (Gervais, 2015; Lobato & Zimmerman, 2019; Wagner-Egger et al., 2018).

All tasks were implemented in jsPsych, an open-source JavaScript library for online experiments (De Leeuw, 2015).

Procedure

Full demonstrations of the study are available (stage 1: `https://pacific-lake-13076.herokuapp.com`; stage 2: `https://dry-headland-31805.herokuapp.com`).

In recruitment stage 1, participants undertook the following tasks in fixed order: the CRT and verbal reasoning items; the R-CAPS scale; and the measures of science knowledge and denial. Finally they provided demographic details (age, gender, education). This study included other tasks, relevant to our broader project on science denial, that are not relevant for the specific research questions here. These are not reported below, but they include Epistemic Curiosity (J. A. Litman & Spielberger, 2003), the Credibility of Science Scale (Hartman, Dieckmann, Sprenger, Stastny, & DeMarree, 2017), a scale measuring supernatural belief (Jong & Halberstadt, 2016), and a debriefing questionnaire about their experiences in the study.

In recruitment stage 2, participants undertook the four contingency illusion tasks in the order listed above. Finally, they rated 10 English sentences for grammaticality (to ensure that participants had reasonable understanding of English), rated their position on a political spectrum (from ‘Very liberal’ to ‘Very conservative’) and rated their voting intentions, assuming they would vote for one of the two main parties in the next US presidential election (from ‘Definitely Democrat’ to ‘Definitely Republican’). As with stage 1, this study included measures not immediately relevant here, including Wason’s 2-4-6 task (Wason, 1960).

Results

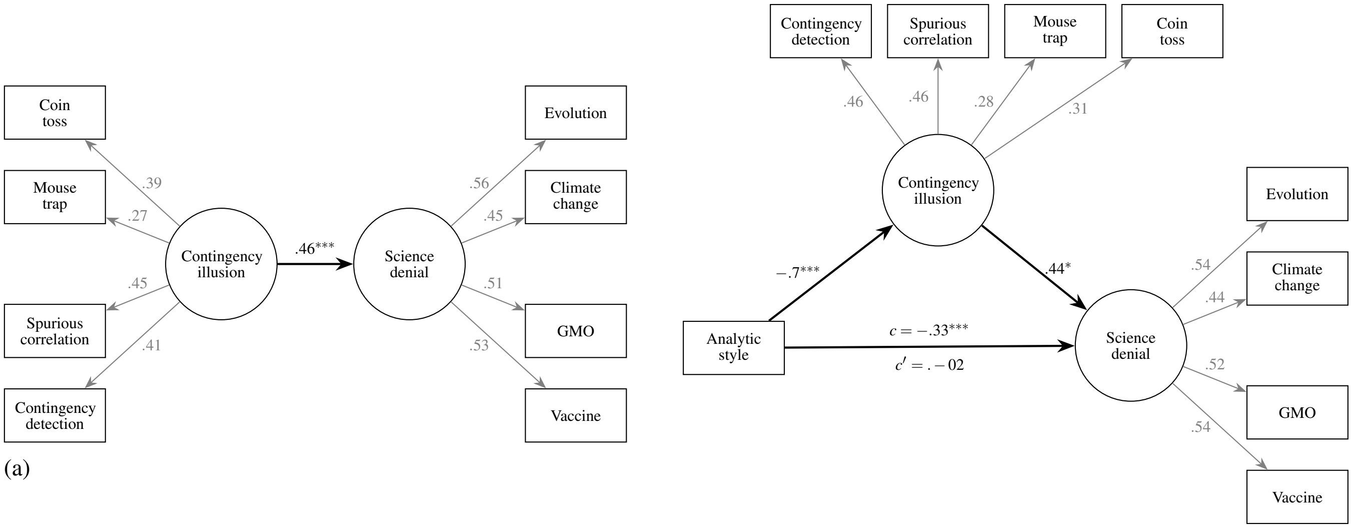
All analyses below involve Structural Equation Models (SEM) built with the `lavaan` package (Rosseel, 2012) in R (R Core Team, 2018). All models were run using a maximum-likelihood estimator with robust standard errors and a Satorra-Bentler scaled test statistic, due to non-normality. We use a typewriter font (e.g., `science denial`) to distinguish names of variables from the corresponding general concepts.

Our first question is whether the measures of contingency illusion bias from the four contingency tasks all load on the same factor (for these measures, see Materials). We test this with a confirmatory factor analysis (CFA), with the four indicators loading on a single latent variable, `contingency illusion`. The resulting model had good fit ($\chi^2_2 = 0.86, p = .65; CLI = 1; TLI = 1.09; RMSEA = .0, SRMR = 0.01$). Loadings are illustrated in Fig. 1a. No loading is very high. Thus, there is a consistent factor common to all these tasks, though the tasks are sometimes noisy indicators of this bias.

Secondly, we ask whether the contingency illusion bias predicts science denial. To model science denial, we define a latent variable `science denial` with our four indicators loading on it (for which, see Materials), scored 0 if they agreed with current consensus and 1 otherwise. Before adding a regression model, we checked that the measurement component shows good fit ($\chi^2_2 = 1.41, p = .49; CLI = 1; TLI = 1.02; RMSEA = .0, SRMR = 0.02$). Adding a structural component to the above model, we regress `contingency illusion` on `science denial`. The regression parameter is significant ($B = 0.46, SE = 0.08, z = 2.87, p = .004$, Fig. 1a): people who are more prone to perceive a contingency where there is none are also more likely to deny scientific consensus.

Thirdly, we test whether the `contingency illusion` variable mediates the previously observed relationship between cognitive style and science denial, using the CRT as a measure of analytic style. For simplicity of presentation, the following results use a traditional scoring method (summing the number of correct CRT responses). However, we confirm that the conclusions are unchanged when using a model with a latent `analytic style` variable, with individual scores for each item loading on it. The model fit indexes were good ($\chi^2_{25} = 24.28, p = .4; CLI = 1; TLI = 1; RMSEA = .0, SRMR = 0.03$). The model showed that `contingency illusion` fully mediates the effect of `analytic style` on `science denial` (Fig. 1b). The total effect of `analytic style` is negative and significant (path c: $B = -0.33, SE = 0.02, z = -3.89, p < .001$), meaning that more intuitive people (with lower scores on the CRT) are more likely to deny scientific consensus, replicating previous findings. However, the direct effect of `analytic style` becomes nonsignficant (path c': $B = -0.02, SE = 0.03, z = -0.14, p = .89$), when the indirect pathway via `contingency illusion` is included.

Finally, we explore how the inclusion of ideology as a co-



(a)

(b)

Figure 1: Structural Equation Models, with latent factors in circles and manifest variables in rectangles. Measurement models are in grey; structural models in black. (a) SEM regression model of the effects of `contingency illusion` on `science denial`. (b) Mediation analysis for the effects of `analytic style` on `science denial`, via `contingency illusion` . All weights and betas are standardized. * $p < .05$, *** $p < .001$.

variate affects the relationship between the contingency bias and science denial. At the same time, we test whether the bias has a consistent relationship with different kinds of misbelief, to ensure that the `contingency illusion` variable is related to science denial *qua* misbelief, as opposed to science denial *qua* social phenomenon.

We define a latent variable `ideology`, with two measures loading onto it: `political spectrum` and `voting intention` (see Procedure). We enter `ideology` and `contingency illusion` as predictors into a multiple regression, with `science denial` and `unscientific explanation` — the measure from the R-CAPS scale — as outcome variables. The model fit is adequate ($\chi^2_{39} = 56.67, p = .03; CLI = .98; TLI = 0.97; RMSEA = .04, SRMR = 0.04$) and the ideology variables both have very high loadings on their factor (`political spectrum`: 0.95; `voting intention`: 0.93). `contingency illusion` and `ideology` are both significantly related to science denial (`contingency illusion`: $B = 0.32, SE = 0.08, z = 2.55, p = .01$, `ideology`: $B = 0.61, SE = 0.02, z = 7.43, p < .001$), with the latter effect looking substantially larger. However, `contingency illusion` is significantly related to `unscientific explanation` ($B = 0.37, SE = 0.35, z = 2.72, p = .007$), whereas `ideology` is not ($B = 0.03, SE = 0.05, z = 0.53, p = .6$).

Discussion

While much research on science denial has focused on social factors, there is evidence that cognitive factors also play a role (Gervais, 2015; Lobato & Zimmerman, 2019; McPhetres & Pennycook, 2019; Wagner-Egger et al., 2018). Understanding the precise contributions of social and cognitive factors — and in particular identifying which cognitive factors are relevant, and how they interact — is crucial for understanding how science denial has become such a widespread problem, and for developing interventions to combat it (cf. Van der Linden, Leiserowitz, Rosenthal, & Maibach, 2017).

Several similar-seeming tasks have been used as measures of various kinds of contingency illusion biases, where people tend to see connections where there are none. Here, we demonstrated that these tasks all loaded on a latent contingency illusion bias, and found that this cognitive factor was positively correlated with science denial. Further, we have shown that this bias mediates the effect of intuitive (vs. analytic) cognitive style. Finally, it explained unique variance even when political ideology was included in the model, and was was related to another kind of misbelief (the tendency to provide unscientific explanations).

One potential concern is that the loadings for the contingency-illusion tasks are low-to-moderate rather than high. On one hand, it would be surprising if measures derived from such complex, higher-cognitive, multi-stage tasks yielded loadings comparable with, say, those for simple statements in personality surveys (where it would be odd indeed if responses to a statement such as ‘I have an assertive personality’ did not load highly on extraversion). On the other hand, we think that these results offer an indication that the field would benefit from improving either the design of such tasks, or the measurement of such biases. If researchers are going to pick just one task to use in a survey, these loadings suggest using either the contingency-detection task (Blanco et al., 2015; Griffiths et al., 2018; Torres et al., in press) or the spurious-correlations task (Van der Wal et al., 2018).

Two further sources of evidence help mollify this concern. The individual tasks have all correlated with various kinds of misbelief in the literature, including pseudoscience beliefs (Torres et al., in press). Further, we found that the latent variable was significantly and positively correlated with a tendency to endorse unscientific explanations of unusual events. This suggests that the latent variable predicts anomalies in the belief-formation process, and does so in multiple tasks concerning scientific belief.

Finally, our broader conclusion is that science denial may — to some extent at least — be understood as involving anomalies in the belief-formation process. One plausible route from intuitive cognitive style to science denial is that scientific beliefs themselves can be counterintuitive (Boudry, Blancke, & Pigliucci, 2015; Miton & Mercier, 2015). Another plausible route is that cognitive style could affect how people go about forming beliefs (i.e., generating hypotheses, gathering data, testing the hypotheses), and that this in turn will have a knock-on effect on how people form beliefs about scientific consensus. The former is a rather direct route; the latter is more indirect, but it does invoke specific cognitive mechanisms. Here, we have shown that the second route is plausible, though our results are merely correlational. Thus, research in the cognition of science denial may benefit from an increased focus on biases (and another anomalies) in hypothesis generation, data gathering, and hypothesis testing.

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