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RUNNING HEAD: ROLE OF SURPRISE IN HINDSIGHT BIAS

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Abstract

Hindsight bias is the well researched phenomenon that people falsely believe that they would have correctly predicted the outcome of an event once it is known. In recent years, several authors have doubted the ubiquity of the effect and have reported a reversal under certain conditions. This article presents an integrative model on the role of surprise as one factor explaining the malleability of the hindsight bias. Three ways in which surprise influences the reconstruction of pre-outcome predictions are assumed: (1) Surprise is used as direct metacognitive heuristic to estimate the distance between outcome and prediction. (2) Surprise triggers a deliberate sense-making process, and (3) also biases this process by enhancing the retrieval of surprise-congruent information and expectancy-based hypothesis testing.

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Introduction

In hindsight, there is little doubt that a certain soccer team would win a championship, or a certain financial investment would prove to be a success. But did we really predict this before the outcome was known to us? In many fields of judgment, this has to be doubted. The almost ubiquitous tendency of people to falsely believe that they would have correctly predicted the outcome of an event once the outcome is known is called hindsight bias (for meta-analyses see Christensen-Szalanski & Willham, 1991; Guilbault, Bryant, Brockway, & Posavac, 2004).

Since Fischhoff and his collaborators (e.g., Fischhoff, 1975, 1977; Fischhoff & Beyth, 1975) first investigated this phenomenon in the mid-seventies, numerous studies on the hindsight bias have been reported (for reviews see Hawkins & Hastie, 1990; Stahlberg & Maass, 1998). In sum, hindsight bias has been found in a wide variety of contexts and several studies have demonstrated its robustness vis-à-vis most attempts to reduce or eliminate it. For example, even if participants were carefully informed about the effect or asked to try not to fall prey to this bias, they were unable to ignore the outcome information (Fischhoff, 1975, 1977). In their meta-analysis of 128 hindsight bias studies, Christensen-Szalanski and Willham (1991) found only six studies without a significant effect.

In recent years, however, several authors have doubted the ubiquity of the hindsight bias phenomenon and have reported even a reversal of the hindsight bias under certain conditions. At least two conditions have been specified under which such a reversed hindsight bias can be expected: (1) A reversed hindsight bias has been postulated and demonstrated for outcomes that are perceived to be highly unexpected or unlikely from a foresight perspective (see Mazursky & Ofir, 1990; Ofir & Mazursky, 1997; Pezzo, 2003; Verplanken & Pieters, 1988). (2) A reversed hindsight bias has also been predicted and found when the outcome was of high personal relevance and at the same time highly self-threatening (see Louie, 1999; Louie, Curren, & Harich, 2000; Mark & Mellor, 1991; Stahlberg, Hintz, & Schwarz, 2005; Stahlberg & Schwarz, 1999). The aim of this paper is to propose a new model explaining the role of surprise in hindsight bias, therefore, we will focus on the first condition, and previous research on this topic is reviewed in detail in the next paragraph.

Differing views on the role of surprise

In the early history of hindsight research, it was assumed that outcome information that is highly inconsistent with participants' expectations would strengthen the hindsight bias (Fischhoff, 1975; Wood, 1978). The argument by Fischhoff and others was that highly unexpected outcomes will elicit a causal search to explain or make sense of that outcome in order to regain control and to render the world predictable. If information is inconsistent with expected outcomes, more cognitive effort is required to solve this sense-making task. During this process, many initial assumptions will be revised, resulting in greater changes in the cognitive structure regarding the outcome in question. Altogether, this more intensive sense-making process, compared to processes elicited by expectancy-congruent outcomes, will result in stronger hindsight bias effects (Roese & Olson, 1997; Schkade & Kilbourne, 1991). In line with this view, several studies have shown that people in fact exhibit greater hindsight bias when confronted with difficult and misleading questions, and therefore, with presumably more surprising answers (Christensen-Szalanski & Willham, 1991; Fischhoff, 1977; Hoch & Loewenstein, 1989; Winman, 1997).

More recently, however, other researchers have introduced an opposing view concerning the influence of surprise on the magnitude and direction of hindsight bias (see Mazursky & Ofir, 1990; Ofir & Mazursky, 1997; Renner, 2003; Verplanken & Pieters, 1988). These researchers argue that at least highly unexpected outcomes can lead to a reduced or even a "reversed" hindsight bias. Verplanken and Pieters were the first to assume that there may be a threshold of surprise where a "I knew it all along" (hindsight bias) judgment actually turns into a ”I could never have expected this to happen” judgment (reversed hindsight bias). The authors demonstrated this reversed hindsight bias in the context of the Chernobyl nuclear power accident in 1986. Although this first study has been criticized on methodological grounds, other studies using more clear-cut experimental methods have meanwhile accumulated further evidence for reversed hindsight biases (Hintz, Stahlberg, & Schwarz, 2000; Mazursky & Ofir, 1990; Ofir & Mazursky, 1997; Pezzo, 2003; Stahlberg, Sczesny, & Schwarz, 1999; Whittlesea & Williams, 2001).

Pezzo’s Sense-Making Model

Following a profound analysis of the contradicting evidence regarding the role of surprise in hindsight bias, Pezzo (2003) offered an integrative model. Based on the differentiation between initial surprise (the spontaneous feeling that is elicited when a person is confronted with an unexpected outcome) and resultant surprise (the residual feeling that can remain after the sense-making process if this process was not entirely successful), Pezzo suggested that a certain amount of initial surprise is necessary to activate a sense-making process. Without such a sense-making process which leads to a restructuring of the cognitive system, no hindsight bias can be expected. If the outcome elicits enough initial surprise, sense-making will occur. This process will result in hindsight bias if it is successful. However, if the individual cannot make sense of this outcome, resultant surprise will prevail and a reversed hindsight bias will be the consequence.

This model allows for the integration of most of the contradicting results regarding the role of surprise in hindsight bias. This can be demonstrated by looking at a series of experiments by Hoch and Loewenstein (1989). Their studies have been cited by some authors (e.g., Hawkins & Hastie, 1990; Louie, 1999; Louie et al., 2000; Pohl, 1998) as evidence for the hypothesis that surprising outcomes (of difficult or misleading items) will result in less or even reversed hindsight bias and by others for the opposite hypothesis that surprising outcomes will lead to a stronger hindsight bias (e.g., Pezzo, 2003). Interestingly, both positions are correct and the series of experiments offers evidence for both hypotheses. On the one hand, Hoch and Loewenstein found that difficult questions led to a stronger *hindsight bias* (overestimation of one's own ability to answer the question correctly) in Experiments 1 to 3. On the other hand, when looking at the correlation between surprise ratings and hindsight bias, in Experiment 4 the authors found that surprise ratings about the outcome correlated negatively with the hindsight bias. Furthermore, Hoch and Loewenstein found in Experiment 5 that for certain incremental, non-insight problems (e.g., anagram-like tasks), feedback led to a reversed hindsight bias while feedback in insight problems led to a strong hindsight bias. They, therefore, assumed (without having actually measured surprise in this experiment), that: "Subjects may simply not experience an appropriate level of surprise when they see the right answer to difficult insight problems" (p. 617). These seemingly contradicting results can easily be reconciled by the Pezzo model if we assume that difficult items lead to high initial surprise, whereas the measured surprise in Experiment 4 very likely assessed resultant surprise: Initial surprise is necessary to trigger the sense-making process but if this sense-making is not successful surprise should prevail and – as a consequence - hindsight bias should be attenuated. In line with these assumptions, difficult insight problems as in Hoch and Loewenstein's Experiment 5, should be expected to produce strong hindsight bias (and low resultant surprise) although the person was initially surprised by the outcome because with insight problems the solution does make complete sense once you have seen it.

Further supporting evidence for this model comes from Pezzo´s (2003) own empirical studies. In the first study, he analyzed the reactions of basketball fans towards the results of wins or losses of their own teams under two conditions that their own team was the visiting or the home team. It was predicted and found that winning the game was more expectancy-congruent for the home-team fans than for the visiting-team fans. As predicted by the model, expected events (the winning of the home team) resulted in no measurable hindsight bias whereas non-expected events (the winning of the visiting team) resulted in at least a marginally significant hindsight bias. In study 3, Pezzo was also able to show that by and large equally surprising outcomes (initial surprise) resulted in a strong hindsight bias when sense-making was easy (e.g., regarding a research finding such as “`Looks are equally important to both men and women”) while no hindsight bias occurred when sense-making was difficult (e.g., “American students are less overconfident than Chinese”).

The sense-making model of Pezzo has been able to integrate seemingly contradicting results and therefore has greatly enhanced our understanding of the role of surprise in hindsight bias. However, in this paper we will argue that this model can profit from integrating theoretical ideas about how subjective experiences can influence judgment and decision making.

Surprise as Metacognitive Information and Surprise-Congruent Information Processing

Our model of surprise as metacognitive information extends Pezzo’s (2003) model in two important ways: Firstly, in Pezzo’s model surprise merely functions as a trigger for the sense-making process, however, it does not predict whether the person will show a hindsight bias, no hindsight bias or even a reversed hindsight bias. In the following we will argue that the feeling of surprise is used as metacognitive information to reconstruct the pre-outcome prediction. This should basically be the case under conditions that invite heuristic information processing. Based on current conceptions of prominent dual process models of judgment and decision making (e.g., Chen & Chaiken, 1999; Forgas, 2000; Petty & Cacioppo, 1986), these conditions can be defined in terms of low motivation and/or low cognitive capacity to process information concerning the issues in question. Secondly, in Pezzo’s model no assumptions are made about how this sense-making process itself may be influenced by feelings of surprise. In our model, surprise is assumed to also lead to experience-congruent information processing by initiating experience-congruent hypothesis testing. This latter process, however, is expected to be of importance only if people are sufficiently motivated and have enough cognitive capacity to process the relevant information. This prediction is again in line with dual process models of judgment and decision making.

These assumptions of the different routes in which surprise can influence the hindsight bias are based on the biased reconstruction approach to explain the hindsight bias (see Stahlberg, Eller, Maass, & Frey, 1995; Stahlberg & Maass, 1998; Schwarz & Stahlberg, 2003). In line with other research in the field (e.g., Erdfelder & Buchner, 1998; Hoffrage, Hertwig, & Gigerenzer, 2000; Pohl, Eisenhauer, & Hardt, 2003), the biased reconstruction approach states that people use the outcome information as a basis for reconstructing the original judgment when asked to remember it. In more detail, the biased reconstruction approach assumes that people asked to remember their original prediction after being informed about the actual outcome of an event, can either remember it or not. Those who do remember their original prediction are likely to reproduce it correctly. Those who have forgotten about their original prediction are forced to reconstruct their prediction or guess, and in the presence of outcome information, are likely to utilize this information as an anchor. Only the latter group who have forgotten their prediction, produce a hindsight bias. The magnitude and direction of the hindsight bias depends on people's subjective assumptions about their predictive ability. Since people are generally overly optimistic about their abilities (Greenwald, 1980), in the majority of cases they will locate their presumed prior estimate closer to the real outcome (anchor) than it originally was, producing a hindsight bias. But, if they have reason to believe that the outcome was unpredictable (e.g., if they doubt their predictive abilities in a certain field of expertise), the hindsight bias might be reduced, non-existent, or even reversed. Following this reasoning, each cue that informs people about the potential distance between the original judgment and the real outcome will affect the strength and direction of hindsight bias. In the following we will argue that subjective experiences may play a major role in this process. Subjective experiences, such as the *accessibility experience*, the *feeling of knowing*, or the *feeling of surprise* can act as metacognitive cues (for an overview, see Bless & Forgas, 2000) that inform people about the most likely distance between original judgments and actual outcomes. We assume that people use the feeling of surprise as such a metacognitive cue to reconstruct their own predictions when they do not remember them.[1]

The feeling of surprise as a direct metacognitive cue

The idea that people use cognitive subjective experiences like the feeling of surprise as metacognitive information about mental processes has been discussed in many domains of judgments and decision making (Bless & Forgas, 2000). Indeed, Koriat and Levy-Sadot (1999) proposed that cognitive experiences are *meta-summaries* of currently activated content or ongoing processes, boiling complex situational data down to single pieces of experiential information. So for example, Tversky and Kahneman (1973) considered the reliance on the accessibility experience (the experience of the “ease with which instances or associations could be brought to mind”, p. 208) in judgment formation as a heuristic strategy to make inferences about the frequency of information stored in our memory. In the context of hindsight bias, the influence of the accessibility experience was investigated by Sanna and his colleagues (Sanna & Schwarz, 2004, 2003; Sanna, Schwarz, & Small, 2002; Sanna, Schwarz, & Stocker, 2002). They doubted the recommendation of Fishhoff (e.g., 1982a, 1982b) and others (e.g., Arkes, Faust, Guilmette, & Hart, 1988; Davies, 1987; Nario & Branscombe, 1995) that the generation of possible alternatives about the outcome is a way to reduce the hindsight bias. Sanna and colleagues assumed (and demonstrated) that this strategy would backfire when it is hard to come up with reasons for an alternative outcome and participants would use this accessibility experience as a metacognitive cue in a (reversed) sense-making process and reconstruct their prediction of the outcome based on the result of this process.

In a similar way, we assume that the feeling of surprise can act as a metacognitive cue. A strong feeling of surprise triggered by the presentation of the outcome signifies that a person did not expect that outcome. Therefore, he or she would assume that his or her prediction was far away from the actual outcome and, therefore, would be expected to show a low or even reversed hindsight bias when trying to reconstruct his or her initial prediction. As with other subjective experiences we assume that people use this information in a direct, heuristic fashion, allowing for fast and frugal information processing. This idea, that the feeling of surprise plays an important role as a predictor of the strength and direction of the hindsight bias, is – as we mentioned before - not entirely new to the hindsight bias literature. In fact, Mazursky and Ofir (1990) saw the feeling of surprise as responsible for their reversed hindsight bias findings. Similarly, Hoch und Loewenstein (1989) – as stated above - argue that people are capable of using the feeling of surprise as information about the difficulty of the prediction task (for additional evidence see Louie, 1999; Whittlesea & Williams, 2001).

We are re-introducing this assumption into a model of the role of surprise on the hindsight bias and assuming that the feeling of surprise as a subjective experience is used as a direct heuristic metacognitive cue to estimate the distance between the actual outcome and the pre-outcome prediction that is not retrievable any more. The stronger the feeling of surprise, the higher the assumed distance between outcome and pre-outcome prediction would be. This would result in a reduced or even reversed hindsight bias. But we are not only re-introducing this idea into a theoretical model, we will also argue that to test this prediction, new forms of experimental designs are needed that allow us to show that it is really the experience of surprise that is used as a metacognitive cue. These designs must be able to disentangle the experience or feeling of surprise from information content as is outlined below. The experiments that we will describe later on in this paper will propose such an experimental design and will offer support for this main assumption of our model. However, before this is done we will elaborate on the second theoretical assumption of our model.

Effects of the feeling of surprise on the sense making process

In the following we will elaborate on the idea that the feeling of surprise is also used in the deliberative process of sense-making. In our opinion surprise serves not only as a trigger to elicit the sense-making process when a certain threshold is reached (as assumed by Pezzo, 2003; see above). We would rather assume that the strength of the feeling of surprise will also influence what kind of initial hypothesis on the likely outcome of the sense-making process will be tested. In other words, the experience of surprise can initiate the biased testing of the hypothesis that the outcome makes no sense. People often limit themselves to test a single hypothesis (e.g., Bruner & Postman, 1951; Sanbonmatsu, Posavac, Kardes, & Mantel, 1998) and the testing process is often focused on hypothesis-consistent information (e.g., Frey, 1986; Klayman & Ha, 1987). Taking these findings into account, the likelihood of a sense-making judgment congruent with the initial feelings of surprise is high. However, note that it is not assumed that the sense-making process following a strong feeling of surprise must inevitably lead to the conclusion that the outcome does not make sense (and will therefore lead to a reduced or reversed hindsight bias). A strong feeling of surprise only increases the likelihood of surprise-congruent judgments (in this case a weak or even reversed hindsight bias). In many situations, a plausible explanation for the outcome will come to mind (and lead to a strong hindsight bias) even when the person was initially surprised by the outcome. So, for example, people solving insight problems (for example in Experiment 5 by Hoch & Loewenstein, 1989, see above), often get a highly surprising solution (outcome) that, however, is perceived as very plausible from a hindsight perspective. In such a situation, the direct heuristic usage of the feeling of surprise and the sense-making process will have opposing influences on the reconstruction of the pre-outcome prediction.

The two routes by which surprise can influence the hindsight bias

In sum, we assume that surprise as metacognitive information can influence the magnitude and direction of hindsight bias via two different routes and in the following three distinct ways: (1) Feelings of surprise can function as a *direct metacognitive heuristic cue* that signifies whether one has or has not predicted the outcome, (2) surprise will trigger the *deliberate process of sense-making* when it reaches a certain threshold, and (3) surprise will also bias this sense-making process. This process can either result in a successful sense-making (no resultant surprise) or in a less successful sense-making (high resultant surprise). The amount of resultant surprise can then again be used as a metacognitive cue that affects the strength of the hindsight bias and is not assumed to be only a mere by-product of the sense-making process, as in the Pezzo model.

Introducing a direct, heuristic and a more deliberate route via sense-making in which feelings of surprise are expected to affect the reconstruction of the pre-outcome prediction also leads to specific assumptions about the differential strength of these routes in different situations. Based on general assumptions of prominent dual-process theories of judgment and decision making (e.g., Chen & Chaiken, 1999; Petty & Cacioppo, 1986) and the research on subjective experiences (e.g., Forgas, 2000), it is assumed that the direct, heuristic influence of surprise is strongest if people are under motivational or capacity constraints. The sense-making process, however, will have the highest influence on the strength and direction of the hindsight bias when people are motivated and capable to integrate given information in a more deliberative way. Furthermore, given that people use the feeling of surprise as metacognitive information we can assume that they can control the use of this information in the judgment formation process, meaning, that they can disregard the information if it is not seen as diagnostic. This assumption, however, does not mean that this judgment formation process is always conscious. Pezzo (2003) stated rightly that it is possible that surprise can elicit the sense-making process unconsciously. Based on the research on other subjective experiences we can assume that while the interpretation of the feeling of surprise in principle is metacognitive and learned (on the learned interpretation of subjective cognitive experiences, see Unkelbach, 2006) in most situations the usage of the feeling is automatic and unconscious (e.g., Whittlesea & Williams, 2001). The sense-making process, however, is a deliberate and effortful process that requires conscious monitoring.

The need to disentangle feelings of surprise from the content of the outcome and potential cues to sense-making

To test the basic assumption of our model that it is the subjective experience of surprise (the feeling of surprise) that is responsible for reduced or reversed hindsight bias one has to come up with an experimental manipulation that allows varying the feeling of surprise independently from subjects' prior expectations and the content information of the outcome. In all hindsight-surprise studies up to date, surprise was manipulated by varying the content information of the outcome or by influencing participants' expectations. This procedure always confounds the feeling of surprise with specific features of the content (e.g., the potential for sense-making, the number of pro- and counter-arguments that can be generated etc.) or of the judging person. Therefore, it cannot be ruled out that these specific features of the content dimension or the judging person rather than the experience of surprise are the main influencing factors responsible for reduced or reversed hindsight biases concerning highly unexpected outcomes. An experimental design that allows for the strongest test of the influences of surprise on hindsight bias therefore calls for a paradigm in which the experience of surprise can be induced while holding constant (1) the content of outcome information and (2) initial expectations and thereby also the potential for sense-making.

We were able to design such a paradigm based on the work of Reisenzein and his colleagues (Meyer, Reisenzein, & Schützwohl, 1997; Niepel, Rudolph, Schützwohl, & Meyer, 1994; Reisenzein, 2000a, 2000b; Reisenzein & Ritter, 2000). The basic idea of Reisenzein´s Interference Theory of Surprise is:

> (…) that the experience of surprise is based, at least in part, on a sensation-like form of awareness (…) of the interference with ongoing mental activity caused by surprising events. Because this feeling is a nonconceptual or nonpropositional form of awareness of the workings of the cognitive mechanisms engaged in surprise, it can be called a `metacognitive´ (Clore, 1992) or `metarepresentational´ (Reisenzein, 2000a, b) feeling. (Reisenzein & Ritter, 2000, p. 3)

This assumption implies that the same information should be experienced as more surprising when presented on the background of a cognitively demanding task compared to an easy task. Interference should be more pronounced in the first condition. In order to test this idea, Reisenzein and Ritter varied the cognitive load of a task that was then interrupted by the surprising event. In the low-load (high-load) condition participants had to calculate 3 one-digit (two-digit) numbers as quickly as possible. The surprising event was presented during the 25th trial when suddenly the mode of presentation changed (color of background and numbers and an extra tone). At the end of the calculation task, participants rated the surprise as a consequence of the change of presentation mode and of their feelings of interference ("How strongly did the change of the stimulus presentation `throw you off the track´ of the addition task?"). Results supported the Interference Theory of Surprise: Participants reported stronger experiences of surprise and stronger feelings of interference under high than under low cognitive load.

Empirical evidence for the Surprise as Metacognitive Information Model

In our own work (Müller & Stahlberg, 2006), we adapted the idea of Reisenzein and his colleagues in a hindsight dual task paradigm and created a situation where participants were led to misattribute the feeling of surprise triggered by the *presentation* of the outcome to its *content*. Outcome information was presented on the background of a highly demanding cognitive task versus a less-demanding task in a hypothetical hindsight bias design. It was assumed that participants would experience more surprise triggered by the presentation of the outcome on the background of a highly demanding task, and would attribute this feeling of surprise to the special outcome content. Therefore, they should show less hindsight bias than participants in the non-demanding task. By using the same stimuli in both groups, the content of the stimuli and the expectations were held constant and only the differential strength of the feeling of surprise could explain differences in the anticipation task between experimental conditions.

In all three experiments the same basic experimental procedure was used: We told participants that they would take part in a “color prediction task”. They should pursue two different tasks simultaneously: The *first task* was to sum up three numbers which consecutively appeared on the screen for 1500 ms each (manipulation of cognitive demand that was very similar to the procedure of Reisenzein & Ritter, 2000). Each of these numbers was presented on a colored square (participants knew the color of the squares could be yellow, orange, red, green and blue and that the same color could appear several times in a trial). The *second task* (outcome prediction) was to predict the color of the final fourth square (without a number) that would appear in a random order after the presentation of the three numbers in half of the trials instead of the sum entrance screen. Participants were told that the colors of the squares on which the numbers appeared followed certain rules, that they were to predict, the color sequences, however, were in fact completely random. After participants had seen the final square, they were asked how surprised they were by the color of the square, if they had predicted this color and how certain they were about this. While the trials with the fourth colored squares were the experimental trials, the sole purpose of the sum-entry-trials was to make sure that participants engaged in the cognitive load manipulation and were under low (or high) cognitive demand when the fourth colored square appeared (because they could not discriminate the two tasks until the sum-entry screen or the fourth colored square appeared and therefore had to calculate the sum even in the trials where a fourth colored square appeared). Being under low (or high) cognitive demand should make them experience less (or more) interference caused by the occurrence of the square which they should attribute to the low (or high) surprise elicited by the color of the square. Note, however, that cognitive demand was the same for both groups when giving their judgments after the colored square, because both groups knew that they would not need to type in the sum in these trials and therefore had stopped calculating at that point. The order of the trials was randomly chosen. Figure 1 depicts all four trial types and their structure.

Insert Figure 1 about here

In Experiment 1 each participant passed 12 trials with double-digit numbers (high-surprise-about-outcome trials) and in 12 trials with single-digit numbers (low-surprise-about-outcome trials). In half of these trials, participants had to type in the sum at the end of the trial, while in the other half, they were shown a fourth colored square. The prediction and certainty ratings that followed the presentation of the fourth colored square were combined into a measure of hindsight bias. In line with the hypothesis, participants rated the occurrence of a color as more surprising for the trials in the high-surprise-about-outcome condition than for the trials in the low-surprise-about-outcome condition. As predicted by our model, participants showed less hindsight bias (less certainty about predicting the color) in the high-surprise-about-outcome trials than in the low-surprise-about-outcome trials (see Table 1). Additional regression analyses showed that feelings of surprise mediated the effect of the surprise-manipulation on the hindsight bias.

In a second experiment, it was tested whether the effects of the direct, heuristic route would be stronger under time-constraints in the judgment phase. Time-constraints limit the mental capacity of the participants and therefore participants should rely more on heuristic cues in information processing. To test this assumption, we used a between-subjects design (participants always had either low- or high-surprise-about-outcome trials) in which half of the participants were told to make their judgments (how surprised they were by the color of the square, if they had predicted this color and how certain they were about this) after the presentation of the outcome as fast as possible (time-constraint condition), whereas the other half of the participants were told to take as much time as they needed for this task (no-time-constraint condition). To test if the direct effect of surprise on the prediction of the outcome also holds when a measure of sense-making is included, participants additionally were asked, after each fourth colored square, how plausible the occurrence of this color was to them in this trial. As predicted by our model, participants in the time-constraint condition stated that they were more certain to have predicted the outcome in the low-surprise-about-outcome condition than in the high-surprise-about-outcome condition. Participants in the no-time-constraint condition did not show any significant differences in their prediction of outcome as a function of the surprise manipulation (significant interaction, see also Table 1). Additionally, a mediation analysis was conducted for the two time-constraint-conditions separately. As can be seen in Figure 2, the predicted partial meditation of the relationship between rated surprise about outcome and prediction of outcome by plausibility of outcome was only found when participants had no time-constraints. However, when participants had time-constraints while making their judgments, surprise predicted plausibility ratings and prediction of outcome, but plausibility of outcome did not predict the hindsight bias measure (prediction of outcome). This strongly indicates that surprise is directly used as a heuristic cue to estimate the distance between outcome and pre-outcome predictions, especially when time constraints are high. The influence of the result of the sense-making process, however, on the hindsight bias is strong only under no time constraint.

Insert Figure 2 about here

In a third experiment, further hypotheses derived from our model were tested. Most prominently, the question whether the use of surprise can be controlled by the participants was examined. Based on previous research on subjective experiences, it is assumed that people use the feeling of surprise as metacognitive information only if the feeling is seen as diagnostic (e.g., Sanna & Schwarz, 2003). It was therefore assumed that surprise will only be used as a metacognitive cue if participants attribute the feeling of surprise to the occurrence of the outcome.

To test this assumption, we again used a between-subjects design in which half of the participants were warned about the non-diagnosticity of the feeling of surprise in this experimental setting. This was done by telling them in the introductory part of the experiment that people react with more surprise to events when solving cognitively demanding tasks. The other half of the participants received no such warning. As a second factor, surprise about outcome was manipulated in the same way as in Experiment 1 and 2. In line with our expectations, in the no-warning condition, participants in the high-surprise-about-outcome condition showed less hindsight bias than participants in the low-surprise-about-outcome condition. In the warning condition, there was no difference between high- and low-surprise-about-outcome conditions on the hindsight bias measure (the interaction was significant, see also Table 1). Participants successfully discounted the feeling of surprise when they were warned about its non-diagnosticity. Without warning, they used their feeling of surprise to reconstruct their prediction.

As stated above, the Surprise as Metacognitive Information Model assumes that surprise cannot only be used as a direct cue in the judgment about the outcome predictability but can also be used as a cue in the sense-making process ("successful sense-making will be unlikely"). To test this hypothesis, participants in Experiment 3, as in Experiment 2, were asked to rate the plausibility of the fourth colored square. As predicted, the plausibility was significantly influenced by the surprise manipulation when participants were in the no-warning condition. In the high-surprise-about-outcome condition, plausibility of the color sequence was rated lower than in the low-surprise-about-outcome condition. No such difference was found in the condition where participants got a warning about the non-diagnosticity of the surprise feeling (significant interaction). As shown in Figure 3, mediation analysis revealed that plausibility as a measure of sense-making partly mediated the relationship of initial surprise with hindsight judgments in the no-warning condition.[2] As expected, in the warning condition, surprise had no influence on the perceived plausibility and the prediction judgment.

Altogether, Experiment 3 revealed that participants use the surprise feeling as a metacognitive cue in the reconstruction of the prediction only if the feeling of surprise is seen as a diagnostic cue. Furthermore, the sense-making process is not only triggered by the surprise feeling but also significantly influenced by this feeling. The mediation-analysis revealed a substantial direct effect of feelings of surprise as metacognitive information on the hindsight bias and also an indirect effect via a tainted sense-making process (in conditions without warning).

Insert Figure 3 about here

Conclusions

The results of three experiments using our new paradigm support the predictions of the Surprise as Metacognitive Information Model. Most importantly, the hypothesis was confirmed that the feeling of surprise indeed influences the strength of the hindsight bias as a metacognitive cue. The results of the second experiment corroborate the idea that this feeling of surprise is used in a heuristic fashion and that its strongest effects on the reconstruction of the pre-outcome prediction occur under capacity constraints. Furthermore, Experiment 3 showed that people are able to control the usage of the metacognitive cue of surprise when making judgments. Additionally, we assumed that feelings of surprise will taint the sense-making process. When experiencing high surprise, participants are expected to selectively retrieve information from memory that stresses the low plausibility of the actual outcome. In the third experiment, we conducted a preliminary test of this hypothesis and found that, indeed, participants found the color sequences more implausible in the high-surprise condition (with no warning).

All the three experiments reported here used the same experimental paradigm and the same dependent measures. In order to conduct a stronger test of the validity of our model, future research should use other, presumably physiological measures of surprise. Additional experimental data is needed to underscore the claim that the direct influence of the feeling of surprise is heuristic in nature and especially strong under mental constraints and low motivation. Furthermore, our data on the second prediction of our model that surprise biases the sense-making process is at this point only preliminary. Future research will have to propose better measures of successful sense-making or resultant surprise that show less conceptual overlap with the hindsight measure than our plausibility measures. Finally and most importantly, the above described experimental design is only able to detect a reduction in hindsight bias. To test the claim of the model about the occurrence of a reversed hindsight bias under certain conditions more refined experimental setups are needed.

Despite this list of needed experimental validations, the Surprise as Metacognitive Information Model, in our opinion, substantially contributes to our knowledge about the different routes via which the feeling of surprise can effect the malleability of the hindsight bias. It combines the idea that the feeling of surprise is used to reconstruct pre-outcome predictions (Hoch & Loewenstein, 1989; Louie, 1999; Mazursky & Ofir, 1990; Ofir & Mazursky, 1997) with the idea of Pezzo (2003) about a sense-making process triggered by the feeling of surprise. By integrating both ideas in one model and including ideas from research on metacognitions and subjective experiences, the model allows for more precise predictions of the role of surprise in the reconstruction of pre-outcome predictions than previous models. It can therefore build a basis for many new research questions.

Apart from the model itself, we hope that our new experimental paradigm, to disentangle feeling from content, might also inspire future research. In our opinion, this new paradigm could be a first step to disentangle the effects of the feeling of surprise from the content of the stimuli in a variety of other fields of decision making where surprise and expectations play a role (e.g., Mellers, 2000; Mellers, Schwartz, Ho, & Ritov, 1997; Mellers, Schwartz, & Ritov, 1999).

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Footnotes

[1] Since our paper focuses on the role of surprise, the potential role of other subjective experiences as metacognitive information is not discussed in detail. It is assumed that besides surprise and the mentioned accessibility experiences, other experiences and feelings can also influence the reconstruction of the original prediction. In fact, already Hoch and Loewenstein (1989) hypothesized that besides the feeling of surprise, the *feeling of knowing* and the *feeling of familiarity* could also function as signals to persons to assess their actual knowledge before the outcome was known. However, its high salience and its attributed diagnosticity will make the feeling of surprise in most situations the most prominent metacognitive cue for a person trying to reconstruct his or her own pre-outcome prediction.

[2] In all three experiments the outcome prediction and the surprise ratings were presented in random order. While in Experiments 1 and 2 the surprise measures was calculated from all surprise ratings, in Experiment 3 only surprise ratings that were asked before the outcome prediction questions were used to calculate the surprise measure. This was done to obtain a purer measure of initial surprise.

Table 1

Means and standard deviations of prediction of outcome as a function of surprise about outcome (Experiment 1), surprise about outcome and time constraint (Experiment 2), and surprise about outcome and warning about low diagnosticity of surprise (Experiment 3)

Experiment 1

	Surprise about outcome	
	Low	High
	-1.80 (2.48)	-2.67 (2.53)

Experiment 2

	Surprise about outcome	
Time constraint	Low	High
Yes	-0.89 (2.50)	-2.70 (2.09)
No	-2.17 (1.83)	-1.17 (2.57)

Experiment 3

	Surprise about outcome	
Warning about low diagnosticity of surprise	Low	High
Yes	-2.61 (2.60)	-2.24 (2.04)
No	-1.26 (1.81)	-2.94 (2.22)

Note. Mean score is given, standard deviation is given in parentheses. Prediction of outcome ranges from -6 to +6; higher values indicate more certainty about the prediction of outcome.

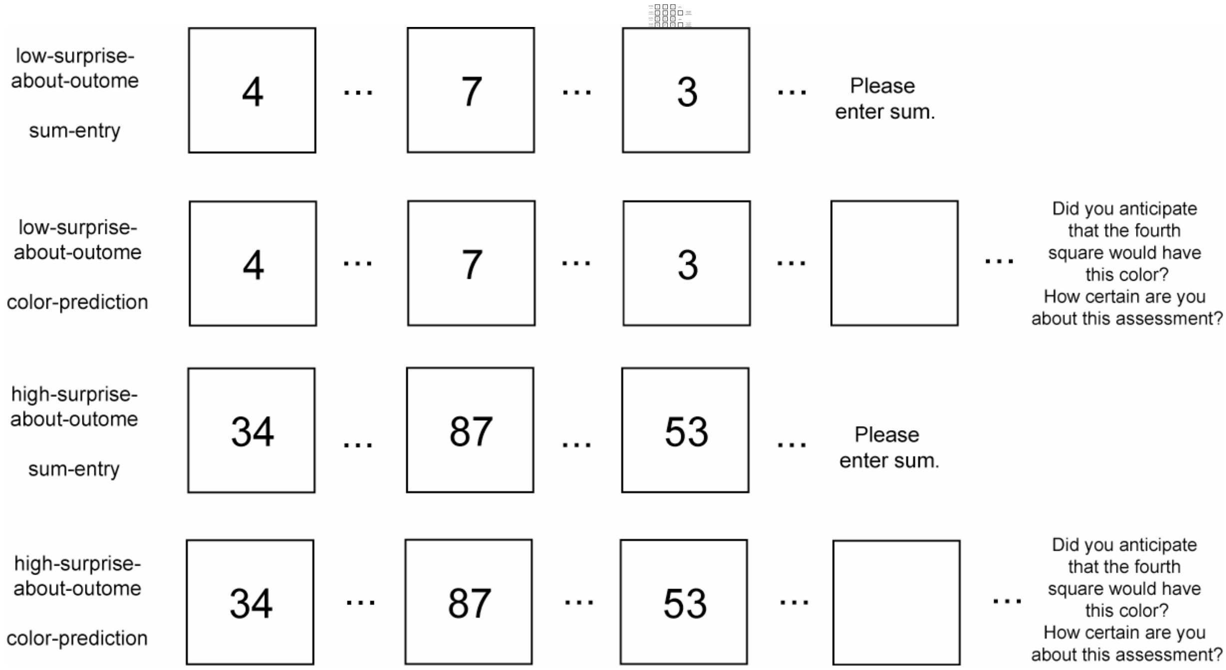
Figure Caption

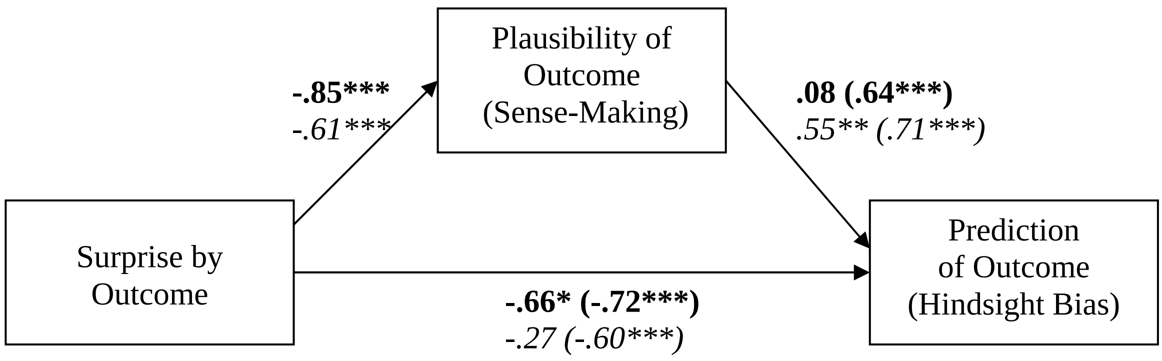
Figure 1: Illustration of the different trial types and their structure. Low-surprise-about-outcome trials consisted of one-digit numbers only. High-surprise-about-outcome trials consisted of two-digit numbers only. Sum-entry trials and color-prediction trials did not differ until after the presentation of the third colored square. In each trial the colored squares were presented for 1500ms on the screen each. The "…" represents the 1900 ms delay before the presentations of the next screen. The color of each square could be yellow, orange, red, green or blue. The color sequences were random, in one trial a color could appear several times.

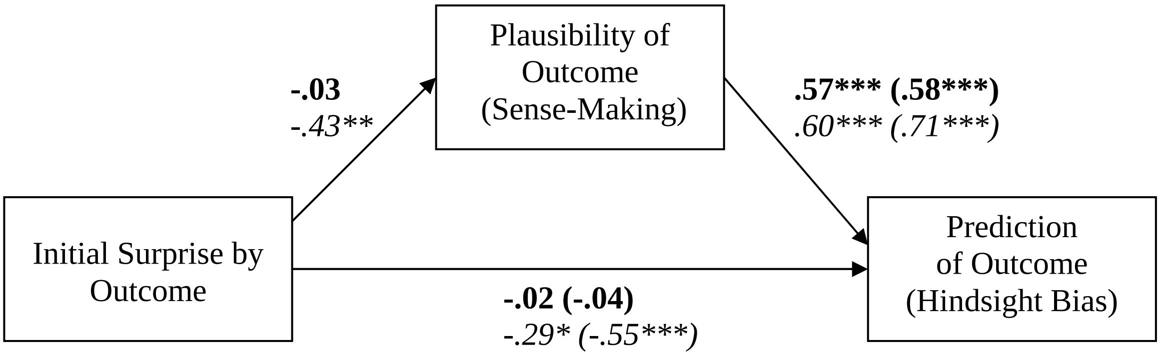
Figure 2: Mediational analysis for Experiment 2 (Müller & Stahlberg, 2006) with prediction of outcome as the dependent variable, plausibility of outcome as the mediator, and surprise by outcome (manipulation check measure) as the independent variable. Path coefficients are standardized beta coefficients from (multiple) regression analyses. The numbers in parentheses represent the direct effect (bivariate beta coefficients) of one of the two predictors (plausibility of outcome or surprise by outcome) on prediction of outcome prior to the inclusion of the other predictor. Numbers in *italics* represent the no-time-constraint condition while the **bold** numbers represent the time-constraint condition.$^{*}p < .05$.$^{**}p < .01$. $^{***}p < .001$.

Figure 3: Mediational analysis for Experiment 3 (Müller & Stahlberg, 2006) with prediction of outcome as the dependent variable, plausibility of outcome as the mediator, and initial surprise by outcome (manipulation check measure) as the independent variable. Path coefficients are standardized beta coefficients from (multiple) regression analyses. The numbers in parentheses represent the direct effect (bivariate beta coefficients) of one of the two predictors (plausibility of outcome or initial surprise by outcome) on prediction of outcome prior to the inclusion of the other predictor. Numbers in *italics* represent the no-

warning-about-low-diagnosticity condition while the **bold** numbers represent the warning-about-low-diagnosticity condition.*p < .05.**p < .01. ***p < .001.


low-surprise-
about-outome
sum-entry
4
7
3
Please
enter sum.
low-surprise-
about-outome
color-prediction
4
7
3
Did you anticipate
that the fourth
square would have
this color?
How certain are you
about this assessment?
high-surprise-
about-outome
sum-entry
34
87
53
Please
enter sum.
high-surprise-
about-outome
color-prediction
34
87
53
Did you anticipate
that the fourth
square would have
this color?
How certain are you
about this assessment?


Plausibility of
Outcome
(Sense-Making)
-.85***
*-.61****
.08 (.64*)**
*.55** (.71***)*
Surprise by
Outcome
Prediction
of Outcome
(Hindsight Bias)
-.66* (-.72*)**
*-.27 (-.60***)*


Plausibility of
Outcome
(Sense-Making)
-.03
-.43**
.57*** (.58***)
.60*** (.71***)
Initial Surprise by
Outcome
Prediction
of Outcome
(Hindsight Bias)
-.02 (-.04)
-.29* (-.55***)

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