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Thinking fast and biased: intuitive thinking style is associated with the illusion of causality

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ABSTRACT

The illusion of causality is a cognitive bias in which individuals believe that a potential cause produces an outcome even when the contingency between the two is null. Although no definitive theoretical explanation has been established for this bias, it has been linked to heuristic or associative processes that operate automatically and rely on intuition rather than deliberate reasoning. In this paper, we present two pre-registered studies examining the relationship between intuitive–deliberate thinking styles and the causal illusion. In Experiment 1, consistent with previous findings, we did not observe a significant association between the variables. However, a re-analysis revealed that participants displaying extreme response patterns (i.e., introducing the target cause in all trials) accounted for this result. Consequently, Experiment 2 addressed this issue by controlling the exposure to cause-present and cause-absent trials, eventually producing the expected pattern: the illusion was positively associated with intuitive thinking styles (Close-Minded Thinking, Preference for Intuitive Thinking) and negatively associated with a deliberate style (Actively Open-Minded Thinking).

1. Introduction

Many important decisions that people make on a daily basis are grounded in some form of causal reasoning. For example, if a person notices that every time they consume a particular food they feel unwell, they may infer that this specific food causes their discomfort or intolerance. Similarly, a technician would find the cause of a machine not working properly after making various adjustments and observing the outcomes.

Causal reasoning can take place in various forms and across very different contexts, but it is often tied to a learning experience in which an individual is exposed to a series of situations that provide the necessary information to reach a causal judgment. Note that since humans cannot perceive causality directly, we are often limited to infer its existence from the information about the temporal arrangement of events and the consistency of their presentation (Hume, 1748). Particularly, because correlation between causes and effects is a requisite for causality (Negri, 2023), people could use observed correlations as useful information to draw causal conclusions. This gives rise to the paradigm known as the "contingency learning task" (Van Hamme & Wasserman, 1994), which consists of presenting a sequence of trials or pieces of information so that the individual can form a causal judgment. In these tasks, fictitious medical contexts are typically employed as a cover-story. For instance, participants may be told that a given medicine could increase the likelihood of curing a disease, and they would then be presented with a series of patients who either did or did not take the medicine, and who either did or did not recover afterward. For simple situations with only one possible cause and one possible outcome, this information can be summarized in a 2x2 contingency matrix such as the one shown in Fig. 1, which displays four possible situations (i.e., four different types of trials): the patient was treated and recovered (trial a), was treated unsuccessfully (trial b), was not treated but recovered nonetheless (trial c), or was neither treated nor recovered (trial d). The crucial aspect of this paradigm is that, by varying the frequencies of each type of trial, the experimenters can manipulate the contingency between treatment and recovery, that is, the statistical correlation between the two events. Contingency can then be used as an often useful (though imperfect) cue to inferring causality (Hume, 1748). That is, although an observed correlation does not imply necessarily that the two correlated events are causally related (i.e., spurious correlations), it is a useful

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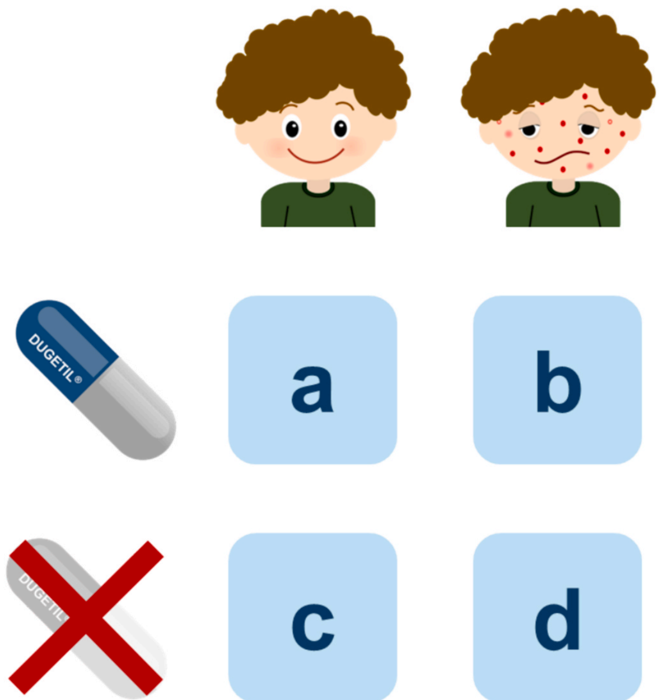

Fig. 1. *The four possible trials that can appear in a contingency learning task with only one potential cause (treatment) and one potential outcome (recovery).* Typically, contingency learning tasks combine the four trial types in different proportions with the aim of conveying one particular value of contingency between the two events.

guide to infer causation because causes and their effects must be correlated in controlled observations. In this paradigm, if patients are more likely to recover after receiving the treatment than without using it, we say that the contingency presented between the two events (medicine and recovery) is positive, which indicates that the medicine is the cause of the recovery (Allan, 1980). On the contrary, if the researchers fix the trial frequencies so that the patients recover equally often when they are treated as when they are not treated, then the information presented corresponds to a null contingency (i.e., a correlation of zero) and this suggests that the treatment is not causally related to the observed healings. The notion of contingency is captured by the Δp index (Allan, 1980), which is expressed as a combination of the frequencies of the four cells (a, b, c, d): $\Delta p = P(outcome|cause) - P(outcome|\ cause) = \frac{a}{a+b} - \frac{c}{c+d}$. Note that the Δp rule entails a comparison between conditional probabilities, and that evidence of causality exists only when this comparison differs from zero.

In general, humans (as well as other animals, Rescorla, 1968) are sensitive to this information, and their causal judgments tend to correspond closely to the presented contingency (Shanks & Dickinson, 1988; Wasserman, 1990). However, several biases or systematic errors have been documented that can lead to inaccurate causal judgments that depart from the actual contingency level. Specifically, one of the most important cognitive biases in this context is known as the illusion of causality, which refers to the perception of a causal relationship between two events that are not statistically correlated (i.e., that show a null contingency; Matute et al., 2015, 2019; Moreno-Fernández et al., 2023). In other words, even when contingency is set to zero, so that participants should conclude that there is no evidence of causality, they often report high levels of perceived causality. Research has shown that the illusion appears more prominently when the outcome (in this case, the recovery from the disease) is observed with high probability despite its null contingency with the cause (Alloy & Abramson, 1979; Blanco et al., 2013; Buehner et al., 2003; Chow et al., 2019). In this type of situations, the potential cause and the outcome co-occur frequently (i.e., there are usually many instances of type a events) and the probability of the outcome given the cause is also high, yet the overall contingency remains zero, as defined by the Δp index.

The consequences of this illusion of causality have been described in previous studies and can be important. For instance, it has been proposed as one of the key mechanisms responsible for pseudoscientific beliefs (Blanco et al., 2015; Torres et al., 2020), pseudomedicine usage (Macfarlane et al., 2020; Matute et al., 2011), and social stereotype and prejudice (Hamilton & Gifford, 1976; Rodríguez-Ferreiro & Barberia, 2017), and it has been linked to novel societal issues like the inability to detect fake-news (Saltor et al., 2023) or conspiratorial thinking (Stanovich & Toplak, 2025).

Although various accounts have been proposed for the causal illusion, it is common to identify this bias with the result of associative or heuristic processing (Musca et al., 2008; Shanks, 1995; Vadillo et al., 2016; Vadillo & Barberia, 2018). That is, the application of simple rules or mental shortcuts that demand little effort and attention, and that therefore operate in situations where the cognitive resources required to form accurate judgments are not fully engaged. Consistent with this assumption, some have proposed that manipulations of cognitive fluency can modulate the illusion (Díaz-Lago & Matute, 2018, 2019), although the results have been a matter of debate (Bona & Vicovaro, 2024). Additionally, certain interventions consisting of simple instructions to pay attention to all available information, or even mere changes in the presentation format, have been found useful in reducing the illusion (Barreiro et al., 2025; Matute, 1996; Vinas et al., 2025). Finally, the causal illusion seems to correlate with a number of epistemically unwarranted beliefs such as pseudoscientific (Blanco et al., 2015; Torres et al., 2020) or superstitious (Griffiths et al., 2019) beliefs, as well as with other cognitive biases (e.g., the "jumping to conclusions" bias; Moreno-Fernández et al., 2021), which indirectly supports the idea of fast heuristic processing.

From this proposed link between heuristic processing and causal illusion follows the prediction that those individuals who tend to develop the illusion should also be more likely to rely on intuitive thinking. A recent work by Saltor et al. (2023) partially addressed this question. Although their goal was to predict the ability of individuals to discern fake news, they included a measure of the causal illusion and two measures of the tendency toward intuitive thinking: Actively Open-Minded Thinking (AOT), and the Cognitive Reflection Test (CRT). To assess the causal illusion, they used a variant of the contingency learning task that we will describe below. Then, the authors measured a trait called Actively Open-Minded Thinking, which is a thinking style characterized by the disposition to weigh new evidence against one's current belief, and considering others' opinions when forming one's own (Baron, 1985, 2019; Stanovich & West, 1997). As for the Cognitive Reflection Test, it is a collection of reasoning problems with an intuitive and apparently easy, but incorrect answer (Frederick, 2005). Thus, both the AOT and the performance in the CRT are measures of the tendency to use reflective, analytic processes when solving problems, as opposed to taking the intuitive route, and therefore high scores on these two measures should protect from the illusion of causality. Indeed, Saltor et al. (2023) found the expected correlations between causal illusion and the CRT (better CRT scores are linked to a reduced illusion). On the other hand, their results were not completely consistent as the AOT did not correlate with the causal illusion.

Nonetheless, we argue that Saltor et al.'s (2023) question is still pertinent and their research deserves a closer inspection, as there are certain details that suggest that it would be worthwhile to replicate this study while extending the predictions. To begin with, the questionnaire that they used to measure AOT (Bronstein et al., 2019) only includes that thinking style, but the instrument has been recently updated and revised (Newton et al., 2023) to include three more styles (CMT: Close-Minded Thinking; PIT: Preference of Intuitive Thinking; and PET: Preference for Effortful Thinking). Thus, it would be interesting to extend the research to these four styles to gain a more complete picture of how individual differences in thinking preferences relate to causal illusions. Second, although the correlation between AOT and causal illusion reported in Saltor et al.'s study did not reach significance, it showed the expected (negative) trend. Third, we note that the contingency learning task employed by Saltor et al. (2023) was a variant known as the "active" version of the task. In this variant, participants, rather than the experimenters, are the ones who decide for each patient whether the treatment will be used or not. Therefore, although the experimenters set the actual contingency to zero, the participants set the number of patients they see in the upper and lower rows of Fig. 1 (see Moreno-Fernández et al., 2023 for a detailed description of active vs. passive contingency learning tasks). This is generally useful to capture many real-life situations in which people have control over the information they receive, but there are many other real-life situations in which the events are given and the individual does not have the opportunity to modify their frequency. In addition, the active procedure can introduce some experimental distortions as one degree of freedom is left for the participant, because in this procedure the tendency to use the treatment varies between individuals, and with it the actual exposure to contingencies might fluctuate (Gibbon et al., 1974; Hannah et al., 2007; Matute, 1996). Moreover, it is a well stablished finding that, when the active task is used, the amount of times participants decide to use the treatment is a strong predictor of their causal judgments (Allan & Jenkins, 1983; Blanco et al., 2011; Matute, 1996), which can make the effect of other predictors hard to interpret. In sum, while active tasks allow for studying how the variables affect the information-seeking behavior of participants, passive tasks provide control over the information they are exposed to, and thus are easier to interpret. Therefore, in the current research we will re-examine the relationship between intuitive vs. deliberate thinking styles and the causal illusion, but using a more comprehensive measure of the thinking styles and considering passive as well as active contingency learning tasks (Experiment 1 vs. 2).

Finally, in addition to the four thinking styles, we complete our study with an additional source of individual differences that could be linked to causal illusions, which is the disposition to correct false information (De keersmaecker & Roets, 2017). This tendency to change one's initial beliefs once they have been flagged as false seems analogous to the correction of intuitive responses by the rational system in early dual-models of decision-making (Kahneman & Frederick, 2007). Both the Disposition to Change and AOT can involve some willingness to correct an initially favoured belief, although they greatly differ in the detail, because disposition to change refers specifically to weighing information that has been labelled as false. Thus, we would expect those people showing higher AOT scores (e.g., by having stronger tendency to consider different points of view) to be more likely to correct beliefs that have been flagged as false, thus showing a positive correlation between the two measures. Additionally, the process of correcting false beliefs seems interesting nowadays as false information is often contradicted by evidence (e.g., fact-checking sites that debunk popular myths and misinformation), and therefore we can make the prediction that those people who are willing to correct assertions that have been labelled as false should also tend to show smaller illusions of causality, because these illusions are supposed to follow from intuitive and fast processes that could be later interpreted as mistakes when considering the evidence more carefully. The inclusion of this new variable should contribute to a more complete assessment of the question of whether variation in the tendency to intuitive vs. reflective thinking is associated to causal illusion, and could eventually help in designing effective debiasing techniques that take into account these individual differences in thinking preferences and disposition to correction.

2. Experiment 1

Experiment 1 assessed the correlations between intuitive vs. reflective thinking styles, the disposition to change false beliefs, and the causal illusion, by using the active version of the contingency learning task similar to that in Saltor et al. (2023). The hypotheses and analyses were pre-registered (https://aspredicted.org/b2p9-92xj.pdf). Data are available at the Open Science Framework (https://osf.io/4jm8x).

2.1. Method

2.1.1. Participants

A sample of 200 participants (90 female, 110 male) with age ranging from 19 to 76 ($M = 41.6$, $SD = 12.4$) was recruited throughout the Prolific Academic platform (Palan & Schitter, 2018). The inclusion criteria were speaking English as first language and not participating in any of the previous studies run by our research group. They were compensated with 1.16 £ payment for about 12 min of their time.

The sample size was decided to achieve a balance between statistical power, stability of the estimates and economic constraints (Schönbrodt & Perugini, 2013). Additionally, a sensitivity analysis conducted with G*Power (Faul et al., 2007) indicates that, with this sample, correlations of small-to-medium size ($r = 0.20$) can be detected with the desired power level (80%) in a two-tailed test with alpha = 0.05.

2.1.2. Design and procedure

The Ethical Committee of the University of Deusto approved the procedure (Ref. ETK-14/17-18). The experiment consisted of three tasks that were programmed in JavaScript, CSS and HTLM. The first one was an adaptation of the standard contingency learning task that has been repeatedly shown capable of reproducing the illusion of causality (see e. g., Matute et al., 2015, 2019; Moreno-Fernández et al., 2023). In this case we used the active version of the task, which was similar to that in Saltor et al. (2023). Participants were asked to imagine that they were medical doctors working at a hospital. A series of 30 trials were presented, each portraying a different patient suffering from a fictitious disease (Lindsay Syndrome). In this active version of the contingency learning task, participants were given the opportunity to decide, on each trial, whether they wanted to use the drug on that particular patient. That is, they were presented with the question "Do you want to administer Dugetil to this patient?" and given two options (two buttons labeled "Yes" or "No"). The position (left–right) of the two buttons was randomized for each participant. Once they clicked the button, the corresponding image appeared (either a pill labelled "Dugetil" or the same pill crossed in red), and after a delay of 1000 ms the outcome was presented (either the patient recovered or not). Then, after a delay of 1000 ms a button labelled "Next medical record" was made available (see Fig. 2). Clicking on this button was followed by the Inter-Trial Interval (500 ms blank screen) and the next trial.

In this experiment, the outcome was programmed to appear in 80% of the trials regardless of whether the medicine was used. This means that, overall, the drug was not effective in healing the patients (because there is no difference in the outcome depending on the drug administration). However, the high probability of observing recovery (80%) is known to bias the judgment producing causal illusions (e.g., Buehner et al., 2003).

After the sequence of trials, participants were asked to judge the causal effect of Dugetil on the recoveries ("How effective is Dugetil?"), from 0 (it "does not have an effect on the recovery") to 100 (it "clearly promotes the recovery"). This causal judgment should reflect the contingency between treatment and recovery presented in the task. Most studies in the field of human causal learning use numerical ratings like this to assess the perception of causal strength from contingency data (see e.g., O'Neill et al., 2022). In this case, the correct value is zero as the contingency was null. However, based on previous literature we expect that many participants show an illusion of causality, overestimating the effectiveness of the drug (Matute et al., 2015).

We also recorded the proportion of trials in which each participant decided to use Dugetil, P(Cause). This is obtained by dividing the total times the drug was used by the number of trials (30), so only values from 0 to 1 are possible: the higher P(cause), the more often the drug was

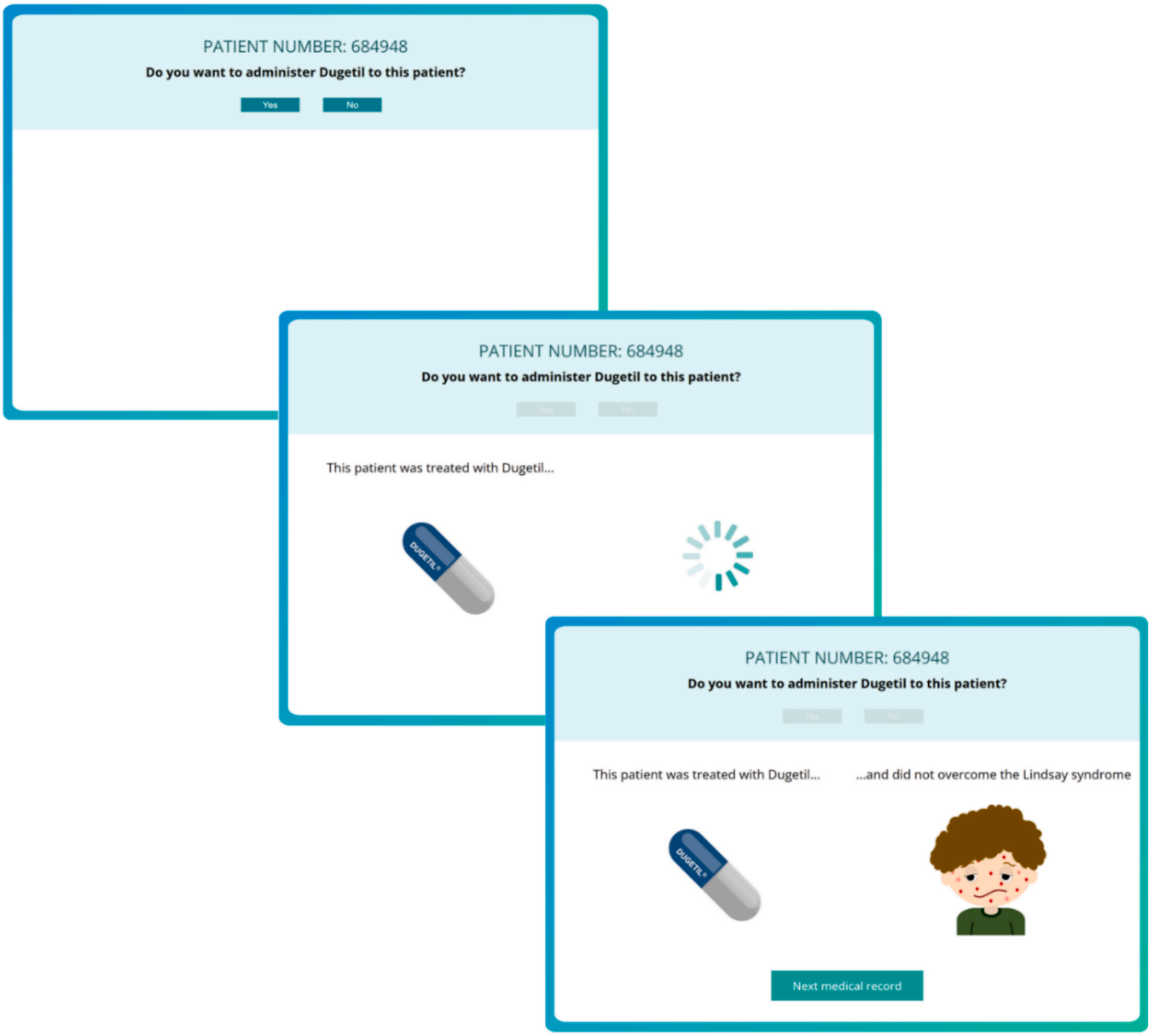

Fig. 2. *Procedure of the active contingency learning task (Experiment 1).* From left to right: The participant must click on a button (Yes/No) to decide whether to use the drug. Then the information was confirmed by presenting either a pill (the drug was used) or a pill crossed in red (the drug was not used). Finally, after 1000 ms the screen showed the outcome information (either the patient recovered or not). After an additional delay of 1000 ms, a button to proceed to "Next medical record" was presented. Once clicked, it was followed by a 500 ms blank screen Inter-Trial-Interval. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

used. As explained above, we expect individual variability in P(Cause), which is a variable known to strongly affect the causal judgment: the more often the cause is present, the more likely it is to coincide with the outcome (recovery), which leads to the causal illusion (Blanco et al., 2011). Indeed, a high P(Outcome) as that used in this experiment, in combination with a high P(Cause), tends to produce even stronger illusions of causality (Blanco et al., 2013).

After the contingency learning task, participants answered to two different questionnaires. First, they were presented with an adaptation of the "Nathalie the thief" task (De keersmaecker & Roets, 2017), aimed at measuring the disposition to correct beliefs based on false information. In this task, participants read a brief story about the fictitious character Nathalie, which ended with an accusation of her for stealing drugs (see the complete instructions in the original article by De keersmaecker & Roets, 2017). This description was followed by an attention check consisting of three multiple-choice questions to ensure participants read the information carefully (if they answered wrong any of the questions, they were requested to read the story again). Then, we asked participants to rate Nathalie on a series of four dimensions (Negative-Positive, Cold-Warm, Hostile-Friendly, Unfavorable-Favorable) using numbers from 0 to 100. Importantly, participants were then warned that the piece of information about stealing drugs was not true, and were invited to read a new version of the story where the last two sentences were strikethrough. Finally, they had to rate again Nathalie in the same four dimensions as before. The difference between the first and second evaluations is interpreted as an index of the disposition to change beliefs when presented with a correction. Thus, higher positive values indicate stronger tendency to correct beliefs based on false evidence. Given that we assumed that those people more willing to correct a false claim would tend to show smaller causal illusions, we predict a negative correlation between the disposition to change and the causal illusion.

The last instrument in being presented was the 24 Item 4-Component Thinking Styles Questionnaire (4-CTSQ; Newton et al., 2023). This consists of 24 statements that must be answered to in a 1–6 Likert scale from 1 (Strongly disagree) to 6 (Strongly agree). The questionnaire merges 15 existing and popular measures of thinking styles, and it contains four subscales: Actively Open-Minded Thinking (AOT), Close-

Minded Thinking (CMT), Preference for Intuitive Thinking (PIT), and Preference for Effortful Thinking (PET). According to the validation study (Newton et al., 2023), all subscales have similar and good reliability: AOT (α = 0.89), CMT (α = 0.83), PIT (α = 0.92) and PET (α = 0.88). As explained in the Introduction section, AOT represents the tendency to suppress the intuitive responses and was already examined by a previous study (Saltor et al., 2023). Additionally, the revised instrument by Newton et al. (2023) includes three new styles: Close-Minded Thinking is akin to black-or-white thinking, or dogmatism, which is associated to the tendency to not change one's mind. Preference for Intuitive Thinking depicts the tendency to rely on intuitive processes and trust one's intuitions. Finally, Preference for Effortful Thinking is the disposition to engage and enjoy effortful cognitive activity. Together, the four scales capture in a more detailed way how people may engage in different types of thinking (intuitive, rational). It is important that the two pairs of styles (CMT and AOT, on the one hand, and PIT and PET, on the other) do not represent the opposite poles along a continuum, but are treated as independent dimensions, defining four different ways of thinking. As to the current research, we note that while AOT and PET indicate the type of rational processing that is typical of analytical thinking, CMT and PIT are more indicative of intuitive processing and resistance to correction. Consistent with the identification of the causal illusion as the result of heuristic processes, we expected that CMT and PIT would correlate positively with the illusion, while AOT and PET would correlate negatively. In the same line of reasoning, it is expected that thinking styles correlate with P(Cause): those more likely to consider a reflective approach to the contingency learning task (i.e., high AOT and PET, low CMT and PIT) would probably tend to use the drug on about half of the available patients, thus obtaining a balanced sample of trials that would help reach a valid conclusions, whereas those more oriented to intuitive strategies would be likely using the drug on most patients (Moreno-Fernández & Matute, 2020).

2.2. Results and discussion

Table 1 contains the descriptive statistics of the variables measured in Experiment 1. The mean P(Cause) is higher than 0.5, which means that in general participants tended to use the drug often. This is a common finding in the literature (Moreno-Fernández & Matute, 2020) and can be interpreted as the result of a confirmation bias (Oswald & Grosjean, 2004). However, the P(Cause) is unusually high in this study, with a median of 0.933 (we will come back to this point later). Causal judgments were also significantly above zero, $t(199) = 33.016$, $p < 0.001$, indicating a general tendency to show an illusion of causality.

Next, we examine the correlations between the variables in Experiment 1 (Table 2). We used Spearman's rho as estimator since the variables were not normally distributed. First, the four thinking styles show the expected pattern of correlations with each other, with the exception of PET (Preference for Effortful Thinking), which does not correlate negatively with PIT (Preference for Intuitive Thinking). But we were more interested in the correlations with the contingency learning task, where we find results that largely align with those by Saltor et al. (2023). First, as is commonly reported in previous studies, P(Cause) strongly correlated with causal judgments: those who used the drug more often tended to show stronger illusion of causality (Blanco et al., 2011; Hannah et al., 2007; Matute, 1996). However, none of the other variables showed significant correlations with either the P(Cause) or the causal judgment. This means that, even when considering additional styles to AOT by using a more complete instrument, these styles seem to be not strongly associated to the causal illusion, as Saltor et al. already found with AOT. The Disposition to change was also not significantly correlated with any other measure.

Table 1
Descriptive statistics in Experiment 1.

	Mean	SD
Causal judgment	66.245	28.376
P(Cause)	0.775	0.268
Disposition to change	56.824	20.261
AOT	3.978	1.050
CMT	3.260	1.019
PIT	3.802	0.982
PET	4.469	1.029

Table 2
Correlations in Experiment 1 (Spearman's rho).

		rho		p
Causal judgment	P(Cause)	0.629	***	<0.001
	Disposition to Change	0.061		0.390
	AOT	−0.110		0.122
	CMT	0.132		0.062
	PIT	0.122		0.086
	PET	−0.056		0.427
P(Cause)	Disposition to Change	0.005		0.938
	AOT	0.063		0.374
	CMT	0.021		0.764
	PIT	−0.013		0.854
	PET	−0.006		0.930
AOT	CMT	−0.362	***	<0.001
	PIT	−0.535	***	<0.001
	PET	0.303	***	<0.001
CMT	PIT	0.290	***	<0.001
	PET	−0.267	***	<0.001
PIT	PET	−0.066		0.351
Disposition to change	AOT	0.082		0.247
	CMT	0.101		0.153
	PIT	0.019		0.794
	PET	0.071		0.316

*$p < 0.05$.
**$p < 0.01$.
***$p < 0.005$.

However, a closer examination (not pre-registered) of the results seems to reveal some insightful patterns. First, although none of the correlations between the four thinking styles and the causal judgments was significant, they were all in the predicted direction (negative for AOT and PET, positive for CMT and PIT). Second, we found an unusually high number of participants who used the medicine in all 30 trials: out of 200 participants, 87 had a P(Cause) of exactly 1 (Fig. 3). In our pre-registered plan, we did not consider excluding participants based on their extreme P(Cause), but in this case it can distort the results because so many showed this behavior (the value 1 is in fact the sample's mode). Bear in mind that those who used the treatment in every trial were never exposed to any type c or type d trials, and hence it is impossible to compute the contingency they were exposed to (Hannah et al., 2007).

With this information in mind, just to get a more complete view of the results, we decided to examine the correlations once we removed all participants with extreme P(Cause) of exactly 1. This non pre-registered analysis reduced the sample to 113 participants, but revealed the following pattern of results (Table 3):

That is, once the extreme respondents were removed from the sample, causal illusion was significantly correlated with AOT, CMT and PIT, all in the expected directions. The conclusions were identical regardless of whether parametric (Pearson) or non-parametric (Spearman)

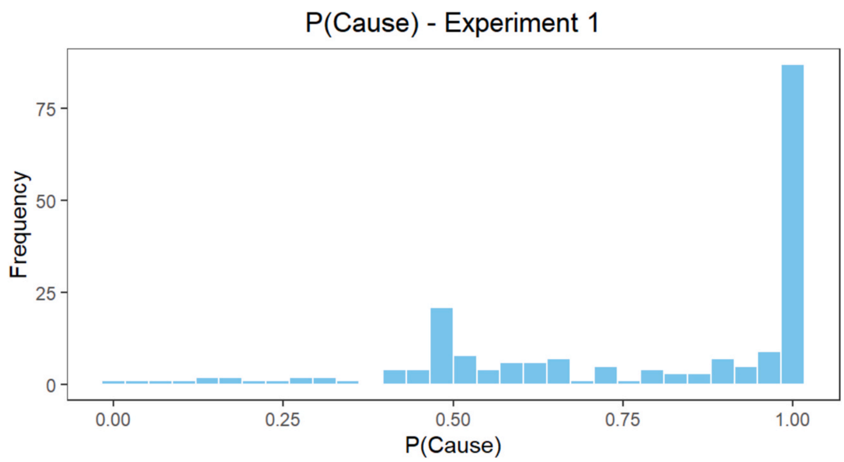

Fig. 3. *Distribution of P(Cause) in Experiment 1.*

Table 3
Correlations in Experiment 1 (subsample of non-extreme respondents only, N = 113).

		rho		p
Causal judgment	P(Cause)	0.594	***	<0.001
	Disposition to Change	0.044		0.640
	AOT	−0.341	***	<0.001
	CMT	0.311	***	<0.001
	PIT	0.318	***	<0.001
	PET	−0.073		0.444
P(Cause)	Disposition to Change	−0.091		0.337
	AOT	−0.055		0.566
	CMT	0.071		0.453
	PIT	0.080		0.400
	PET	−0.077		0.417
AOT	CMT	−0.425	***	<0.001
	PIT	−0.587	***	<0.001
	PET	0.315	***	<0.001
CMT	PIT	0.363	***	<0.001
	PET	−0.260	**	0.005
PIT	PET	−0.060		0.529
Disposition to change	AOT	0.097		0.305
	CMT	0.073		0.442
	PIT	0.015		0.872
	PET	0.137		0.148

*p < 0.05.
** p < 0.01.
*** p < 0.005.

estimators were used to analyze this subsample.[1]

Moreover, we repeated the same analyses on Saltor et al. (2023)'s original dataset. After removing all participants with P(Cause) = 1, which reduced their sample size to 142, we found that their data also supported a weak correlation between AOT and causal illusion, with Spearman's rho = −0.172, p = 0.041. The association of causal illusion with CRT that was reported in the original article remained significant after the exclusion.

To sum up, Experiment 1 did not find a reliable correlation between causal illusion and the four thinking styles, in line with a previous study (Saltor et al., 2023). However, both our results and those from Saltor et al. seem dependent on a high number of participants with extreme P (Cause). Once these are removed from the sample, both Saltor et al.'s data and our current study reveal significant associations between the variables, in the expected direction. It is important to remind that these analyses on a subsample of non-extreme respondents were not pre-registered and thus they must be taken cautiously. In any case, Experiment 2 will attempt to clarify these results.

3. Experiment 2

Experiment 1 used an active contingency learning task to examine the relationships between the four thinking styles, disposition to change, P(Cause) and causal illusion. The results of this experiment were in line with the finding by Saltor et al. (2023) that AOT does not predict causal illusion, and extended it to the three additional thinking styles measured in the questionnaire (CMT, PET, PIT). However, a closer inspection at the data revealed that P(Cause), which reflects the frequency with which participants decide to use the drug on the fictitious patients, was a critical variable to observe the expected correlations. In particular, since many participants in our experiment showed an extreme P(Cause) of 1, they were not exposed to type c and d trials, which represent half of the contingency table in Fig. 1, and thus they have a strongly biased sample of information. It is therefore difficult to determine how thinking-style differences would shape judgments when the information provided is poorly representative.

Consequently, in Experiment 2 we used a different version of the contingency learning task, the so-called passive procedure in which the frequencies of each trial type (a, b, c, d) are pre-determined by the experimenters. We decided to fix P(Cause) to exactly 0.50, which grants a balanced exposure to both cause-present and cause-absent trials. Thus, if an extreme value of P(Cause) impedes to observe the expected correlations between causal judgments and the other variables, as our previous analyses suggest, then fixing P(Cause) to 0.50 would improve our chances of finding the effect. The study was pre-registered (https://aspredicted.org/3nvt-3z3m.pdf). Data are available at the Open Science Framework (https://osf.io/4jm8x).

3.1. Method

3.1.1. Participants

We recruited 200 participants from Prolific Academic (109 female, 90 male, 1 non-disclosed gender; with age ranging from 18 to 88, *M* =

[1] Additionally, we compared the two groups of participants, those who responded in all trials vs. those who did not, and found no significant differences in any of the questionnaires (all ps > 0.15), which suggests that none of the examined variables was important to induce high probability of administering the drug in the task.

42.7, SD = 14.0), based on the same arguments and inclusion criteria that were described for Experiment 1. The payment was set to 1 £ for about 10 min of their time.

3.1.2. Design and procedure

The procedure was conceptually identical to Experiment 1 except that the contingency learning task was passive. Participants were asked to imagine that they were medical doctors working at a hospital. A series of 40 trials were presented, each portraying a different patient suffering from a fictitious disease (Lindsay Syndrome). Each patient was either given a fictitious drug (Dugetil) or not. Immediately after, either the patient overcame or did not overcome the disease (see a schematic summary of the procedure in Fig. 4). After the sequence of trials, we collected the causal judgment in a similar way to Experiment 1.

The sequence of patients was programmed to have a null contingency between taking the drug and overcoming the syndrome. Specifically, out of the 40 patients presented, 20 patients took the drug and 20 patients did not take the drug, and in both cases 16 recovered and 4 did not. This implies two important things. First, note that we are fixing the number of treated patients, unlike the active procedure described for Experiment 1. Since half of patients were treated, the proportion of trials in which the cause was observed, P(Cause), was exactly 0.50. Second, the probability of recovery, P(Outcome), was identical regardless of whether the patients were treated, and therefore the drug was completely ineffective. However, the probability of recovery was overall high, 0.80, which is known to bias the participants' judgments producing illusions of causality (Buehner et al., 2003; Matute et al., 2015), as we exposed above. The order of the trials was randomly determined for each participant.

Fig. 4. *Procedure of the passive contingency learning task (Experiment 2).* The trial starts by presenting the cue information (i.e., either the patient was treated or not treated). After 1000 ms the outcome information was added (i.e., either the patient recovered or not). In this particular example, the patient was treated and then recovered from the illness (i.e., trial "a" in Fig. 1). Participants had to wait for an additional 1000 ms before the button to proceed to the next patient was available. Once pressed, it was followed by a 500 ms blank screen Inter-Trial-Interval.

3.2. Results and discussion

Table 4 contains the descriptive statistics of all the relevant variables in Experiment 2. Although the fictitious drug was completely ineffective, the mean judgment was significantly higher than zero, $t(199) = 27.84$, $p < 0.001$, indicating that participants tended to show an illusion of causality.

But we were more interested in examining the correlations between these variables (see Table 5). Given that the variables were not normally distributed, we present non-parametric (Spearman's rho) coefficient estimations, but the conclusions hold when using parametric (Pearson) estimation. First, we found that causal judgments correlated with three of the thinking styles that we measured: AOT, CMT, and PIT, all in the expected directions (negative for AOT, positive for CMT and PIT). The correlation with the fourth style, PET, was not significant ($p = 0.543$). The disposition to change did not correlate significantly with either causal judgments or any other variable (all ps > 0.099). With respect to the correlations between thinking styles, they show the expected pattern except for PET, which does not correlate significantly with CMT and PIT.

In sum, the results from Table 5 suggest that the causal illusion was positively associated with Intuitive thinking and Close-Minded thinking, and negatively associated with Actively Open-Minded thinking. The pattern of results contrasts with the null finding reported in Experiment 1 (also in Saltor et al., 2023), but coincides with the one that emerged from the reanalysis of the subsample of non-extreme respondents in both Experiment 1 and Saltor et al.'s dataset, and suggests an association between the illusion of causality and heuristic or intuitive processing, with the only exception that Preference for Effortful Thinking and causal illusion do not show the expected negative correlation.

Table 5
Correlations in Experiment 2.

		rho		p
Causal judgment	Disposition to change	0.066		0.357
	AOT	−0.183	**	0.009
	CMT	0.144	*	0.041
	PIT	0.179	*	0.011
	PET	−0.043		0.543
AOT	CMT	−0.330	***	<0.001
	PIT	−0.551	***	<0.001
	PET	0.271	***	<0.001
CMT	PIT	0.231	**	0.001
	PET	−0.048		0.500
PIT	PET	−0.098		0.168
Disposition to change	AOT	0.011		0.872
	CMT	0.109		0.125
	PIT	0.041		0.569
	PET	0.117		0.099

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.005$.

4. General discussion

Causal illusions, or illusions of causality, represent a type of cognitive bias with significant real-world consequences, such as usage of pseudomedicine or belief in paranormal phenomena (e.g., Blanco et al., 2015; Matute et al., 2011; Torres et al., 2020). Although the mechanisms underlying the causal illusion are not yet fully understood, the phenomenon is generally attributed to intuitive or low-effort processing (Díaz-Lago & Matute, 2018, 2019; Matute, 1996; Musca et al., 2008; Vadillo et al., 2016). This assumption leads to predicting that those individuals with stronger tendency to rely on intuitive thinking (or weaker tendency to think analytically) should be more vulnerable to the illusion. A previous study (Saltor et al., 2023) indirectly tested this prediction, and found that the causal illusion was not associated to Actively Open-Minded Thinking (AOT; Bronstein et al., 2019), a thinking style characterized by the questioning of own beliefs. The current study attempted to re-examine this question by (a) using a more comprehensive set of thinking styles (Newton et al., 2023) in addition to AOT, as well as (b) including a related measure (the disposition to correct false beliefs; De keersmaecker & Roets, 2017), and (c) testing two different versions of the contingency learning task: active (Experiment 1) and passive (Experiment 2). This latter procedural change has been shown critical to obtain the predicted results, as we will discuss below.

We start discussing the findings from Experiment 2. This study contributes a test of the association between causal illusion and the rest of the variables that is conducted in well controlled settings, because in the passive procedure that this study used the experimenters have the ability to fix the exact frequencies of each type of trial, and thus to ensure that all participants are exposed to the same information. We chose a P(Cause) of 0.50, meaning that the exposure to cause-present and cause-absent trials was identical. This experiment produced results that seem straightforward to interpret and largely in line with our initial predictions: Actively Open-Minded thinking was negatively associated with the causal illusion. Conversely, Close-Minded thinking (CMT, or "dogmatism") and Preference for Intuitive Thinking (PIT) were both positively correlated with the illusion. These findings align with our proposal that the causal illusion reflects the operation of a heuristic or intuitive process, which is also consistent with prior research.

The fourth thinking style, Preference for Effortful Thinking (PET), did not show significant correlations with causal illusion (although the sign was negative, as expected, in both Experiments 1 and 2). The reasons for this null result remain uncertain. The finding that the four subscales correlate with each other significantly and in the expected directions in both studies, with the notable exception of PET (e.g., it does not show a significant negative correlation with the PIT subscale) suggests that this subscale is not as sensitive to capture differences as the others. A second plausible explanation is that having a general disposition to engage in effortful processing is not enough to produce better judgments. Thinking effortfully does not necessarily imply thinking better: cognitive effort may contribute to accuracy, but it may not be sufficient to guarantee correct conclusions in all cases. Thus, the judgment may not change if resources are invested, for example, in the analysis of irrelevant information. In any case we must be cautious when interpreting null results like this.

Regarding the Disposition to correct false information, we employed the "Nathalie the thief" task (De keersmaecker & Roets, 2017), designed to assess resistance to changing an initial response once the information provided has been shown to be erroneous. Note that in the contingency learning task, participants were initially led to consider that a fictitious medicine (Dugetil) might be responsible for patients' recoveries, and that participants could have disconfirmed this initial belief by just examining the evidence provided across the trials, which conveyed a null contingency (i.e., the medicine had no effect at all). According to our rationale, those individuals who are more resistant to revising their initial beliefs about Nathalie should also refrain from correcting them in

Table 4
Descriptive statistics in Experiment 2.

	Mean	SD
Causal judgment	51.320	26.068
Disposition to change	59.439	21.053
AOT	3.996	1.077
CMT	3.277	1.038
PIT	3.802	1.034
PET	4.374	1.103

the contingency learning task, and therefore they should have exhibited stronger illusions. In this case, however, neither of the two studies revealed a correlation between the two variables. It is possible that the process of correcting erroneous information is not as closely related to causal illusion as we had proposed, and therefore the correction task may not be measuring aspects truly relevant to causal illusion (at least within the design used in our two studies). Although early dual-process models of decision-making stressed the role of rational processes in correcting the biased output of intuitive processes (Kahneman & Frederick, 2007), further evidence questions the importance of correction (Bago & De Neys, 2019) and in fact indicates that being correct often implies having accurate intuitions (Thompson et al., 2018), which led to current models that are more nuanced in this sense (see a discussion in Pennycook et al., 2018). The null results seem to indicate that the willingness to correct mistakes does not influence the causal illusion. This is in line with newer theories of decision making that do not assign such a critical role to correction, although we must be cautious when interpreting non-significant results. Note that AOT and Disposition to change measure different, yet possibly related constructs. Both involve a disposition to revise own beliefs and consider evidence in making an opinion, but Disposition to change relates specifically to the correction of information that has been flagged as false. This difference in the mechanisms involved might explain why AOT consistently correlated with the causal illusion in Experiment 2, while the Disposition to change task did not.

We next discuss Experiment 1, which failed to produce the expected results. This experiment differed in the procedure used for the contingency learning task. Instead of just presenting the trials to the participants, this active version of the task allows them to decide when they want to use the drug. While the passive task aims to represent many real-life situations in which people are presented with information but have no control over the amount or type of information (e.g., when watching the news), the active task mirrors other situations in which people have some control over the type of information they receive (e.g., when surfing the Internet and choosing which page to visit). Not only this task captures better certain scenarios that are at least as interesting as the ones described for the passive task, but it opens the possibility that thinking styles affect the way people engage with the information and potentially bias how it is collected. Thus, we speculated that participants with low AOT and PET (or high CMT and PIT) would be more naturally inclined to collect proportionally more cause-present trials (i.e., to use the drug on most patients), as this is compatible with a strong endorsement of the intuitive belief that the treatment works, with an unwillingness to consider that the belief could be wrong, and represents an information-seeking strategy that seems intuitively right at first glance but introduces a bias (e.g., confirmation bias). These correlations between the individual traits and P(Cause) can only be observed in active procedures. However, in this research, when we used the active procedure (Experiment 1), we failed to detect significant correlations. A number of procedural details can help understand why this happened. First, participants in the active task have control over the number of trials in which the cause is present, or P(Cause). As we mentioned, previous research has found that P(Cause) is a strong predictor of causal illusions (Blanco et al., 2011), so that those who use the treatment often are more likely to believe that there is a strong causal relationship, as it was also found in Experiment 1. This could result in blurring the contribution of other predictors, such as thinking styles, to the causal illusion, because the variance and range in the judgments are effectively reduced when P(Cause) = 1, which attenuates the correlations with other variables (Cohen et al., 2003). Second, while the contingency presented in the passive task (Experiment 2) is fixed by the experimenters and therefore all participants see the same information, this aspect becomes uncontrolled in the active task (Blanco et al., 2011; Hannah et al., 2007), as there is individual variability in the exact frequencies shown for each trial type. Although the deviations from the programmed contingency value are generally small and random, the problem appears when there are many extreme respondents. That is, if a participant chooses to use the medicine in every trial, then there is no exposure to any type c or d trials, thus making the contingency value impossible to calculate. Additionally, it is very difficult to realize that there is no actual contingency if one does not collect all the necessary information, so these participants might not be able to engage in analytical thinking (Matute, 1996; Vinas et al., 2025), and they would therefore show overall high judgments. While this is not generally a problem in this research field, if many participants in the sample show a pattern of extreme responding, then the information they have available to solve the task is biased, and consequently it is difficult to use their data to investigate their thinking styles, i.e., how they use such information to arrive at a causal conclusion. Thus, it is not surprising that thinking styles or other variables related to reasoning do not correlate with causal judgment in the particular case of extreme respondents. In conclusion, the high number of participants with an extreme P(Cause) of 1 that we had in Experiment 1 appears to have distorted the results. Indeed, removing all extreme respondents from the sample revealed the familiar pattern of correlations with the illusion (AOT, CMT, PIT) that were reported in Experiment 2 when P(Cause) was fixed to 0.50. Moreover, the same exclusion criterion, when applied to Saltor et al's (2023) original data, turned the correlation with AOT significant in the expected direction. Although one must remain cautious concerning these additional analyses as they were not pre-registered, they also provide a compelling argument as to why the active procedure can mask some correlations with the causal illusion, and together with the convergent results from the more controlled Experiment 2 they suggest that thinking styles do affect the way people interpret the contingency information to form causal judgments.

The results from our experiments could possess some practical relevance, as they can help us identify individuals who are particularly vulnerable to the causal illusion, which can lead, as it has been explained above, to a number of undesired behaviors such as pseudomedicine usage, etc. Thus, those people who rarely question their intuitions (low in AOT) would more likely fall prey of causal illusions, which is compatible with the observation that they tend to fail to discern true information from fake news (Bronstein et al., 2019; Newton et al., 2023; Saltor et al., 2023). Similarly, those who do not admit nuance (high CMT), or who trust their intuition (high PIT) are at risk. This opens the field for devising targeted interventions, perhaps based on strategies such as prompting for accuracy (i.e., explicitly asking participants to be careful and do their best to arrive to correct conclusions, although we currently lack solid evidence that they can prevent causal illusions in particular; Vinas et al., 2025), or specific training (in the line of previous attempts like those by Barberia et al., 2013; Martínez et al., 2023, 2024) to compensate for these natural dispositions. It may be relevant to mention that thinking styles do not seem to affect the way people collect and search for information, because we found no significant correlation with P(Cause) in Experiment 1 (consistent with Saltor et al. 2023), and therefore the proposed interventions should probably focus on how people interpret the evidence rather than on improving their information search strategies (unlike some of the cited works, e.g., Barberia et al, 2013).

Our two experiments have several limitations that must be considered. First, we only measured the four thinking styles and the Disposition to Change, in addition to the causal illusion. In contrast, the study by Saltor et al. included other variables such as CRT and the ability to discriminate fake news, both of which showed significant correlations with causal illusion. Therefore, our study does not constitute a full replication attempt of this previous work. Examining these additional variables is thus left for future research, although we would expect to find similar results. Second, our conclusion that causal illusions are linked to intuitive processing comes from the observed correlations with a self-reported measure (the thinking styles questionnaire). It would be highly valuable to obtain convergent evidence from other measures. For instance, because intuitive processes are typically fast and heuristic-based, intuitive responses would be expected to require shorter response times than reflective responses. Accordingly, reaction times are commonly used in decision-making research as indicators of intuitive processing (e.g., Thompson et al., 2011). However, obtaining reliable and informative reaction times is particularly challenging in the standard contingency learning task that we use in this research. Specifically, our main dependent variable (the judgment) is collected only once, at the end of a lengthy training phase that takes several minutes to complete, which makes reaction times for judgment responses particularly noisy. This means that other procedures should be developed to further investigate whether causal illusions stem from intuitive processes.

To sum up, Experiment 2 (and, partially, Experiment 1) presents some evidence that three thinking styles (Actively Open-Minded Thinking, Close-Minded Thinking, and Preference for Intuitive Thinking) are connected to the illusory belief of causality that is revealed in the contingency learning task, at least when using a passive version of the procedure in which P(Cause) is set to 0.50, which ensures balanced exposure to all the trials. This completes previous works (Saltor et al., 2023) by using a revised instrument to assess a wider variety of thinking styles, and suggests that exposure to an extremely biased sample of trials (i.e., not collecting any trial of types c and d) can be detrimental to reveal this association. These results are interesting as they reinforce the idea, in line with what we have previously noted, that the processes underlying causal illusion are linked to intuitive or heuristic mechanisms. Moreover, the relevance of this research may extend beyond the laboratory, as it allows for the potential identification of individual profiles that are, in principle, more vulnerable to exhibiting causal illusions, thus providing a first step toward developing targeted interventions for such individuals. Finally, we believe that the individual-differences approach to causal illusions holds promise both for advancing our understanding of the mechanisms behind the illusion and for designing intervention strategies.

CRediT authorship contribution statement

Fernando Blanco: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **María Manuela Moreno-Fernández:** Writing – review & editing, Software, Conceptualization. **Helena Matute:** Writing – review & editing, Supervision, Funding acquisition.

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Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data are linked in the manuscript.

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