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Hindsight bias redefined: It's about time

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ABSTRACT

Four experiments introduced a new conceptual and methodological approach to hindsight bias, traditionally defined as the tendency to exaggerate the a priori predictability of outcomes after they become known. By examining likelihood estimates rooted to specific time points during an unfolding event sequence (videos and short text stories), judged both in foresight and hindsight, we conceptualized hindsight bias as a contrast between two “inevitability curves,” which plotted likelihood against time. Taking timing into account, we defined three new indicators of accuracy: *linear accuracy* (how well hindsight judgments capture the linear trend of foresight judgments over time), *rate accuracy* (how well hindsight judgments reflect the slope of foresight judgments over time), and *temporal accuracy* (how well hindsight judgments specify the overall timing of the full envelope of foresight judgments). Results demonstrated that hindsight judgments showed linear and rate accuracy, but were biased only in terms of lack of temporal accuracy. The oft-used catchphrase “knew it all along effect” was found to be a misnomer, in that participants were well aware in hindsight that their earlier foresight judgments reflected uncertainty. The current research therefore points to one way in which retrospective judgments can be considered biased, yet simultaneously suggests that considerable accuracy exists when people render such judgments.

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How well do people reconstruct the developmental trajectory of past event sequences? From public policy initiatives to marketing strategy, from political campaigns to romantic relationships, from military tactics to pedagogical innovation, very often the best way to understand success or failure is to understand the timeline of those specific events that led up to a focal outcome. Research on the hindsight bias suggests that people are biased in their retrospective judgments about unfolding event sequences. The hindsight bias, a tendency to view outcomes in hindsight as more predictable than they actually were in foresight (Blank, Musch, & Pohl, 2007; Hawkins & Hastie, 1990; Roese, 2004) has, however, rarely been studied with regard to events that unfold over time. Instead, hindsight bias has been understood largely in terms of summary judgments that do not have a specific time focus. For example, research has examined retrospective judgments that center on generic conclusions about a focal event, such as the successful opening of trade relations with China by US President Nixon (Fischhoff & Beyth, 1975), the resolution of a labor dispute involving firefighters (Pennington, 1981), the outcome of a football match (Roese & Maniar, 1997), and the verdict in the O. J. Simpson criminal trial (Bryant & Brockway, 1997). Hindsight has been the

topic of much interest, as it threatens sound decision-making in terms of evoking overconfidence, inflating blame attributions, and thwarting learning from experience (Harley, 2007; Hastie, Schkade, & Payne, 1999; Hawkins & Hastie, 1990). Although hindsight bias has been labeled a “knew it all along effect” (e.g., Christensen-Szalanski & Willham, 1991; Wood, 1978) thus implicitly referencing the element of timing, no research has directly examined how hindsight bias varies as a function of the judgment time point *during* an unfolding sequence. By taking time into account, the present research permits the specification of the “bias” from hindsight with regard to three unique indicators of accuracy.

Although several theories have been offered, common to most views is that hindsight bias derives primarily from memory processes involved in knowledge updating (Arkes, 1991; Hawkins & Hastie, 1990). As people learn the details of a particular outcome, those details selectively activate information from memory that is consistent with the outcome (as opposed to information that is more consistent with an alternative outcome; see Mussweiler, 2003). New information is then rapidly integrated within a network of interconnected knowledge structures, such that new semantic links are created between new outcome information and old knowledge. For example, learning that a struggling employee has been fired may bring to mind memories of consistent information (e.g., bad days on the job, a few absences), whereas

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inconsistent information (e.g., good days on the job, some favorable supervisor evaluations) tends not to be activated (Carli, 1999; Louie, 2005).

In nearly all previous research, hindsight bias has been measured via a pairwise contrast between a likelihood estimate of a specific event given in hindsight versus foresight (Pohl, 2007). Such a contrast could be made on a within-subject basis (e.g., a hockey fan might believe in preseason that the Detroit Red Wings have a 30% chance of winning the Stanley Cup; looking back after Red Wings indeed won the cup in 2008, the same fan might believe that his preseason estimate had been 60%; e.g., Fischhoff & Beyth, 1975; Lowe & Reckers, 1994) or on a between-subject basis (one group of naïve participants read about the 2007–2008 hockey season but do not learn who won the Stanley Cup, whereas a second group reads the same information also learns who won the Cup; e.g., Fischhoff, 1975). The key issue of timing centers on whether it matters at which point in time the foresight likelihood estimate is made. It seems intuitively obvious that the prediction of who will win a particular hockey game, for example, will vary over the beginning, middle, and final moments of the game. A win by the home-team might seem unlikely in the opening minutes, but may become far more likely in the closing minutes. After the game is over, hindsight bias may be defined in terms of post hoc certainty relative to a prior foresight estimate. But at which point in time should that corresponding foresight judgment be taken? One possibility would be to ensure specificity by assessing foresight estimates at the end of the first period of play, and then assessing hindsight estimates by asking observers to focus specifically on what the likelihood of victory had been at the end of the first period. The time point selected is arbitrary, however, foresight and hindsight judgments could as easily focus on the closing minutes of the game, or on any and all moments between the game's start and finish.

The issue of timing was invisible to prior research that was based on the presentation of static text stimuli. Earlier studies often assessed hindsight bias by comparing likelihood judgments made with or without the benefit of outcome information (e.g., how the game ended), as presented within a paragraph-length text. The outcome could be conveyed with a single phrase (“the Red Wings won”). With such a method, no particular moment in time need be specified nor even mentioned for likelihood judgments to be rendered. Timing did become an issue, however, in recent research that examined hindsight bias in judgments of dynamically unfolding events, i.e., video depictions of automobile accidents (Roese, Fessel, Summerville, Kruger, & Dilich, 2006). In this research, timing was found to be theoretically important, in that a hindsight bias reversal (termed the *propensity effect*) was discovered when judgments were made temporally near (as opposed to far) from the moment of collision. That is, when hindsight bias was benchmarked against foresight judgments that were made at a time point that was well before any indication of an impending collision, the traditional hindsight bias was observed: hindsight judgments of collision likelihood were substantially higher than foresight estimates. A different result emerged, however, when hindsight bias was benchmarked against foresight judgments made at the moment in time immediately prior to an impending collision. In that case, foresight judgments were greater than hindsight judgments, indicating that when participants felt “near” to a focal outcome that was nevertheless still in the future, they became hyperconfident of its likelihood.

Some other research has touched indirectly on the element of timing. Greater time periods separating foresight versus hindsight judgments are associated with larger hindsight bias (Blank, Nesler, von Collani, & Fischer, 2008; Bryant & Brockway, 1997). Bryant and Guibault (2002) examined likelihood judgments made both well before and immediately prior to the Senate impeachment verdict of U.S. President Clinton in 1999, and found that participants'

retrospective recognition of shifts in their own pre-outcome likelihood estimates faded as the event receded further into the past. Harley, Carlsen, and Loftus (2004) defined “visual hindsight bias” in terms of participants' post hoc judgments of when they had first recognized an obscured image that was gradually “unveiled.” In this work, although timing was a critical aspect of measurement, hindsight bias was nevertheless defined in terms of a pairwise contrast between a single foresight and a single hindsight judgment value (that is, the dependent measure used to define hindsight bias was the moment in time when recognition occurred, as opposed to the subjective likelihood of an outcome). Thus, although some research has examined aspects of timing in hindsight bias, no research has yet examined systematically how likelihood estimates shift over time in both foresight and hindsight.

To unpack the role of time in the hindsight bias, the present research deployed a new empirical approach based on assessment of multiple likelihood estimates, made both in foresight and hindsight, and compared on a within-subject basis. The likelihood estimates are made by participants at various time points during the unfolding of an event sequence (presented via video or text). In foresight, participants are naïve as to how the event sequence turns out. These multiple assessments may be plotted to express a type of learning curve called an *inevitability curve* (Tetlock & Lebow, 2001; see also Robinson & Hastie, 1985), in which the pattern of foresight judgments reflect a shift over time from relative uncertainty to complete certainty as “plot developments” converge on the focal outcome. At the moment of the focal outcome's occurrence, that outcome becomes, by definition, certain. After a suitable pause or filler task, participants then repeat the task. That is, they observe the same event sequence and make the same likelihood judgments, but this time with the benefit of hindsight. Accordingly, even though participants now know the outcome of the event sequence, their goal is to recapture their earlier, naïve frame of mind. This second series of likelihood judgments comprise a hindsight inevitability curve. Hindsight bias may then be conceptualized in terms of the difference between these two inevitability curves.

By unpacking hindsight bias in terms of the shift in judgment over time during an unfolding event sequence, it becomes possible to assess the extent of bias in terms of three new indicators of accuracy: linear accuracy, rate accuracy, and temporal accuracy (see Fig. 1).

Linear accuracy refers to how well an individual's hindsight judgments, for particular sequential points earlier in time, correspond to the foresight judgments made at those same sequential points in time. Because multiple likelihood estimates are given over time in both foresight and hindsight, the simple correlation between foresight and hindsight judgments (computed on a within-subject basis) yields an index of linear accuracy. Individuals may be considered accurate in a linear sense if their judgments in hindsight show a similar linear pattern as did their foresight judgments, as reflected by a significant, positive correlation (for a similar approach see Buehler & McFarland, 2001; Burson, Larrick, & Klayman, 2006; Krueger & Mueller, 2002; Moore & Healy, 2008). By contrast, bias in linear accuracy would be evidenced by a correlation that is close to zero or negative. For instance, a correlation of zero implies that hindsight judgments lack consistent correspondence with judgments that were made earlier at the same sequential points in time. A negative correlation suggests that individuals associate, in hindsight, the reverse linear pattern for judgments they gave in foresight at the same time points. A reader, for example, may erroneously remember that she considered the actual outcome successively more likely when starting to read the novel, when in fact she was led at first on the wrong track regarding the novel's ending.

Rate accuracy centers on the shape of the inevitability curve, and the extent to which participants correctly appreciate in hindsight

Fig. 1. Three kinds of accuracy defined via the timing of likelihood judgments.

the rate of increase in their earlier likelihood estimates over time. If, for example, foresight likelihood estimates rose sharply (i.e., a steep slope, or rapid rate of increase), rate accuracy is reflected by a pattern of hindsight likelihood estimates that embody the same steep slope. However, hindsight bias may involve misinterpreting the slope of the foresight curve, such that participants believe it to be steeper or shallower than it actually was. For instance, a subject might in foresight see the home-team's chance of victory shoot from 20% to 80% within a few moments during the third period of the hockey game (high rate). In hindsight, however, she might remember that her insight into the actual outcome came at a slower rate, i.e., a progression from 20% to 80% stretched over the entire game.

Finally, *temporal accuracy* refers to whether participants see in hindsight the overall trajectory of their foresight inevitability curve as occurring earlier or later in time than it actually was. One might accurately recapture the overall linear pattern of foresight judgments (linear accuracy) and also the slope of the inevitability curve (rate accuracy), but assume that the entire curve happened earlier in time. That is, each level of perceived likelihood would be seen as having been reached earlier in time than it actually was. Temporal accuracy may thus be defined in terms of the location of the inevitability curve's inflection point along the x-axis, which represents time. If accurate, the subject's hindsight inevitability curve is centered at the same time point as the foresight inevitability curve. Hindsight bias may, however, take the form of the hindsight inevitability curve being shifted earlier in time than the foresight inevitability curve. Importantly, it is conceptually possible for hindsight bias to involve bias on all, a few, or none of linear, rate, and temporal accuracy.

One additional exploratory aspect was addressed in this research. The hindsight bias has sometimes been referred to as a "knew it all along effect." Most often, this term has been applied to a particular paradigm in which people answer trivia questions, rate the confidence they have in their responses, then express heightened retrospective confidence after getting feedback on the accuracy of their responses (Wood, 1978). However, the term has also been used to describe the sorts of studies we have reviewed above, involving judgments of the likelihood of particular events and outcomes (Blank et al., 2008). Although a "knew it all along effect" is more a catchy phrase than formal empirical description, it is nevertheless fascinating to examine the extent to which people retrospectively profess certainty across earlier time points. We expected that people instead recognize that there were earlier points in time that involved lower likelihood estimates that then increased with the passage of time. We tested this idea by examining the slope of the hindsight inevitability curve. A slope that departs significantly from zero would indicate that participants do not believe that they "knew it all along," but rather that they recognized that there were indeed early points in time at which they did not "know it."

We summarize four experiments that employed this new approach of examining the inevitability curves derived from repeated likelihood judgments made both in foresight and hindsight. All experiments used a within-subject design, but varied in the stimuli used and the number of time points examined.

Method

Participants

Participants in all experiments were undergraduate students at the University of Illinois at Urbana-Champaign, participating for course credit.

Stimuli

In all experiments, participants watched or read about an unfolding event sequence, during which they were prompted repeatedly to make likelihood judgments about three possible outcomes.

In Experiments 1 and 2, the event sequence was a video depiction of an automobile collision (duration = 11.5 s), taken from Rose et al. (2006). This video was a computer-animated reconstruction of an actual traffic accident, and it depicted a semi-trailer truck avoiding a slow moving automobile that had just turned in front of it onto a two-lane highway. As the truck maneuvers to the left of the automobile, it passes into the oncoming lane and collides head-on with a bus.

In Experiment 3, participants read a short story, *After Twenty Years*, by O. Henry (word count: 1219). The story was presented as a sequence of computer slides, each consisting of a few sentences. The story focuses on a man named Bob who is fulfilling an appointment, made 20 years earlier, to meet his friend Jimmy on a street corner in New York City. A policeman appears and questions Bob about whom he is waiting for. Bob tells the policeman about the appointment, and the policeman leaves. Afterwards, a person who seems to be Jimmy appears. However, Bob realizes after a while that the man is not Jimmy. The stranger turns out to be a policeman who arrests Bob and hands him a note. The note is from the first policeman who explains that he in fact is Jimmy and showed up to keep the appointment they had made. Jimmy, however, recognized Bob as a wanted criminal and, unwilling to arrest his former friend, sent a colleague to do so.

In Experiment 4, participants read via computer an abridged version of the short story, *Letter From the Understudy*, by Kathryn Simmonds (word count: 1576). The story is written in a letter format from the perspective of an understudy to a director of a play. In the letter, the understudy voices his frustration with the leading man. Toward the end of the letter, it becomes apparent that the understudy severely assaulted the leading man to obtain his part.

Procedure

In all experiments, participants first watched or read about the event sequence in naïve state (i.e., in foresight). During this foresight phase, the event sequence was paused at specific time points, during which participants were prompted to make likelihood judgments (along a scale ranging from 0% to 100%) for three possible outcomes, one of which did eventually occur. For example, in the video depicting an automobile accident (Experiments 1 and 2), participants assigned likelihoods to the following possible outcomes: no accident, minor accident, and serious accident (see Appendix). An interface appeared on the computer screen that forced participants to assign likelihoods for the three possible outcomes such that they summed to 100%. The number of time points at which the presentations were interrupted was 4, 11, 10, and 6 across the respective four experiments. Only likelihood estimates for the outcome that eventually occurred were used in our analyses. Likelihood estimates for the other two event outcomes were disregarded.¹

Except for Experiment 2 in which likelihood judgments were evenly distributed over each second of the event sequence, time points for the other experiments were chosen so as to capture interesting story line progressions (i.e., before and after plot developments). As a result, the video in Experiment 1 was divided into parts that were between 2.4 s and 4.3 s in length. The story in Experiment 3 was divided into parts with between 51 and 215 words, and the story in Experiment 4 into parts with between 140 and 395 words.

Participants in Experiments 1 and 2 were instructed that the experiment would be about people's perception of driving, and that they were to make predictions about the outcome of the traffic scene. They were told that the computer would randomly select a traffic scene from a pool that included animations about normal traffic patterns and accidents (in fact, all participants saw the same traffic scene which resulted in an accident). For Experiments 3 and 4, the instructions read that the experiment was about participants' "gut reactions" when it comes to making predictions as a story unfolds. They were further told that the story would be interrupted at various time points and they would be asked to make predictions about how the story would end.

After completing this series of foresight likelihood judgments, participants completed filler tasks so as to introduce a delay between foresight and hindsight judgments. In Experiments 1 and 2, the delay was between 5 and 10 min, during which participants completed a separate questionnaire that included questions about the video they had seen, but also unrelated self-report measures. In Experiments 3 and 4, the delay was between 20 and 30 min, during which participants completed an unrelated experiment. Prior to completing the hindsight series of judgments, participants received a discounting instruction.

In measuring hindsight bias, the discounting instruction carries special importance. Hindsight bias is not merely use of new knowledge (i.e., learning), but rather the difficulty in setting aside this new knowledge when assessing past states of affair. In a between-subject assessment of hindsight bias, participants in the foresight condition receive no outcome information, whereas participants in hindsight condition receive outcome information, but are also instructed to disregard it, and make judgments as though they did not receive that outcome information. For example, hindsight condition participants in a study by Wasserman, Lempert, and Hastie (1991) were asked to put themselves "in the shoes" of the foresight participants when judging the likelihood of various

possible outcomes (p. 32). We used two variations of discounting instructions across the four experiments, so as to attain some generality of results. In Experiments 1 and 2, the instructions were akin to those used by Wasserman et al., in that they focused on others' naïve point of view:

Next, you will see the same traffic video again, and be asked to answer the same questions just as before. Even though you know how the story turns out, try to estimate the probabilities as they seemed to the drivers involved.

In Experiments 3 and 4, participants were given instructions to try to recapture their own naïve point of view:

This part of the experiment is basically the same as the one you completed earlier. However, some participants will receive the exact same information, while other participants will receive a story that has minor alterations. Please re-read the story (and try to notice any changes), and then complete the same ratings. Of course, you now know how the events turn out. Your job is to answer all the likelihood questions that follow as you did during the first half of the experiment, before you knew the outcome of the story.

In both of Experiments 3 and 4, the aspect of the instruction that notes that there were minor alterations was in fact a cover story, intended merely to increase participants' motivation to read the story attentively a second time. After completing the hindsight judgments, participants in all four experiments were fully debriefed, thanked, and released.

Results

Although we assessed multiple foresight and hindsight judgments, a global index of hindsight bias could be summarized in a manner analogous to prior research, by comparing the mean of all foresight judgments to the mean of all hindsight judgments. This resulted in a pairwise contrast (i.e., *t*-test), performed for each experiment and tabulated in Table 1 as "global HSB." Using this definition, hindsight bias was significant in Experiments 1, 3, and 4 ($ps < .01$), but was only marginally significant in Experiment 2 ($p = .09$). In all four cases, the direction of the effect was indicative of hindsight bias, such that the hindsight mean likelihood was greater than the foresight mean likelihood. Thus, the present four experiments were consistent (at least at a very general level), with the findings reported in the hindsight bias literature. The inevita-

Table 1
Hindsight bias.

	Stimulus	Time points	Global HSB (<i>t</i>)	Hindsight beta
Expt. 1 (<i>n</i> = 18)	Video	4	3.96**	.92**
Expt. 2 (<i>n</i> = 19)	Video	11	1.79†	.89**
Expt. 3 (<i>n</i> = 26)	Text	10	4.06**	.57**
Expt. 4 (<i>n</i> = 53)	Text	6	2.90**	.92**

Note: Stimulus refers to the type of stimulus event sequence about which participants made likelihood judgments. Time points refers to the number of discrete likelihood judgments participants made in both foresight and hindsight. Global HSB is analogous to the traditionally defined hindsight bias: the contrast between the mean of all foresight versus the mean of all hindsight judgments (given as *t*-statistic testing this pairwise contrast). Hindsight beta refers to the standardized beta in a regression model that relates time to subjective likelihood estimate; a significant beta indicates a non-zero slope, such that likelihood estimates increase over time.

† $p < .10$.

** $p < .01$.

¹ The initial outcome likelihood estimates tended to be low but not zero. The means across the four experiments were 7.8%, 9.0%, 25.4%, and 15.0% (*SDs* = 12.2, 14.3, 15.5, 15.6).

Fig. 2. Foresight and hindsight inevitability curves derived from mean likelihood estimates.

bility curves based on likelihood judgments regarding the actual outcomes in both foresight and hindsight are depicted for each experiment in Fig. 2.

Linear accuracy

Linear accuracy was defined in terms of the extent to which participants were able, in hindsight, to recapture the likelihood estimate for particular points in time, i.e., the linear increase in likelihood estimates over time. Accordingly, linear accuracy was indexed by the within-subject correlation between the foresight and hindsight judgments of the actual outcome, with higher correlations indicating greater linear accuracy. As Table 2 shows, this mean within-subject correlation was substantial and significant in all four experiments, ranging from $r = .67$ (Experiment 3) to $r = .92$ (Experiment 2), weighted mean $r = .86$. Thus, in terms of linear accuracy, the first of the three indicators to be examined, participants were relatively accurate. Hindsight bias could therefore not be defined as difficulty with linear accuracy.

Logistic regression

To examine the next two kinds of accuracy (rate accuracy and temporal accuracy), we used a logistic regression to capture the shape of the inevitability curve. The logistic curve, with its rich history of application in psychology (from learning curves to item response theory) and other sciences (e.g., animal and plant growth curves in biology), is bound on the y-axis by 0 and 1, making it highly suitable for modeling subjective likelihood estimates for specific outcomes. Moreover, the logistic curve permits us to extract information regarding the pattern or shape of inevitability curves that would be invisible to simple aggregation within means. Accordingly, we estimated the best-fitting curve through the data points that comprised both the foresight and hindsight inevitability curves for each subject. The curves were estimated using the 2-parameter logistic function:

$$\text{Likelihood} = \frac{1}{1 + e^{a(x-b)}}$$

In this equation, participants' likelihood estimates are equated to time point (x) and two parameters (' a ' and ' b '), along with the constant ' e '. The ' a ' parameter represents the slope at the inflection point, and thus may be used as the indicator of rate accuracy. The ' b ' parameter reflects position of the inflection point along the x-axis (time) and thus may be used as the indicator of temporal accuracy. The logistic regression was completed on a within-subject basis, for each of the foresight and the hindsight likelihood estimates, using a gradient descent (i.e., least squares) routine involving 1000 iterations. This resulted in the extraction of a unique value for both the ' a ' and the ' b ' parameter, for both foresight and hindsight curves, for each subject.² As an illustration, Fig. 3 depicts the foresight and hindsight inevitability curves as plotted via the mean logistic regression parameter estimates from Experiment 1. That is, the parameter estimates, computed on a within-subject basis, were averaged across participants, then plugged into the logistic equation to specify the corresponding curves. Although the graph in Fig. 3 plots exactly the same data as the graph located in the top-left quadrant of Fig. 2, the approach based on logistic regression represents a strikingly elegant means of representing hindsight bias.

² In the logistic regression, we used arbitrary time-point markers corresponding to each moment at which a likelihood judgment was made. In Experiment 2, judgments were made at equal time intervals. In the other three experiments, however, the time intervals were chosen so as to capture unique plot developments. This results in a slight distortion in the logistic regression's ability to capture the "true" slope and position of the inevitability curve. However, we had no theoretical interest in the parameter estimates in and of themselves, but rather only in the relative difference between the foresight and hindsight parameter estimates. Because any such distortion applies equally to both foresight and hindsight parameter estimates, the mean difference between the two parameter estimates is unaffected by this distortion.

Table 2
Indicators of accuracy.

	Linear accuracy (<i>r</i>)	'a' Foresight	'a' Hindsight	Rate accuracy (<i>t</i>)	'b' Foresight	'b' Hindsight	Temporal accuracy (<i>t</i>)
Expt. 1	.80**	−4.22	−2.61	1.90†	3.04	2.51	−2.51*
Expt. 2	.92**	−4.78	−4.56	.30	2.51	2.33	−.91
Expt. 3	.67**	−2.23	−1.76	.63	4.17	2.31	−2.66**
Expt. 4	.90**	−2.92	−2.75	.46	2.32	2.06	−2.78**
Bias?	No			No			Yes

Note: Linear accuracy refers to how well participants could, in hindsight, recapture the foresight likelihood estimates made at particular points in time. The value given is the mean within-subject correlation between foresight and hindsight judgments. Greater correlations indicate greater linear accuracy. For each participant, one 'a' and 'b' parameter in foresight and hindsight was computed. Above are the mean coefficients for each experiment in foresight and hindsight, averaged across participants. The 'a' foresight and hindsight parameters represent the slope at the inflection point in foresight and hindsight, which indicated rate accuracy. The 'b' foresight and hindsight parameters represent the position of the inflection point along the x-axis (time) in foresight and hindsight, which indicated temporal accuracy. Rate and temporal accuracy were assessed via the contrast between the respective parameters in foresight and hindsight, using a *t*-statistic.

† *p* < .10.* *p* < .05.** *p* ≤ .01. **Fig. 3.** Foresight and hindsight inevitability curves derived from mean logistic regression parameters (Experiment 1).

Rate accuracy

Regarding rate accuracy, the mean (i.e., averaged across participants) value for the 'a' parameter did not differ between foresight versus hindsight judgments in any of the four experiments (see Table 2). Thus, participants demonstrated rate accuracy, in that they were able to reconstruct in hindsight the slope of their earlier foresight judgments. In other words, participants in hindsight accurately reconstructed the rate of increase within the trajectory of their foresight judgments. We therefore concluded that hindsight bias does not involve difficulty with rate accuracy.

Temporal accuracy

Turning next to temporal accuracy, we defined this type of accuracy by comparing the mean value for the 'b' parameter between foresight and hindsight judgments. Using a *t*-test to accomplish this within-subject contrast, we found it to be significant in three of the four experiments (see Table 2). The direction of the effect was consistent across the experiments: participants in hindsight gave likelihood estimates which were positioned earlier in time than was actually the case in foresight. Accordingly, we concluded that hindsight bias may be defined specifically in terms of temporal accuracy, but not in terms of linear accuracy or rate accuracy.

A question that arises with regard to our three indicators of accuracy is the extent to which they are independent versus overlapping indicators. To be sure, they are conceptually distinct, but we may also assess their empirical independence by computing the between-subject correlations between them. For linear

accuracy, the correlation coefficient was used as the data point. For both of rate accuracy and temporal accuracy, the difference score between the foresight and hindsight parameter estimates were used (foresight subtracted from hindsight). These indices were first correlated within each experiment separately (see Table 3). The mean correlation between linear and rate accuracy was $r = 0$ (range: −.19 to .27 across the four experiments); the mean correlation between linear and temporal accuracy was $r = .2$, $p = .11$ (range: −.41 to .44); the mean correlation between rate accuracy and temporal accuracy was $r = -.09$, $p = .47$ (range: −.32 to .08). As can be seen in Table 3, the lack of consistent correlation between these indicators of accuracy substantiates their use as independent indicators.

Knew it all along?

Finally, we investigated the merit of the catchphrase "knew it all along effect" as a description for hindsight bias. To "know it

Table 3
Correlations among hindsight bias indices.

Accuracy Index	A	B	C
<i>Experiment 1</i>			
A. Linear	–	−.19	−.41†
B. Rate		–	−.16
C. Temporal			–
<i>Experiment 2</i>			
A. Linear	–	.02	−.25
B. Rate		–	−.32
C. Temporal			–
<i>Experiment 3</i>			
A. Linear	–	.27	.42*
B. Rate		–	.08
C. Temporal			–
<i>Experiment 4</i>			
A. Linear	–	−.07	.44**
B. Rate		–	−.06
C. Temporal			–
<i>Overall mean</i>			
A. Linear	–	.00	.20
B. Rate		–	−.09
C. Temporal			–

Note: Linear accuracy is the within-subject correlation between foresight and hindsight judgments, averaged across participants for each experiment. Rate and temporal accuracy indices were created with difference scores (hindsight minus foresight) of the 'a' and 'b' parameters. The overall mean correlations were computed across the four experiments using the Fisher's *Z*-transformation and weighted by sample size.

† *p* < .10.* *p* < .05.** *p* < .01.

all along” means, in essence, that the subjective likelihood of a once-future event, now known in hindsight, was relatively invariant over time. That is, one says the likelihood of home-team victory was 80% in the third quarter of a football game, then “knowing it all along” means that the subjective likelihood was 80% in the second and first quarters as well. Phrased in terms of an inevitability curve, it means that the slope of the hindsight curve is relatively flat. Because the beta weight in a regression that relates hindsight likelihood estimates to time represents the slope of likelihood estimates over time, a “knew it all along” effect suggests that the slope should not depart significantly from zero. In fact, as Table 1 shows, we found that in all four experiments, the standardized beta weights were significantly different from zero, indicating instead substantial slope (i.e., positive linear relation between likelihood estimate and time). As is evident from Fig. 2, in all four experiments the likelihood estimates for the target outcome increased over time. Hence, these four experiments show that people, when looking at their own pre-outcome judgments of outcomes, do not convey the belief that they “knew it all along.” Rather, hindsight bias is better captured by the description that people “knew it *earlier*” than they actually did.

Discussion

Many of the predictive and retrospective judgments made in everyday life involve events that are ongoing, unfolding, evolving. How an initiative or strategy is unfolding may appear radically different when viewed early on rather than later on. Hindsight bias is a widely studied judgment phenomenon involving the exaggeration of the earlier predictability of outcomes. Yet because of the relative simplicity of past research designs and stimulus materials, the importance of time was never captured empirically. In the present research, we show that taking time into account provides a new way of conceptualizing the hindsight bias. Whereas past research defined accuracy via the single index of the contrast between likelihood judgments made at two time points (one in hindsight and one in foresight), we used the element of time to unpack three distinct indicators of accuracy in hindsight judgments.

By examining predictive likelihood judgments at different key moments in time, an inevitability curve (Tetlock & Lebow, 2001) may be derived that characterizes the trajectory of judgments as an event sequence unfolds. With likelihood on the y-axis and time on the x-axis, and inevitability curve describes the subjective shift in predictive likelihood of a focal outcome as it progresses from possibility to actuality. By definition, after an event has occurred it may be said to be definite, or to have a probability of occurrence of 1.0. Thus, the inevitability curve is always anchored at its far-right end-point at the 1.0 level on the y-axis. In the present research, we chose event sequences that were initially ambiguous, but as plot developments occurred, a particular outcome became more likely. Thus, the shape of the inevitability curves had a positive slope, rising over time to the point of subjective certainty. The shape of the inevitability curve may be described via logistic regression, in which the best-fitting S-shaped curve is estimated for each set of time-dependent data points. The logistic equation embodies two parameters, one focusing on the slope at the inflection point and the other the position on the x-axis (i.e., time) at the inflection point. These two parameters provide a new way to assess accuracy versus bias in hindsight judgments.

We specified three indicators of accuracy. Linear accuracy was the simplest of the three. It was assessed by the simple correlation between the foresight and hindsight percentage likelihood judgments over time that participants assigned to the outcome that eventually occurred. It reflects (within each subject) how well hindsight judgments correspond to the foresight judgments made at the same sequential points in time. Linear accuracy therefore

captures the extent to which participants can describe in hindsight their own linear pattern of previous judgments. The next two indicators, rate accuracy and temporal accuracy, are the ones derived from the logistic regression. Rate accuracy reflects the ability of participants to correctly state in hindsight the rate of increase of their earlier likelihood estimates over time, hence it was assessed using the slope parameter (the ‘a’ parameter) from the logistic regression. Temporal accuracy refers to whether participants see in hindsight the overall trajectory of their foresight inevitability curve as occurring earlier or later in time than it actually was. Temporal accuracy was assessed using the parameter that indicates the position of the inflection point on the x-axis (the ‘b’ parameter).

To benchmark our findings against previous research, we created a “global hindsight index” by contrasting the mean of all foresight judgments to the mean of all hindsight judgments. Because this index boils down to a pairwise contrast, it is analogous to the standard definition of hindsight bias used in the published literature. This index indicated that our four experiments had evoked hindsight bias of roughly equivalent effect size as has been reported in this literature (see meta-analytic summaries in Christensen-Szalanski & Willham, 1991; and Guibault, Bryant, Brockway, & Posavac, 2004). Our three new indicators of accuracy suggested, however, that judgments in hindsight may be further characterized as being accurate both in the linear sense and the slope sense. In terms of linear accuracy, participants were accurate in recognizing the general linear trend of their earlier judgments over time. That is, the correlations between foresight and hindsight judgments (computed on a within-subject basis) were significant, with a weighted mean of $r = .86$. In terms of rate accuracy, there was no significant difference between the slope of participants’ inevitability curves in hindsight versus foresight. Thus, as participants reconstructed their earlier likelihood estimates in hindsight, they accurately gauged the rate at which likelihood for the target outcome increased. It was only temporal accuracy that revealed a clear bias. In examining the ‘b’ parameter describing participants’ inevitability curves, a consistent bias emerged in which participants judged in hindsight that the trajectory of their foresight inevitability curve had occurred earlier than it in fact had.

The term “knew it all along effect” (sometimes used as a synonym for hindsight bias) has perhaps been used primarily as attention-grabbing jargon rather than precise hypothesis. Even so, our research method permitted an examination of the “all along” aspect of hindsight bias. Our results showed that “knew it all along effect” is a misnomer, in that participants easily sidestepped the mistake of claiming to have known something all along when they actually did not. Rather, their retrospective judgments were accurate in recalling their progression from not knowing to knowing. Moreover, participants were accurate in reporting the general trajectory (i.e., slope) of their earlier judgments over time.

The hindsight bias literature bears a certain similarity to research on affective forecasting errors, in that both have defined a bias in terms of the gap between two means (in affective forecasting research, the gap is between the predicted versus actual emotional reaction to a specific outcome, e.g., Kermer, Driver-Linn, Wilson, & Gilbert, 2006; Wilson & Gilbert, 2003). Buehler and McFarland (2001), however, examined not only this mean difference but also an index of accuracy based on the correlation between predicted and actual emotional response. Thus, when making predictive judgments of one’s own emotional reactions, people are accurate, in the sense that participants who predicted strong emotional reactions relative to their peers were indeed those who experienced strong reactions. This earlier study, like ours, “simultaneously revealed evidence of both accuracy and bias” (p. 1492). The same connection can be made to research on overconfidence that is defined in terms of participants’ predicted versus actual performance (labeled “overestimation” by Moore & Healy,

2008). Research has sometimes assessed overconfidence as the gap between mean predicted versus mean actual performance, but other times as the correlation between the two (Burson et al., 2006; Krueger & Mueller, 2002).

Our use of logistic regression to estimate curves that describe within-subject patterns is new to the hindsight bias literature, but bears similarities to approaches used in other areas of psychology. For example, Rouder, Lu, Speckman, Sun, and Jiang (2005) used the 3-parameter Weibull function to describe within-subject patterns of reaction time data. Whereas most research assesses only the within-subject means of reaction times, the Rouder et al. approach permitted the data to be described in terms of three parameters: shift (the position of the distribution along the x -axis, akin to mean), scale (akin to kurtosis), and shape (akin to skewness). These three aspects were in turn postulated to signify distinct psychological processes: the shift parameter was connected to automatic, heuristic processes whereas the scale and shape parameters were connected to controlled, effortful processes (cf. Chaiken & Trope, 1999; Stanovich & West, 2000). In the present research, we have not gone so far as to similarly connect the two parameters of the logistic function to distinct psychological functions, but we recognize this prospect as an intriguing avenue for further research (cf. Blank et al., 2008).

It should be pointed out that the event sequences used as stimuli in this research all involved outcomes that were unexpected. That is, in all four experiments the outcome that did occur was judged to be relatively unexpected at the outset (see Fig. 2). Importantly, unexpected outcomes have been found to trigger a sense-making mechanism that, if successful, reduces initial surprise and produces hindsight bias (Ofir & Mazursky, 1996; Pezzo, 2003; Roese & Olson, 1996, 1997; Schkade & Kilbourne, 1991). In dynamic plot development, the sense-making process might not affect hindsight judgments uniformly at all time points. Therefore, plot developments that lead to the resolution of otherwise surprising or unexpected outcomes might lend themselves to stronger higher hindsight bias than more mundane story line developments. Future research may employ the present methods to explore the role of the timing of surprise effects on sense-making.

Results from the current studies might also extend our understanding of existing models of hindsight bias. According to one prominent view, hindsight bias is a by-product of an otherwise adaptive learning process (e.g., Blank & Nestler, 2007; Hoffrage, Hertwig, & Gigerenzer, 2000; Müller & Stahlberg, 2007). In this view, people in foresight use the most discriminative cue to infer the true state of affairs. After receiving outcome knowledge, cue values show systematic shifts towards feedback, leading awareness of previously missing links between aspects and features of a situation. In the case of continuous story development, however, the number of available cues at each particular time point might vary, as might their associated predictive validity for the outcome. Future research should therefore more directly test how plot developments affect the availability and value of cues at various time points, and how this, in turn, leads to fluctuating hindsight bias over time.

In assessing the overall value of our research method, it is important to note both the benefits and drawbacks. In terms of benefits, likelihood estimates made at various time points allow for a “snapshot” depiction of judgment changes over time, and how hindsight judgments differ from foresight judgment at each respective time point. This method mirrors the process of how people render judgments in real life, at least under some circumstances. For instance, during political campaigns such as presidential elections, individuals may periodically assess the likelihood of their preferred candidate’s victory. Likewise, readers of detective novels may assess and dynamically readjust their likelihood estimates of the main suspect’s guilt as the story unfolds.

However, the current methodology also differs in some important aspects from real world judgments. Most notably, even though movies, TV shows, or books can be viewed or read a second time, exact repeats of events in everyday life are the exception rather than the rule. The “replay” aspect of our method allowed cues (both accurate and inaccurate) to be experienced in foresight then re-experienced in hindsight. This replay aspect may have drawn more attention in hindsight to the uncertainty people experienced in foresight than otherwise would be the case. As a result, our method might provide an underestimate of hindsight bias.

To summarize, time has been the missing element in past theoretical depictions of hindsight bias. In introducing the method of “inevitability curves” to hindsight bias research, we used multiple assessments of likelihood estimates during an unfolding event sequence to define three new indicators of accuracy. Hindsight bias, we found, involves a temporal bias in seeing past levels of likelihood being attained earlier than they actually were. This temporal bias, however, was juxtaposed against accuracy in recognizing the earlier trajectory of one’s judgments over time. We hope to see further research on how judgments shift with dynamically changing stimuli.

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Appendix

Response options in Experiment 1

Using a number between 0% and 100%, estimate the likelihood of the following possible events:

- (A) No accident
- (B) Minor accident
- (C) Major accident³

Response options in Experiment 2

Use a number between 0% and 100% to make your prediction for the chances of three different outcomes. Remember: 0% means that the outcome is impossible and 100% means that that outcome is certain. Outcomes A, B, and C must add up to 100%.

- (A) No accident
- (B) Minor accident
- (C) Major accident³

Response options in Experiment 3

Use a number between 0% and 100% to make your prediction for how the story will end.

Remember: 0% means that the outcome is impossible and 100% means that that outcome is certain. Outcomes A, B, and C must add up to 100%. When done, press “Continue.”

- (A) Friend shows up after main character finishes talking to policeman.
- (B) The policeman is the friend who has the main character arrested.³

³ Actual outcome.

- (C) Policeman tells main character that friend will not show up because he was shot in a robbery one week before.

Response options in Experiment 4

Use a number between 0% and 100% to make your prediction for how the story will end.

Remember: 0% means that the outcome is impossible and 100% means that that outcome is certain. Outcomes A, B, and C must add up to 100%. When done, press “Continue.”

- (A) Gavin (narrator) confronts Alex (colleague) and accuses Alex of intriguing against him to cling onto his role.
 (B) Gavin (narrator) calmly persuades Alex (colleague) to temporarily give him his part.
 (C) Gavin (narrator) severely beats up Alex (colleague) to get his part.³

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