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Debiasing causal inferences: Over and beyond suboptimal sampling

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Abstract

Background: We have previously presented two educational interventions aimed to diminish causal illusions and promote critical thinking. In both cases, these interventions reduced causal illusions developed in response to active contingency learning tasks, in which participants were able to decide whether to introduce the potential cause in each of the learning trials. The reduction of causal judgments appeared to be influenced by differences in the frequency with which the participants decided to apply the potential cause, hence indicating that the intervention affected their information sampling strategies.

Objective: In the present study, we investigated whether one of these interventions also reduces causal illusions when covariation information is acquired passively.

Method: Forty-one psychology undergraduates received our debiasing intervention, while 31 students were assigned to a control condition. All participants completed a passive contingency learning task.

Results: We found weaker causal illusions in students that participated in the debiasing intervention, compared to the control group.

Conclusion: The intervention affects, not only the way the participants look for new evidence, but also the way they interpret given information.

Teaching implications: Our data extend previous results regarding evidence-based educational interventions aimed to promote critical thinking to situations in which we act as mere observers.

Keywords: causal illusion, cognitive bias, critical thinking, paranormal beliefs, debiasing

Debiasing Causal Inferences: Over and Beyond Suboptimal Sampling

Everyday thinking and decision making frequently present systematic reasoning errors that lead us to incorrect conclusions (Arkes, 1991; Larrick, 2004; Tversky & Kahneman, 1974). These cognitive biases have been shown to play a role in important situations such as medical diagnosis (Croskerry, 2013; Phua & Tan, 2013) or financial decision making (Frydman & Camerer, 2016), as well as social phenomena like prejudice (Rodríguez-Ferreiro & Barberia, 2017) or ideological extremism (Lilienfeld et al., 2009). The influence of cognitive biases in our lives is such that some authors have pointed out the design of effective techniques, aimed to diminish the frequency or intensity of cognitive biases, as one of the most important contributions that Psychology could make to humanity (Lilienfeld et al., 2009).

In previous studies (Barberia et al., 2013, 2018), our group has presented two different educational interventions aimed to diminish causal illusions and promote critical thinking. Causal illusions are a type of cognitive bias that implies the incorrect perception of a causal relationship between two events when there is no such causal relationship (Alloy & Abramson, 1979; Hannah & Beneteau, 2009; Matute et al., 2015). In some situations, this tendency to perceive non-existent causal patterns between events might be more adaptively advantageous than failing to detect a real causal connection. For instance, it is preferable to falsely identify a plant as poisonous even if it is innocuous than to mistakenly identify a poisonous plant as edible. In other words false positives might be generally the “least-costly mistake” (Blanco, 2017; Haselton & Nettle, 2006). Nevertheless, this evolutionary tendency might also play a central role in the proliferation of pseudoscientific beliefs and superstitions (Blanco et al., 2015; Matute et al., 2011, 2015; Torres et al., 2020). Note that, in many cases, pseudoscience and superstition or paranormal

beliefs rely on false causal impressions lacking objective evidence to support them, such as the erroneous belief that the specific configuration of the stars during birth influences one's personality or that seeing a black cat increases the chances of experiencing a negative event. Although many of these beliefs might be considered relatively innocuous, in some cases, they can be connected with a variety of negative consequences. For example, using an ineffective pseudoscientific remedy may lead to the rejection of an effective conventional treatment (Johnson et al., 2018).

Our educational interventions (Barberia et al., 2013, 2018) are based on different cognitive debiasing strategies (Larrick, 2004) implemented in a two-stage procedure. During the initial phase of each intervention, students are induced first-hand experiences of cognitive biases, as part of a training-in-bias approach (Larrick, 2004). The second phase of the interventions applies training-in-rules techniques (Larrick, 2004), aiming to teach the students how to reduce the impact of cognitive biases. This phase focuses on the “consider the opposite” strategy, which diminishes confirmatory tendencies and favors discovery and evaluation of new information, by promoting the search for possible reasons why an initial consideration or hypothesis might be wrong (Larrick, 2004). This intervention, hence, follows the general rule of first activating the misconception we want to address and, immediately afterwards, providing evidence-based refutation for it, as recommended for educational interventions aimed to reduce misinformation (Cook et al., 2015). The “consider the opposite” rule is of special relevance in this situation because it might prevent the appearance of causal illusions by promoting the consideration of the two assessed events (e.g. the positions of the stars during birth and personality) being actually unrelated.

In both studies (Barberia et al., 2013, 2018), participants who received the intervention showed reduced causal illusions in a subsequent contingency learning task in

comparison to a control group. In these tasks, students are typically asked to evaluate the potential causal relation between taking a drug and recovering from a disease. The volunteers took part in a computer test in which they were presented with cases of fictitious patients suffering from the disease. For each patient, the participants actively decided whether to administer the drug or not. Immediately after that, they received a report stating if the patient was healed. The recovery rate was equally high for patients who received the drug and for those who did not, so there was no real association between drug administration and healing. After going through the full set of patients, the students were asked to assess the effectiveness of the drug producing the healings. The results showed that the participants in the control groups judged the drug as more effective than those in the intervention groups, and that this difference was influenced by differences in the frequency with which the participants decided to administer the drug. This suggests that the intervention worked, at least in part, because the students learned to sample information in a more balanced and rational way in the experimental group. By administering the drug to fewer patients, the participants in the intervention group had more opportunities to realize that the rate of recovery was similar for the patients who received the drug and those who did not. In the control group, the participants administered the drug to more patients and, as a result, they were exposed to more information that confirmed the belief that the drug worked.

Contingency learning tasks in which participants are allowed to actively modulate the presence of the potential cause are interesting because they mimic many real-life situations, such as trying to ascertain whether a given remedy is helping us with our present headache or whether following a specific diet is improving our wellbeing. More specifically, performance in these tasks can reveal biased sampling tendencies when

actively looking for causal information. However, the universe of events that can be potentially causing the multiple situations we are exposed to in our daily life clearly exceeds that of the events over whose occurrence we have a direct influence. As an example, we learn that smoking deteriorates health or that driving fast causes accidents even if we are not smokers or drive a car, and even if we cannot manipulate the smoking or driving habits of most of the people surrounding us.

With this in mind, the goal of the present study was to explore to what extent our previous debiasing interventions impact the intensity of causal illusions in situations in which a potential causal relationship needs to be inferred from an observational situation, analogous to the one just described. This task has been previously called a *passive* contingency task (Matute et al., 2015) as opposed to the *active* contingency tasks in which the participants can decide, on each trial, if they want the potential cause to be present or absent. In passive versions of the task, participants are exposed to several trials in which they observe if the potential cause is present or absent, instead of allowing them to decide if they want to introduce the potential cause or not. If our debiasing interventions only impact information sampling strategies but not the way the available information is processed, passive tasks in which causal illusions are prone to appear should provoke strong causal illusions even in participants that have received the intervention. On the other hand, if the intervention impacts, not only sampling strategies, but also the students' ability to draw causal conclusions from given information, those receiving the intervention should still outperform control participants when exposed to passive contingency tasks.

To test these hypotheses, we conducted a new experiment applying the intervention designed by Barberia et al. (2018) although, this time, participants were assessed with a passive version of the contingency learning task. In the original study, Barberia et al. also

observed an influence of their intervention over, at least, some aspects of the students' paranormal beliefs. As noted above, paranormal beliefs have been proposed to stem from flawed causal detection (Blanco et al., 2015). Therefore, if the intervention is effective in making participants reconsider their way of inferring causal relationships, we can expect an impact over their pre-existing unwarranted beliefs. This result would imply that the intervention is effective not only in reducing the tendency to develop new causal illusion but also in promoting the reevaluation of previously acquired false beliefs, thus indicating a generalized improvement of critical thinking abilities in the students.

In this respect, in Barberia et al. (2018) we observed a reduction of paranormal beliefs as measured by the Spanish adaptation of Tobacyk's Revised Paranormal Beliefs Scale (Díaz-Vilela & Álvarez, 2004). Specifically, the participants who received the intervention obtained reduced scores on the *Precognition* dimension of the questionnaire as compared to those who did not. This dimension reflects the respondents' beliefs about the possibility of predicting future events through paranormal means. In the present study, we included the same questionnaire in an attempt to replicate that finding.

Method

Participants

A group of 72 third-year psychology undergraduates participated in the experiment (58 females, 11 males, two participants did not disclose their gender). Forty-one students (M age 23.26, SD 3.26) received the intervention whereas 31 students received the control condition (M age 23.77, SD 6.96). This sample size exceeds the minimum of participants (Soper, 2019) needed to detect the effect size of $d = -0.65$ observed in our previous study (Barberia et al., 2018).

We implemented the study into a regular class of the Psychology degree, as part of a teaching initiative focused on encouraging scientific thinking among students. Therefore, all the students attending the class received the intervention and its assessment. However, the students had the option of completing a consent form regarding their results to be used anonymously for research purposes. We analyzed only the data from those who gave their written consent. The ethics committee of the University of Barcelona approved the study protocols (Institutional Review Board IRB00003099, Comissió de Bioètica de la Universitat de Barcelona).

Procedure

We applied the intervention described by Barberia et al. (2018) and adapted their assessment to include a passive version of the contingency learning task. The students received the educational intervention and the assessment in a 90 min session. The study was conducted in two sessions. In each session, the students were split in two groups according to their last name initials, and each of the resulting groups was invited to go to one of two rooms. Each of the rooms was randomly assigned to the intervention or the control condition. As a result, in one of the sessions the first half of students received the control condition and the second half received the intervention condition, whereas, in the other session, the first half of students received the intervention condition and the second half received the control condition. The only difference between the two conditions was the order of presentation of the educational intervention and the assessment. Students in the intervention condition received the educational intervention first, whereas students in the control condition started with the assessment. The rooms were equipped with one desktop computer per student. One of two instructors, JRF and IB, conducted the study session in

each room. Their participation in the intervention or control conditions was counterbalanced across the two sessions.

A more detailed explanation of the intervention is provided in Barberia et al. (2018). The intervention begins with the students completing different tasks aimed at inducing two cognitive biases as part of a training-in-bias approach (Larrick, 2004). First, they were presented with a mock personality test aimed to induce a Barnum effect. The Barnum effect, also called Forer effect (Forer, 1949), refers to the tendency to accept and rate as highly accurate vague personality descriptions that are presented as specific and personalized but are actually so common that they can be applied to almost anyone. The on-line test consisted of a Stroop-like task, in which the participants were asked to state either the color in which different color names were printed or the actual color name written. Then the students were asked to select which of three images best corresponded to a model image composed of geometrical shapes. No data were really being gathered during the completion of these tasks. Nevertheless, after finishing them, the students were provided with a personality description composed of different general sentences (Spanish translation from https://es.wikipedia.org/wiki/Efecto_Forer). based on the ones used in the original study by Forer (1949). All the students received the same personality description, although the order of the sentences was randomized to minimize the possibility that any of them could realize that the content of the descriptions was identical. A demo of our Barnum task can be accessed at <http://www.ub.edu/practpensament/ThoughtMode/>.

Then, they completed a computer version of the classic 2-4-6 task (Wason, 1960). In this task, participants are asked to discover the rule used to generate sequences of three numbers by inventing triplets of numbers for which they receive immediate feedback. The sequence 2-4-6 is provided as an initial example of a sequence which follows the rule,

which is “three ascending numbers”. Most of the volunteers completing this task tend to apply a confirmatory information-search strategy (Nickerson, 1998; Wason, 1960) which leads them to erroneously conclude that the rule is more specific than necessary (e.g. “even numbers ascending by two”). This strategy is of special relevance for our purpose because a confirmatory bias has been proposed to underlie causal illusions (Barberia et al., 2013). A demo of our 2-4-6 task, which is based on the materials provided by Grobman (2003) can be accessed at <http://www.ub.edu/practpensament/HTest/>.

Once the students had finished these tasks, the second phase of the intervention started, as the instructor provided information regarding the two biases and how to overcome them as part of a training-in-rules approach (Larrick, 2004). First, the instructor explained the original study by Forer (1949), thus revealing the false nature of the alleged personality test. Then, the original Wason (1960) study was explained, thus clarifying the mechanics of the 2-4-6 task and how the most frequently applied confirmatory strategies almost certainly lead to erroneous conclusions, whereas disconfirmatory strategies are more adequate to discover the actual rule (Grobman, 2003). Finally, the students were provided with several examples of everyday situations or beliefs in which these cognitive phenomena play a relevant role, in order to enhance the perceived personal relevance of cognitive biases, a factor that might influence the success of debiasing interventions (Arkes, 1991; Harkness et al., 1985). Specifically, the instructor explained how confirmatory strategies play a role in the acceptance of personality descriptions such as those provided by our mock personality test as well as disciplines like graphology or the horoscope, or in generalized but questionable beliefs like the supposed increase in violence among humans during a full moon (Rotton & Kelly, 1985) and the apparent association between relative humidity and articulatory pain (Smedslund & Hagen, 2011).

Regarding the assessment phase, the students started completing the contingency learning task. After this task was finished, they answered a paranormal beliefs questionnaire. The contingency learning task was similar to that used by Barberia et al. (2018) although, in this case, the volunteers could not decide whether to administer the drug or not to the patients.

The participants were instructed to find out whether a drug (called Batatrim) was linked to the recovery from the crises produced by a fictitious syndrome (Matute et al., 2011). For reaching this goal, they observed different patients suffering a crisis, presented one by one. We informed them whether each patient took the drug or not and they had to predict if the patient would overcome the crisis. Then, they could see if each patient recovered or not. After observing 48 patients, participants were asked to evaluate the effectiveness of the drug in a scale from 0 to 10.

The task was designed to facilitate the development of the illusion, defined as a judgment significantly higher than zero. The probability of a patient taking the pill was .75, because high cause density is known to promote the appearance of causal illusions (Allan & Jenkins, 1983; Hannah & Beneteau, 2009; Matute et al., 2011; Vadillo et al., 2011). Given that high effect densities are known to promote causal illusions too (Allan & Jenkins, 1983; Blanco et al., 2013), the probability of recovery was also .75 whether the patients was administered the pill or not. Specifically, 27 patients took the drug and recovered, 9 patients took the drug and did not recover, 9 patients did not take the drug and recovered, and 3 patients did not take the drug and did not recover. Note that the contingency between taking the drug and recovering is zero, because the probability of recovery is the same for patients taking the drug (27 out of 36) and for patients not taking the drug (9 out of 12). Therefore,

the effectiveness rating given to the drug can be considered an index of the intensity of the causal illusion developed in the task.

We assessed paranormal beliefs by means of the 30-item Spanish adaptation (Díaz-Vilela & Álvarez, 2004) of the Revised Paranormal Beliefs Scale (Tobacyk, 2004). This scale provides a global score of paranormal beliefs as well as subscores for eight different subscales: *Witchcraft*, *Psi*, *Traditional religious beliefs*, *Spiritualism*, *Extraterrestrial life and actual visits*, *Precognition*, *Superstition* and *Extraordinary life forms*. When any response was missing in either the global scale or any subscale, we calculated the mean scores by averaging the rest of the items. Following Barberia et al. (2018), we modified item 20, from "There is life on other planets" corresponding to the *Extraordinary life forms* subscale to "There is intelligent life on other planets".

Since Barberia et al. (2018) observed that students who received the intervention showed reduced *Precognition* scores, we were particularly interested in this subscale which consists of four items: "Astrology is a way to accurately predict the future"; "The horoscope accurately tells a person's future"; "Some psychics can accurately predict the future" and "Some people have an unexplained ability to predict the future".

Results

We analyzed our data with JASP (JASP Team, 2019). We performed Bayesian *t*-tests modeling the alternative hypothesis with JASP's default Cauchy prior with the scaling parameter *r* set to 0.707. We followed Table 1 by Wagenmakers et al. (2018) for the interpretation of Bayes factors.

We analyzed the effects of the educational intervention over our two dependent variables, causal illusion and paranormal beliefs. A summary of these results is presented in Fig 1. A one-tailed *t*-test for independent samples (intervention < control) over the causal

judgments showed a significant effect of the intervention, with participants in the control condition experiencing a stronger causal illusion, ($M = 5.57$, $SD = 2.17$), than those in the intervention condition, ($M = 3.32$, $SD = 2.45$), $t(66) = -3.90$, $p < .001$, $d = -0.96$, $BF_{-0} = 213.64$. These results can be considered extreme evidence in favor of the alternative hypothesis, as the data are 213.64 times more likely under the hypothesis that ratings in the intervention group are lower than those in the control group.

Barberia et al. (2018) also observed an effect of the educational intervention over the *Precognition* dimension of the Paranormal Beliefs Scale. Our present data replicate this result (see Figure 1). A one-tailed independent samples *t*-test (intervention < control) showed that participants in the intervention condition produced lower scores, ($M = 1.68$, $SD = 0.83$), than those in the control condition, ($M = 2.23$, $SD = 1.259$), $t(66) = -2.21$, $p = .015$, $d = 0.53$, $BF_{-0} = 3.74$. This indicates moderate evidence in favor of the alternative hypothesis. Exploratory analyses of the results of the other dimensions of the Paranormal Beliefs Scale showed no significant differences between the scores corresponding to the two conditions, $ps > .168$, replicating the lack of effects observed in Barberia et al. (Barberia et al., 2018).

Discussion

In this study, we applied a previously designed debiasing intervention aimed to promote critical thinking (Barberia et al., 2018). Students participated in an educational seminar in which they were presented with first-hand experiences of two cognitive biases (the Barnum effect and the confirmation bias) after which they were provided with explanations of these cognitive phenomena and how they can affect our everyday life. We assessed whether the participation in our seminar influenced the tendency to develop causal

illusion (i.e. overestimating the presence of a causal illusion between two events which are actually unrelated) and to present paranormal beliefs.

Crucially, participants who received the intervention produced lower causal ratings in the contingency learning task compared to those who did not, hence evidencing the success of our debiasing intervention for the reduction of causal illusions. In our previous study (Barberia et al., 2018), the observed effect seemed mainly attributable to a decrease of the exposure to the potential cause. That is, volunteers who applied a sampling strategy that diminished the probability of cause-effect coincidences (i.e., generating more cause-absent trials) displayed weaker causal illusions.

Our present results indicate that the intervention also modulates the way in which volunteers process passively acquired information. Even when the rates of drug administration and recovery were held constant across the two groups, those who received the intervention appeared to differentially interpret the data we provided them with. Furthermore, the effect of the manipulation on causal ratings was, if anything, numerically larger in the present study than in the previous study with the active contingency learning task ($d_{\text{active}} = -0.65$ vs. $d_{\text{passive}} = -0.96$). Note that the task was programmed to induce strong causal illusions (Blanco et al., 2013), because both effect and cause densities were set up to be high, thus generating a context in which many cause-effect coincidences occurred. Previous studies have demonstrated that these coincidences strongly impact causal impressions (Kao & Wasserman, 1993; Perales & Shanks, 2007; Wasserman et al., 1990). To this respect, we could hypothesize that our educational intervention affects how participants weight different pieces of information when asked to interpret covariation data. Specifically, it might diminish the generalized tendency to overestimate the relevance of cause-effect coincidences during the detection of possible causal relationships, thus, leading

to a reduction of causal illusions even when we act as mere observers and we are exposed to suboptimal sampling of data (i.e., to many occasions in which to observe if the effect happens when the candidate cause is present, and much less occasions to observe what happens when the cause is absent).

Regarding paranormal beliefs, they were confirmed by our data to be affected by the educational intervention. However, like in the previous study, the effects were restricted to a reduction of the scores corresponding to the *Precognition* subscale of the paranormal beliefs test, which refers to abilities to predict the future through paranormal means. Precognition-related disciplines, such as horoscope, were explicitly used as examples during the training-in-rules phase of the intervention because they largely rely on Barnum-like descriptions. This could explain why the effectiveness of our intervention was restricted to this specific dimension of the paranormal beliefs questionnaire.

As noted by a reviewer, a potential limitation of the present work is that our design does not allow us to rule out the alternative hypothesis that the intervention produced a general tendency to increase skepticism to any possible causal relationship. That is, participants who received the intervention might have developed a more distrustful attitude towards any subsequently presented evidence, regardless of the evidence showing a contingent relationship or not. In this respect, although we have shown a specific impact over non-contingent situations when applying a similar debiasing intervention (Barberia et al., 2013), it remains unclear whether this would be the case for the present one. Further studies should compare the effect of the intervention described here over both contingent and non-contingent situations to ascertain whether it specifically makes the students more accurately evaluate causal evidence (i.e. increasing their critical thinking abilities) or it

simply lowers their general tendency to accept the presence of causal relationships based on the sampled data.

In sum, this study confirms the effectiveness of evidence-based educational interventions for significantly improving scientific thinking skills in adults. Our debiasing intervention has been shown to influence both the students' information sampling strategies (Barberia et al., 2018), as well as their way of interpreting given information (present study), resulting in a decrease of the probability to develop causal illusions.

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Figure 1. Intensity of the causal illusion and scores in the *Precognition* dimension of the Paranormal Beliefs Scale (Tobacyk, 2004). Each point represents the response of each individual participant. The horizontal lines represent the mean responses for each condition. The semi-transparent rectangular boxes represent 95% confidence intervals.

