

The Sin of Prediction: When Mentally Simulated Alternatives Compete With Reality

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Abstract

Experiential and associative learning are essential to optimal decision making. However, research shows that, even when exposed to repeated trials, people often fail to learn probabilities and cause/effect covariations. Consistent with the counterfactual inflation hypothesis, it is proposed that counterfactuals can interfere with memory of repeated exposures and therefore inhibit learning. Five experimental studies tested counterfactual thinking as a potential mechanism underlying this learning deficit using a simple, biased coin flipping paradigm. Participants were instructed to either simply observe or to predict and observe outcomes of a biased coin being flipped in multiple trials (Experiments 1–4). In all four experiments, counterfactual thought frequency mediated the relationship between task instructions and the extent of bias detection (i.e., learning). Experiment 5 showed that mental simulations of alternative outcomes were especially deleterious to learning and decision making. Findings are discussed in light of experiential learning theory and applied implications.

Keywords

counterfactual thinking, decision making, prediction, learning

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Knowledge gained from experience is critical to optimal decision making (Gershman, Markman, & Otto, 2014; Yechiam & Busemeyer, 2005). People use the information they gain from the events they experience as building blocks of their decision-making process (e.g., Ariel, 2013; Bohil & Wismer, 2014; Collins, Percy, Smith, & Kruschke, 2011). Clearly, without the ability to call on knowledge gained from experience, one's ability to make good decisions would be severely compromised.

However, after exposure to repeated trials of the same stimulus event, people often draw conclusions from their experience that are not supported by the data they gain, suggesting a lapse in experiential and associative learning (Petrocelli & Harris, 2011; Petrocelli, Seta, & Seta, 2013). Furthermore, people are more sensitive to contingency information when it is displayed in summary (e.g., organized in a table) than when the same information is presented via exposure to repeated trials (Kao & Wasserman, 1993; Ward & Jenkins, 1965). Unfortunately, in practice, information is rarely presented in summary format. Instead, learning the associations between events, situational features, or stimuli can often only be acquired through experiencing or recognizing their covariation.

Despite the commonly held assumption that experience improves people's judgments, human learning from outcome feedback tends to be surprisingly slow and limited (Hammond, Summers, & Deane, 1973). Furthermore, people appear to be very poor at learning probabilities from repeated-trial tasks

(Newell & Rakow, 2007; Wasserman, Elek, Chatlosh, & Baker, 1993). In his review of the experiential learning literature, Brehmer (1980) argued that people often have an incorrect conception of experience and that outcome feedback is unlikely to result in substantial improvements in performance in probabilistic tasks. For instance, when people are shown statistical properties over blocks of trials, rather than the outcomes of single trials, learning is generally faster and better than with outcome feedback (Todd & Hammond, 1965).¹

The study of how people infer causation and covariation also reveals less-than-optimal associative learning from trial-by-trial series studies (see Kao & Wasserman, 1993; Lober & Shanks, 2000; Shanks, 2004; Ward & Jenkins, 1965; Wasserman et al., 1993). If learning interference underlies the repeated-trial experiential learning deficit, an investigation into what might be causing such a memory deficit is warranted.

Counterfactual Thinking

We propose that a potential cause of repeated-trial experiential learning deficiency is counterfactual thinking. Counterfactual

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thinking involves post-hoc, spontaneously generated, mental simulations of alternatives to reality (Byrne, 2005; Kahneman & Tversky, 1982; Markman, Gavanski, Sherman, & McMullen, 1993; Roese, 1997). Counterfactual statements have a tendency to take the form of an “if only . . . then . . .” structure, in which an alternate precursor to an event is mentally simulated, which is then followed by a mental simulation of an alternate outcome. Counterfactual thoughts can be upward (i.e., mental simulations better than reality) or downward (i.e., mental simulations worse than reality; Markman et al., 1993). Counterfactual thoughts are quite ubiquitous; research shows that they are generated regularly and throughout an individuals’ life (Landman & Manis, 1992).

What is the connection between counterfactual thinking and learning? Clearly, it is intuitive to expect counterfactual thoughts to enhance learning. In fact, a functional view of counterfactual thinking was endorsed by earlier accounts (Markman et al., 1993; Roese, 1997), as counterfactual thoughts often prescribe behavioral changes for the future. The functional view of counterfactual thinking contends that counterfactuals aid in performance by aiding in identifying cause–effect/if–then relationships and by enhancing preparation or planning behavior (see Epstude & Roese, 2008; Markman et al., 1993; Roese, 1997). Studies, such as Nasco and Marsh (1999) offer support for this conclusion. More recently, when differentiating upward counterfactuals further into additive (“If only I had . . .”) versus subtractive (“If only I hadn’t . . .”), it was found that additive counterfactual thoughts specifically improved future performance on a negotiation task (Kray, Galinsky, & Markman, 2009). There also seems to be some support for the mechanism of the content-neutral pathway (Epstude & Roese, 2008), in which ancillary effects from the generation of counterfactual thoughts cause beneficial behavioral change.

However, we propose that the functional or dysfunctional possibilities of counterfactual thinking depend on the mechanisms that facilitate versus inhibit performance on a task. One key property of a focal task that may result in a dysfunctional effect of counterfactuals is when memory plays a key role in discovering a pattern or concept rule across repeated trials. In fact, research conducted by Petrocelli and Crysel (2009), Petrocelli and Harris (2011), and Petrocelli et al. (2013) suggests that counterfactuals may impair memory, learning, and decision making in probabilistic tasks. Thus, we further propose that counterfactuals may lead to a repeated-trial experiential learning deficit due to their impact on memory.

Related research, conducted by Petrocelli and Harris (2011), examined decision behavior and counterfactual thinking in the context of the Monty Hall Problem.² Petrocelli and Harris showed that repeated trials did not increase performance on a task, and that the more counterfactuals that were generated, the less success individuals had in learning the concept rule necessary for maximizing performance. Indeed, the Monty Hall problem is one in which participants are often stubborn in their tendency to persist using suboptimal strategies. Specifically, Petrocelli and Harris showed

that switch-losses (in which the correct strategy leads to a loss) lead to a greater frequency of counterfactual thoughts than stick-losses (in which the incorrect strategy leads to a loss), and that counterfactualized switch-losses were negatively associated with improvement on the task (i.e., learning as evidenced by subsequent switch-decisions).

Another study conducted by Petrocelli, Seta, Seta, and Prince (2012) showed that counterfactual thought generation was associated with worse performance on future academic tests. Furthermore, this relationship was mediated by studying behavior: those who generated counterfactual thoughts were less likely to study. It was reasoned that mentally simulating a performance better than reality in a particular domain reduced one’s perceived need to study material in that domain.

Koehler (1991) argued that mentally simulating future events leads one to temporarily treat the event as if it were actually true in the present time, thereby strengthening one’s confidence and perceived likelihood of the event taking place in the future. Similarly, we believe that counterfactual thoughts, which mentally alter the past, distort memory either by temporarily treating the alternatives as if they actually occurred or by simply taking focus off of what actually occurred. Using a repeated-trial task, Petrocelli et al. (2013) supported this assertion by demonstrating a learning deficit linked to counterfactual thoughts. Participants were asked to judge fictitious stock performances that followed a simple and predictable pattern, of which the participants were not explicitly informed; the participants who spontaneously generated counterfactuals were less likely to discover the simple pattern of outcomes (i.e., 40 trials of A, B, A, B, A, B . . .). In another study, those who were asked to generate counterfactuals following repeated trials were also less likely to notice the pattern than were their counterparts who were asked to simply list the first thoughts that came to mind. A memory interference process was theorized to underlie the link between counterfactuals and experiential learning.

The memory trace interference underlying the theory of dysfunctional counterfactual thoughts is made more explicit by Petrocelli and Crysel’s (2009) report, which elucidates the “counterfactual inflation hypothesis.” The production of counterfactual thoughts led to inflating the number of blackjack wins players thought they had experienced. Thus, the actual act of generating counterfactuals can lead to distortions in memory. Essentially, as they form memory representations of reality, people appear to also store representations of alternatives to reality, which appear to distort their personal versions of reality. Such phenomena are consistent with evidence suggesting interference between counterfactual thoughts and memory (also see Garry, Manning, Loftus, & Sherman, 1996; Garry & Polaschek, 2000; Gerlach, Dornblaser, & Schacter, 2014; Goff & Roediger, 1998).

However, a focus of the current investigation is absent from earlier accounts of the effect of counterfactual thoughts: memory, and the possibility that counterfactual thoughts mediate the connection between experiential learning and

memory and decision making. If counterfactuals influence behavior as described by the functional theory, then there should be no repeated-trial experiential learning deficit. That is, the more exposure to a stimulus or environment a person receives, the more functional counterfactuals should be, and learning should be facilitated. However, the dysfunctional view of counterfactuals makes a very different prediction. That is, under the dysfunctional model, counterfactuals generated by a repeated trial paradigm should obscure the true nature of any associations, leading to a repeated-trial experiential learning deficit.

Overview of Experiments

If counterfactual thoughts interfere with learning in the context of multiple observations of the same event, then conditions under which the generation of counterfactuals is reduced should reduce the deleterious effect of counterfactuals. Thus, we designed a very simple procedure to test this hypothesis. Participants in each of five studies were repeatedly exposed to videos of a single coin being flipped. Unbeknownst to our participants, the coin was biased to land on one easily identifiable side more than the other in either 67% or 75% of the trials. The association to be learned from the repeated trials was between the coin itself and its probability of a biased outcome. Ability to recognize the bias was measured by how well participants recalled the frequency of the biased side, as well as predictions of future outcomes.

In Experiment 1 and Experiment 2, participants were assigned to either (a) observe, or (b) predict, and then observe, several coin flips. Experiment 3 employed a manipulation whereby participants were assigned to either (a) predict and observe the coin flips, or (b) predict and focus on the actual outcome of the coin flips. Experiment 4 also explored the possibility that a memory distortion is manifested at the moment of prediction rather than during the processing of outcomes. We were interested in spontaneous counterfactual responses, and thus in each of the first four experiments we asked participants how frequently they generated counterfactual thought responses after collecting data on variables necessary to calculate recognition of the bias in the coin. Finally, Experiment 5 explored more directly the particular content of counterfactuals (i.e., mental simulations of alternative antecedents vs. alternative outcomes) that appears to negatively affect learning.

There are at least two reasons to believe that predicting coin flip outcomes would lead to the generation of significantly more counterfactuals than simply observing the same outcomes. First, and more generally, predictors are conceivably more invested in the outcomes of the activity, as they are active rather than passive participants. The more involved an individual is in the situation, the more counterfactuals they tend to generate (Macrae & Milne, 1992; Meyers-Levy & Maheswaran, 1992). Second, predicting the outcomes of events sets the stage for being either correct or incorrect over

multiple trials, whereas simply observing the outcomes of the same events does not. Undesirable outcomes are closely tied with greater counterfactual thought production; they are more readily available when outcomes are negative (Gavanski & Wells, 1989), and are more often produced by negative outcomes than neutral or positive outcomes (Markman et al., 1993). By definition, the observation of mundane experiences, such as coin flips, should be neutral and associated with lower levels of counterfactual thought generation.

Consistent with earlier research on the connections between counterfactual thinking, vested interest, and personally experienced, undesirable outcomes (Gavanski & Wells, 1989; Macrae & Milne, 1992; Markman et al., 1993; Meyers-Levy & Maheswaran, 1992), we hypothesized that participants assigned to the prediction conditions would report a greater frequency of counterfactual thought responses than participants assigned to the observer (and prediction/focus on the actual outcome) conditions. Consistent with earlier research connecting counterfactual thinking to memory distortions (e.g., Petrocelli & Crysel, 2009; Petrocelli & Harris, 2011), we hypothesized that counterfactual thinking would also set the stage for an indirect effect of our task condition manipulation on experiential learning and decision making. In other words, we expected the frequency of counterfactuals to mediate the relationship between our task condition manipulation and the recognition of bias in the stimulus, as well as the relationship between our task condition manipulation and subsequent decisions that are relevant to such experiential learning.

Experiment 1

Experiment 1 was designed to test the effects of observing versus predicting outcomes on counterfactual thinking and experiential learning. Participants were asked to either observe or predict, and then observe, the same coin (one side blue and one side black) being flipped in 40 trials. In each of five blocks of eight trials, separated by a brief anagram task, the coin landed on the blue (biased) side in six of the trials (75%) and landed on the black side in two of the trials (25%). We then asked participants to recall the number of trials in which the coin landed on the blue and black sides as well as their estimates of spontaneous counterfactual thought responses. We hypothesized that counterfactual thinking would mediate the relationship between the task condition and learning that the coin was biased.

Method

Participants and design. A total of 30 (46.9% female) Wake Forest University undergraduate students participated in the study. The experiment employed a single-factor, between-subjects experimental design in which participants were randomly assigned to one of two conditions, the observation

condition ($n = 16$) and the prediction condition ($n = 14$). Dependent variables included Outcome Performance, Proportion of Biased Outcome Predictions, Estimated Number/Proportion of Biased Outcomes, as well as self-report measures to determine the frequency by which counterfactual thoughts were spontaneously generated by the participants.

Procedure. All of the participants were recruited through the online Wake Forest University participant pool, signed an informed consent form to participate in a 60-min research session, and received partial course credit for their participation. Participants were then led to a private cubicle equipped with a personal computer. The experiment employed MediLab v2012 (Jarvis, 2012) to present all experimental instructions and stimuli. Participants remained in their assigned cubicles for the duration of the experimental protocol. Participants were informed that they would be asked to observe pre-recorded videos of a blue/black coin being flipped and to complete a self-administered questionnaire.

Task conditions. All participants were instructed to pay attention to the pre-recorded coin flip videos as they were also informed that they would be asked about the coin flips later in the study. Participants were randomly assigned to one of two task conditions. Participants assigned to the *observation condition* were instructed to simply observe each coin flip. Participants assigned to the *prediction condition* were asked to make predictions concerning the outcome of each upcoming coin flip by checking a BLUE or BLACK box on the screen frame prior to each video.

Anagram task. The addition of a cognitive load task was employed to ensure that the coin flipping task was not so simple that participants could count the number of blue and black outcomes. Thus, both task conditions were informed that, to vary cognitive load they would be periodically presented with an anagram task in which they were to unscramble five letters given to them to make a word. It was explained to participants that, in previous studies, researchers found an association between performance on the task and intelligence. Such subterfuge was employed to help ensure attention and precision on the upcoming task.

Coin flipping trials. Participants in both task conditions were then forwarded to the primary experimental procedures. These procedures involved a questionnaire in which 40 coin flip videos were displayed, divided into five blocks of eight videos each, with associated prompts around the videos depending on the condition and one anagram task (consisting of a single anagram item) at the end of each block. The blocks were not delineated for the participants beyond the regular occurrence of the anagram tasks. The bias of the videos within each block was always six videos of the coin landing on the biased blue side ("blue flips") to two videos of the coin landing on the black side ("black flips"). The order of the vid-

eos within each block was randomized during questionnaire construction but remained consistent between participants.

Observation condition participants were instructed to simply observe each video and to proceed to the next video by clicking a continue button. Prediction condition participants were instructed to make a selection for each trial, by clicking a black or blue button.

After the first block of eight trials, participants in both conditions were given the instructions for the anagram task, examples for completed anagrams, and then given one to solve themselves. After typing in their completed anagrams, participants moved on the next block of videos. At the completion of the 40 videos and five anagram tasks, both task conditions answered the three sets of questions. The first set of questions concerned the anagram tasks and was not relevant to the conclusions of the current study.

Dependent variables. The next set of questions served as the dependent variables, addressing the degree to which participants detected the 75% bias of the coin that they observed. Specifically, participants were asked two questions: "With regard to the black/blue coin, how many black [blue] outcomes did you see?" Responses to these items were used to calculate Estimated Number/Proportion of Biased Outcomes; Outcome Performance and Proportion of Biased Outcome Predictions were calculated for prediction condition participants on the basis of their predictions and outcomes.

Counterfactual Thought Frequency. The final set of questions concerned the potential mediator, how frequently participants generated counterfactual thoughts during the coin flipping task. Specifically, participants answered "Now we would like you to think back to the coin flipping task. After you received feedback for coin flipping trials, how often did you generate an 'If only . . . ' thought (i.e., think about alternatives to what actually occurred in the trial)?" and "When the black/blue coin was flipped, how often did you think about alternatives to what actually happened in the trial?" using responses scales with 1 (*very infrequently*) and 7 (*very frequently*) as the anchor labels. Responses to these two items were averaged, producing a single Counterfactual Thought Frequency score.

Once each participant had finished the protocol, he/she was debriefed and permitted to leave without further interaction with the research assistant.

Results and Discussion

Learning. Overall, the sample reported an average of 23.93 ($SD = 6.97$) Estimated Number of Biased Outcomes (i.e., estimated number of blue outcomes indicated by the participants) and an average of 0.63 ($SD = 0.12$) Estimated Proportion of Biased Outcomes (i.e., estimated number of blue outcomes divided by the sum of the estimated blue and black outcomes). Using single-sample t tests, we found these

estimates to be significantly different from 20.00 and 0.50 respectively (i.e., the values that would be expected given a complete lack of bias detection), $t(29) = 3.09, p = .004$, and $t(29) = 6.14, p < .001$. Thus, participants reported observing significantly more biased-side coin flip outcomes than chance would predict. However, the biased-side outcome estimates were also significantly different from the actual bias displayed by the coin (i.e., 30.00 and 0.75 respectively), $t(29) = -4.77, p < .001$, and $t(29) = -5.41, p < .001$. These results suggest that, while both conditions did detect some bias in the coin, they were unsuccessful at detecting it to the extent that it existed.

Although consistent with the expected direction of the results, one-way analysis of variance (ANOVA) tests revealed that observation condition participants failed to report a greater Estimated Number of Biased Outcomes ($M = 25.13, SD = 7.09$) and Estimated Proportion of Biased Outcomes ($M = 0.64, SD = 0.11$) than did their prediction condition counterparts ($M = 22.57, SD = 6.84$ and $M = 0.62, SD = 0.13$), $F(1, 29) = 1.00, p = .33$, and $F(1, 29) = .15, p = .70$, respectively.

Among the prediction condition participants, Outcome Performance (i.e., proportion of correct predictions; $M = 0.54, SD = 0.11$) was uncorrelated with both Estimated Number of Biased Outcomes, $r(12) = .31, p = .29$, and Estimated Proportion of Biased Outcomes, $r(12) = .09, p = .77$. Likewise, the Proportion of Biased Outcome Predictions (i.e., proportion of trials in which the blue side was selected; $M = 0.55, SD = 0.16$) was uncorrelated with both Estimated Number of Biased Outcomes, $r(12) = .42, p = .13$, and Estimated Proportion of Biased Outcomes, $r(12) = .32, p = .27$. These results suggest that learning was not enhanced during the task by the performance achieved in predicting outcomes.

Counterfactual Thought Frequency. The sample mean for the Counterfactual Thought Frequency measure was 4.20 ($SD = 1.90$). Consistent with expectations, prediction condition participants reported generating significantly more counterfactuals in response to the coin flips ($M = 5.07, SD = 1.57$) than did observation condition participants ($M = 3.44, SD = 1.87$), $F(1, 29) = 6.62, p = .02$.

Mediation analysis. The results suggest that while there was a significant effect of Task Condition on Counterfactual Thought Frequency, Task Condition failed to directly affect our indicators of bias detection. However, our hypothesis regarding mediation via Counterfactual Thought Frequency requires an indirect test of the effect of Task Condition on the bias detection indicators. To test this potential mediation, a bootstrap procedure, as recommended by Preacher and Hayes (2004, 2008), was employed. This method tests the significance of the indirect effect of Task Condition on detection of the bias, through the mediator of Counterfactual Thought Frequency. Furthermore, this method constructs bias-corrected confidence intervals (CIs) based on 5,000 random samples with replacement from the full sample. Specifically, this method

tests whether or not the size of an indirect effect differs significantly from zero. In this analysis, the observation condition was coded as 0 and the prediction condition was coded as 1.

Reflecting the ANOVA results reported above, the correlation between the Task Condition and Counterfactual Thought Frequency was statistically significant, $r(28) = .44, p = .02$. Also reflecting the ANOVA results, the correlations between the Task Condition and Estimated Number and Proportion of Biased Outcomes were not statistically significant; see the top and bottom panels of Figure 1. Consistent with expectations, however, the correlations between the proposed mediator (Counterfactual Thought Frequency) and Estimated Number and Proportion of Biased Outcomes were statistically and marginally significant, respectively.

Using the Estimated Number of Biased Outcomes as the dependent variable, the bootstrap procedure revealed the size of the indirect effect to be 2.48 ($SE = 1.16$); the CI excluded zero, 95% CI [.662, 5.565].

Using the Estimated Proportion of Biased Outcomes as the dependent variable, the bootstrap procedure revealed the size of the indirect effect to be -0.04 ($SE = 0.03$); the CI excluded zero, 95% CI $[-.113, -.003]$.

These results indicate that, while the effects of Task Condition on the dependent variables were not direct, there was a significant indirect effect through Counterfactual Thought Frequency. Thus, prediction condition participants produced significantly more counterfactuals than their observation condition counterparts. Subsequently, those participants who produced greater frequencies of counterfactual thoughts were less likely to detect the bias in the coin flips.

Experiment 1 supported our hypotheses regarding the links between the act of predicting outcomes, counterfactual thinking, and recognition of bias in a stimulus. The data suggest that learning is inhibited by counterfactual thinking. However, it is also possible that the act of predicting outcomes requires greater attention than does simply observing the same outcomes, thereby leaving predictors less attentive to reality than their counterparts. Experiment 2 was designed to examine this possibility and serve as an initial replication of our findings.

Experiment 2

Experiment 2 employed the same methods as those employed in Experiment 1 with two exceptions. First, the coin was biased to land on the blue side in 67.50% of the 40 trials (27 times). Second, after participants in both the prediction and observation conditions viewed each coin flip video, they were asked to report the actual outcome of the flip. Although this additional task, measuring proximal attention, may create an otherwise artificial focus on reality, it does not necessarily reduce the likelihood of counterfactual thinking and its potential deleterious effects. In fact, some degree of attention to reality is needed for the default mode of counterfactual thinking (i.e., evaluative counterfactual thinking; see Markman & McMullen, 2003) whereby people compare

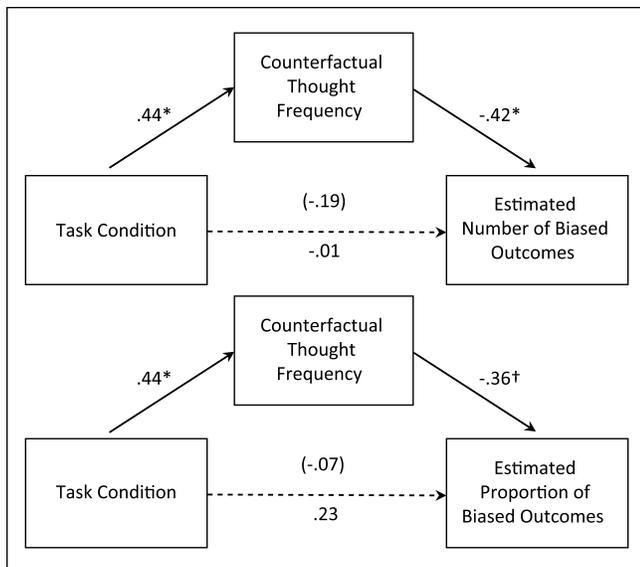


Figure 1. Mediation of the relationships between Task Condition and Estimated Number of Biased Outcomes and Estimated Proportion of Biased Outcomes by Counterfactual Thought Frequency (Experiment 1).

† $p = .09$. * $p < .05$.

reality to its alternatives. Furthermore, we reasoned that if failure to detect bias in the coin occurred even when attention to reality was not diminished (especially for prediction condition participants), such findings would demonstrate the robustness of the effect.

Method

Participants and design. A total of 128 (67.2% female) Wake Forest University undergraduate students participated in the study. All of the participants were recruited through the online Wake Forest University participant pool, signed an informed consent form to participate in a 60-min research session, and received partial course credit for their participation.

The experiment employed a single-factor, between-subjects experimental design in which participants were randomly assigned to one of two conditions, the observer condition ($n = 64$) and the predictor condition ($n = 64$). Dependent variables included Outcome Performance, Proportion of Biased Outcome Predictions, Estimated Number/Proportion of Biased Outcomes, Attention Accuracy, as well as self-report measures to determine the frequency by which counterfactual thoughts were spontaneously generated by the participants.³

Procedure. The procedures employed in Experiment 2 were identical to those employed in Experiment 1. However, the coin was biased to land on the blue side in 67.50% of the 40 trials (27 times). Also, after the display of each coin flipping video, we probed for attention to the actual outcome of the

coin flip. Specifically, participants were asked, “What was the outcome of the last coin flip that you observed?” Participants selected BLACK or BLUE, and then advanced to the next trial (or anagram).

Results and Discussion

Learning. Overall, the sample reported an average of 21.02 ($SD = 4.84$) Estimated Number of Biased Outcomes and an average of 0.52 ($SD = 0.11$) Estimated Proportion of Biased Outcomes. These estimates were significantly different from 20.00 and 0.50 respectively (i.e., the values that would be expected given a complete lack of bias detection), $t(127) = 2.37, p = .02$, and $t(127) = 1.96, p = .05$. Thus, participants reported observing significantly more biased-side coin flip outcomes than chance would predict. However, the biased-side outcome estimates were also significantly different from the actual bias displayed by the coin (i.e., 27.00 and 0.67 respectively), $t(127) = -13.98, p < .001$, and $t(127) = -15.48, p < .001$. Similar to our Experiment 1 results, these results again suggest that, while both conditions did detect some bias in the coin, they were unsuccessful at detecting the extent that it existed.

Consistent with expectations, observation condition participants reported a greater Estimated Number of Biased Outcomes ($M = 22.00, SD = 4.73$) than did their prediction condition counterparts ($M = 20.03, SD = 4.79$), $F(1, 126) = 5.48, p = .02$. Observation condition participants also reported a marginally greater Estimated Proportion of Biased Outcomes ($M = 0.54, SD = 0.10$) than did their prediction condition counterparts ($M = 0.50, SD = 0.11$), $F(1, 126) = 2.91, p = .09$.

Among the prediction condition participants, Outcome Performance (i.e., proportion of correct predictions; $M = 0.44, SD = 0.16$) was uncorrelated with both Estimated Number of Biased Outcomes, $r(62) = .15, p = .25$, and Estimated Proportion of Biased Outcomes, $r(62) = .08, p = .50$. Likewise, the Proportion of Biased Outcome Predictions (i.e., proportion of trials in which the blue side was selected; $M = 0.58, SD = 0.26$) was uncorrelated with both Estimated Number of Biased Outcomes, $r(62) = .08, p = .52$, and Estimated Proportion of Biased Outcomes, $r(62) = .14, p = .26$. These results suggest, again, that learning was not enhanced during the task by the performance achieved in predicting outcomes.

Attention Accuracy. Attention Accuracy was calculated by dividing the total number of correct outcome responses by 40. The sample mean for Attention Accuracy was 0.92 ($SD = 0.10$), indicating excellent attention to the proximal outcomes; in fact, 33% of the sample recorded a perfect Attention Accuracy score. A one-way ANOVA revealed that prediction condition participants ($M = 0.92, SD = 0.11$) did not differ from their observation condition counterparts ($M = 0.93, SD = 0.09$), $F(1, 126) = .12, p = .74$. Furthermore, Attention Accuracy did not correlate significantly with

Estimated Number of Biased Outcomes ($r = -.01, p = .95$), Estimated Proportion of Biased Outcomes ($r = .04, p = .67$), nor Counterfactual Thought Frequency ($r = -.06, p = .51$). Thus, we conclude that any differences in attention between the task conditions cannot explain the differences we observed with regard to Counterfactual Thought Frequency, and we thereby excluded Attention Accuracy from all subsequent analyses.

Counterfactual Thought Frequency. The sample mean for the Counterfactual Thought Frequency measure was 4.45 ($SD = 0.73$). Consistent with expectations, prediction condition participants reported generating significantly more counterfactuals in response to the coin flips ($M = 4.79, SD = 1.72$) than did observation condition participants ($M = 4.10, SD = 1.69$), $F(1, 126) = 5.21, p = .02$.

Mediation analysis. Building on the results of Experiment 1, our Experiment 2 results suggest that Task Condition can affect both Counterfactual Thought Frequency and indicators of bias detection. We were also interested in the possibility of an indirect effect of Task Condition on the bias detection indicators, via the mediation of counterfactual thinking. To test our hypothesis, we employed the same mediation procedures as those employed in Experiment 1.

Reflecting the ANOVA results reported above, the correlation between the Task Condition and Counterfactual Thought Frequency was statistically significant, $r(126) = .20, p = .02$. Also reflecting the ANOVA results, the correlations between the Task Condition and Estimated Number and Proportion of Biased Outcomes were statistically and marginally significant, respectively; see the top and bottom panels of Figure 2. Consistent with expectations, however, the correlations between Counterfactual Thought Frequency and Estimated Number and Proportion of Biased Outcomes were statistically significant.

Using the Estimated Number of Biased Outcomes as the dependent variable, the bootstrap procedure revealed the size of the indirect effect to be -0.46 ($SE = 0.25$); the CI excluded zero, 95% CI $[-1.101, -.076]$.

Using the Estimated Proportion of Biased Outcomes as the dependent variable, the bootstrap procedure revealed the size of the indirect effect to be -0.01 ($SE = 0.006$); the CI excluded zero, 95% CI $[-.025, -.002]$.

These results indicate that Counterfactual Thought Frequency mediated the effects of Task Condition on the dependent variables. As in Experiment 1, prediction condition participants produced significantly more counterfactuals than their observation condition counterparts. Subsequently, those participants who produced greater frequencies of counterfactual thoughts were less likely to detect bias in the coin.

Our results also suggest that attention to the actual outcomes was, on average, nearly perfect. Consistent with associative learning principles, we would expect better attention to the actual outcomes to align with detection of bias in the

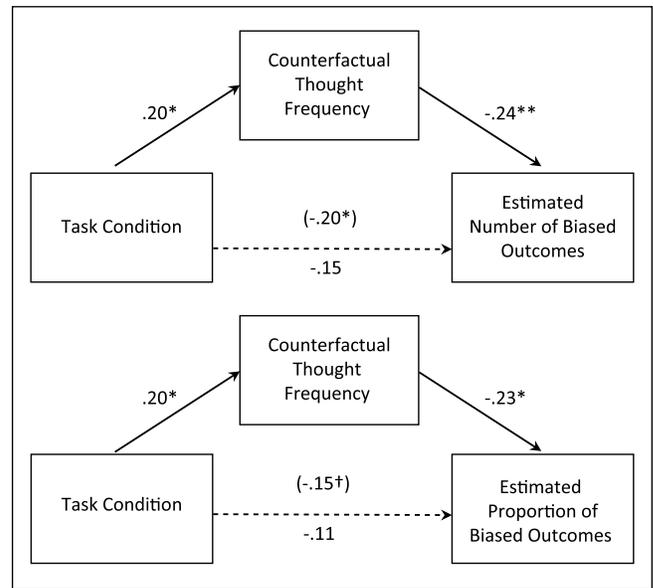


Figure 2. Mediation of the relationships between Task Condition and Estimated Number of Biased Outcomes and Estimated Proportion of Biased Outcomes by Counterfactual Thought Frequency (Experiment 2).

† $p = .09$. * $p < .05$. ** $p < .01$.

coin. However, we found no such evidence in favor of this assumption. Although attention appeared to be excellent for the proximal outcomes, we believe that counterfactual thinking permits the aggregated representation of the outcomes, or the more distal pattern emerging from several trials, to become distorted. Consistent with earlier research on learning inhibition via counterfactual thinking (e.g., Petrocelli & Harris, 2011), the coin flipping paradigm appears to be another context whereby minimal to moderate frequencies of counterfactual thoughts can distort memory for actual occurrences. Because attention to detail appeared to be very good while the coin flipping outcomes were occurring, yet did not appear to contribute to learning, the deleterious effect of counterfactuals appears to be characterized by a memory-based, as opposed to an online, processing effect.

Although we successfully replicated our findings from Experiment 1, and ruled out attention as an explanation for our effects, there remain inherent differences between simply observing outcomes and consciously predicting and then observing them. For instance, it is possible that our prediction condition participants were more motivated to perform well and expended greater regulatory resources than their observation condition counterparts, thereby reducing resources necessary to accurately process outcomes. It is also possible that prediction condition participants may have also been more affectively impacted by the outcomes. Thus, in Experiment 3, we again attempted to replicate our effects by comparing two prediction conditions that would retain the difference in counterfactual thinking needed to test our mediation hypothesis.

Experiment 3

Experiment 3 was designed to again test the possibility that counterfactual thinking mediates the link between predicting and learning inhibition. Importantly, we do not contend that there is anything inherently wrong with simply predicting the outcomes of events. We propose that the “sin” of prediction is not found in the act of predicting itself, but rather in the mental activity that can occur after the prediction is made. It seems that in the context of making several predictions and observing their outcomes, the predictor’s memory of reality can become distorted as he/she forms a mental representation of the aggregated set of outcomes, shaped in part by counterfactual alternatives. If such mental activity is in fact underlying the effects we demonstrated in Experiment 1 and Experiment 2, it should be possible to eliminate or reverse the deleterious effect of counterfactual thinking on learning. We suggest that one way to eliminate the effect is to focus the predictor’s attention on reality (i.e., the actual outcomes) rather than permitting them to divide it across reality and its alternatives. In fact, Seta, Seta, Petrocelli, and McCormick (2015) have shown that instructing people to focus only on what actually happened can significantly reduce the frequency of spontaneous counterfactual thought responses.

In Experiment 3, all participants were asked to predict the outcomes of coin flips. However, half of the participants were assigned to the same prediction task instructions employed in Experiment 1 and Experiment 2. The other half of the participants followed the same instructions with one exception. Specifically, the latter participants were instructed to focus only on the outcome of each coin flipping trial. We expected our prediction/focus on actual outcomes condition to be less likely to generate counterfactuals but more likely to show evidence of learning than their prediction condition counterparts.

Ultimately, the degree of bias detected in a stimulus or system is only functional to the degree by which it affects behavior. To determine the degree to which recognized bias in the coin affected behavior, we asked participants to make 10 additional predictions of outcomes for the same coin they had observed over the 40 previous trials. The proportion of the biased outcome responses constituted this measure.

Method

Participants and design. A total of 43 (58.1% female) Wake Forest University undergraduate students participated in the study. All of the participants were recruited through the online Wake Forest University participant pool, signed an informed consent form to participate in a 60-min research session, and received partial course credit for their participation.

The experiment employed a single-factor, between-subjects experimental design in which participants were randomly assigned to one of two conditions, the prediction and focus on actual outcomes condition ($n = 21$) and the predictor condition ($n = 22$). Dependent variables included

Outcome Performance, Proportion of Biased Outcome Predictions, Estimated Number/Proportion of Biased Outcomes, Behavioral Intentions, Attention Accuracy, as well as self-report measures to determine the frequency by which counterfactual thoughts were spontaneously generated by the participants.

Procedure. Experiment 3 employed the same basic procedures employed in Experiment 1 (using the 3:1 ratio of blue-to black-side outcomes), but also included the attention measure first employed in Experiment 2.

Half of the participants were assigned to the same *prediction condition* task instructions employed in Experiment 1 and Experiment 2. The other half of the participants, comprising the *prediction and focus on actual outcomes condition*, followed the same instructions but were instructed to focus only on the outcome of each coin flipping trial. Specifically, the prediction and focus on actual outcomes condition read the following instructions before the first coin flipping trial: “Importantly, for each trial we just want you to focus on what actually happens in the trial. That is, don’t think about other things such as what might have happened; just focus on what actually happens.” Furthermore, during the display of each coin flip, the words “Focus only on what actually occurs in this trial.” were displayed above the video frame.

Behavioral Intentions. Following the final coin flipping trial, participants were asked to “Imagine that the BLACK/BLUE coin you have been witnessing was flipped in another 10 trials. What is your prediction of the first (X) trial?” This same question was repeated nine more times and in each instance participants responded by selecting the blue or black side.

Results and Discussion

Learning. Overall, the sample reported an average of 25.37 ($SD = 11.19$) Estimated Number of Biased Outcomes and an average of 0.63 ($SD = 0.12$) Estimated Proportion of Biased Outcomes. These estimates were significantly different from 20.00 and 0.50 respectively (i.e., the values that would be expected given a complete lack of bias detection), $t(42) = 3.15, p = .003$, and $t(42) = 7.06, p = .001$. Thus, participants reported observing significantly more biased-side coin flip outcomes than chance would predict. However, the biased-side outcome estimates were also significantly different from the actual bias displayed by the coin (i.e., 30.00 and 0.75 respectively), $t(42) = -2.71, p = .01$, and $t(42) = -6.57, p < .001$. Similar to our Experiment 1 and Experiment 2 results, these results again suggest that, while both conditions did detect some bias in the coin, they were unsuccessful at detecting the extent that it existed.

Consistent with expectations, prediction/focus condition participants reported a greater Estimated Number of Biased Outcomes ($M = 29.71, SD = 12.10$) than did their prediction condition counterparts ($M = 21.23, SD = 8.61$),

$F(1, 41) = 7.08, p = .01$. Prediction/focus condition participants also reported a greater, but non-significant, Estimated Proportion of Biased Outcomes ($M = 0.66, SD = 0.12$) than did their prediction condition counterparts ($M = 0.60, SD = 0.11$), $F(1, 41) = 2.14, p = .15$.

The relationships between performance and decisions favoring the bias of the coin depended greatly on Task Condition. Among participants who simply predicted coin flipping outcomes, the pattern of data mirrored the results found in Experiments 1 and 2. Outcome Performance (i.e., proportion of correct predictions; $M = 0.47, SD = 0.10$) was uncorrelated with both Estimated Number of Biased Outcomes, $r(20) = .11, p = .63$, and Estimated Proportion of Biased Outcomes, $r(20) = -.06, p = .79$. Likewise, the Proportion of Biased Outcome Predictions (i.e., proportion of trials in which the blue side was selected; $M = 0.47, SD = 0.18$) was uncorrelated with both Estimated Number of Biased Outcomes, $r(20) = .13, p = .58$, and Estimated Proportion of Biased Outcomes, $r(20) = .11, p = .65$. However, among participants who predicted coin flipping outcomes and focused on the actual outcomes of the flips, the pattern of data was very different. Among these participants, Outcome Performance ($M = 0.48, SD = 0.15$) was marginally correlated with Estimated Number of Biased Outcomes, $r(19) = .41, p = .06$, and significantly correlated with Estimated Proportion of Biased Outcomes, $r(19) = .58, p = .01$. Likewise, the Proportion of Biased Outcome Predictions ($M = 0.45, SD = 0.26$) was significantly correlated with both Estimated Number of Biased Outcomes, $r(19) = .42, p = .05$, and Estimated Proportion of Biased Outcomes, $r(19) = .62, p = .003$. Interestingly, Task Condition did not significantly affect Outcome Performance, $F(1, 41) = .06, p = .81$, nor Proportion of Biased Outcome Predictions, $F(1, 41) = .05, p = .80$. In sum, these results suggest, again, that learning was enhanced during the task by the performance achieved in predicting outcomes, but only when participants were asked to focus on the actual outcomes of the events.

Attention Accuracy. The sample mean for Attention Accuracy was 0.95 ($SD = 0.04$), indicating excellent attention to the proximal outcomes. Prediction condition participants ($M = 0.96, SD = 0.04$) did not differ from their prediction/focus condition counterparts ($M = 0.95, SD = 0.03$), $F(1, 41) = .87, p = .36$. Furthermore, Attention Accuracy did not correlate significantly with Estimated Number of Biased Outcomes ($r = -.03, p = .83$), Estimated Proportion of Biased Outcomes ($r = .01, p = .94$), Counterfactual Thought Frequency ($r = .08, p = .63$), nor Behavioral Intentions ($r = .22, p = .14$). Attention Accuracy was excluded from all subsequent analyses.

Behavioral Intentions. For each participant, we calculated the proportion of predictions favoring the biased side of the coin. Our expectations were confirmed. Prediction/focus condition participants more frequently predicted outcomes favoring the biased side of the coin ($M = 0.71, SD = 0.24$) than did

their prediction condition counterparts ($M = 0.58, SD = 0.15$), $F(1, 41) = 4.17, p = .04$.

Counterfactual Thought Frequency. The sample mean for the Counterfactual Thought Frequency measure was 4.30 ($SD = 1.73$). Consistent with expectations, prediction condition participants reported generating significantly more counterfactuals in response to the coin flips ($M = 5.09, SD = 1.32$) than did prediction/focus condition participants ($M = 3.48, SD = 1.75$), $F(1, 41) = 11.77, p = .001$.

Mediation analysis. Reflecting the ANOVA results reported above, the correlation between the Task Condition and Counterfactual Thought Frequency was statistically significant, $r(40) = .47, p < .01$. Also reflecting the ANOVA results, the correlations between the Task Condition and Estimated Number of Biased Outcomes and Behavioral Intentions were statistically significant, whereas the correlation between Task Condition and Estimated Proportion of Biased Outcomes was marginally significant (see Figure 3). Consistent with expectations, however, the correlations between Counterfactual Thought Frequency and Estimated Number and Proportion of Biased Outcomes, and Behavioral Intentions, were statistically significant.

Using the Estimated Number of Biased Outcomes as the dependent variable, the bootstrap procedure revealed the size of the indirect effect to be -3.50 ($SE = 2.36$); the CI excluded zero, 95% CI $[-10.300, -3.999]$.

Using the Estimated Proportion of Biased Outcomes as the dependent variable, the bootstrap procedure revealed the size of the indirect effect to be -0.04 ($SE = 0.02$); the CI excluded zero, 95% CI $[-.104, -.011]$.

Using Behavioral Intentions as the dependent variable, the bootstrap procedure revealed the size of the indirect effect to be -0.11 ($SE = 0.04$); the CI excluded zero, 95% CI $[-.204, -.053]$. Because Behavioral Intentions were significantly correlated with Estimated Number of Biased Outcomes, $r(41) = .44, p = .003$, as well as Estimated Proportion of Biased Outcomes, $r(41) = .64, p < .001$, a final mediation model was calculated to determine if Counterfactual Thought Frequency mediated the Task Condition–Behavioral Intentions link above and beyond that which could be explained by any detection of bias by including Estimated Number and Proportion of Biased Outcomes as mediators in the model. The total effect of this model was -0.08 ($SE = 0.04$) and the CI excluded zero, 95% CI $[-.175, -.001]$. Estimated Number of Biased Outcomes did not indicate significant mediation -0.02 ($SE = 0.03$), 95% CI $[-.103, .013]$ nor did Estimated Proportion of Biased Outcomes 0.01 ($SE = 0.03$), 95% CI $[-.040, .061]$. However, the analysis did support the conclusion that Counterfactual Thought Frequency significantly mediated the Task Condition–Behavioral Intentions link above and beyond that which could be explained by any detection of bias -0.06 ($SE = 0.03$), 95% CI $[-.150, -.012]$.

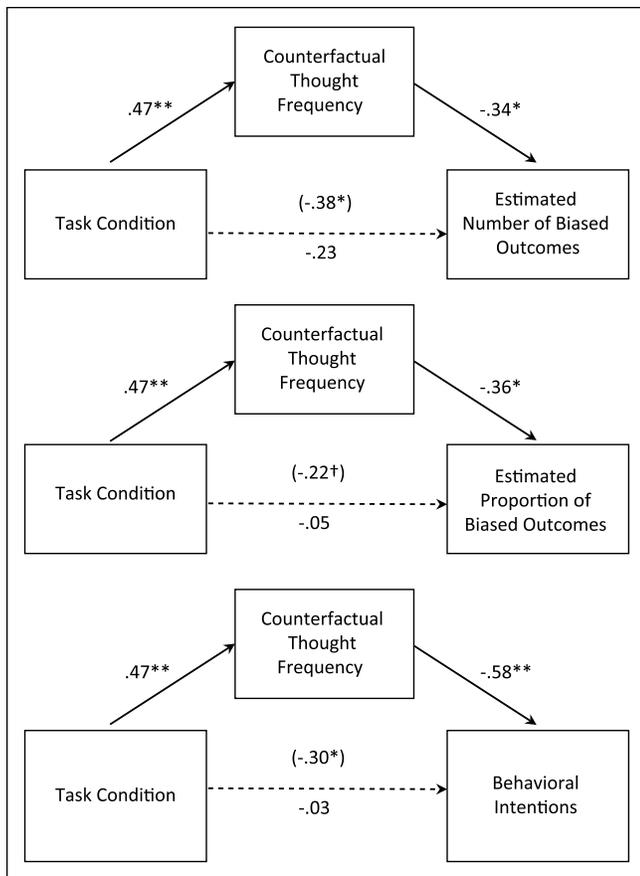


Figure 3. Mediation of the relationships between Task Condition and Estimated Number of Biased Outcomes, Estimated Proportion of Biased Outcomes, and Behavioral Intentions by Counterfactual Thought Frequency (Experiment 3).

† $p = .15$. * $p < .05$. ** $p < .01$.

These results mirror the conclusions drawn in Experiment 1 and Experiment 2. Those participants who produced greater frequencies of counterfactual thoughts were not only less likely to detect the bias in the coin flips, but they were also less likely to make optimal predictions regarding future trials using the same coin. Furthermore, counterfactual thinking appeared to sustain its effect on behavioral intentions beyond that which could be explained by any recognition of bias in the coin.

These results also provide important applied implications in the way of potentially reducing the unwanted effects of counterfactual thinking in decision-making contexts such as that of predicting coin flips. Indeed, whatever can be done to reduce the distortion of counterfactuals in the context of making decisions is useful information. However, a plausible alternative explanation for the results of Experiment 3 is the possibility that instructing people to focus on the outcomes of events may take less focus off of their predictions and thereby enable them to learn more from the outcomes. It seems unlikely that our *predict and focus on actual outcomes condition* participants were willing (and able) to disregard their predictions altogether. These participants physically

logged decisions and it is clear that instructing them to focus on the outcomes of the coin flips reduced the unwanted effect that counterfactual thinking can have on repeated-trial experiential learning.

Experiment 4

A fundamental distinction of mental simulation, as it pertains to simulating alternatives to reality, is that between counterfactual thinking and *prefactual thinking*. Whereas counterfactual thinking involves simulations of alternatives to reality after the outcome is already known/experienced, prefactual thinking involves simulating possible alternatives to reality before the outcome is known/experienced (see Petrocelli, Seta, & Seta, 2012; e.g., “If only Joe would tell Rachel how he really feels, she might go out with him.”). Prefactual thinking can have important implications for one’s expectations and predictions (Hoch, 1985; Sherman, Skov, Hertz, & Stock, 1981), anticipatory affect (McConnell et al., 2000; Petrocelli, Seta, & Seta, 2012; Sanna, 1996), and performance (Criado del Valle & Mateos, 2008; Sanna, 1996, 1998). Furthermore, people’s tendency to generate prefactuals before making decisions appears to be a spontaneous mental activity (McConnell et al., 2000).

One possibility is that prefactual thinking, rather than counterfactual thinking, is the mechanism linking the deleterious effect of prediction on learning observed in Experiments 1 to 3. That is, the effect of prediction on learning (e.g., discovering bias in a stimulus through associative learning) may have little to do with counterfactual thinking and may be the result of enhanced prefactual thinking occurring along with prediction activities. Specifically, when a person makes a prediction, it likely involves at least some level of simulation of the event (Dijksterhuis & Nordgren, 2006). Even without any post-event reflection on the outcome or post-event generation of an alternative outcome, the pre-event prediction/simulation could also serve as a source of a memory trace that could be confused with the actual outcomes. Such confusion in source monitoring may ultimately distort the memory for the actual outcomes (see Johnson, Hashtroudi, & Lindsay, 1993). Such reasoning is consistent with research demonstrating predecisional distortion (see: Carlson & Russo, 2001; Simon, Pham, Le, & Holyoak, 2001). Rather than forming a decision once all of the available information is processed and integrated, people often form a prejudgments that operate as expectancies, biasing the interpretation of information processed later. Interestingly, this effect can occur even when people are warned not to make such prejudgments (Carlson & Russo, 2001).

In other words, the “sin of prediction” might still be found in the act of predicting itself, but it may do so through prefactual thinking rather than counterfactual thinking. Thus, in addition to counterfactual simulations, prefactual simulations of events can lead one to temporarily treat events as if they were actually true in their present times

(Koehler, 1991; Sherman, Cialdini, Schwartzman, & Reynolds, 1985; Sherman, Zehner, Johnson, & Hirt, 1983). On the other hand, if pre-event mental simulations of one's predictions or expectations inhibit learning, then performance should be positively associated with learning because one such predictor would thereby experience relatively more actual outcomes that matched their prefactual simulations. Matching of prefactual simulations to actual outcomes would appear to leave one less susceptible to a memory distortion inhibiting learning. However, performance among the predictor condition participants of Experiments 1 to 3 failed to correlate with learning unless predictors were directly instructed to focus on the actual outcomes of the coin flips. To more directly examine the possibility of a memory distortion connected to memory traces at the time of prediction, Experiment 4 employed a measure of Prefactual Thought Frequency in addition to the measure of Counterfactual Thought Frequency.

Method

Participants and design. A total of 160 (53.1% female) Wake Forest University undergraduate students participated in the study. All of the participants were recruited through the online Wake Forest University participant pool, signed an informed consent form to participate in a 60-min research session, and received partial course credit for their participation.

The experiment employed a single-factor, between-subjects experimental design in which participants were randomly assigned to one of two conditions, the observer condition ($n = 80$) and the predictor condition ($n = 80$). The dependent variables included Outcome Performance, Proportion of Biased Outcome Predictions, Estimated Number of Biased Outcomes, Attention Accuracy, Prefactual Thought Frequency, and Counterfactual Thought Frequency.

Procedure. The procedures employed in Experiment 4 were identical to those employed in Experiment 2 with four exceptions. First, the coin was biased to land on the blue side in 75% of the 40 trials. Similar to Experiment 2, after the display of each coin flipping video, we probed for attention to the actual outcome of the coin flip. Second, a straightforward measurement of learning (i.e., the perceived bias in the coin) was employed. Third, the anagram task was not included between blocks of trial. Finally, in addition to the measure of Counterfactual Thought Frequency, Experiment 4 employed a measure of Prefactual Thought Frequency.

Estimated Number of Biased Outcomes. Following the 40 coin flipping trials, participants responded to the following question to probe for learning: "The black/blue coin was flipped 40 times. How many times did it land blue?"

Prefactual Thought Frequency. Next, participants responded to four items measuring their frequency of prefactual thoughts

using 1 (*very infrequently*) and 7 (*very frequently*) as the anchor labels. The items included, "During the coin flipping trials task, how often did you think about a coin flip outcome any time before the actual result of the coin flip?"; "During the coin flipping trials task, how often did you visualize a coin flip outcome any time before the actual result of the coin flip?"; "During the coin flipping trials task, how often did you mentally simulate a coin flip outcome any time before the actual result of the coin flip?"; and "During the coin flipping trials task, how often did you imagine a coin flip outcome any time before the actual result of the coin flip?" The four items were averaged to form a single Prefactual Thought Frequency score (Cronbach's $\alpha = .83$).

Counterfactual Thought Frequency. Finally, participants responded to an initial set of two items measuring their frequency of counterfactual thoughts using 1 (*very infrequently*) and 7 (*very frequently*) as the anchor labels, and a second set of three items using 1 (*very difficult*) and 7 (*very easy*) as the anchor labels. The items included, "After a coin flipping trial, how often did you generate an If only . . . thought (i.e., think about alternatives to what actually occurred in the trial)?"; "After the coin was flipped, how often did you think about alternatives to what actually happened in the trial?"; "After a coin flipping trial, on average how easy or difficult would it have been for you to think about alternatives to what actually occurred in the trials?"; "After a coin flipping trial, on average how easy or difficult was it for you to generate If only . . . thoughts (i.e., think about alternatives to what actually occurred in the trials)?"; and "After the coin was flipped, how easy/difficult was it to think about alternatives to what actually happened in the trial?" The five items were averaged to form a single Counterfactual Thought Frequency score (Cronbach's $\alpha = .77$).

Results and Discussion

Learning. Overall, the sample reported an average of 26.10 ($SD = 5.07$) Estimated Number of Biased Outcomes; this estimate was significantly different from 20.00, $t(159) = 15.22$, $p < .001$. Thus, participants reported observing significantly more biased-side coin flip outcomes than chance would predict. However, the biased-side outcome estimates were also significantly different from the actual bias displayed by the coin (i.e., 30.00), $t(159) = -9.73$, $p < .001$. Similar to our earlier results, these results again suggest that, while both conditions did detect some bias in the coin, they were unsuccessful at detecting the extent that it existed.

Consistent with expectations, observation condition participants reported a greater Estimated Number of Biased Outcomes ($M = 26.90$, $SD = 5.48$) than did their prediction condition counterparts ($M = 25.30$, $SD = 4.51$), $F(1, 158) = 4.06$, $p = .04$.

Among the prediction condition participants, Outcome Performance (i.e., proportion correct predictions; $M = 0.51$, $SD = 0.11$) was again uncorrelated with Estimated Number of

Biased Outcomes, $r(78) = .17$, $p = .14$. However, the Proportion of Biased Outcome Predictions (i.e., proportion of trials in which the blue side was selected; $M = 0.51$, $SD = 0.18$) was marginally correlated with Estimated Number of Biased Outcomes, $r(78) = .21$, $p = .07$. These results suggest, again, that learning was not significantly enhanced during the task by the performance achieved in predicting outcomes.

Attention Accuracy. The sample mean for Attention Accuracy was 0.94 ($SD = 0.07$), indicating excellent attention to the proximal outcomes. A one-way ANOVA revealed that prediction condition participants ($M = 0.93$, $SD = 0.09$) did not differ from their observation condition counterparts ($M = 0.94$, $SD = 0.06$), $F(1, 158) = .81$, $p = .37$. Again, Attention Accuracy did not correlate significantly with Estimated Number of Biased Outcomes ($r = .04$, $p = .63$); Attention Accuracy was excluded from all subsequent analyses.

Prefactual Thought Frequency. The sample mean for the Prefactual Thought Frequency measure was 5.06 ($SD = 1.86$). However, prediction condition participants did not report generating significantly more prefactuals ($M = 5.18$, $SD = 1.89$) than did observation condition participants ($M = 4.94$, $SD = 1.83$), $F(1, 158) = .67$, $p = .42$.

Counterfactual Thought Frequency. The sample mean for the Counterfactual Thought Frequency measure was 4.99 ($SD = 1.49$). Consistent with expectations, prediction condition participants reported generating significantly more counterfactuals in response to the coin flips ($M = 5.27$, $SD = 1.52$) than did observation condition participants ($M = 4.71$, $SD = 1.41$), $F(1, 158) = 5.90$, $p = .02$.

Mediation analysis. To test our hypothesis, we employed the same mediation procedures as those employed in Experiment 2. Reflecting the ANOVA results reported above, the correlation between the Task Condition and Counterfactual Thought Frequency was statistically significant, but the correlation between the Task Condition and Prefactual Thought Frequency was not (see Figure 4). Also reflecting the ANOVA results, the correlations between the Task Condition and Estimated Number of Biased Outcomes was statistically significant. Although the correlation between Counterfactual Thought Frequency and Estimated Number of Biased Outcomes was statistically significant, the correlation between Prefactual Thought Frequency and Estimated Number of Biased Outcomes was not.

Using the Estimated Number of Biased Outcomes as the dependent variable and both Prefactual and Counterfactual Thought Frequency as simultaneous mediators, the bootstrap procedure revealed the size of the total indirect effect to be -0.38 ($SE = 0.26$); the CI excluded zero, 95% CI $[-1.11, -.006]$. The size of the indirect effect through Prefactual Thought Frequency was $.05$ ($SE = .12$); the CI included zero, 95% CI $[-.07, .47]$. The size of the indirect effect through Counterfactual Thought Frequency was -0.42 ($SE = 0.26$);

the CI excluded zero, 95% CI $[-1.15, -.06]$. These results indicate that Counterfactual Thought Frequency mediated the effect of Task Condition on the dependent variable.

As in Experiments 1 to 3, prediction condition participants produced significantly more counterfactuals than their observation condition counterparts. Subsequently, those participants who produced greater frequencies of counterfactual thoughts were less likely to detect bias in the coin. Our results also suggest that mental simulations following the outcomes of events can distort the learning process, when engaged in predicting a series of outcomes, as opposed to mental simulations that may occur before outcomes of the events.

Experiment 5

Experiments 1 to 4 demonstrated that experiential learning and optimal decision making may be inhibited through the act of predicting outcomes via counterfactual thought responses. However, each experiment relied on the self-report of counterfactual thought frequency and does not speak to the content of counterfactuals that may be especially deleterious of learning.

Counterfactual thoughts often involve mentally undoing two things, including the antecedent (e.g., “If only I hadn’t bought the car on impulse yesterday, . . .”) and the outcome (e.g., “. . . then I would have received a better deal today.”). We propose that counterfactual content focused on mentally undoing the actual outcome, as opposed to the antecedent, should be especially deleterious for learning and optimal decision making. For example, thinking, “If only I had gone with my gut and picked blue, I would have been right.” would seem relatively unlikely to create difficulty remembering that the outcome really was blue. In fact, this type of counterfactual seems to reinforce that which we argue enhances experiential learning—the actual outcome. In the case of a coin biased to land on blue, focusing more on the actual outcomes of the flips should not result in a memory deficit and should optimize decision making. In comparison, thinking, “If only that last edge of the coin had not caught, it would have been black, and I would have been right.” would seem more likely for one to misremember the outcome as black. Such counterfactual seems to distort memory because they mismatch the actual outcome to create an artificial effect or justify the decision made. In the case of making predictions about the outcomes of a biased coin, memory for mentally simulated alternatives should create some “mixture” of memories for blue and black when the actual outcome was dominated by blue.

Experiment 5 was designed to shed light on how the memory deficit comes about. Participants made outcome predictions for a biased blue/black coin which landed on the blue side in 75% of the trials. Participants were randomly assigned to one of three conditions whereby they were exposed to a particular set of comments made by an alleged observer. All of the participants received neutral comments

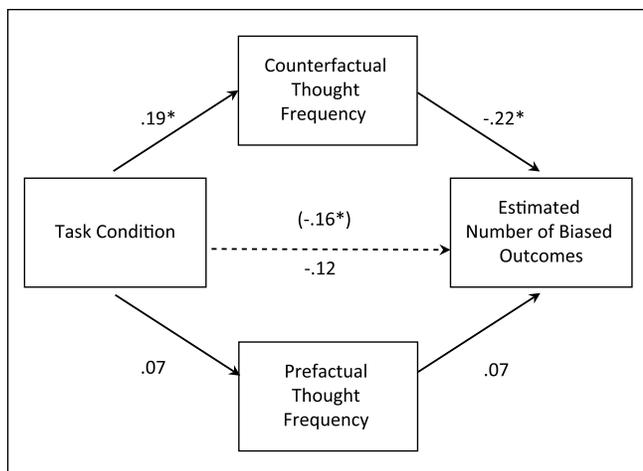


Figure 4. Mediation of the relationships between Task Condition and Estimated Number of Biased Outcomes and Estimated Proportion of Biased Outcomes by Counterfactual and Prefactual Thought Frequency (Experiment 4).

[†] $p = .09$. * $p < .05$.

following each correct decision (e.g., “Correct decision—nice job.”). However, following each incorrect decision, one third of the participants received neutral comments (e.g., “Got that one wrong, oh well.”), one third received comments that altered only the antecedent (e.g., “If only you had picked blue.”), and one third received comments that altered only the outcome (e.g., “Almost—that one was really close to being black.”). We hypothesized that predictors who were “spoon-fed” counterfactuals focused on undoing the outcomes would be especially unlikely to learn from experience in our paradigm.

Method

Participants and design. A total of 64 (42.2% female) Wake Forest University undergraduate students participated in the study. All of the participants were recruited through the online Wake Forest University participant pool, signed an informed consent form to participate in a 60-min research session, and received partial course credit for their participation.

The experiment employed a single-factor, between-subjects experimental design in which participants were randomly assigned to one of three Thought Exposure conditions, the neutral condition ($n = 21$), the alternative antecedent condition ($n = 22$), and the alternative outcome condition ($n = 21$). The dependent variables included Proportion of Biased Outcome Predictions and the Estimated Number of Biased Outcomes.

Procedure. The procedures employed in Experiment 5 were identical to those employed in the predictor condition of Experiment 4 with the addition of an alleged observer of the participant’s decisions and outcomes of the coin flips.

Participants arrived at the lab in groups of six and were led to believe that the study concerned understanding decision-making outcomes for the self and for others. Participants were allegedly matched with another participant in their study session. Participants were also led to believe that the coin flipping task involved playing the role of decision maker or of a friendly observer/commentator. It was explained that the decision maker would be asked to make decisions about coin flips and the observer would be asked to consider the decision for each coin flip trial, observe the coin flip, and type brief comments about each trial. The decision maker would then get to see those comments following a random delay of 8 s to 13 s. All participants were “randomly” assigned to play the role of decision maker.

Thought Exposure. Participants were randomly assigned to one of three conditions that varied in alleged commentator comments they received. Following each correct decision, all of the participants received neutral comments (e.g., “Correct decision—nice job.”). Following each incorrect decision, one third of the participants received neutral comments (e.g., “Got that one wrong, oh well.”), one third received comments that altered only the antecedent (e.g., “If only you had picked blue.”), and one third received comments that altered only the outcome (e.g., “Almost—that one was really close to being black.”).

Estimated Number of Biased Outcomes. Following the 40 coin flipping trials, participants responded to the following question to probe for learning: “The black/blue coin was flipped 40 times. How many times did it land blue?”

Results and Discussion

Learning in the coin flipping paradigm was reflected by both decisions and self-reported estimates of the bias in the coin. Thought Exposure revealed a marginally significant effect on decisions (i.e., Proportion of Biased Outcome Predictions), $F(2, 61) = 2.32, p = .10$. Importantly, the observed means of the three conditions were in the direction expected, with the neutral condition ($M = 0.62, SD = 0.26$) and alternative antecedent condition ($M = 0.64, SD = 0.15$) selecting the biased side more frequently than the alternative outcome condition ($M = 0.51, SD = 0.19$).

Thought Exposure revealed a statistically significant effect on self-report of biased outcomes (i.e., Estimated Number of Biased Outcomes), $F(2, 61) = 4.00, p = .02$. As expected, alternative outcome condition participants estimated significantly fewer biased-side outcomes ($M = 24.95, SD = 4.31$) than both neutral condition participants ($M = 28.81, SD = 7.00$), $t(61) = -2.39, p = .02$, and alternative antecedent condition ($M = 28.95, SD = 3.86$), $t(61) = -2.51, p = .01$. Neutral condition and alternative antecedent condition participants did not differ in Estimated Number of Biased Outcomes, $t(61) = .09, p = .93$.

These results further support our theoretical stance that predicting outcomes can inhibit learning and optimal decision making through counterfactual thinking. However, the results suggest that not all counterfactuals (or components of counterfactuals) have such deleterious effects. Specifically, counterfactual thought content focusing on alternative outcomes appear to matter more to learning inhibition in our coin flipping paradigm, as opposed to counterfactual thought content focusing on alternative antecedents (e.g., decisions).

General Discussion

The roles of predicting versus observing stimulus outcomes and counterfactual thinking were directly examined in an experiential learning paradigm. The observed experimental data supported our hypotheses. Experiments 1 to 4 participants assigned to the standard predictor conditions generated significantly more counterfactual thoughts than did the participants assigned to the observer and predict/focus on reality conditions. Importantly, an indirect effect was supported such that counterfactual thought frequency mediated the relationship between task instructions and learning as evidenced by recognition of bias in the coin. Thus, the current research further confirms the counterfactual inflation hypothesis and growing evidence that counterfactual thinking may impair memory, learning, and decision making in probabilistic tasks like the Monty Hall dilemma (Petrocelli & Harris, 2011), black jack (Petrocelli & Crysel, 2009), and biased coin flipping paradigms.

Experiment 5 refined our knowledge regarding the content of counterfactual thoughts that appears to have deleterious effects on learning and optimal decision making. It is important to note that learning and optimal decision making in our coin flipping paradigm was seemingly enhanced by accurately recalling the outcomes. Surely our participants would have more readily recognized and accurately estimated the degree of bias in the coin had they accurately remembered 30 out of 40 outcomes landing to one side than the other. Thus, counterfactual thoughts that focused on mentally altering the outcome, and were thus most detrimental to accurate memory, interfered with learning and optimal decision making the most. However, in situations whereby it is more important to accurately recall one's decisions, we estimate that learning and decision making may be inhibited via counterfactual content that focus on mentally altering the antecedent.

We believe that our findings provide some clarity for earlier findings suggesting that people are poor at learning probabilities from repeated-trial tasks. Importantly, earlier studies (e.g., Newell & Rakow, 2007; Wasserman et al., 1993) did not investigate the potential role of counterfactual thinking.

The present research also adds to the literature concerning the functional and dysfunctional views of counterfactual thinking. Evidence suggests that counterfactuals can be functional in some contexts (Kray et al., 2009; Markman et al., 1993; Nasco & Marsh, 1999; Roese, 1997), but dysfunctional

in others (Petrocelli & Harris, 2011; Petrocelli et al., 2013, 2012; Sherman & McConnell, 1995; for reviews see Epstude & Roese, 2008; Markman, Karadogan, Lindberg, & Zell, 2009). The present research provides further support for the dysfunctional view of counterfactuals. The significant mediation model, presented in the current research, supports the memory interference theory of dysfunctional counterfactual thoughts. The participants who generated more counterfactuals were less likely to detect bias in the coin. Such findings are consistent with previous evidence indicating that counterfactual thoughts have the potential to create interference in memory (De Brigard, Szpunar, & Schacter, 2013; Ferrante Girotto, Stragà, & Walsh, 2013; Gerlach et al., 2014; Petrocelli & Crysel, 2009; Petrocelli & Harris, 2011; Petrocelli et al., 2013, 2012).

There may be several reasons for competing narratives concerning the effect that counterfactual thought generation has on future performance. In some cases of support for the functional view, the research fails to differentiate between counterfactual thoughts and, more simply, attention to the task at hand. For instance, Nasco and Marsh (1999) asked some of their participants to generate counterfactual thoughts concerning test-taking behavior following a course exam. The effect of the counterfactual thoughts was measured by determining participant performance on future tests. Participants who generated counterfactuals concerning the first exam performed better on the second exam. However, the participants in the counterfactual condition were contacted the day before the follow-up exam and reminded of their counterfactuals, confounding any potential report of the beneficial nature of counterfactuals with demand characteristics and cognitive salience.

We do not contend that all counterfactual thoughts are dysfunctional, however, and we conclude that our coin flipping paradigm is one context in which counterfactuals appear to be dysfunctional. Counterfactual thoughts in our predictor conditions were almost certainly concrete and specific because participants received immediate visual feedback concerning their predictions and because external stimuli were extremely limited in this context. That is, if a participant selected black for a trial, but the coin landed blue, a counterfactual thought (e.g., "If only the coin had landed on black, I would have won.") would be highly potent because the participant can easily imagine winning the trial had the alternative actually occurred (see: Petrocelli, Percy, Sherman, & Tormala, 2011). Such counterfactuals have a greater chance of distorting the memory for the actual event, and even supplanting it as the memory the participant believes is reality-accurate.

The functional or dysfunctional potential of a counterfactual may also depend on its content. If a counterfactual prescription has a strong actionable component and includes situational cues signaling alternative actions, it seems much more likely to have a functional result. The counterfactuals most likely generated in the present research (i.e., "If only I had not picked black . . .") possessed no specific action plan and no specific situational decision cues; a participant would

have no way of knowing if there would be future trials for which the counterfactual thought should apply more or less. However, other situations might lend to more actionable counterfactual thoughts along the lines of Epstude and Roese's (2008) content-specific pathway (i.e., "Before the next exam, I should study more.").

Given the similarities in the conclusions of previous research (e.g., Petrocelli et al., 2013), we find it important to note three important differences that separate the present research from any prior research. First, the paradigm employed in the present research is relatively free of context features that were not ruled out as explanatory factors (e.g., spontaneous vs. directed counterfactual generation, distracting stimuli, clarity on what is to be learned) in previous studies. The current designs involved two to three conditions interacting with the same stimuli. The only assumptions that participants might have brought into the experimental context would concern the coin, which is not a topic many people have rich associations with; this contrasts with a relatively more complicated problem, such as the Monty Hall problem (Petrocelli & Harris, 2011), or one in which people hold many associations and assumptions prior to the study, such as the stock market (Petrocelli et al., 2013).

The second important difference is that our participants were never explicitly asked to generate counterfactuals in the current paradigm (even in Experiment 5, counterfactual thoughts were "spoon-fed" and participants were never directly asked to generate the counterfactual thoughts). Instead, the observation and prediction conditions were expected to differentially generate counterfactuals spontaneously.

Most importantly, the current research tested the observer versus predictor division as a proxy for differential counterfactual generation, which holds potential for understanding how to remove the unwanted effects of counterfactual thinking. Because predictors do indeed generate more counterfactuals and perform more poorly on the bias detection measure, there is potential to generalize those conditions as a learning technique and thus have concrete, real-world benefits. For instance, when learning a complex system that contains biases, it may behoove individuals to first process machinations of the system before creating predictions or guesses about how it operates. Our Experiment 3 results also suggest focusing more on reality than its alternatives as a way to debias the processing of multiple exposures to event outcomes.

Applied and Theoretical Implications

Given that gambling over time closely resembles trial-by-trial experiential learning, the present research has implications concerning the persistence of gamblers. Gamblers who tend to counterfactualize seem likely to form inaccurate estimates of their previous wins and losses. Because gambling losses, and wins associated with more desirable but forgone outcomes, tend to produce upward counterfactuals (i.e., "If only I had made a different decision, I would have won more

money."), gamblers may have rosier pictures of their performance than reality warrants.

Such a process may also contribute to an illusion of control (Langer, 1975; Wortman, 1975). By manipulating the way that random betting events occurred, Langer's (1975) participants believed they had a modicum of control over purely random events, which led to overconfidence when betting and gambling persistence. These control beliefs might be enhanced by counterfactual thoughts—leading participants to imagine a hypothetical scenario where they possess control over a situation, and/or leading to the belief that they actually have control. It seems quite possible that some forms of gambling persistence are caused by a memory distortions originating from counterfactual thoughts. Such a possibility warrants future research.

Financial investing is another field in which repeated exposures to probabilistic representations form mental aggregates that one might hope to learn. Kahneman (2011) noted that investment bankers can develop an "illusion of skill," even when confronted with hard evidence that their performance was merely due to random chance. Counterfactual thought generation could be a mechanism underlying such delusions. That is, inaccurate mental representations of overall investment performance may be just as vulnerable to the memory distortion effect demonstrated in the present research. In fact, given that our participants were not distracted by any other externally provided information, and not provided with any other event features to mentally undo their learning, it seems that the effects displayed here may be even more likely to emerge in the real world where such attention distractors and event features are abundant.

Conclusion

Using a simple biased coin flipping paradigm, we demonstrated experimentally that counterfactual thinking is differentially linked to observation versus prediction of event outcomes as well as prediction versus prediction and intentional focus of actual outcomes. Subsequently, entertaining alternatives to reality, however brief, appeared to affect the degree to which repeated exposures of the same event outcome shaped learning.

There appears to be nothing inherently wrong with simply predicting the outcomes of events. That is, the "sin" of prediction is not found in the act of predicting itself, but rather in the mental activity that can occur after the prediction is made and the outcome is known. It seems that in the context of making several predictions and observing their outcomes, the predictor's memory of reality can become distorted as he/she forms a mental representation of the aggregated set of outcomes, shaped in part by counterfactual alternatives. Relative to the predictor, the observer (or the predictor who focuses only on reality and not its alternatives) does not have the same tendency to consider alternatives to reality and is relatively more accurate at encoding reality. Subsequently,

more accurate encodings of reality will serve decision makers well relative to those with less accurate, experienced-based mental representations of reality.

Among the “seven sins” of memory, Schacter (2001) detailed the sin of misattribution whereby people incorrectly remember events or mistake desired outcomes for reality. Counterfactual thinking can lead to incorrect remembering of events and/or mistaking desired outcomes for reality in the context of repeated-trials in probabilistic tasks. Given that counterfactual thinking also appears to be more strongly associated with prediction/observation than mere observation, the act of prediction appears to carry some unwanted effects of its own.

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Supplemental Material

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Notes

1. Fortunately, better forms of feedback, such as cognitive feedback (Balzer, Doherty, & O'Connor, 1989) and process feedback (Cannon-Bowers & Salas, 2001), are available.
2. The Monty Hall problem places a decision maker in a situation in which one of three doors has a desirable prize behind it, and asks him/her to choose one; one of the non-selected doors is opened to reveal that it did not have the prize behind it. The decision maker is then asked to either switch to the remaining door or to stick with his/her previously selected door. The correct action is to switch (uniformly, regardless of the number of trials), because there is a 2/3 chance that the initially non-selected door will have the prize while only a 1/3 chance that previously selected door will have the prize.
3. After asking participants how many blue and black outcomes they saw, we also asked participants following question: “The BLACK/BLUE coin was flipped 40 times. How many times did it land BLUE?” For the sake of brevity, we do not include analyses regarding this dependent variable here. However, we find it important to note that the results pertaining to this dependent variable mirrored the pattern of results found for the Estimated Number of Biased Outcomes in all respects. Thus, even when participants were aware that they had observed a total of 40 coin flip trials, prediction condition participants underestimated the number of biased outcomes relative to their observation condition counterparts; this relationship was also mediated by Counterfactual Thought Frequency.

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