Understanding "almost": Empirical and computational studies of near misses

Tobias Gerstenberg (tger@mit.edu) & Joshua B. Tenenbaum (jbt@mit.edu)
Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139

Abstract

When did something almost happen? In this paper, we investigate what brings counterfactual worlds close. In Experiments 1 and 2, we find that participants' judgments about whether something almost happened are determined by the causal proximity of the alternative outcome. Something almost happened, when a small perturbation to the relevant causal event would have been sufficient to bring it about. In contrast to previous work that has argued that prior expectations are neglected when judging the closeness of counterfactual worlds (Kahneman & Varey, 1990), we show in Experiment 3 that participants are more likely to say something almost happened when they didn't expect it. Both prior expectations and causal distance influence judgments of "almost". In Experiment 4, we show how both causal proximity and beliefs about what would have happened in the absence of the cause jointly explain judgments of "almost caused" and "almost prevented".

Keywords: causality; counterfactuals; almost; mental simulation; intuitive physics.

> "*We have come to think of the actual as one among many possible worlds. We need to repaint that picture. All possible worlds lie within the actual one.*" – Goodman (1983, p. 57)

Contemplating what could or should have been is a pervasive feature of human cognition (Kahneman & Miller, 1986; Reid, 1986; Roese, 1997; Teigen, 1996). As the quote above suggests, our actual world is infused with different possible worlds. Despite the appeal of dozens of self-help books to live in the "now", we often cannot help but dwell on how the "now" could have turned out differently (Johnson, 1986). The word "almost" provides a window into counterfactual thoughts (cf. Kahneman & Varey, 1990). The penalty taker who almost missed the goal, the researcher who almost missed her plane, or the dentist who almost drilled the wrong tooth. In each of these situations, actual and counterfactual worlds came dangerously close. The goal of this paper is to better understand when it is that something almost happened. By investigating what factors influence whether people agree with the statement that something almost happens, we learn more about people's concept of "almost" specifically, as well as about counterfactual thinking more generally.

A linguistic analysis of the word "almost" yields two key results (cf. Nouwen, 2006; Penka, 2006): first, *almost q* implies that q didn't actually happen and, second, that the actual outcome p was close to q on some scale. While the relevant scale of comparison is often times obvious ("Awesome, almost 100 people came to my talk!"), other times this is less so ("I was so nervous, I almost blanked."). One way to deal with the problem of multidimensionality is by trying to project the different relevant dimensions onto a single scale such as probability. For q to have almost happened, its probability must now be zero, and its (subjective) probability at some earlier stage must have been high. In their investigation of close counterfactuals, Kahneman and Varey (1990) draw a distinction between two different kinds of outcome probabilities: *dispositions* and *propensities*. We can think of a disposition as the prior probability of the outcome before the relevant episode started to unfold. A reliable penalty taker has a strong disposition to score a goal. We can think of propensities as dynamic updates to the outcome probability as a consequence of what happens as the episode unfolds. When the penalty taker's ball is headed toward the post, it now has the propensity to miss the goal.

When judging propensity we need to assess the causal proximity of different possible outcomes. One way of doing so is through the process of mental simulation (Kahneman & Tversky, 1982). In the penalty example above, we mentally extrapolate the trajectory of the ball to estimate whether it's going to hit or miss (cf. Gerstenberg, Goodman, Lagnado, & Tenenbaum, 2012, 2014). We can say that an outcome was close if it's the case that a small perturbation to the relevant causal event would have been sufficient to bring about the alternative outcome (cf. Gerstenberg, Goodman, Lagnado, & Tenenbaum, 2015). If the penalty taker had kicked the ball slightly differently, then the ball would have missed the goal. We investigate the influence of causal as well as spatial proximity on people's judgments about whether something almost happened in Experiment 1.

Kahneman and Varey (1990) argued that whether something almost happened is more strongly influenced by propensity than by disposition. In fact, dispositions are thought to be neglected entirely when they are not supported by the propensities of the situation. Accordingly, whether the penalty taker is normally good or bad shouldn't make much of a difference for whether we think that the player almost missed. What matters is how close the ball came to the post.

We believe that there is more to "almost" than propensity – prior expectations matter. Imagine the following scenario: The first author plays a one-on-one basketball game against Michael Jordan. Whoever scores 11 points wins the game. Let's say that the outcome of Game 1 is 11 (Jordan) to 10 (Gerstenberg). Here, it sounds fine to say that "Gerstenberg almost beat Jordan". The outcome of Game 2 is 11 (Gerstenberg) to 10 (Jordan). Now, it sounds strange to say that "Jordan almost beat Gerstenberg" even though he came very close to doing so. If anything, we'd be inclined to say that (wow!) "Jordan lost to Gerstenberg".

The asymmetry between these two situations is difficult to accommodate by considering causal proximity only. If anything, the counterfactual world in which Gerstenberg would have won in Game 1 seems further away from what actually happened than the counterfactual world in which Jordan would have won in Game 2. Intuitively, what seems to be driving the difference between these two situations is our prior expectation: we expected that Jordan would beat Gerstenberg. We look at the influence of prior expectations on people's judgments of "almost" in Experiments 2 and 3.

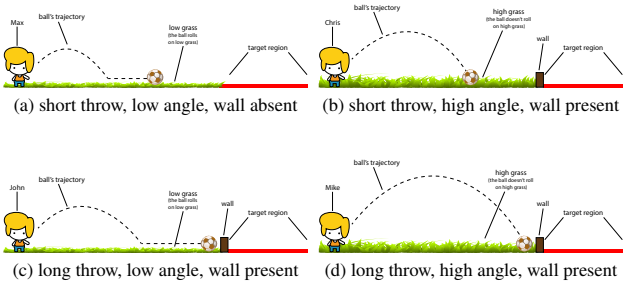
In Experiment 4, we examine in what situations people say that something "almost caused" an outcome to happen or "almost prevented" it from happening. In previous work (Gerstenberg et al., 2012, 2014, 2015), we have developed the *counterfactual simulation model* of causal judgment which predicts that people make causal judgments by comparing what actually happened with what would have happened if the candidate cause had been absent or different. Here, we apply and extend this model to capture people's judgments about "almost caused".

Experiment 1: Causal distance

For an outcome to have almost happened it has to be close to what actually happened. But close in what way? Consider the scenarios depicted in Figure 1. In each scenario, a boy tosses a ball with the goal to get it into a target region. In some of the situations, the spatial distance to the target region is large, in other situations the distance is small. If spatial distance matters, then participants should be more likely to say that the character's ball almost reached the target region in situations c) and d) than in situations a) and b).

The situations also differ in whether the character throws the ball at a low or high angle, and whether there is a wall in front of the target region. If participants only cared about the spatial distance between the ball's final location and the target region then these aspects should not matter. However, if they care about causal distance, these aspects should matter. Recall that to estimate causal distance, we imagine a small perturbation to the relevant causal event and see whether this would have been sufficient to generate the counterfactual outcome (cf. Gerstenberg et al., 2015).

Let's compare situations c) and d). In both situations the ball comes to a stop at the exact same location. Thus, spatial distance to the target does not distinguish between the two. However, the two situations differ in terms of the causal distance to the counterfactual outcome. In situation d) the boy's ball could have reached the target region if he had thrown the ball just a little bit harder. In contrast, in situation c) the boy's throw would have needed to be substantially harder for the ball to reach the target region. Since the causal distance to the alternative outcome is closer in d) than it is in c), we predict that participants are more likely to say that the boy's ball almost reached the target region in d) than in c). Note that



(a) short throw, low angle, wall absent (b) short throw, high angle, wall present

(c) long throw, low angle, wall present (d) long throw, high angle, wall present

Figure 1: Example of stimuli presented in Experiments 1 and 2. Note that the character throws the ball at a high angle when then grass is high and the ball doesn't roll (b and d), and at a low angle when the grass is low and the ball rolls (a and c).

the difference between the two situations disappears if we remove the wall in front of the target region. Now both situations are similar in their causal distance to the counterfactual outcome – the target region would have been reached if each character had just tossed the ball a little harder. Thus, we expect participants' judgments to be similarly high for these two situations.

Methods

Participants Participants in each experiment of this paper were recruited via Amazon's Mechanical Turk and compensated at a rate of $6 per hour. No participant participated in more than one experiment. 40 participants ($M_{age} = 33.8$, $SD_{age} = 11.6$, $N_{female} = 14$) completed this experiment.

Design We manipulated three factors within participants: (1) How far the character threw the ball (*throw*: short vs. long), (2) at what angle the ball was thrown (*angle*: high vs. low), and (3) whether there was a wall in front of the target region (*wall*: present vs. absent). Figure 1 shows four examples of the stimuli shown to participants.

Procedure After having received instructions, participants saw the eight different situations presented in randomized order. Participants were asked to say to what extent they agree with the sentence that "Max's ball almost reached the target region." They indicated their response on a sliding scale with the endpoints labeled "I completely disagree" (-50) and "I completely agree" (50). A different character name was used on each trial. It took participants 2.4 minutes ($SD = 1.8$) on average to complete the experiment.

Results and Discussion

Figure 2 shows participants' mean agreement ratings for the eight different situations. There was a main effect of *throw*; agreement ratings were higher for longer than for shorter throws ($F(1,39) = 132.24, p < .0001, \eta_p^2 = .77$). There was also a main effect of *wall*; ratings were higher when the wall was absent ($F(1,39) = 49.37, p < .0001, \eta_p^2 = .56$). There was no main effect of the *angle* in which the ball was thrown. However, there was an interaction effect between *angle* and *wall* ($F(1,39) = 11.37, p < .001, \eta_p^2 = .23$). As predicted, the presence of the wall reduced participants' agreement ratings more strongly for the low angle throws (e.g. situation 7 vs. 8 in Figure 2) than for the high angle throws (e.g. situation 5 vs. situation 6). There was also a

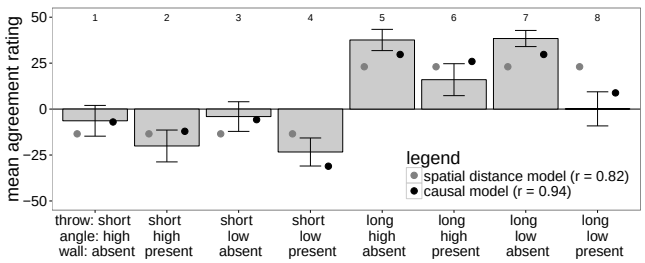


Figure 2: Mean agreement ratings for each of the 8 different stimuli together with the predictions of the spatial model (gray points) and the causal model (black points). *Note*: Error bars in all figures indicate 95% confidence intervals.

significant interaction between *throw* and *wall*. The presence of the wall reduced participants' agreement ratings more for long throws rather than short throws ($F(1,39) = 12.66, p < .001, \eta_p^2 = .25$).

We implemented a causal model by recreating the stimuli with the physics engine Box2D.[1] For each situation, we determined the minimum additional impulse to the throw that would have been required to get the ball into the target region. We contrast the causal model with a spatial distance model that predicts participants' ratings based on the geometrical distance between the final position of the ball and the target region. As Figure 2 shows, participants' mean agreement ratings are better accounted for by the causal model ($r = .94$) than the spatial distance model ($r = .82$). The causal model correctly captures that the presence of the wall makes a bigger difference when the character tossed the ball at a low angle, as the throw would have needed to be substantially harder in these situations to reach the target region. Thus, participants' judgments of whether the boy's ball almost reached the target region are determined by the causal rather than the spatial distance between the actual and counterfactual situation.

Experiment 2: Expectations

Experiment 1 showed that people's concept of "almost" requires that the counterfactual outcome was causally close to what actually happened. In Experiment 2, we investigate how prior expectations influence participants' judgments. As argued in the introduction, we expect that in addition to considering causal distance, participants' are more likely to say that an outcome *almost happened* when they had low prior expectations, and that it *didn't happen* when they had high prior expectations.

Methods

Participants 40 participants ($M_{age} = 31.3, SD_{age} = 10.8, N_{female} = 14$) completed this experiment.

Design and Procedure The design was identical to Experiment 1 except for two changes: First, we introduced information about the character's usual performance as an additional factor. For each of the different types of stimuli used in Experiment 1, participants were either told that the character normally gets his ball in the target region, or does not. Thus, this experiment follows a 2 (*throw*: short/long) $\times$ 2 (*angle*: high/low) $\times$ 2 (*wall*: absent/present) $\times$ 2 (*norm*: positive/negative) within-subjects design. Participants saw the 16 trials in randomized order. The information about the character's normal performance ("Normally, Max does / doesn't get his ball into the target region.") was provided in large font underneath the same stimuli images that were used in Experiment 1.

Second, participants were asked to indicate their agreement with two different statements on independent sliding scales. The statements were "This time, Max's ball *almost reached* the target region." and "This time, Max's ball *didn't reach* the target region." The order of the statements was counterbalanced between participants. It took participants 4.6 minutes ($SD = 1.9$) on average to complete the experiment.

Results and Discussion

Participants' responses to the "almost reached" question closely mirrored the pattern of responses in Experiment 1. Again, there was main effect of *throw* ($F(1,39) = 12.17, p < .01, \eta_p^2 = .24$), a main effect of *wall* ($F(1,39) = 10.27, p < .01, \eta_p^2 = .21$), and interaction effects between *throw* and *wall* ($F(1,39) = 6.56, p < .05, \eta_p^2 = .14$), and between *angle* and *wall* ($F(1,39) = 4.69, p < .05, \eta_p^2 = .11$).

In general, participants tended to disagree with the "almost reached" statements in situations in which the throw was short, and tended to agree with the statement when the throw was long. In contrast, participants never disagreed with the "didn't reach" statements. As expected, there was a strong negative correlation between participants' agreement ratings with the "almost reached" and "didn't reach " statements ($r = -.72$). The more participants agreed that the character's ball almost reached the target region, the less they agreed that the character's ball didn't reach the target region. In contrast to what we hypothesized, manipulating the character's normal performance did not affect participants' agreement ratings. There was neither a main effect of norm nor any interaction effects involving norm.

Why did the norm manipulation fail to influence participants' judgments? The Jordan vs. Gerstenberg scenario mentioned above strongly suggests that prior expectations matter. We believe that the manipulation may have failed for the following reasons: First, in none of the stimuli does the character actually manage to get his ball into the target region. Participants may have simply ignored the information about normal performance since it was not indicative at all for how the character actually performed. Second, the norm manipulation was rather weak – we just presented text underneath the figure stating what the character's normal performance was. Participants may have focused on the image and ignored the text underneath. However, it is also possible that our intuition

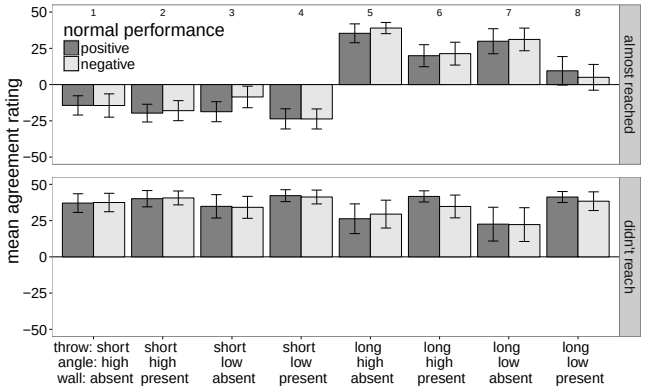


Figure 3: Mean agreement ratings with the "almost reached" sentence (top panel) and the "didn't reach" sentence (bottom panel) as a function of each character's normal performance (bar color) for each of the 8 different types of stimuli (x-axis).

[1] You can test the implementation of the model here: http://web.mit.edu/tger/www/demos/almost/almost_model_wrap.html.

was wrong and prior expectations do not influence people's belief that something almost happened.

Experiment 3: Expectations revisited

Experiment 2 found no influence of prior expectations. In this Experiment, we tried again. This time, we made the norm manipulation stronger. We used a different scenario in which participants were presented with outcomes of a darts game (see Figure 4, cf. Gerstenberg, Ejova, & Lagnado, 2011). The darts scenario gives us a nice way of visually manipulating prior expectations. In the experiment, participants were shown an image that summarized the character's practice performance. Some characters had performed poorly in the practice (Figure 4a) while others had done well (Figure 4b). On the same screen that showed the practice performance, we also presented the character's shot in the crucial test trial. Some characters' test shots just missed the center region (Figure 4c) while other characters' shots were further off (Figure 4d). We hypothesized that both practice performance and quality of the test shot would influence participants' judgments that the character almost hit the center region. We expected that participants' agreement with the "almost" statement will be greater for test shots that were close and for characters who had performed poorly in the practice.

Methods

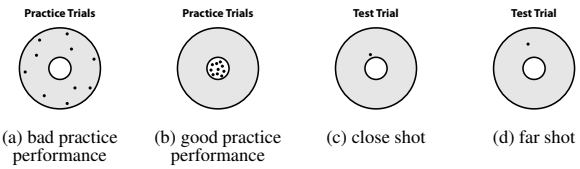
Participants 40 participants ($M_{age} = 31.4$, $SD_{age} = 8.7$, $N_{female} = 16$) completed this experiment.

Design The experiment follows as 2 (*practice performance*: good/bad) $\times$ 2 (*test shot*: close/far) within-subjects design.

Procedure After having received instructions, participants saw four trials in randomized order. On each trial, participants viewed the practice performance on the left and the test shot on the right. We generated different practice trial and test shot stimuli by simply rotating the dots around the dart board center. Participants were asked to indicate on a sliding scale which statement better describes what happened on the test trial. The left endpoint of the scale was labeled "This time, Max missed the center region." (-50), the right endpoint was labeled "This time, Max almost hit the center region." (50), and the center was labeled "unsure". It took participants 2.2 minutes ($SD = 1.6$) on average to complete the experiment.

Results and Discussion

Figure 5 shows participants' agreement ratings as a function of practice performance and the distance of the test shot to the center region. There was a main effect of distance ($F(1,39) = 78.25, p < .0001, \eta_p^2 = .67$). When the test shot was close, participants tended to say that the character almost hit the center region ($M = 19.61$, $SD = 34.24$). When the test shot was far, participants tended to say that he missed the center region ($M = -23.74$, $SD = 28.67$).



(a) bad practice performance (b) good practice performance (c) close shot (d) far shot

Figure 4: Stimuli manipulating the norm (practice trial performance) and distance of the actual shot.

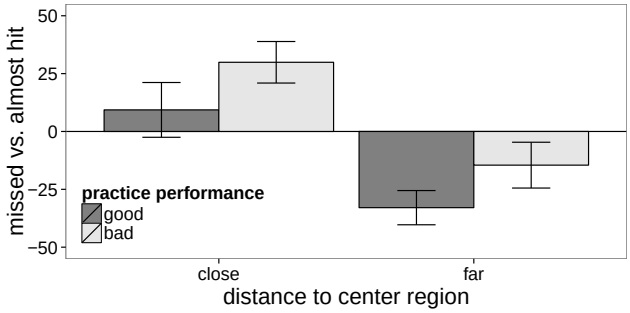


Figure 5: Mean agreement ratings as a function of how close the test shot was to the center region (x-axis), and of how well the character had performed in the practice (bar color).

Importantly, there was also a main effect of practice performance ($F(1,39) = 12.76, p < .0001, \eta_p^2 = .25$). When the character had performed poorly in the practice, participants tended to say that he almost hit the center region ($M = 7.67$, $SD = 36.90$), whereas when the character had performed well, they tended to say that he missed the center region ($M = -11.80$, $SD = 37.31$). There was no significant interaction between practice performance and distance of the test shot.

The results of this experiment show that in line with the intuition motivated by the Jordan vs. Gerstenberg scenario, judgments about whether something almost happened are affected by prior expectations. Participants agreed more with the statement that the character almost hit the center region when he had failed to do so in the practice. The results nicely demonstrate how both causal proximity to the counterfactual outcome, as manipulated by the test shot's distance to the center region, as well as prior expectations influence participants' judgments of "almost". Interestingly, 15 out of 40 participants tended to say that the character almost hit the center region (i.e. their rating was above 0) even when the distance to the center was far, provided that the character's performance in the practice had been poor (only 5 participants' ratings were above 0 for a far shot when the practice performance was good). If our prior expectation is very low, then we may say that a counterfactual outcome almost happened even if the distance between actual and counterfactual outcome was still relatively big. If Michael Jordan throws an air ball, we wouldn't say that he almost scored. However, if a small child who never even came close to the basket so far, finally makes a shot that is close to the rim, we would be happy to say that she almost scored this time.

Experiment 4: Almost caused

The results of Experiments 1–3 have demonstrated that people's judgments of whether something almost happened are sensitive to the causal distance between the actual and counterfactual world (Experiments 1 and 2), as well as prior expectations about what will happen (Experiment 3). In this experiment, we investigate what it means for something to

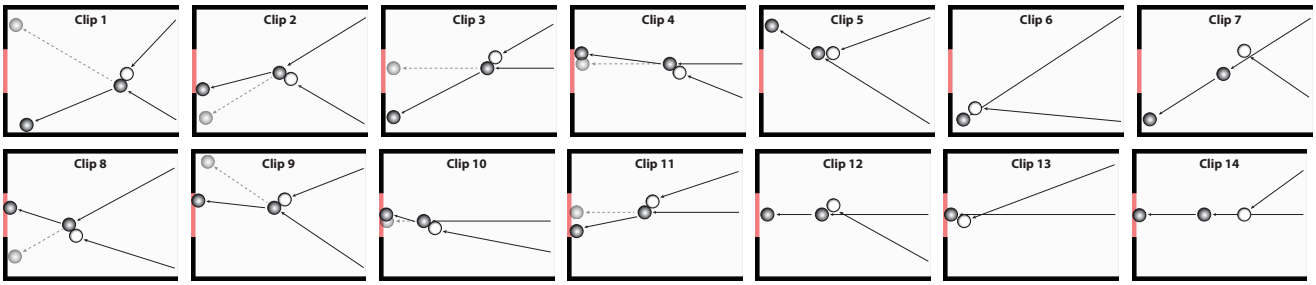


Figure 6: Stimuli used in Experiment 4. The top row shows clips in which the black ball (B) misses the gate. The bottom row shows clips in which the black ball goes through the gate. *Note*: Solid lines show the balls' actual paths, dotted lines show the black ball's trajectory if the white ball (W) had been absent.

have "almost caused" an outcome to happen or "almost prevented" it from happening.

We showed participants video clips of colliding billiard balls (see Figure 6). In half of the clips, the black ball (B) didn't go through a red gate (top row), while in the other half, B went through the gate. The clips also differed in a) how close the outcome actually was, b) whether the outcome would have been different if the white ball (W) had not been present in the scene, and c) whether the outcome would have been different if W's trajectory had been a little different from what it actually was.

For example, in Clip 1, B clearly missed the gate. It would also have missed the gate if W hadn't been present in the scene, or if W's trajectory had been slightly different from what it actually was. In Clip 9, B almost missed the gate. It would not have gone through the gate if W had been absent, and it could well have missed the gate if W's trajectory had been somewhat different. In some of the clips, the two balls didn't collide at all. For example, in Clip 5, W just misses B. If W's trajectory had been a little different, it could have knocked B into the gate.

Based on what we found in Experiments 1–3, we expected that participants agreement ratings with the "almost caused" or "almost prevented" statements, would be influenced by the perceived closeness of the counterfactual outcome, as well as the prior expectation about what will happen. Specifically, we hypothesized that participants would say that W almost caused B to go through the gate when 1) the actual outcome was close, and 2) it was clear that B would have missed the gate if W had been absent (cf. Gerstenberg et al., 2012, 2015). Conversely, we predicted that participants would agree with the "almost prevented" statement, if the outcome was close, and it was clear that B would have gone through the gate if W hadn't been there.

Methods

Participants 80 participants ($M_{age} = 31.6$, $SD_{age} = 10.2$, $N_{female} = 33$) completed this experiment.

Design and Procedure We manipulated what questions participants were asked to answer between participants. Participants in the *cause condition* ($N = 40$) indicated on a sliding scale to what extent they agreed with the statement that "The white ball almost caused the black ball to go through the gate." (when the black ball missed), or that "The white ball almost prevented the black ball from going through the gate." (when the black ball went through the gate). Participants in the *counterfactual condition* ($N = 40$) indicated to what extent they agreed with three different statements about the clip: 1) "The black ball almost went through the gate.", 2) "The black ball would have gone through the gate if the white ball had not been present in the scene.", and 3) "The black ball would have gone through the gate if the white ball's path had been slightly different from what it actually was." The statements were adapted based on whether the black ball went through or missed the gate. The endpoints of the sliders for all of the statements were labeled "not at all" (-50) and "very much" (50) and the order of the statements was randomized between participants.

The clips and statements were shown on the same page. Each clip was played in a loop so that participants were able to watch a clip as many times as they wanted while making their judgments. Two practice clips were presented at the beginning of the experiment. It took participants 7.2 minutes ($SD = 3.5$) on average to complete the experiment.

Results and Discussion

We will discuss the results from the counterfactual and causal condition in turn.

Counterfactual condition Figure 7 shows participants' mean agreement ratings for the three different questions they were asked for each clip. Participants judged that B almost went through the gate in Clips 2 and 4, and that it almost missed the gate in Clips 9 and 11. Participants had no trouble simulating what would have happened if W had been removed from the scene. They correctly believed that the out-

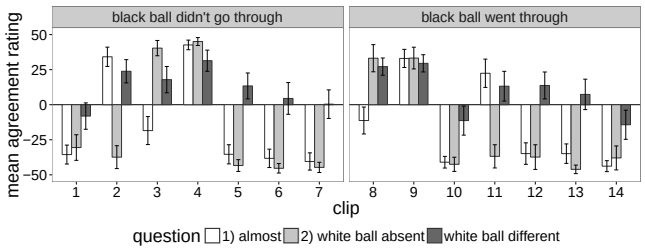


Figure 7: Mean agreement ratings for the different questions. *Note*: The question labels 1), 2), and 3) correspond to the questions as written in text.

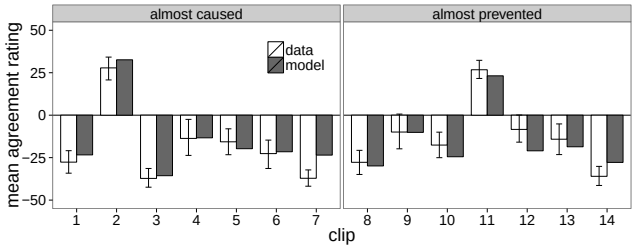


Figure 8: Mean agreement ratings (white bars) and model predictions (gray bars, $r = .95$).

come would have been different from what it actually was if W had been removed for Clips 3, 4, 8 and 9. Finally, they believed that the outcome would have been different if the W's trajectory had been somewhat different for Clips 2, 3, 4, 5, 8, 9, 11, and 12. While the answers to questions 1) and 3) were highly correlated ($r = .77$), there were situations in which they came apart. For example, for clips in which B missed the gate and the two balls didn't collide (Clips 5–7), participants disagreed that B almost went through the gate. However, they tended to agree that B would have gone through the gate if the W's trajectory had been somewhat different.

Causal condition Figure 8 shows participants' agreement ratings with the "almost caused" and "almost prevented" statements. Participants agreed that W almost caused B to go through the gate for Clip 2, and that it almost prevented B from going through for Clip 11. In all other situations, participants tended to disagree with the statement.

To explain people's agreement ratings in the causal condition, we use participants' responses from the counterfactual condition. The model that best accounts for participants' judgments in the causal condition combines participants' answers to questions 1) and 2) in the counterfactual condition [Model R^2 =.90; question 1 ($\beta = .96, p < .001$); question 2 ($\beta = -0.79, p < .001$); interaction ($\beta = -0.26, p = .046$)]. Question 3) was not a significant predictor of participants' causal judgments.

These results confirm our hypotheses: Participants say that W almost caused B to go through the gate when a) it actually missed the gate, b) it was clear that B would have missed if W hadn't been present, and c) it was actually close to going in. Interestingly, in situations in which W failed to collide with B, participants tended to disagree with the statement – even when a small perturbation to W's path would have been sufficient to bring about the alternative outcome (e.g. Clips 5 and 12). Thus, W must have actually made a difference for participants to say that it "almost caused" the alternative outcome: W "almost caused" when it "caused to almost".

General discussion

When do people say that something almost happened? In this paper, we have expanded on previous work that has investigated when counterfactual worlds come close (Kahneman & Miller, 1986; Kahneman & Varey, 1990; Teigen, 1996). In line with Kahneman and Varey (1990), Experiments 1 and 2 showed that the perceived causal distance between actual and counterfactual world affects participants' judgments that something almost happened. If a small perturbation to the relevant causal event would have been sufficient to generate the alternative outcome, then that outcome almost happened. In contrast to Kahneman and Varey (1990), Experiment 3 showed that participants' "almost" judgments were, in addition to causal distance, significantly influenced by manipulating prior expectations. Participants were more likely to say that an event almost happened, when their prior expectation was low. Finally, Experiment 4 extended these findings to modeling people's judgments about causation. In line with the *counterfactual simulation model* (Gerstenberg et al., 2015), participants judged that a candidate cause "almost caused" an event to happen when the cause actually made a difference to the outcome, it was clear that the outcome wouldn't have happened had the cause been absent, and when the counterfactual outcome was close.

Goodman's (1983) quote says that all possible worlds lie within the actual one. In this paper, we have shown what makes some worlds lie a little closer to the actual world than others (cf. Phillips, Luguri, & Knobe, 2015). In future work, we will further investigate how prior expectations and causal distance help us to bring order into possible worlds.

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