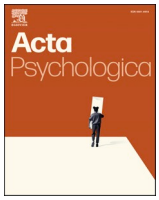
Acta Psychologica 239 (2023) 104007

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy



Scarcity affects cognitive biases: The case of the illusion of causality☆

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ARTICLE INFO

Keywords:
Scarcity
Causal illusion
Causal judgment
Decision-making
Cognitive bias

ABSTRACT

Previous research indicates that economic scarcity affects people's judgments, decisions, and cognition in a variety of contexts, and with various consequences. We hypothesized that scarcity could sometimes reduce cognitive biases. Specifically, it could reduce the causal illusion, a cognitive bias that is at the heart of superstitions and irrational thoughts, and consists of believing that two events are causally connected when they are not. In three experiments, participants played the role of doctors deciding whether to administer a drug to a series of patients. The drug was ineffective, because the percentage of patients recovering was identical regardless of whether they took the drug. We manipulated the budget available to buy the drugs, tough all participants had enough for all their patients. Even so, participants in the scarce group reduced the use of the drug and showed a lower causal illusion than participants in the wealthy group. Experiments 2 and 3 added a phase in which the budget changed. Participants who transitioned from scarcity to wealth exhibited a reduced use of resources and a lower causal illusion, whereas participants transitioning from wealth to scarcity were unaffected by their previous history.

1. Introduction

Scarcity refers to situations in which there is limited availability of any type of resource (economic resources, products, or time, among others). We can find recent examples of the critical consequences of scarcity in the lack of healthcare resources during the COVID-19 pandemic (Solomon et al., 2020; Wang & Tang, 2020), or the lack of vital commodities caused by the war in Ukraine (Endam & Forcha, 2022; Ozili, 2022). Moreover, scarcity underlies major social challenges such as hunger, and many others that we do not automatically identify with shortages (Mullainathan & Shafir, 2013), such as the widespread prevalence of stress, which is partly due to a lack of economic resources and time (Haushofer & Fehr, 2014; SEAS, 2017).

Previous research shows that scarcity, particularly economic scarcity, influences the judgments and decisions of individuals, with consequences in a wide range of areas such as health, social relationships, and consumer behavior (Bertrand et al., 2004; De Bruijn & Antonides, 2022; Shah et al., 2012; Shah, Mullainathan, & Shafir, 2018; World Bank, 2015). Numerous studies have explored how scarcity affects cognition. First, it has been documented that scarcity commonly causes so-called tunnel vision. According to Mullainathan and Shafir (2013), the lack of a resource captures the attention so that people focus excessively on getting the resource as soon as possible, ignoring the future consequences of their actions. For example, a person who lacks financial resources could make decisions such as getting into debts to obtain money in the short time. In addition, several studies associate this tunnel vision effect with reduced cognitive abilities in people who suffer from scarcity. That is, since scarcity imposes a cognitive load, cognitive fatigue appears which impairs cognitive ability (Mani et al., 2013 & 2020; Shah et al., 2015, although see Carvalho et al., 2016 and Dalton et al., 2020). As a result of these effects of scarcity on cognition, several negative behaviors that are linked to scarcity have been identified. For example, excessive borrowing (Bos et al., 2022; Shah et al., 2012 and 2018), and bad health-related decisions, such as discontinuation in medical treatments (Abeyta et al., 2017; Haushofer & Fehr, 2014; Sommet & Spini, 2022), have been reported in individuals who lack enough resources. Nonetheless, some researchers have stressed that scarcity might also entail positive, in addition to negative, cognitive consequences (Frankenhuis & Nettle, 2019). For example, research suggests that scarcity can improve goal-oriented behavior (Roux et al., 2015), creativity (Hamilton, Thompson, et al., 2019; Mehta & Zhu, 2012), and abstract thinking (Caballero et al., 2021 and 2022; Roux &

☆ Preregistration: Experiments 2 and 3 were preregistered in https://aspredicted.org.

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https://doi.org/10.1016/j.actpsy.2023.104007
Received 15 September 2022; Received in revised form 20 June 2023; Accepted 7 August 2023
Available online 11 August 2023

Goldsmith, 2013).

To sum up, recent research indicates that scarcity affects human cognition and decision making in both positive and negative ways. However, to the best of our knowledge, there is no research on how scarcity affects well-studied and documented cognitive biases that are widespread. Understanding how scarcity affects these biases would have interesting practical applications, particularly in nudging and boosting programs (see Hertwig & Ryall, 2020 for a review) aimed to help people make better decisions.

Causal illusion, which is the erroneous belief that two events are causally related when they are not, is one such cognitive bias that has not been investigated in relation to scarcity and has important consequences in people's lives. Therefore, the current research will test another potentially positive consequence of economic scarcity on cognition, which is a likely reduction of the causal illusion. Although this cognitive bias is known to have some positive consequences (it is negatively associated with helplessness and depressive symptoms, Alloy & Abramson, 1979; Blanco, 2017; Damisch et al., 2010; Matute, 1994; Taylor & Brown, 1988), the causal illusion has been widely proven to be at the root of superstitions, irrational thoughts, and pseudoscientific beliefs and practices (Matute et al., 2015, 2019), all of which can have serious negative consequences for wellbeing (Freckelton, 2012).

It is worth noting that causal illusions can be reliably reproduced and studied in laboratory experiments using computer tasks in which participants observe how two events covary. These events are the potential cause (e.g., taking a fictitious medical treatment) and the outcome (e.g., symptom relief). Even when these events are statistically unrelated, people can form the impression that they are connected so that the cause produces the outcome. This procedure has allowed researchers to investigate the factors that can increase or reduce the causal illusion. One such factor is the probability with which the presumed cause occurs. This is known as the effect of the probability of the cause, or the P(C) effect: In general, the higher the P(C), the greater the illusion of causality.

In many experiments, participants can decide when to introduce the potential cause (e.g., a fictitious medical treatment) during the task, and therefore they have control over P(C). Previous research shows that, in those experiments, people usually tend to introduce the cause with probabilities higher than 0.50 in their attempt to obtain the outcome (see e.g., Barberia et al., 2020; Blanco et al., 2012; Matute, 1996; Moreno-Fernández & Matute, 2020). However, by responding with high probability, they become highly exposed to what happens when the cause is present and less exposed to what happens when the cause is absent. As a result, they usually encounter a disproportionate amount of spurious coincidences between cause and outcome, which increases the chances of developing a causal illusion. Moreover, the causal illusion is enhanced when the outcome also occurs with high probability (Blanco et al., 2013; Chow et al., 2019; Musca et al., 2010).

However, even though participants in those experiments have control over P(C), experimenters can also influence this variable in different ways. For example, they can directly reduce the P(C) through explicit instruction by asking participants to try to respond in 50 % of the trials so that they get exposed and learn what happens both when the cause is present and when it is absent (Hannah & Beneteau, 2009; Matute, 1996; Yarritu et al., 2014). Researchers can also influence P(C) indirectly, through educational interventions designed to reduce causal illusions by reducing P(C) and thus reducing exposure to spurious cause-outcome coincidences as well (Barberia et al., 2013, 2018; MacFarlane et al., 2018). Additionally, it is possible to influence the P(C) in more subtle ways by manipulating certain attributes of the causal scenario. For example, Blanco et al. (2014) manipulated the P(C) indirectly by telling participants that a fictitious drug (the potential cause) produced either mild side effects or no side effects at all. In the former case, participants spontaneously reduced their P(C) (i.e., they gave the drug to a lower number of fictitious patients), and this, in turn, reduced their causal illusion.

The present research (experiment 1) aims to investigate whether scarcity manipulations could affect P(C) and thus causal illusion. The literature on scarcity indicates that knowing that a resource is scarce influences how people use it (Shah et al., 2012, 2015; Shah, Mullainathan, & Shafir, 2018). This means that economic scarcity could impact how often people decide to use their resources. Therefore, we hypothesized that manipulating the scarcity of a potential cause (e.g., a fictitious drug) could lead participants to lower their P(C), which in turn should reduce their causal illusion. This research would connect the findings in the scarcity literature (De Bruijn & Antonides, 2022 O'Donnell et al., 2021 for reviews) to those in the causal learning and causal illusions literature (see Matute et al., 2015, 2019, and Shanks, 2007 for reviews) paving the way for further research not only on these areas but also, more broadly, on how scarcity can influence cognitive biases.

Additionally, this research also investigates a related question, which has to do with changes in the availability of resources over time. People usually go through periods of relatively greater or lesser wealth during their lives. This is reflected in indicators such as the households' savings capacity and in the percentage of the population at risk of poverty among others. Both indicators fluctuate yearly (INE, 2022; World Bank, 2022), which suggests that moving between periods of relative scarcity and wealth in resource availability is common in real life. Several studies have shown that economic scarcity influences decisions even after it is no longer present (Carvalho et al., 2016; Dalton et al., 2020; Fehr et al., 2022; Folkes et al., 1993; Hamilton, Mittal, et al., 2019; Huijsmans et al., 2019; Jiang et al., 2021; Malmendier & Nagel, 2011). Therefore, inspired by these previous studies on scarcity, experiments 2 and 3 explore how changes in resource availability (e.g., from scarcity to wealth and vice versa) affect the bias of causality. To the best of our knowledge, there are no previous studies exploring this issue.

2. Ethics statement

The procedure of these experiments was approved by the Ethical Review Board of the University of Deusto. No personal information was collected. Before the experiment, we informed participants that the data collected would be sent anonymously to the experimenters only if they granted their explicit permission by clicking on a “Submit” button.

3. Experiment 1

3.1. Method

3.1.1. Participants

This experiment comprised two different samples of participants: One sample included 96 Psychology students who participated in exchange for course credit. The other one included 64 anonymous Internet users recruited through the snowball procedure. The computer program randomly assigned each participant to one of two groups: scarce group ($n = 85$) or wealthy group ($n = 75$).

Because there were no differences in the results as a function of the sample (students vs. Internet users), we collapsed the two samples for all the descriptive and inferential analyses presented below.

An ex-post sensitivity analysis showed that, with the current sample size ($n = 160$), we obtained a power of 0.80 to detect a medium-sized effect ($d = 0.44$ or bigger) in the differences between the groups.

3.1.2. Procedure

The experiment was conducted through the Internet and the experimental task was an adaptation of the standard causal illusion task (see Matute et al., 2019), programmed in JavaScript. First, we asked all the participants to imagine they were doctors working at a hospital and treating a rare fictitious disease. We then instructed them to visit a series of patients and decide whether to administer a fictitious drug to each of them. Participants were advised that this drug was still under development, so its effectiveness was not well established.

After reading the instructions, participants visited a total of 30 patients, presented sequentially, one per trial. In each trial, participants had to decide whether or not to administer the drug (Fig. 1, step 1). After that, they received information about whether the patient healed or not (Fig. 1, step 2). We calculated the participants' P(C) by dividing the number of patients to whom the participants administered the drug by the total number of patients (i.e., 30). Unbeknownst to the participants, and regardless of whether they administered the drug or not to each patient, 70 % of the patients healed. This means that the outcome (healing) was highly frequent and that there was no causal connection between using the drug and healing. We used a high percentage of healing because, as we previously stated, a high probability of the outcome favors the development of causal illusions (Blanco et al., 2013; Chow et al., 2019). The order of healed and not healed patients was randomized for each participant. In order to ensure consistency in the number of outcomes experienced by participants, we programmed the experiment such that, for each participant, every block of 10 trials contained 7 outcome-present trials and 3 outcome-absent trials. This was done to maintain a programmed probability of the outcome, or P(O), of 0.70 for all participants throughout the 30 trials, with 21 trials having an outcome and 9 without it. Although there could have been some discrepancies in the number of outcomes experienced by different participants due to the randomization of trial order, they were unlikely to happen systematically between groups. To verify that there were no errors, we checked the specific P(O) experienced by each participant in Experiment 1, and it was exactly 0.70 for all of them. The same approach was used in the programming of the other two experiments.

The difference between the two groups was in their budget, and this was manipulated through instructions. In the scarce group, the instructions stated that the budget for buying drugs was limited, so it could run out at any time. In the wealthy group, instructions stated that the budget was very large and there was usually a surplus. Additionally, to reinforce these different instructions, participants in both groups constantly saw a reminder of the instructions and a budget bar. Each time they used one dose of the drug, the budget bar was updated by showing a reduction. This reduction was quicker in the scarce group, where each drug dose administered reduced the bar by 1/30, as compared to the wealthy group, in which each drug dose administered reduced the bar by 1/300. Thus, participants in the scarce group would often see an almost completely depleted budget bar, while those in the wealthy group would see the bar almost untouched for most of the experiment. Additionally, the experience of scarcity was reinforced by using colors: if the budget bar decreased to 1/2 or 1/3 of the initial budget, the color of the progress bar changed from the original green to orange, and then to red, respectively (note that, since the wealthy group had a very large number of drug doses available, they never reached either of these points and the bar was always green). Importantly, despite this manipulation of the budget, both groups had enough resources to buy doses for all their patients. That is, the scarce group had 30 doses to be administered on the whole sequence of 30 patients (though they did not know in advance how many doses and patients they would have). Fig. 1 shows two screenshots of a sample trial in each group.

Once the participants had visited all 30 patients, we measured their causal judgments in both groups by asking them to assess how effective the drug was in healing the patients. We used a scale from 0 (completely ineffective) to 50 (moderately effective), to 100 (completely effective). The correct answer is zero because the percentage of healed patients is identical regardless of whether or not they received the drug. Therefore, any judgment higher than zero shows some degree of causal illusion. We predicted that participants in the scarce group would administer the drug less often than those in the wealthy group, and that, as a result, participants in the scarce group should exhibit a lower causal illusion than those in the wealthy group.

Lastly, several studies in the scarcity literature suggest that people value resources more when they are scarce (John et al., 2018; Lynn,

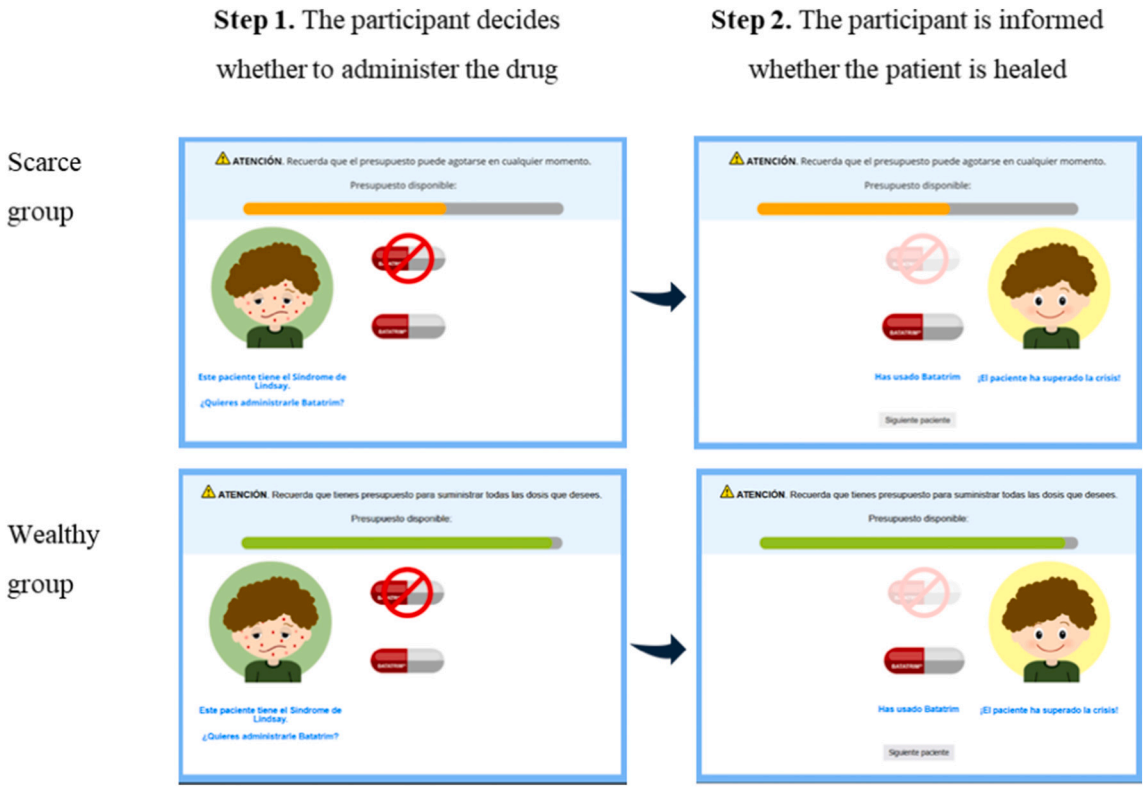

Fig. 1. Screenshots showing the two consecutive screens (steps) within each trial.
Note. The left panel shows an example of the first screen in each trial, prompting participants to decide whether to administer the drug to each fictitious patient. The right panel shows an example of the second screen in each trial, informing participants whether the patient has been healed.

1991; Sehnert et al., 2014; Shah et al., 2015, and 2018; Williams et al., 2016). That is why we also measured the resource valuation in both groups by asking participants to assess to what extent they thought that having a larger budget available would have helped them in their task. For this purpose, we used a scale from 0 ("it would not have helped me") to 50 ("it would have helped me a little"), to 100 ("it would have helped me a lot"). We expected to replicate the results of previous studies so that the participants in the scarce group would assign a higher value to the resource. The materials (including instructions) and data of these experiments are openly available at the Open Science Framework.

3.2. Results and discussion

Fig. 2 shows the mean values for the probability of the cause, P(C), and the causal illusion in the three experiments. In experiment 1 (top row), as we expected, participants in the scarce group displayed a significantly lower P(C) than those in the wealthy group, $t\,(158) = 2.65$, $p = .009$, $d = 0.419$. That is, scarcity worked as expected and reduced the frequency with which participants decided to administer the drug. Secondly, we examined their causal illusions. These were also significantly lower (i.e., closer to zero, the correct value) in the scarce group as compared to the wealthy group, $t(158) = 2.06$, $p = .041$, $d = 0.327$.

Next, we tested the possibility that the differences in the causal illusion that we have just reported were mediated by the differences in P(C). That is, we tested whether those participants showing stronger causal illusions did so because they were using the drug more often. Our mediational analysis revealed first a significant total effect of the budget (group) on causal illusions, $Z = 2.068$, $p = .039$, showing that the scarcity manipulation reduced the causal illusion, as we already showed in the previous analyses. Then, we found that the indirect effect through P(C) was also significant, $Z = 2.583$, $p = .010$. Finally, the direct effect (which is the portion of the total effect that is left once the contribution of P(C) has been partialed out) was not significant, $Z = 0.464$, $p = .642$. Taken together, these results show a significant and complete mediation of P(C) between the budget and causal illusion. That is, the effect of the scarcity manipulation on the causal illusion was probably due to a difference in the number of drugs administered in each group: because participants in the scarce group administered the drug less often, they

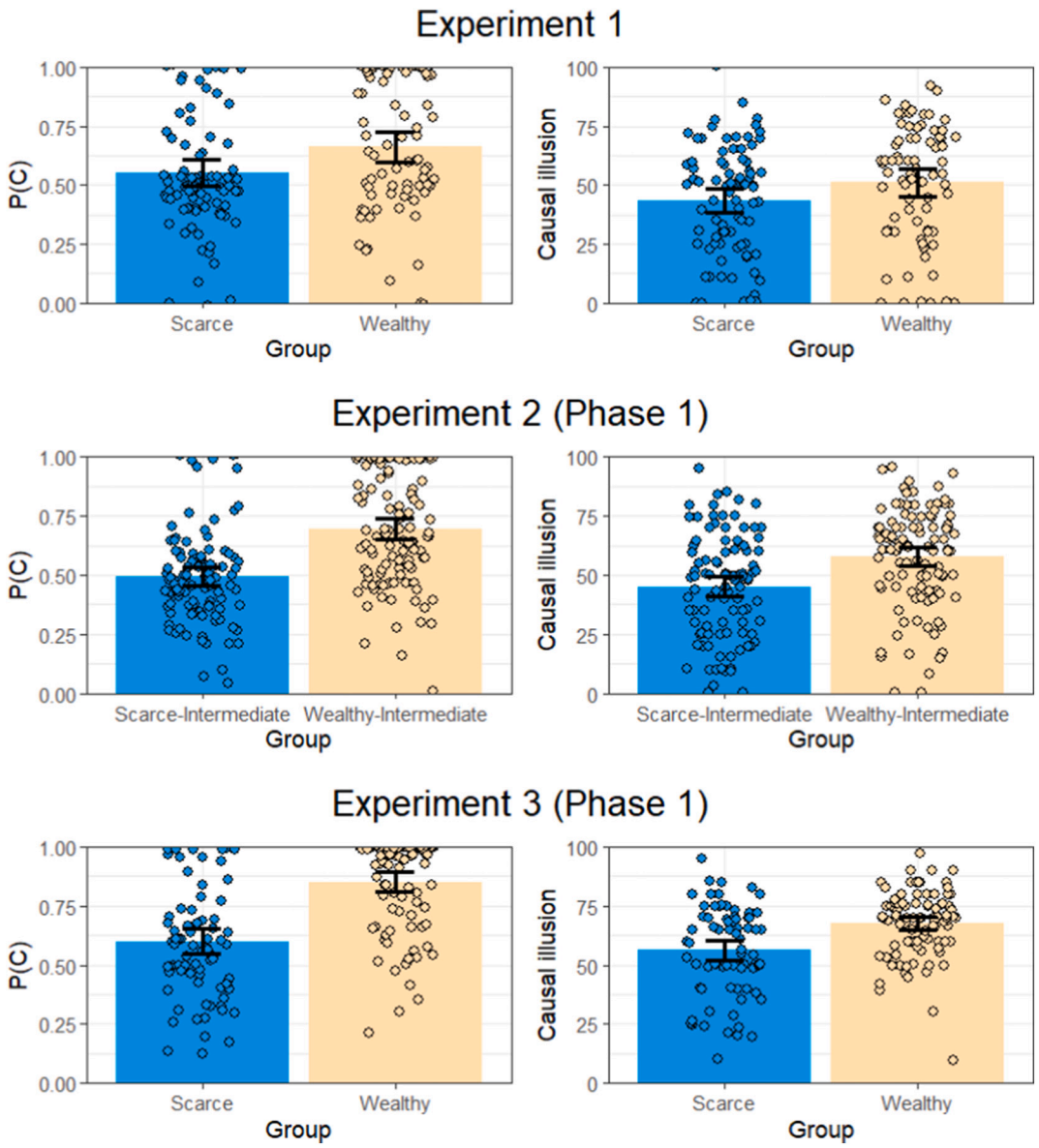

Fig. 2. Mean P(C) and mean causal illusion as a function of the group in Experiments 1–3 during Phase 1.
Note. The plot shows the mean values for P(C) (left) and causal illusion (right) in experiment 1 (top) and the first phase of experiment 2 (middle) and experiment 3 (bottom). Error bars represent 95 % confidence intervals for the mean. Data points are jittered to avoid overplotting.

showed a lower causal illusion than the wealthy group.

Finally, we examined the resource valuation responses. Participants in the scarce group valued the scarce resource higher ($M = 42.0$, $SD = 31.1$) than those in the wealthy group ($M = 39.9$, $SD = 34.5$), but despite previous reports (John et al., 2018; Sehnert et al., 2014; Shah et al., 2015 and 2018; Williams et al., 2016), this difference was not significant, $t(158) = 0.389$, $p = .698$, $d = 0.061$.

In sum, as we expected, we found that a scarce budget reduced the causal illusion, and did so by limiting the number of drug doses that participants administered (i.e., the effect was mediated). However, we did not replicate previous studies according to which the scarce group should value the resource significantly more than the wealthy group.

4. Experiment 2

People usually go through different periods of scarcity, sufficiency, and wealth throughout their lives. Therefore, we can ask whether a previous situation of scarcity can continue to influence judgments and decisions (in this case, by reducing the causal illusion) once scarcity is no longer present. There are different possibilities. First, people might not be impacted by previous experiences of scarcity, so they may use the resources according to their availability at any given time, and, as a result, their causal illusion will increase when the availability of resources increases. The second possibility is that people may overrespond when scarcity disappears. That is, once they become wealthy, they might engage in levels of resource usage that surpass those of people who are equally wealthy but who had never experienced scarcity, and in consequence, they will also increase their causal illusions in those subsequent periods of sufficiency or wealth. Finally, the opposite might also occur, that is, people having experienced scarcity in the past might remain cautious and lower their resource usage even in later periods of sufficiency or wealth and, as a result, they would reduce their causal illusions as well. To answer this question, we conducted Experiment 2.

In Experiment 2, we included two phases with an identical procedure, changing only the instructions and the available budget. Whereas in the first phase, we compared the scarce and wealthy conditions, thus becoming a replication of Experiment 1, in the second phase all participants were exposed to an intermediate budget condition (i.e., lower than the wealthy budget, higher than the scarce budget). Our aim in this second phase was to explore whether previous experience with scarce vs. wealthy budgets influenced behavior in a later phase with a different budget. We chose an intermediate budget condition as it allowed a fairer comparison of the two groups with different initial conditions (i.e., scarce and wealthy) during a second phase in which the two of them had the same budget. Preregistration for this experiment is available at https://aspredicted.org/gd3gu.pdf.

4.1. Method

4.1.1. Participants

Two hundred and sixteen psychology students participated in this experiment in exchange for course credit. The computer program randomly assigned participants to one of two groups, which differed in the budget available in the first phase: scarce-intermediate group ($n = 104$) and wealthy-intermediate group ($n = 112$).

An ex-post sensitivity analysis showed that, with the current sample size ($n = 216$), we obtained a power of 0.80 to detect a medium-sized effect ($d = 0.38$ or bigger) in the difference between the two groups.

4.1.2. Procedure

The procedure was similar to the one described in Experiment 1. After participants had emitted their causal judgments in Phase 1, we added a second phase in which both groups of participants (those who were initially allocated to the scarce and the wealthy conditions) had an intermediate budget. In this second phase, the hospital and the drug were different from those in the previous phase. This means that participants had to learn again if the drug caused the healing without being influenced by the results observed in Phase 1. Like in Phase 1, during Phase 2 participants also visited a total of 30 patients, one per trial, and 70 % of the patients healed regardless of whether participants administered the drug. Thus, there was no causal connection between using the drug and healing.

The budget conditions were identical for both groups during Phase 2: The instructions told participants that the budget for buying drugs was now "intermediate". Also, each time the participant administered one dose of the drug, the budget bar was updated, showing a reduction of 1/135 (which is an intermediate value between the 1/30 reduction in the scarce condition and the 1/300 in the wealthy condition). In this phase, given that the budget was more than enough for using the drug in all 30 patients, the bar was never close to depletion, and thus no participant ever reduced the budget bar to a point in which it changed color to orange or red. After the participants had visited all 30 patients, we measured their causal judgment in Phase 2 in a similar way as in Phase 1. Lastly, we also measured their resource valuation in Phase 2.

4.2. Results and discussion

4.2.1. Phase 1 (replication of Experiment 1)

The first phase of this experiment was an identical replication of Experiment 1. The middle panel of Fig. 2 shows the results of Phase 1. As the figure suggests, we found the same results as in that experiment for both P(C) and causal illusions: First, participants in the scarce-intermediate group showed a lower PC) in Phase 1 than those in the wealthy-intermediate group, $t(214) = 6.704$, $p < .001$, $d = 0.913$. Second, causal illusion in Phase 1 was also lower in the scarce-intermediate group as compared to the wealthy-intermediate group, $t(214) = 4.330$, $p < .001$, $d = 0.560$.

Next, as in Phase 1 of Experiment 1, we run a mediational analysis to confirm whether the effect of the budget on causal illusion could be explained through P(C). We found a significant total effect of the budget (group) on the causal illusions, $Z = 5.823$, $p < .001$. Then, we found that the indirect effect through P(C) was significant, $Z = 4.340$, $p < .001$, while the direct effect that partials out the contribution of P(C) was not significant, $Z = 0.208$, $p = .835$. That is, P(C) completely mediated the effect of budget manipulation on causal illusions in Phase 1, thus replicating the results of the previous experiment.

Finally, during Phase 1 participants in the scarce-intermediate group valued the scarce resource higher ($M = 40.7$, $SD = 26.8$) than those in the wealthy-intermediate group ($M = 31.1$, $SD = 34.7$), $t(214) = 2.266$, $p = .024$, $d = 0.308$. This aligns with the prediction that scarcity increases resource valuation.

4.2.2. Phase 2 (budget change)

During Phase 2, the two groups that had initially been exposed to different budgets (scarce vs. wealthy) dealt with an intermediate budget, so this allowed us to test whether their different previous budgets impacted them during the second phase of the experiment. Their mean P(C) and causal illusion in Phase 2 are depicted in Fig. 3.

We first conducted two separate mixed ANOVAs with factors group (scarce-intermediate/wealthy-intermediate) and phase (Phase 1/Phase 2) on P(C) and on causal illusions. The main effect of the group was significant for both P(C) and causal illusion, $F(1,214) = 14.1$, $p < .001$ and $F(1,214) = 10.3$, $p = .001$ respectively. The main effect of the phase was not significant for P(C) nor for causal illusion, $F(1,214) = 3.58$, $p = .06$ and $F(1,214) = 0.024$, $p = .877$ respectively. Most importantly, the Phase x Group interaction was significant for both P(C) and causal illusion, $F(1,214) = 50.40$, $p < .001$ and $F(1,124) = 7.614$, $p = .006$ respectively.

We examined the significant interactions using post hoc contrasts. The two groups did not significantly differ from each other in Phase 2, either with respect to their P(C) or with respect to their causal illusions (both $ps > .68$, after correcting for multiple comparisons with the Tukey

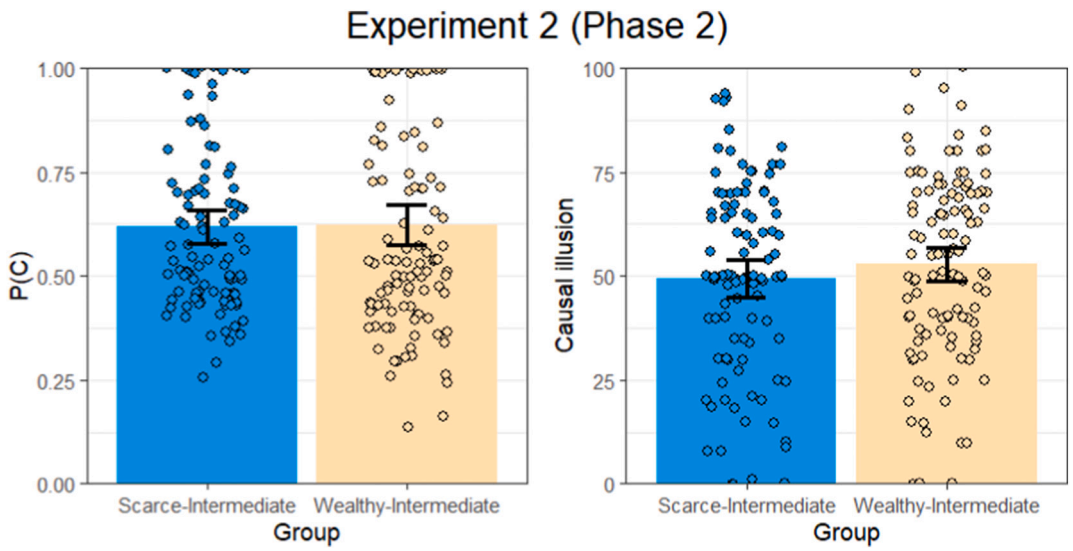

Fig. 3. Mean P(C) and causal illusion in Phase 2 of Experiment 2.
Note. The plot shows the mean values for P(C) (left) and causal illusion (right) in Phase 2 of Experiment 2. Error bars represent 95 % confidence intervals for the mean. Data points are jittered to avoid overplotting.

procedure). This suggests that they adapted their behavior (and in consequence, their judgments as well) to the intermediate budget that they had now in Phase 2 (and which was identical for both groups). In addition, both groups significantly changed their P(C) between phases, a result that also suggests that the two of them adapted their behavior to the intermediate budget they had in Phase 2: while the group with an initial scarce budget significantly increased P(C) from Phase 1 to Phase 2, $t(214) = 6.243$, $p_{tukey} < .001$, the group with an initial wealthy budget reduced P(C) significantly, $t(214) = 3.753$, $p_{tukey} = .001$. However, their causal judgments did not show significant differences between phases (both *p*s, corrected for multiple comparisons, > 0.156). This seems to suggest that our switching to an intermediate budget in Phase 2, may have been a weak manipulation that was enough to influence the participants' P(C) in Phase 2 but not strong enough to affect their causal judgments as well.

In addition, during Phase 2, participants in both groups gave similar valuation ratings ($M = 29.0$, $SD = 28.4$ for scarce-intermediate group and $M = 28.4$, $SD = 27.4$ for wealthy-intermediate group). The difference in resource valuation in Phase 2 was not significant, $t(214) = 0.18$, $p = .858$, $d = 0.024$.

To sum up, the results from Phase 1 successfully replicated those from Experiment 1, not only the effect of the budget on P(C) and causal illusion but also the mediational effect through P(C). Then, during Phase 2 both groups showed a similar level of P(C), that is, they both administered similar intermediate amounts of the drug. This result suggests that both groups adapted their behavior to the new situation with an intermediate budget. The causal illusion was also intermediate in both groups during Phase 2, although it did not significantly differ from their causal illusions in Phase 1. Experiment 3 will test a more intense budget change.

5. Experiment 3

Based on the previous experiments, we decided to conduct Experiment 3, which follows the same logic as Experiment 2 but features a more extreme budget manipulation and two additional groups. That is, in Experiment 3 we had four groups: scarce-wealthy, wealthy-scarce, wealthy-wealthy, and scarce-scarce. As in Experiment 2, all participants went through two consecutive phases. In Phase 1, we expected to replicate the results of Experiments 1 and 2, so the same predictions hold. In Phase 2, half of the participants went through a more extreme budget change than in Experiment 2 (i.e., from scarce to wealthy, from wealthy to scarce). Like in that experiment, there are several possible results. First, the previous budget may not influence the behavior and judgments of participants when conditions change during Phase 2 so they just respond as if they always had the resources they have now. Alternatively, having a scarce budget in Phase 1 could influence the subsequent behavior and judgments in Phase 2. Thus, these participants would either (a) over-respond once they become wealthy, and thus develop stronger illusions of causality than those who have always been wealthy, or (b) be cautious and maintain their scarcity-like behavior and judgments even when they become wealthy in Phase 2. Preregistration for this experiment is available at https://aspredicted.org/ma6vi.pdf.

5.1. Method

5.1.1. Participants

One hundred and seventy-four psychology students participated in exchange for course credit. The computer program randomly assigned participants to the following groups as a function of the budget they had available in Phase 1 and Phase 2: scarce-wealthy group ($n = 43$), wealthy-scarce group ($n = 42$), wealthy-wealthy group ($n = 54$) and scarce-scarce group ($n = 35$).

An ex-post sensitivity analysis showed that, with the current sample size ($n = 174$), we obtained a power of 0.80 to detect a medium-sized effect ($d = 0.21$ or bigger) in the difference between the groups.

5.1.2. Procedure

The procedure was similar to the one described in Experiment 2. In this case, instead of using an intermediate budget in Phase 2, two groups of participants (i.e., scarce and wealthy) drastically changed their budget to their respective opposites (i.e., scarce-wealthy and wealthy-scarce). For comparison purposes, we also included two additional groups that did not change their budget between phases. Thus, group scarce-scarce had an identical budget in Phase 2 as group wealthy-scarce, but with a different history in Phase 1, while group wealthy-wealthy had an identical budget in Phase 2 as group scarce-wealthy, but differed from it in its Phase 1 history. These additional groups maintaining the same budget through the task were added in order to compare the Phase 2 results of the groups suffering a budget change against the neutral baselines of groups who always received the same budget. That is, group scarce-scarce provided a baseline against to which

the results of group wealthy-scarce should be compared during Phase 2, while group wealthy-wealthy served as the baseline against which the Phase 2 results of group scarce-wealthy should be compared.

5.2. Results and discussion

5.2.1. Phase 1 (replication of Experiment 1)

We first analyzed the P(*C*)s and causal illusions in Phase 1 (Fig. 2, bottom panel). We had two pairs of groups with the same budget in Phase 1 (scarce-scarce and scarce-wealthy, on the one hand, and wealthy-wealthy and wealthy-scarce, on the other), and, as should be expected, there were no differences in the results between these pairs of groups in Phase 1. Thus, we collapsed the data of those groups with an identical budget during Phase 1 in order to achieve better power. This results in a design identical to Experiment 1 and Phase 1 of Experiment 2. As expected, we found similar results as in the previous two experiments for the P(C) and causal illusions in Phase 1. Participants in the scarce budget condition showed a lower P(C) in Phase 1 than those in the wealthy budget condition. This difference was statistically significant, $t(172) = 7.50$, $p < .001$, $d = 1.143$. Moreover, the causal illusion was also significantly lower during Phase 1 in the scarce budget condition than in the wealthy budget condition, $t(172) = 4.62$, $p < .001$, $d = 0.705$.

Next, we tested the same mediational model as in the previous experiments during Phase 1. First, we found a significant total effect of the budget on the causal illusion in Phase 1, $Z = 4.636$, $p < .001$. Then, we found that the indirect effect through P(C) was significant, $Z = 6.154$, $p < .001$, while the direct effect that partials out the contribution of P(C) in Phase 1 was not significant, $Z = 0.098$, $p = .922$. That is, as in Experiments 1 and 2, we found evidence for a complete mediation of P(C) on the effect of budget: Because participants in the scarce group administered the drug less often, they showed lower causal illusions than those who had a wealthy budget. Thus, we replicated the results of Experiments 1 and 2 concerning the role of scarcity in reducing the causal illusion.

Finally, and as in the previous experiments during Phase 1, participants in the scarce budget condition valued the resource ($M = 55.6$, $SD = 28.7$) more than those in the wealthy budget condition, ($M = 43.0$, $SD = 37.7$), and this difference in Phase 1 was significant, $t(173) = 2.42$, $p = .017$, $d = 0.369$.

5.2.2. Phase 2 (budget change)

The P(C) and causal illusions in Phase 2 are shown in Fig. 4 for all four groups. We were interested in the possibility that the initial budget that participants had during Phase 1 influenced how they administered the resources and formed their causal illusions later in Phase 2. Thus, we analyzed the possibility that P(C) and causal illusions in Phase 2 depended on (a) the budget in Phase 2 (scarce vs. wealthy) and (b) whether the budget had changed between phases (yes vs. no). Therefore, we conducted two separate 2 (budget in Phase 2: scarce/wealthy) x 2 (budget change: yes/no) ANOVAs on P(C) and on causal illusion in Phase 2. The results were as follows. First, there was a significant main effect of the current budget on the P(C) in Phase 2, $F(1,170) = 15.68$, $p < .001$, but this effect did not reach statistical significance with respect to causal illusion, $F(1,170) = 3.164$, $p = .077$. Second, the main effect of the budget change was not significant either on P(C) or on causal illusions: $F(1,170) = 3.14$, $p = .078$, and $F(1,170) = 0.377$, $p = .540$, respectively. However, our prediction was an interaction of those two factors. As expected, we found that the budget in Phase 2 and the budget change interacted significantly on both the P(C) in Phase 2, $F(1,170) = 4.96$, $p = .027$, and the causal illusion in Phase 2, $F(1, 170) = 4.93$, $p = .028$.

We explored these two interactions using post hoc contrasts. Note that we were only interested in two of the contrasts, as shown in Fig. 4 (i.e., the two groups with a wealthy budget in Phase 2, on the one hand, and the two groups with a scarce budget in Phase 2, on the other), as all other contrasts were meaningless because they compared groups with a different budget in Phase 2. We observed no significant differences in P(C) between the two groups with a scarce budget in Phase 2, $t(170) = 0.305$, $p = .761$. This suggests that those two groups behaved similarly during Phase 2, adapting their behavior to the identical budget that they had during this phase. It also suggests that their differential previous budget during Phase 1 did not seem to influence their subsequent behavior in Phase 2. By contrast, the two groups with a wealthy budget in Phase 2 did differ in their P(C) as a function of their previous budget, $t(170) = 3.001$, $p = .003$. That is, the behavior of the two groups with a wealthy budget during Phase 2 did differ as a function of their previous history, with those exposed to scarcity during Phase 1 being more careful when spending their wealthy budget of Phase 2 than those who had always been wealthy.

With respect to their causal illusion in Phase 2, we found similar results. The two groups with a scarce budget in Phase 2 did not differ significantly between them in their causal illusion, suggesting that their previous budget did not affect their causal judgments in Phase 2, $t(170) = 1.076$, $p = .283$. The two groups with a wealthy budget in Phase 2 did

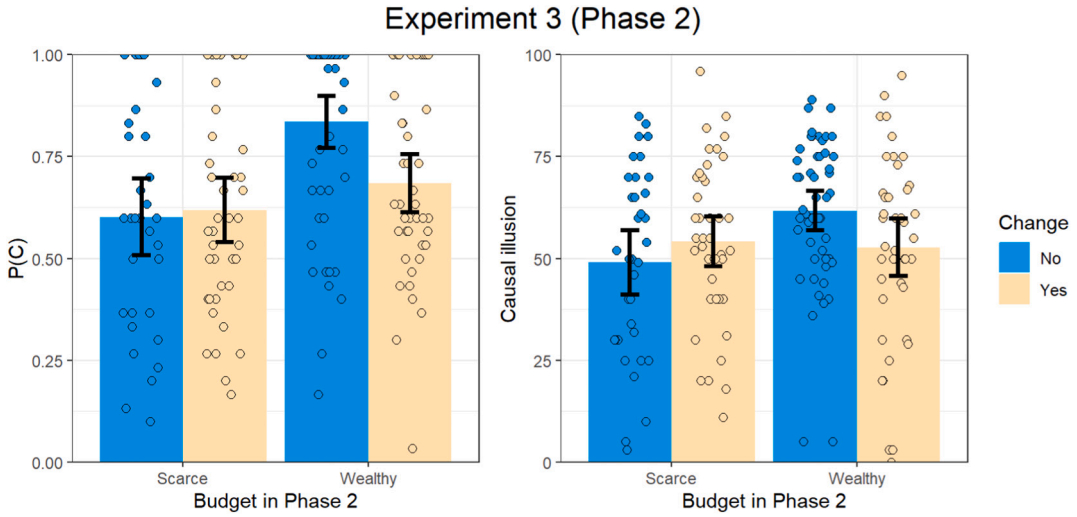

Fig. 4. Mean P(C) and causal illusion in Phase 2 for Experiment 3.
Note. The plot shows the mean values for P(C) (left) and causal illusion (right) in Phase 2 of Experiment 3. The color of the bars indicates whether the budget changed from the previous phase or not. Error bars represent 95 % confidence intervals for the mean. Data points are jittered to avoid overplotting.

differ from each other in their causal illusion in Phase 2, $t(170) = 2.127$, $p = .035$, suggesting that those having scarce resources in Phase 1 showed a lower causal illusion in Phase 2 that those who had always been wealthy. That is, having experienced a previous period of wealth did not influence resource usage and causal illusions when participants switched to scarce resource conditions. By contrast, those participants who experienced a previous period of scarcity tended to administer their Phase 2 resources more carefully when they became wealthy, and their causal illusion was also lower as compared to those who were always wealthy. This asymmetry between the two starting conditions (wealthy vs. scarce) was unexpected but it is interesting, as it suggests that people adapt their behavior differently when they switch from scarcity to wealth than vice versa.

Finally, we analyzed the resource valuation responses to check whether the budget in Phase 1 and the change in the budget between phases affected this variable. Thus, we conducted a 2 (budget in Phase 2: scarce/wealthy) x 2 (budget change: yes/no) ANOVA on resource valuation in Phase 2. There was a significant main effect of the budget of Phase 2 on resource valuation in Phase 2, $F(1,170) = 13.29$, $p < .001$, so that participants in the scarce condition in Phase 2 valued their resources, $M = 53.6$ (32.2), more than participants in the wealthy condition, $M = 44.7$ (35.8). The main effect of the budget change was not significant on resource valuation in Phase 2, $F(1,170) = 0.90$, $p = .344$. Finally, the interaction between the budget in Phase 2 and budget change was not significant, $F(1,10) = 0.382$, $p = .537$.

For completeness, we describe now the results of an additional analysis that was not pre-registered, but can complement the previous ones. For this analysis, we conducted two separate mixed ANOVAs with Phase (1, 2), Budget in Phase 1 (scarce/wealthy) and Budget in Phase 2 (scarce/wealthy) as factors on our dependent variables, P(C) and causal illusion. Concerning the former variable, we found a main effect of phase, $F(1, 170) = 7.12$, $p = .008$, indicating that, overall, the P(C) tended to reduce from Phase 1 to Phase 2; and main effects of budget Phase 1, $F(1, 170) = 25.8$, $p < .001$, and budget Phase 2, $F(1, 170) = 5.16$, $p = .024$. We also found a Phase x Budget in Phase 1 interaction, $F(1, 170) = 27.09$, $p < .001$, meaning that the change in P(C) between phases depended on the budget in Phase 1; a Phase x Budget in Phase 2 interaction, $F(1, 170) = 24.88$, $p < .001$, with similar interpretation but concerning Phase 2; and a Budget Phase 1 x Budget Phase 2 interaction, $F(1, 170) = 4.26$, $p = .040$. We conducted the same analyses on the causal illusion, finding: a main effect of phase, $F(1, 170) = 24.60$, $p < .001$; a main effect of budget in Phase 1, $F(1, 170) = 13.901$, $p < .001$, and a Phase x Budget in Phase 2 interaction, $F(1, 170) = 4.85$, $p = .029$. Fig. 5 depicts the mean P(C) and causal illusion in the two phases and for the four groups as a function of their budget in Phase 1 and in Phase 2.

6. General discussion

The goal of these experiments was twofold. First, we wanted to test whether participants with a scarce (but sufficient) budget would spontaneously reduce the number of drugs administered in the experimental task and, therefore, exhibit a lower causal illusion, as compared to participants in the wealthy group. Second, we were interested in whether this previous experience of scarcity would influence the number of drugs that they administered and their causal illusion in subsequent phases when scarcity was no longer present.

First, through the three experiments (experiment 1 and its replications in the first phase of the two subsequent experiments), we provide robust evidence that the available budget influences the causal illusion, and it does so by reducing or increasing the P(C). That is, when participants in these experiments knew that a shortage existed, they reduced the number of drug doses administered and, as a result, they had a lower causal illusion than participants in a situation of wealth. This result goes beyond previous research in showing that scarcity can produce certain positive consequences on cognition and decision making (Frankenhuis & Nettle, 2019), in this case by limiting the effect of causal illusion. No previous research that we are aware of investigated the possibility that scarcity could reduce or prevent causal illusions. It is also possible that other cognitive biases are reduced by scarcity manipulations, although this is a matter for future research. Additionally, the current experiments add to a set of previous studies that report how people bias their behavior, and hence, their observations, when collecting information to make causal decisions. For instance, participants who aim to heal patients by using a fictitious drug will tend to administer it often, thus displaying a high P(C) and increasing the chances of a causal illusion (Barberia et al., 2020; Blanco et al., 2012; Matute, 1996; Moreno-Fernández & Matute, 2020). Educational interventions (Barberia et al., 2013, 2018; MacFarlane et al., 2018) or instructional manipulations (Hannah & Beneteau, 2009; Matute, 1996; Yarritu et al., 2014) can reduce this biased behavior, and hence the resulting causal illusion. Here, we show that the mere instruction that resources are scarce can lead to a spontaneous reduction in P(C), and therefore, to weaker illusions as well.

Secondly, we considered it important to test not only whether

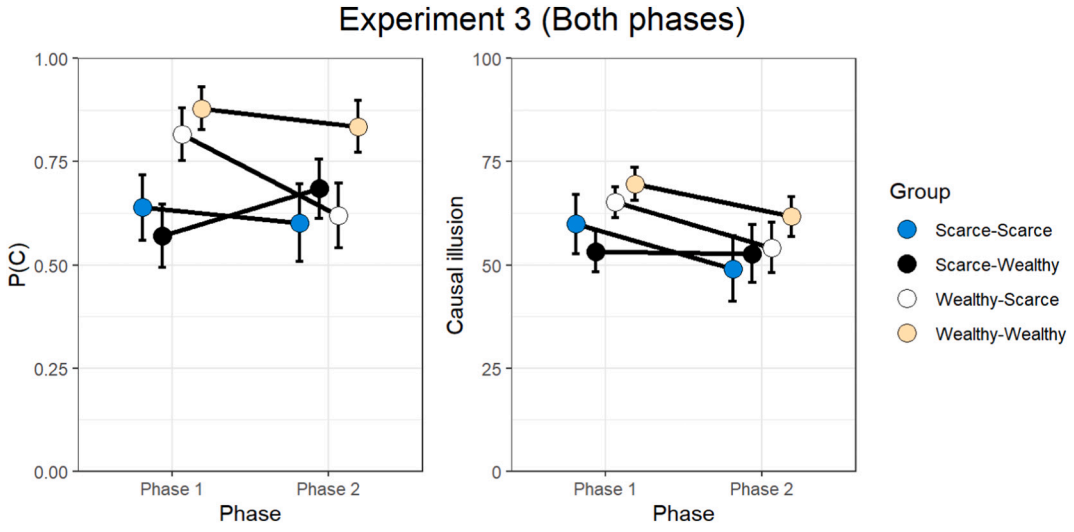

Fig. 5. Mean P(C) and causal illusion in the two phases of Experiment 3, for the four groups, as a function of their budget in Phase 1 and Phase 2.
Note. The plot shows the mean values for P(C) (left) and causal illusion (right) in the two phases of Experiment 3. Error bars represent 95 % confidence intervals for the mean.

economic scarcity influenced the causal illusion, but also whether this influence lasted when the situation changed (e.g., from scarcity to an intermediate budget, in Experiment 2, or from scarcity to wealth, in Experiment 3), a type of manipulation that has not been previously studied. In Experiment 2, we found evidence that participants seemed to change their P(C) when they moved from a scarce or wealthy budget to an intermediate one, but we did not find differences in the causal illusion between those groups in Phase 2, once they were exposed to the identical intermediate budget. This suggests that our manipulation of an intermediate budget might have been not strong enough to affect both the P(C) and the subsequent causal illusion. There are many possible explanations for this result. If we were to speculate, P(C) might be a more sensitive measure than causal illusion, or perhaps, given that P(C) mediates causal illusions, it might be that for a budget change to affect not only P(C) but also the causal illusion, a stronger manipulation than the one that we used in Experiment 2 might be necessary. That is why, in Experiment 3, we aimed a stronger manipulation by changing from either scarce or wealthy budget during Phase 1 to the opposite budget during Phase 2. In this case, we did find evidence that the initial budget influenced both P(C) and causal illusion when participants moved from scarcity to wealth. During the second phase, wealthy participants who had experienced scarcity during Phase 1 did not behave like those who had always been wealthy: they tended to administer fewer drugs and consequently showed a weaker causal illusion as well. That is, their behavior and judgments differed from those who did not experience an initial period of scarcity. On the other hand, participants exposed to scarcity during Phase 2, behaved similarly regardless of whether they had been wealthy in the past or whether they had always had scarce resources.

It is an interesting (yet somewhat unexpected) result that previous experience affects further behavior and judgments differently as a function of what the starting conditions are: whereas starting wealthy and switching to scarce resources seems not very different from having a scarce budget all along, those who switched from scarcity to wealth were more careful in their use of resources than those who were always wealthy, and this lower P(C) was reflected on a weaker causal illusion. This latter result is coherent with previous literature based on neuroimage studies which has found that a scarcity mindset causes changes in brain activity and neural mechanisms that are different from the ones recorded in an abundance mindset and that this difference is modulated by previous experiences of scarcity/abundance (Huijsmans et al., 2019; Jiang et al., 2021). In addition, and although our experiments were not designed to tap into this question, we found that participants facing scarcity valued the scarce resource more, thus replicating the results of previous research (Shah et al., 2015 and 2018; Williams et al., 2016).

The current study has some limitations. The most important one is that it is a laboratory experiment with fictitious scenarios. Laboratory studies are useful because they allow us to experimentally manipulate scarcity without affecting the real resources of the participant, and still gain insight into how their judgments and behavior change as a result. On the other hand, the generalizability of the conclusions is to some extent compromised as we have not tested whether our results would be similar in real-life situations. Thus, further studies should test the generality of the present results in natural conditions in which economic scarcity exists (see Willett & Rottman, 2021, for an example of ecological research in the causal learning domain). Nonetheless, the effect of economic scarcity on the causal illusion that we have documented seems robust (i.e., three experiments in the present report) and the effect size is large by psychology standards. This suggests that it would be likely to observe the effect in real-life situations.

We would like to conclude by arguing that understanding how to reduce the causal illusion can be highly relevant to improving performance in real-life situations. Thus, the present study opens a broad range of implications in real life, applying to situations where scarcity or abundance exist and where the accurate detection of causal relationships is important. For example, people with more resources to spend on so-called Complementary-Alternative Medicine (CAM) might end up using these treatments more often and hence might develop the illusion that they are causally effective against certain diseases. In fact, this is coincident with survey data suggesting that rich people are more likely to resort to pseudomedicine, and also with the high irrational beliefs and pseudoscience use in wealthy countries (European Commission 2020 and 2021). The same logic can be applied to other domains in addition to health: detecting ineffective educational methods, unprofitable investments, or worthless consumer products, in general, might be harder in conditions of abundance. Thus, it is possible that causal illusions can produce problems and bad decisions in many of these domains, especially for those who have plenty of resources to invest. Our research can be useful in these situations because (a) it helps identify those profiles who are more likely to fall prey to the illusion (e.g., those with plenty of resources to invest in health or educational products not supported by evidence), and (b) it proposes ways to limit the causal illusion. Specifically, in those situations in which resource use can be limited without negative consequences for people, highlighting scarcity might be an effective strategy to prevent causal illusions. This can easily be done, for instance, by reminding people that a resource (for example budget) is limited so it must be used carefully. Such reminders have proven to help people manage their resources more effectively (Mullainathan & Shafir, 2013) and they might as well reduce the causal illusion.

To conclude, we suggest that it would be interesting to explore whether scarcity can also influence other cognitive biases, in addition to the causal illusion. In case scarcity is found to be a variable that modulates other cognitive biases, it would be possible to identify individuals or collectives at higher risk of biases, as well as to design interventions to reduce them and improve quality of life.

Declaration of competing interest

The authors declare no conflicts of interest.

Data availability

Data and materials for these experiments are openly available in the Open Science Framework at https://osf.io/dh2jn/

Acknowledgements

Support for this research was provided by Grant PID2021-126320NB-I00 funded by MCIN/AEI/10.13039/501100011033 and by ERDF A way of making Europe, as well as Grant IT1696-22 from the Basque Government. A.V. was supported by Fellowship FPU20/01009 from Ministerio de Universidades. The funders had no role in the study design, data collection, and analysis, decision to publish, or preparation of the manuscript.

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