

I knew it all along - Hindsight bias before and after the fact.

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Was den Menschen vom Tier unterschied, war die Fähigkeit, im Angesicht der Katastrophe «Siehste!» zu denken. - Juli Zeh (2016), Unterleuten, S. 277

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1 Introduction

In hindsight, events often seem simpler, more predictable, and more inevitable than in foresight. This tendency of overestimating the predictability or probability of an event once one knows that it happened is a psychological phenomenon called *hindsight bias*.

Hindsight bias is a pervasive judgment error that has been shown in adults and children (e.g. Bernstein, Erdfelder, Meltzoff, Peria & Loftus, 2011), in experts and novices (e.g. Gray, Beilock & Carr, 2007), around the world (Pohl, Bender & Lachmann, 2002) and across a variety of disciplines (e.g. consumer satisfaction: Zwick, Pieters & Baumgartner, 1995; business startups: Cassar & Craig, 2009; medical diagnosis: Arkes, 2013; personality judgments: Nestler, Egloff, Küfner, & Back, 2012) and events (court trials: Bryant & Guilbault, 2002; athletic competitions: Roese & Maniar, 1997; elections: Blank, Fischer & Erdfelder, 2003; disasters: Verplanken & Pieters, 1988). All these studies, however, focus on the effect of knowledge about what happened as a dichotomous feature: present or absent. In this dissertation, I inspect hindsight bias from a wider scope, taking different phases of knowledge about what happened into account.

First, I examine whether hindsight distortions necessarily require definite knowledge or whether a plausible assumption might be sufficient. Two studies confirmed the hypothesis that hindsight bias can develop on the basis of conjectures. Furthermore, I demonstrate that the magnitude of the resulting bias is comparable to hindsight bias based on definite knowledge.

Second, I explore the dynamics of hindsight bias after the initial knowledge gain. How does hindsight bias transfer into written artefacts? What are the consequences of reading material that is distorted by hindsight bias? Does the reader's hindsight bias increase even further? Four studies offer further insights into the answers of these questions. I found that hindsight distortions in written artefacts are directly related to the

author's level of bias and that reading such a distorted article can increase a reader's hindsight bias in turn. Furthermore, two of the studies were conducted with a cross-cultural sample, offering novel insights into cultural variation in the communication of hindsight bias.

Taken together, the aim of this dissertation is to explore hindsight bias from a broader perspective, providing novel insights into its theoretical prerequisites and applied consequences.

1.1 Hindsight Bias

Hindsight bias was first examined in a seminal article by Fischhoff (1975, but see also Walster, 1967). In a series of studies, participants were given information about a war between the British troops and the people of the Gurkha in Nepal in the 19th century. The information about how the war terminated was experimentally manipulated. Some participants were led to believe that the British won the war, some that the Gurkha forces won, and some that there was a stalemate with or without peace settlement, a control group received no feedback at all. When asked to ignore their knowledge and judge the most likely outcome from a foresight perspective, participants regarded the outcome they knew about as more likely than the other outcomes. They were unable to ignore their own outcome knowledge and reproduce a more naïve state of mind. This phenomenon even persisted when participants were made aware of hindsight bias and instructed to avoid it (Fischhoff, 1977, Study 2). The author concluded that knowledge about the outcome is instantly assimilated with the knowledge one already has, making it impossible to retrieve one's foresight judgment. This may lead to the (wrong) impression an event could have been predicted or was predetermined (Fischhoff, 1975).

Since this first study on hindsight bias, numerous theoretical explanations of the bias have been put forward, often tailored to specific conceptualizations of hindsight bias (e.g., Blank, Nestler, von Collani & Fischer, 2008; Hawkins & Hastie, 1990) or specific

research paradigms (e.g. the SARA model for hindsight bias in memory designs with almanac questions, Pohl, Eisenhauer & Hardt, 2003; RAFT model for hindsight bias in comparisons, Hoffrage, Hertwig & Gigerenzer, 2000).

For hindsight bias after events, causal reasoning processes are considered to be a crucial factor (Blank & Nestler, 2007; Hawkins & Hastie, 1990; Louie, 2005; Nario & Branscombe, 1995; Pezzo, 2003; Roese & Olson, 1996; Yopchick & Kim, 2012). Nestler, Blank and von Collani (2008a) integrated multiple theoretical considerations into a framework called *Causal Model Theory (CMT)*. Within this framework, the authors suggest a process model of hindsight bias: People have an innate desire to understand the world and what is happening around them (see also Renner, 2003). Once one learns that something happened, this motivation to understand the event's occurrence leads to a search for (causal) antecedents of this event, which are then integrated into a cognitive model of the event's development. However, the search for antecedents is biased in the direction of the actual outcome (i.e., a search for event-consistent antecedents). Additionally, antecedents subjectively perceived as event-consistent are given more weight and are evaluated as being more important, than event-inconsistent antecedents. As a result, the causal model of the event does not represent the actual foresight reality, but, unbeknownst to the person succumbing to hindsight bias, is geared towards the specific outcome one knows about. Consequently, the event appears more likely, foreseeable or inevitable than it was in foresight (Nestler et al., 2008a; 2008b; Yopchick & Kim, 2012).

Blank et al. (2008) argued that hindsight bias is not a unitary phenomenon, but an umbrella term describing three distinct processes: memory distortions, inevitability impressions and foreseeability impressions (see also Blank & Nestler, 2007). These "components" (Blank et al., 2008) are distinct with regard to their underlying mechanisms as well as their consequences.

Memory distortion. The component of memory distortion describes a false recollection of one's earlier judgments: The memory of one's initial answer to a question

is distorted by later acquired knowledge about the (true) answer to this question (Erdfelder & Buchner, 1998). For example, after a person learns that an accident has happened, s/he may overestimate how likely s/he thought an accident was in foresight. The key process underlying memory distortion is knowledge updating (Erdfelder, Brandt & Bröder, 2007; Erdfelder & Buchner, 1998). New information is automatically integrated into the memory, blurring earlier memory traces. The easier it is to integrate the new information in existing memory structures, the more predictable the past appears (Arkes, 1991; Blank & Nestler, 2007; Hawkins & Hastie, 1990; Pohl & Erdfelder, 2017). Related to this, several scholars argue that knowledge updating selectively activates consistent memory traces and ignores inconsistent memory traces (Blank & Nestler, 2007; Hoffrage, Hertwig & Gigerenzer, 2000; Mussweiler, 2003; Pohl, Eisenhauer & Hardt, 2003), resulting in increased feelings of clarity. These are also important with regard to impressions of inevitability.

Impression of inevitability. Impressions of inevitability refer to the feeling that an event was “bound to happen” or predetermined. These beliefs develop on the basis of judgments about the objective state of the world. For example, after a car accident under icy road conditions, one might have the impression this accident was unavoidable, or happened inevitably, because the road conditions were too rough for safe travelling. Impressions of inevitability are directly related to causal reasoning processes and sense-making efforts (Nestler et al., 2008b). The easier it is to make sense of the past, the greater the impression of inevitability (Jennings, Lowe, & Reckers, 1998; Trabasso & Bartolone, 2003; Wasserman, Lempert & Hastie, 1991; Yopchick & Kim, 2012). This is a direct result of an oversimplification of cause and effect – relationships in hindsight. When reasoning about why something happened, the current knowledge is a crucial retrieval cue for the selection of causal antecedents (Nestler et al., 2008a). In other words, knowledge distorts the evidence sampling process in a way that favors antecedents which are directly linked to the final event. This leads to distorted assumptions about causal connections

(Dawes, 1993) and the impression of a “crystal clear” signal all along (Wohlstetter, 1962 in Fischhoff, 1975). In turn, when sense-making fails and antecedents that sufficiently explain the outcome cannot be found, no hindsight bias occurs (Nestler et al., 2008b; Pezzo, 2003).

Impression of foreseeability. Impressions of foreseeability result from metacognitions about one’s own, subjective state of knowledge and ability (Mark, Reiter Boburka, Eyssell, Cohen & Mellor, 2003; Nestler, Blank & Egloff, 2010). “I could have foreseen this”, is a typical utterance related to this component of hindsight bias. For example, after learning about someone else’s car crash on an icy road, a person might say “I knew it was too dangerous to drive” and hence conclude that s/he would have predicted the accident. Moreover, and potentially dangerous, this person could also conclude such an accident would never happen to him- or herself, due to obviously superior skills of judgment (Bradfield & Wells, 2005).

Foreseeability and inevitability impressions operate on different levels of cognition and are partly dissociated (Nestler, Blank & Egloff, 2010). Whereas inevitability impressions rest on objective beliefs about the world, foreseeability impressions rest on metacognitions about one’s own subjective understanding of the world. Hence, an event that appears to have been inevitable must not necessarily appear to have been foreseeable, but an event that appears to have been foreseeable can also appear to have been inevitable (Nestler et al., 2010; Roese & Vohs, 2012).

There is no such link between memory distortions and inevitability impressions, because heightened inevitability impressions are possible in the absence of memory distortions. For example, one remembers one’s earlier prediction for an election perfectly, but is still convinced of its inevitability, in hindsight. In the same vein, one may remember to have made poor predictions regarding the foreseeability of an event, but may still perceive it as un-foreseeable.

1.2 Is there hindsight bias without hindsight?

One feature all the above mentioned theoretical considerations of hindsight bias share is the assumption that outcome knowledge is a) the ultimate trigger of hindsight distortions and b) dichotomous. It is either present (hindsight) or absent (foresight). However, I argue that knowledge about what happened is not necessarily a dichotomous dimension (present vs. absent). It can also be seen as a continuum, varying from high uncertainty to high certainty in what happened. Events can evolve over time and people may have different assumptions, beliefs and more or less certain knowledge about what is happening during this time. When, for example flight *MH370* with 239 people on board disappeared from radar on March 8th, 2014, it quickly became apparent that something tragic had happened. Final clarification, however, is still amiss. Nevertheless, people may have assumptions or conjectures about what happened. Some of these may be more speculative, others more certain, some less and some more plausible and they may change over time. Based on this observation, the following research question emerges:

Can hindsight bias emerge on the basis of a conjecture, in the absence of definite knowledge about an event?

Events with an unknown ending are – by definition – uncertain and are thus in conflict with people’s innate desire to understand what is going on around them (Nestler et al., 2008a). To resolve this uncertainty, one tries to make sense of the situation and find out what most plausibly could have happened (cf. Bruckmüller, Hegarty, Teigen, Böhm & Luminet, 2017; Van den Bos, 2009). If one fails to make sense of an event, no hindsight bias occurs (Pezzo & Pezzo, 2007). Moreover, hindsight bias has been found to increase, the more plausible the outcome appears and also the easier it is to find causal antecedents (Hardt & Pohl, 2003; Pezzo, 2003; Roese & Maniar, 1997; Yopchick & Kim, 2012). In the case of conjectures, these sense-making processes are not restrained by definite knowledge or reality, but based on what one currently considers the most plausible event. I argue that

these underlying reasoning processes may be similar to hindsight bias based on definite knowledge.

In terms of CMT (Nestler, Blank & von Collani, 2008a), the person would likely use the current conjecture as a clue to search for antecedents that explain their assumption. In this search, information supporting the current conjectures (consistent information) would thus be favored, whereas information suggesting a different conjecture (inconsistent information) would be ignored or at least weighed to be less important. In consequence, it may seem easy to come up with a causal model of what could have happened, strengthening hindsight bias for one's conjecture. This argumentation is supported by theoretical accounts of confirmation bias (e.g. Nickerson, 1998; Klayman, 1995), which argue that the search for information to support one's own opinion is biased to support rather than disprove an already established opinion, and research on motivated reasoning, which suggests that people are more likely to search for consistent than for inconsistent evidence when spontaneously testing a hypothesis (Kunda, 1990).

In addition, causal models on conjectures are developed by oneself, there is no information causing confusion and there can be no feelings of surprise, which would decrease hindsight bias or even lead to reversed hindsight bias (Calvillo & Gomes, 2011; Pezzo, 2003). Then again, conjectures, by definition, are based on possibilities and therefore raise awareness of alternative outcomes, too. Thinking about alternative (or opposite) outcomes has been found to be a mechanism decreasing hindsight bias (e.g., Hirt & Markman, 1995; Mussweiler, Strack & Pfeiffer, 2000; Nestler & von Collani, 2008; Sanna, Schwarz & Small, 2002), because it makes the a-priori uncertainty more salient and thus decreases feelings of inevitability or foreseeability (Dawes, 1993; Roese & Vohs, 2012).

That a given feedback is true, however, is not necessarily needed for hindsight distortions to occur. Pohl (1998) has found that even feedback which is described as "another person's estimate" and thus potentially wrong, still results in hindsight bias. Only

a combination of an uncertain source and a highly implausible feedback eliminated hindsight bias (Pohl, 1998; cf. Hardt & Pohl, 2003). The authors concluded that these findings show that hindsight bias is not an entirely automatic process, but also informed by reasoning processes such as plausibility considerations. As elaborated above, these plausibility considerations could well be triggered when one just has a conjecture about what happened and does not have definite knowledge (yet).

I hypothesize that a (subjectively) plausible conjecture, thus an assumption about what happened, is sufficient to cause distortions similar to hindsight bias, even in the absence of definite knowledge.

1.3 Can hindsight bias be transferred?

If yes, what is the consequence?

In past research on hindsight bias, the main variable of interest was the effect of singular outcome knowledge on a participant's retrospective judgment (Pohl, 2007). This knowledge could have been the final score of a soccer game or, in case of an accident, the mere fact that it happened. However, in the case of events, learning about the outcome may only be the beginning of a long sense-making process (Pezzo & Pezzo, 2007). Besides, hindsight bias does not necessarily have to be an "all or nothing" phenomenon, but can be gradual (Bernstein, Aßfalg, Kumar & Ackerman, 2016). In case of the Fukushima nuclear disaster, for example, it was soon evident that the nuclear fallout happened because of an earthquake and a tsunami. Only later did the public learn that more antecedents contributed to the nuclear catastrophe, for example unpreparedness of staff at the Fukushima nuclear power plant (Funabashi & Kitazawa, 2012). Most likely, the public received the majority of new insights through the media, through newspapers, broadcasting services and the Internet. However, such input is often produced with the intent to explain why a particular event happened, thus offering an ideal setting for hindsight bias to develop. Indeed, Oeberst et al., (2017), found that a few Wikipedia articles, namely articles on disasters (which elicit a particular need for explanation (Bruckmüller et al., 2017)), contain hindsight distortions. Comparing versions of Wikipedia articles about the same event, the authors found that, in retrospect, articles may contain and present information in such a way that it suggests that this event was foreseeable and more likely. In prospect, this suggestion was amiss. This finding forms the foundation for the second part of my dissertation, as two questions emerge:

- 1) How does hindsight bias enter information sources such as Wikipedia articles?
- 2) Does reading such a biased article influence individual hindsight bias?

Wikipedia is currently on rank five of the most popular websites worldwide (alexa.com). In contrast to classic encyclopedias, Wikipedia is entirely written by volunteers, often laypeople (Oeberst, Halatchliysky, Kimmerle & Cress, 2014), who produce the content in a collaborative manner. To ensure encyclopedic quality of the content and prevent biases, Wikipedia authors must follow several guidelines, such as the principle of verifiability and a neutral point of view (Wikipedia, 2018). Nevertheless, hindsight bias may enter Wikipedia articles, because it is not necessarily affected by Wikipedia's bias prevention principles. As mentioned above, hindsight bias distorts the information search itself. Thus, it is theoretically possible for an author to create an objectively written article including only verifiable sources, but the sources one-sidedly support a specific event, because the author may have never considered alternative explanations.

Another process that may affect hindsight bias is collaboration. On the one hand, one could expect that individual biases cancel each other out, as in the "intelligence of the masses"-phenomenon (Surowiecki, 2004). On the other hand, previous research on hindsight bias at the group level suggests that working in a group leads to the same magnitude (Bukshar & Connolly, 1988; Stahlberg, Eller, Maass & Frey, 1995) or even a greater magnitude of hindsight bias (Choi & Choi, 2010). Collaboration between authors may further foster hindsight bias, because hindsight bias is so pervasive, that it is likely shared among authors (e.g. Roese & Vohs, 2012). In this case, it is likely that authors collectively overlook a less biased event representation. Hence, I propose that individual hindsight bias is transferred into informational texts, even under strong bias preventions guidelines such as on Wikipedia. This assumption has, to the best of my knowledge, not been tested before.

The second research question, which follows up on the above considerations, is: How does reading a biased information source alter individual hindsight bias? This question takes into account that hindsight bias may be a dynamic phenomenon, an

assumption that extends previous research on hindsight bias (but see Bryant & Brockway, 1997; Bryant & Guilbault, 2002, for investigations of hindsight bias over time). A dynamic hindsight bias could, for example, resemble this scenario: One is already quite certain that a disaster could have been foreseen or happened inevitably. However, one might be even more convinced after following up on the event and receiving further information, as I outline in the next paragraphs.

Further information, for example from a Wikipedia article, can make an initial causal model more salient. Reading up on the latest state of knowledge could, in this case, act as a reminder. This process, in turn, could also make the causal model more readily available, increasing hindsight bias (see also accounts about the influence of processing fluency on hindsight bias, e.g. Werth & Strack, 2003). These processes could be especially pronounced when the information source is biased itself and thus transports a one-sided event explanation. Here, the additional information strengthens an already existing causal model, leading to an ever more distorted event perception.

A related cognitive process is the availability bias (Tversky & Kahnemann, 1973). It describes the tendency to judge the likelihood of events as a result of how easy similar events and associations come to mind. Hence, when reading that something was bound to happen after already having developed a hindsight bias, one is just more likely to follow along with this thought, which should increase hindsight bias (c.f. Bryant & Brockway, 1997; Sanna & Schwarz, 2007). Furthermore, research in belief perseverance shows that accessibility experiences contribute to the perceived plausibility of an event. The easier a thought comes to mind, the more plausible this thought seems (Nestler, 2010). Plausibility impressions are strongly related to causal reasoning processes in terms of Causal Model Theory (Nestler et al., 2008a).

The aforementioned components of hindsight bias can be assumed to change for different reasons: Whereas impressions of foreseeability are susceptible to influencing factors because they rely on subjective impressions which can easily change over time

(Roese & Vohs, 2012), impressions of inevitability are susceptible to a coherent story and may increase with multiple plausible antecedents (Nario & Branscombe, 1995; Nestler & von Collani, 2008). However, there is only very little research on hindsight bias after the initial knowledge gain. In a study preceding and following the O.J. Simpson criminal trial in the US (Bryant & Brockway, 1997), scholars found that the estimated prior probabilities of the actual outcome were *not* distorted by hindsight in a second measurement two days after the trial. In a third measurement a week later, however, the same participants perceived the acquittal of O.J. Simpson to have been significantly more likely a priori. The authors conclude that hindsight distortion “was only partial at first and required time to develop fully” (p. 234). Furthermore, they argue that the intense coverage of the case in the mass media, where the unexpectedness of the verdict was immensely stressed, may have influenced participants. Crucially, however, participants’ media consumption was neither assessed nor controlled and participants may have gotten important information between measurements, influencing their hindsight perception of the trial. Likewise, Bryant and Guilbault (2002) analyzed the content of media articles at the time of data collection with regard to hindsight bias, but did not directly test media influence on their participants’ judgments. Thus, the role of new and potentially already biased information remained unclear in the development of late hindsight bias. After all, it is possible that more time simply led to forgetting foresight predictions (e.g., Pohl et al., 2003) or to a successful construction of a (one-sided) causal model (Nestler et al., 2008a). I hypothesize that hindsight bias can increase after receiving further (biased) information, even if the event outcome is already known. I use the online encyclopedia Wikipedia as a source of such information, because previous studies found that Wikipedia articles contain hindsight distortions and these may affect their readers (Oeberst, von der Beck & Nestler, 2014; Oeberst, von der Beck, Back, Cress & Nestler, 2017).

Being in the top five most used websites, Wikipedia provides information for people around the world. At the same time, information processing has been found to differ between people from different cultural backgrounds. Whereas people from (South East) Asian countries tend to think in a more holistic manner, people from Western countries think in a more analytical manner (Nisbett, Peng, Choi & Norenzayan, 2001; Norenzayan, Choi & Peng, 2007). Holistic thinking is characterized by the belief that opposing propositions can be equally true at the same time and causality is usually attributed to an interaction of the situation and the agents' dispositions. An analytical thinking style, in contrast, is characterized by formal logic and the basic tendency to avoid contradiction. Causality is usually attributed to the agents' dispositions only (Choi, Dalal, Kim-Prieto & Park, 2003; Miller, 1984; Nisbett & Masuda, 2003; Norenzayan et al., 2007; Peng & Nisbett, 1999).

In this regard, readers from different cultural backgrounds may come to different conclusions after reading the same informational source, potentially resulting in differences in hindsight bias. Indeed, scholars have found that hindsight bias is larger in Asian cultures (Choi & Nisbett, 2000; Yama et al., 2010). Choi & Nisbett (2000) attributed the effect to the holistic thinking style: Attending to large amounts of information in complex object-situation-interactions may facilitate causal reasoning processes in holistic thinkers. If there is a large pool of potential causal antecedents for an event, generating a plausible chain of events leading up to the outcome may ultimately be facilitated, resulting in the feeling an event was inevitable or foreseeable. Moreover, this mindset leaves less room for surprise, which in turn should strengthen hindsight bias (Choi & Nisbett, 2000; Pezzo & Pezzo, 2007).

Based upon the explications above, I propose that hindsight bias will increase after reading biased material. Furthermore, I propose that the effect will be moderated by cognitive thinking style.

1.4 Objectives

Hindsight bias is an extensively studied, pervasive human error (e.g. Guilbault, Bryant, Brockway & Posavac, 2004). Nevertheless, several research questions remain unanswered. This dissertation aims to contribute to the following research gaps:

Previously, scholars have argued that outcome knowledge is a necessary prerequisite for hindsight bias (e.g. Fischhoff, 1975; Hawkins & Hastie, 1990; Erdfelder & Buchner, 1998; Hoffrage, Hertwig & Gigerenzer, 2000; Blank et al., 2008). But maybe conjectures are enough to elicit hindsight distortions? The two studies examining this question are presented in Chapter 2: 1) a two-wave study surrounding the case of the missing Malaysian Airlines flight MH 370 and 2) an experimental lab study replicating and extending the previous results by providing a direct comparison between conjecture-based and knowledge-based hindsight bias. Centering on the development of hindsight bias *before* definite outcome knowledge is available, this research goal offers a new perspective on hindsight bias and challenges its preconditions.

The second research goal focuses on the development of hindsight bias *after* definite outcome knowledge became available. Can an already established hindsight bias be transferred? This question was examined using the intensely popular and widely used online-encyclopedia Wikipedia, offering further insights how hindsight bias appears in collaborative settings. Furthermore, I examine the consequences of hindsight distortions in information sources. Can reading such biased material increase hindsight bias? In other words, does a once-established hindsight bias increase with further information? The four studies investigating this research objective are presented in Chapters 3 and 4. In Chapter 3, I present 1) a laboratory study investigating whether individual hindsight bias can enter Wikipedia articles. Building on these findings, I conducted 2) an experimental study to test whether reading such a biased media report has an incremental effect on hindsight bias. Finally, in Chapter 4, I tested 1) the external validity and cross-cultural reliability of an

increase in hindsight perceptions after reading with a large international sample and 2) replicated & extended my findings in a second study with US American and Vietnamese participants. The novel contribution of this research question is that it extends the knowledge about potential factors that can increase hindsight bias, and thus are a potential caveat one should be aware of, especially seeing the potential distribution of bias via written artefacts.

2 Hindsight bias without hindsight

In two studies, I sought to establish that hindsight bias can develop even in the absence of outcome knowledge. The first study was conducted surrounding the disappearance of flight *MH370*, a real event where definite knowledge about what happened never emerged. The second study was conducted to replicate and extend the findings of the first study using a fictitious scenario. In both studies, based on the theoretical assumptions of Causal Model Theory (Nestler et al., 2008a), I hypothesized that assuming a certain outcome would suffice to trigger sense-making mechanisms which result in hindsight bias, or in other words in a feeling of “having thought so all along” (see also Birch, Brosseau-Liard, Haddock, & Ghrear, 2017).

2.1 Study 1

Method overview. This study was conducted over the course of one year and had two data collection waves. The first wave was conducted only days after flight MH 370 had gone missing in March 2014. Four hundred and thirty-two participants responded to an email invitation for a short survey surrounding the missing flight. They reported how likely they thought different outcomes were and how foreseeable the event was altogether (e.g. “I knew all along what happened to flight MH 370”, three items, Cronbach’s $\alpha = .69$ and $.76$ for t_1 and t_2 , respectively). The different outcomes for the likelihood estimates were, after careful consideration, taken from the media coverage at the time of the disappearance. The four outcomes were: (1) The plane was hijacked and later crashed because of fuel shortage” (*hijacking and crash*), (2) “The plane was hijacked and safely landed somewhere else”, (*hijacking and landing*), (3) “The plane crashed because of a technical failure (no human intervention)” (*technical failure*), (4) “The plane was deliberately damaged and crashed (e.g. terrorist attack)” (*deliberate damage*). Participants were asked to assign percentages to these options, adding to a total of 100%. After rating

how much they knew about the event, participants answered some general demographic questions and provided an anonymous code for later matching. On a separate page, participants who wished to participate in a second wave left their e-mail address for future contact ($N = 406$).

One year later, in March 2015, the participants were contacted again and $N = 100$ participated again (71.0% women, $M_{\text{age}} = 24.49$, $SD = 4.67$). The plane had not been found in the meantime and no new information about what happened on board had emerged. However, several conjectures about what could have happened were discussed in the media, for example that one of the pilots had hijacked the plane (tagesschau.de). In this second survey (t_2), participants were assigned to two different conditions: (a) the *current conjecture group* ($N = 42$). These participants were asked to answer the same questions about the missing plane again, now from their current perspective. This condition was necessary to capture whether participants' conjectures had changed during the course of the year, a prerequisite for hindsight bias to occur. (b) the *reproduced conjecture group* ($N = 58$). These participants were asked to reproduce their earlier estimates to the likelihood and foreseeability items, to measure a potential hindsight bias.

Main results. A mixed-model ANOVA with experimental group (current conjecture, reproduced conjecture) as between-participant factor and point in time (t_1 , t_2) and event alternative (hijacking and crash, hijacking and landing, technical failure) as within-participant factors and likelihood estimates as dependent variable revealed a significant main effect of point in time, $F(1, 98) = 6.67$, $p = .011$, $\eta_p^2 = .06$, a significant main effect of event alternative, $F(1.84, 180.53) = 8.13$, $p = .001$, $\eta_p^2 = .08$, and a significant interaction between event alternative and point in time, $F(2, 196) = 56.49$, $p < .001$, $\eta_p^2 = .37$. None of the other effects were significant, all F s $< .25$, all p s $> .083$.

Post-hoc t -tests showed that likelihood estimates for the given scenarios differed between the two points in time (see Table 1). Likelihood ratings for hijacking and crash significantly decreased from t_1 to t_2 . The outcome "hijacking and landing" showed the

same pattern. A technical failure, in contrast, was perceived significantly more likely at t_2 than at t_1 .

Participants – across conditions - considered both hijacking scenarios less likely at t_2 and the technical failure more likely, meaning their conjectures significantly changed over time. This result also demonstrates that current conjectures changed over time although no new information emerged. This change is a necessary precondition for hindsight bias without hindsight, because there could be no shift of reproduced conjectures towards current conjectures without previous change (cf. Fischhoff, Gonzalez, Lerner & Small, 2005). Furthermore, there was neither a significant main effect of experimental group, nor a significant interaction of experimental group and point in time. This indicates that participants' conjectures at t_1 were comparable, fulfilling the second necessary precondition for conjecture-based hindsight bias. The most important finding here lies within the absence of a significant difference between experimental groups. This indicates a conjecture-based hindsight bias in its most extreme form: Participants, who were asked to reproduce their prior conjectures at t_2 did not only significantly shift their reproductions into the direction of current conjectures, but arrived at reproductions that did not differ from current conjectures anymore. Hence, participants erroneously believed to have had their current conjectures all along.

Current foreseeability ratings were comparable at t_1 and t_2 in a paired t -test, $t(41) = 1.70$, $p = .096$, $M_{diff} = .22$, 95% CI [-.04, .46]. However, participants' *reproduced* foreseeability ratings were significantly higher than their initial ratings at t_1 , $t(57) = -2.86$, $p = .006$, $d = 0.47$, $M_{diff} = .36$, 95% CI [.11, .60], see Table 1.

Table 1

Means and standard deviations of the perceived likelihood of event alternative and the foreseeability scale as a function of point in time and experimental group.

	Current conjecture		Reproduced conjecture	
	t ₁	t ₂	t ₁	t ₂
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Hijacking and crash	29.43 (24.61)	15.24 (16.97)	32.50 (19.57)	22.98 (19.89)
Hijacking and landing	35.50 (26.99)	11.28 (15.59)	27.16 (22.02)	12.41 (13.09)
Technical failure	19.95 (22.82)	50.16 (31.06)	21.00 (21.43)	41.26 (25.83)
Foreseeability	1.86 (.73)	2.08 (.87)	1.79 (.67)	2.15 (.84)

Summary. In this study, I found that reproduced conjectures had significantly shifted towards and were even comparable to current conjectures, a distortion pattern as in classic hindsight bias (e.g., Erdfelder & Buchner, 1998; Fischhoff & Beyth, 1975). As these results are the first to suggest a conjecture-based hindsight bias, it was necessary to replicate them under controlled conditions and to compare conjecture-based to knowledge-based hindsight bias.

2.2 Study 2

Method overview. The set-up of Study 2 closely followed the general design of Study 1, but adapted to meet the needs of a laboratory study. Thus, the time interval between t₁ and t₂ was not one year but several days ($M = 4.02$, $SD = 1.6$ days), simulating

the delayed information reception. At t_1 , participants ($N = 94$, 73 female, $M_{age} = 23.13$, $SD = .50$) received ambiguous information about a missing ferryboat. The material was designed to suggest a particular cause for the ship's disappearance (technical failure). Participants received further information at t_2 , now suggesting a different cause, in order to establish a change in conjectures, which is necessary for hindsight bias to occur. The additional information was that the ferry had not been found yet, but investigations revealed that the accident was most likely due to capacity overload. Crucially, apart from a *current conjecture group* and a *conjecture-based reproduction group*, Study 2 included a third condition, the *knowledge-based reproduction group*. In this condition, participants were told that the ferry had been found and the accident indeed happened due to capacity overload. Dependent variables were the same as in Study 1, adapted to the ferry scenario.

Main results. In Study 2, participants' reproductions again shifted towards current conjectures indicating hindsight bias, because participants were unable to reproduce their more naïve earlier perspective (see Appendix A for detailed results). Crucially, in this study, I was able to directly compare the magnitude of conjecture-based hindsight bias to knowledge-based hindsight bias. To this end, I conducted a mixed-model ANOVA with point in time (t_1 , t_2) and event alternatives (technical failure, capacity overload) as within-participants factors and experimental group (conjecture-based reproduction, knowledge-based reproduction) as a between-participant factor. There was only a significant main effect of event alternative, $F(1, 58) = 52.24, p < .001, \eta_p^2 = .47$, and a significant interaction of point in time by event alternative, $F(1, 58) = 17.15, p < .001, \eta_p^2 = .23$, all other F 's $< 2.4, p$'s $> .12$.

Summary. Study 2 replicated the basic effect of hindsight bias based on conjectures under controlled conditions. Furthermore, it provided the means to compare the magnitude of conjecture based and knowledge based hindsight bias, finding that there are no significant differences.

2.3 Discussion

In two studies, I found that participants falsely reported to have had a conjecture all along. In both studies, their conjectures had changed over time, but this was not reflected in participants' memory reports. In other words, participants failed to reconstruct an earlier state of mind in the light of new information. This memory distortion is typical for hindsight bias (Bernstein et al., 2016). Whereas previous research on hindsight bias has repeatedly shown this distortion after definite outcome knowledge (Guilbault et al., 2004), the studies reported here are – to the best of my knowledge – the first showing hindsight bias in the absence of real hindsight (i.e., in the state of knowing what happened). Moreover, the findings from Study 2 show that the magnitude of conjecture-based and knowledge-based hindsight bias are comparable, indicating that definite outcome knowledge might not be a necessary precondition for hindsight bias. At first glance, this seems counter-intuitive, after all, conjectures always carry uncertainty and knowledge about possible other events and considering alternatives or opposites has been found to decrease hindsight bias (Hirt & Markman, 1995; Roese & Vohs, 2012). Still, theoretical models of hindsight bias can be used to explain these findings: Based on sense-making theories of hindsight bias (Pezzo, 2003; Pezzo & Pezzo, 2007; Nestler et al., 2008), a plausible conjecture, just like definite knowledge, can make consistent information more accessible and subjectively more important than inconsistent information (Guilbault et al., 2004; Hawkins & Hastie, 1990; Hoffrage et al., 2000; Nestler et al., 2008a), leading to a hindsight bias similar to that after definite knowledge. Besides, it is likely that participants do not only rely on their memory, but also on inferential strategies (cf. Werth & Strack, 2003) and metacognitive assumptions about what they could have known (Ross, 1989; Stahlberg & Maass, 1997). These strategies could also result in hindsight distortions when trying to “confirm” a conjecture (cf. *confirmation bias*, Nickerson, 1998) instead of knowledge.

On another note, studies have found that hindsight bias cannot be eliminated when the source of feedback was manipulated (Pohl, 1998; 2000) or the truth of the feedback is left unclear (Pohl, 1998). Certainly, more research is needed to examine whether a conjecture-based hindsight bias is based on the same underlying mechanisms as a knowledge-based hindsight bias, but these studies demonstrate that a conjecture can lead to a similarly distorted reproduction of past perceptions as in ‘classic’ hindsight bias studies.

3 Hindsight bias in and from information sources

Whereas the last chapter focused on the prerequisites of hindsight bias, this chapter will focus on its consequences. In case of a disaster such as the Fukushima nuclear disaster, learning that something has happened is usually only the beginning of a long process of knowledge gain. Especially negative events like accidents and disasters trigger the need to explain how they could have happened, which is a result of the wish to prevent another catastrophe in the future (Nestler et al., 2008a; Pezzo, 2003; Pezzo & Beckstead, 2008). One possible source to gather further information about such an event, for example the Fukushima nuclear disaster, is the online encyclopedia Wikipedia. On Wikipedia, information is collected, collaboratively processed, and publicly shared by volunteers, under the premise that they objectively and accurately describe the topical state of knowledge. I used Wikipedia to explore the novel questions how hindsight bias is communicated after a negative event and if it is transferred between an information source and its authors, and also its readers. The answers to these questions have important implications for real-world consequences of hindsight bias, as they tackle the topic of the distribution and potential proliferation of hindsight distortions from individuals to others and finally to the public. On a public level, hindsight bias is relevant because it has been linked to false attributions of blame and responsibility (Carli, 1999), which can lead to false convictions of people who made an honest mistake.

Despite Wikipedia's guidelines to prevent bias, Oeberst et al. (2017) found that some Wikipedia articles contain hindsight distortions. The authors compared foresight and hindsight versions of articles about the same event, and found that, in retrospect, articles on disaster and accidents may present information in such a way, that it suggests that the event was foreseeable and more likely. This suggestion was absent in foresight. This comparison is possible, because whenever the content of an article is altered, the previous version is stored and remains publicly available. Thus, previous research has found that

hindsight bias can enter Wikipedia articles, however, it remains unclear whether the authors of the distorted articles really displayed individual hindsight bias, which transferred into their articles, or the distortion is a result of their collaboration. I report on the transfer of hindsight bias in collaboratively written articles in Study 1 and follow up on how reading such an article can influence individual hindsight bias in Study 2.

3.1 Study 1

Method overview. Study 1 was designed to simulate the writing process of a Wikipedia article in the laboratory. All one hundred seventy-six participants (141 female, $M_{age} = 22.80$, $SD = 5.32$) received identical information about a fictitious dam in Spain in the form of eleven short bogus newspaper articles. The material was pretested in a pilot study with $N = 56$ participants and elicited hindsight bias to a sufficient extent.

The study had a 2x2 between-subjects design with four experimental conditions (information condition: foresight vs. hindsight; writing condition: individual vs. collaborative). Participants in the foresight condition did not learn about an accident at the dam at all, participants in the hindsight condition learned that the dam collapsed. All participants used the available information from the newspaper snippets to write a “Wikipedia-like” article about the dam. These articles were written either individually or collaboratively via an online collaboration tool (etherpad) and should follow common Wikipedia guidelines. Participants’ personal hindsight bias was assessed in a questionnaire by asking for perceptions of likelihood, inevitability, and foreseeability. Likelihood ratings were assessed for four mutually exclusive events, inevitability and foreseeability perceptions were measured using four, respectively, seven items, e.g. “Sooner or later there had to be an accident” (inevitability, Cronbach’s $\alpha = .76$), or “I would have foreseen that this accident was going to happen” (foreseeability, Cronbach’s $\alpha = .69$). As usually the case in hindsight research, participants in the hindsight condition were asked to ignore their hindsight knowledge when answering these items.

The articles produced by the participants were subsequently coded by three independent raters blind to the experimental condition of the authors. All raters read all articles. The main dependent variable was the extent to which the articles suggested that a disaster at the dam was likely, inevitable, and foreseeable (1 = *not at all*, 5 = *very much*). The raters trained on a subset of 20 articles (ICC = .864) and had acceptable agreement later on, too (ICC = .712).

Main results. A multivariate ANOVA with likelihood, inevitability and foreseeability ratings of the individual participants as dependent variables and information condition (foresight, hindsight) as well as writing condition (individual, collaborative) yielded only a significant main effect of information condition, Wilk's $\lambda = .631$, $F(3, 84) = 16.393$, $p < .001$, $\eta_p^2 = .369$. Post-hoc testing showed that there were significant differences between participants with foresight vs. hindsight knowledge on all three dependent variables, $F_{likelihood}(1, 86) = 28.651$, $p < .001$, $\eta_p^2 = .250$, $F_{inevitability}(1, 86) = 40.476$, $p < .001$, $\eta_p^2 = .320$, $F_{foreseeability}(1, 86) = 6.501$, $p = .013$, $\eta_p^2 = .070$. Thus, outcome knowledge altered participants' perception of the event. With hindsight, a collapse of the dam appeared more likely, inevitable, and foreseeable, indicating hindsight bias.

An ANOVA with the averaged hindsight ratings of the three raters as dependent variable and with information condition and writing condition as between-article factors was conducted, to investigate whether hindsight bias led to distorted articles. It yielded only a significant main effect of information condition, $F(1,86) = 12.298$, $p = .001$, $\eta_p^2 = .125$. Thus, articles from participants with hindsight knowledge were rated to be significantly more suggestive of a disaster ($M = 2.49$, $SD = 0.75$) than the articles from participants of the foresight condition ($M = 1.92$, $SD = 0.78$). There was no significant difference as a result of collaboration.

How are individual hindsight bias and the articles bias related? A multilevel model, accounting for the partial nesting of individuals in groups in the collaboration condition (see Bauer, Sterba, & Hallfors, 2008; Sterba, 2017), was used to predict individual

measures from the article ratings (likelihood, inevitability, foreseeability). Results of the multilevel model showed that article ratings were significantly associated to individual likelihood ratings, $b = 6.41$, $t(96.09) = 4.69$, $p < .001$, inevitability ratings, $b = 0.17$, $t(110.08) = 2.80$, $p = .006$, but not foreseeability ratings, $b = 0.06$, $t(111.13) = 0.99$, $p = .32$.

Summary. In this study, I found that outcome knowledge led to hindsight bias. In a second step, I found that the magnitude of hindsight distortion in the article was directly related to the magnitude of individual hindsight bias, hence hindsight bias transferred from authors to text despite of bias preventing writing instructions. Collaboration, however, did not influence the extent of distortion in the article.

3.2 Study 2

Having established that hindsight bias can enter Wikipedia articles by means of the authors who contribute to it, the question arises if reading such a biased article can further increase the reader's hindsight bias. Theoretically, a biased article could a) remind the reader of an initial causal model or b) strengthen an already existing causal model by providing crucial new information. In this case, the biased article could result in an even larger hindsight bias than mere event knowledge, indicating dynamic hindsight bias. I explored these possibilities in Study 2.

Method overview. I conducted an online study with $N = 135$ participants (106 female, $M_{age} = 24.99$, $SD = 6.90$). The material, a description of an accident at the Sayano-Shushenskaya hydroelectric power station in Russia, was chosen, because its retrospective Wikipedia article was found to contain hindsight distortions (Oeberst et al., 2017). Furthermore, the accident was unknown to participants. Participants were randomly assigned to three conditions: a) foresight condition ($N = 53$), b) hindsight condition ($N = 44$), c) hindsight plus article condition ($N = 38$).

After reading general information about the site, participants in the hindsight condition received additional information about an accident in the power station. Participants in the hindsight plus article condition additionally read the biased Wikipedia article about the power station. Dependent variables were perceptions of likelihood for four mutually exclusive alternative events, including the real accident. Three items measuring inevitability (Cronbach's $\alpha = .63$) and foreseeability impressions ($\alpha = .67$) were averaged into scales, respectively.

Main results. Given that I expected a linear increase in participants' perceptions of likelihood, inevitability, and foreseeability (foresight < hindsight < hindsight plus article), I computed linear contrasts for all three dependent variables with foresight condition coded as $c = -1$, hindsight condition coded as $c = 0$, and hindsight plus Wikipedia article condition coded as $c = 1$. All three contrasts yielded significant linear increases for each of the three dependent variables, $F_{likelihood}(1,132) = 5.08, p = .03, \eta_p^2 = .03$, $F_{inevitability}(1,132) = 35.83, p < .001, \eta_p^2 = .21$, $F_{foreseeability}(1,132) = 4.53, p = .04, \eta_p^2 = .03$.

A direct comparison of the hindsight condition and the hindsight plus Wikipedia article condition yielded a significant difference with regard to perceived inevitability, $t(80) = 2.85, p < .01, d = 0.62$, and a marginally significant difference into the predicted direction with regard to perceived likelihood, $t(80) = 1.73, p = .09, d = 0.38$. The difference in perceived foreseeability fell short of significance, $t(80) = 1.44, p = .15$.

Summary. Learning about a previously unknown event elicited hindsight bias, and reading the distorted Wikipedia article about this event led to an incremental increase in hindsight bias, at least with regard to inevitability impressions.

3.3 Discussion

The studies reported in this chapter investigated the consequences of hindsight bias. They provide first insights that hindsight bias can indeed be communicated or carried from an author to a written artefact. Despite clear instructions to provide objective coverage of the topic and verify all information in the article, the authors' individual hindsight bias transferred to their articles. This finding supports the finding from Oeberst et al. (2017, Study 1) that hindsight distortions can enter Wikipedia articles. Furthermore, this happened independent of a collaborative or individual article writing procedure, which is in line with previous findings of Bukszar & Connolly (1988) and Stahlberg et al. (1995), who found no difference between hindsight bias in small groups vs. individuals (note that Choi & Choi (2010) found larger hindsight bias in groups).

Study 2 explored the aftermath of hindsight distortions in Wikipedia articles. I found that hindsight bias can expand after initial knowledge gain by means of reading a distorted article. This finding has not been explicitly shown before. Participants who had received outcome knowledge and read the distorted Wikipedia article about the event afterwards reported even higher perceptions of likelihood and inevitability of the disaster. This finding is important because hindsight bias is closely linked to perceptions of guilt and shame, particularly in the context of negative events (e.g. Louie, 1999). If hindsight bias can dynamically increase after first outcome knowledge, distorted information sources can have negatively influence the public opinion towards relevant agents, regardless of when they are published. These processes may be especially important to know about given that hindsight bias is very hard to eliminate (e.g. Roese & Vohs, 2012). The present findings also offer important implications for the historical sciences, as these rely – by default – on a hindsight perspective. Historians should be aware of and try to overcome hindsight bias as well as possible to prevent hindsight distortions in the public understanding of events (von der Beck, Oeberst, Cress, Back & Nestler, 2015).

Study 2 was a singular study involving only one event. This called for replication. Moreover, previous research has found that hindsight bias may differ between people from different cultures (e.g. Choi & Nisbett, 2000) and Wikipedia articles are read around the world. Could the effect of further biased information on hindsight bias be found in readers from different cultures and, more importantly, with different causal reasoning preferences?

4 Hindsight bias from Wikipedia around the world

I conducted two online studies to examine the finding that existing hindsight bias can increase after reading Wikipedia articles. Previous research on cultural differences in hindsight bias is rather scarce (Heine & Lehman, 1996; Pohl, Bender & Lachmann, 2002; Choi & Nisbett, 2000; Yama et al, 2010), but has established that differences are most likely due to differences in thinking style (e.g. Choi & Nisbett, 2000; Yama et al., 2010). Whereas people from Western nations usually display an analytic thinking style, which is (among other things) characterized by rule-formal logic, direct cause-effect relationships and the avoidance of contradiction, people from (South-) Eastern nations prefer a holistic thinking style, preferring a dialectical reasoning style, many-to-many-attribution and embrace contradiction (Choi et al., 2003; Miller, 1984; Nisbett & Masuda, 2003; Norenzayan, Smith, Kim & Nisbett., 2002; Peng & Nisbett, 1999; Spencer-Rodgers, Williams & Peng, 2010). Choi and Nisbett (2000) proposed that holistic thinkers display more hindsight bias, because it is easier to explain an event in hindsight, when a) the pool of potential antecedents is larger, and b) all aspects are potentially interconnected, meaning that even distal actions can have important consequences (cf. Choi et al., 2003).

In a first study exploring this question, I had gathered inconclusive results (Oeberst, von der Beck & Nestler, 2014). It remained unclear whether the observed effects were really due to differences in cognitive thinking style. Hence, the studies reported here had a dual focus: 1) replicate that reading further information can increase hindsight bias with a diverse, ecologically valid sample. 2) Examine the potential moderating effect of cognitive thinking style on hindsight bias.

The first study included participants from Germany, Japan, Sweden, Singapore, the United States, and Vietnam, providing for a rather diverse sample in holistic vs. analytic thinking style. I translated materials in a Vietnamese and US-American sample to further investigate potential cultural influences on hindsight bias after reading Wikipedia articles.

4.1 Study 1

Method overview. Four hundred and forty six participants ($M_{age}=32.41$, $SD = 11.24$) participated in Study 1 (Germany, $N = 108$; Japan, $N = 20$; Singapore, $N = 32$; Sweden, $N = 88$; USA, $N = 106$; and Vietnam, $N = 92$), which were recruited via the online platform crowdflower.com. The countries were chosen to represent a wide range of holistic and analytic thinking, based on previous research (Klein et al., 2008). The study was conducted using the Wikipedia article about the Fukushima nuclear power plant in Japan. This power plant was destroyed by an earthquake and subsequent tsunami in March 2011, resulting in a nuclear spill over and major and long-lasting damage to the power plant's direct environment and strong media attention around the world. In a previous study (Oeberst et al., 2017, Study 1), this article's hindsight version (available online eight weeks after the disaster happened), but not the foresight version (online directly before the accident), had been found to be highly suggestive of the event and thus contained a hindsight bias. This hindsight bias was mainly due to the mention of information that was known, but not part of the article, before the disaster happened, for example risks of the reactor type.

Participants were asked to rate the likelihood for the Fukushima nuclear disaster ("What is your personal opinion: How likely was this accident?") on a 11-point scale from 1 (*very unlikely*) to 11 (*very likely*). Next, participants read one of the two versions of the original English Wikipedia article about the Fukushima I Nuclear Power Plant, either the foresight article version or the hindsight article version (see above). After reading, participants estimated the likelihood of the accident again and also rated perceived inevitability (three items, Cronbach's $\alpha = .61$; e.g. "Under the given circumstances, the event had to happen") and foreseeability (two items, Cronbach's $\alpha = .65$; e.g., "It was clear all along that an accident had to happen") on a 5-point Likert scale from 1 (*disagree*) to 5 (*agree*). Since participants came from different cultural backgrounds, a measurement invariance analysis was conducted to test for possible measurement variance. It yielded a

very good fit to a strict measurement model for the inevitability items across nationalities, $X^2(7) = 9.09$, $CFI = .987$, $RMSEA = .037$, and a good fit for a strong measurement model for the foreseeability items, $X^2(2) = 4.75$, $CFI = .981$, $RMSEA = .078$. Hence, measurement invariance was fulfilled.

Then, all participants filled out the Analysis-Holism Scale (AHS, Choi, Koo & Choi, 2007) to assess analytic vs. holistic thinking style. Responses were made on a 7-point Likert scale, a higher score indicates more holistic thinking. The AHS consists of 24 items on 4 subscales (*attitude toward contradiction, locus of attention, causality, & perception of change*), which yielded good internal consistencies (Cronbach's α ranged between .69 - .79). Finally, participants indicated how much they already knew about the Fukushima disaster, rated the text difficulty of the article and reported their general attitude towards nuclear energy.

Main results. In a first step, I compared analytic vs. holistic thinking style between the Western and the Eastern subsample. Unexpectedly, there were no significant differences between the subsamples on the AHS total score: Western sample ($M = 4.82$, $SD = .57$); (South) East Asian sample ($M = 4.76$, $SD = .63$), $F(1, 444) = 1.352$, $p = .24$. However, given sufficient variation within participants' scores on the AH-scale, I conducted moderator analyses using the PROCESS macro in SPSS to test for the expected increase in hindsight bias and simultaneously for a moderating influence of thinking style (via the AHS subscale *causality*). For all three dependent variables, the overall models were significant, all F 's > 4.06 , p 's $< .007$, R^2 's $> .03$. Reading the hindsight article had an increasing effect on participant's personal hindsight bias. I found that participants who had read the hindsight as opposed to the foresight article version reported higher levels of likelihood, $b = 1.21$, $t(442) = 4.24$, $p < .001$, and foreseeability, $b = .27$, $t(442) = 2.83$, $p = .005$. Impressions of inevitability were not influenced by reading the Wikipedia article, $b = .022$, $t(442) = .255$, $p = .80$. Regarding the moderating role of cognitive thinking style, I found that more holistic thinking generally led to larger hindsight bias, all b 's $> .155$, t 's $>$

2.53, all p 's $< .012$. There were, however, no significant interactions of thinking style and article version, all t 's < 1.01 , all p 's $> .31$.

Summary. The results confirmed the hypothesis that reading the biased Wikipedia article would lead to an increase in hindsight bias, at least regarding likelihood and foreseeability impressions. The second hypothesis that the increase in bias would be larger for participants with a holistic thinking style, was, however, not supported. This could have been due to unexpected language effects, resulting in more analytic thinking style in the East Asian participants (Bui & Flicker, 2013; Boucher & O' Dowd, 2011; Ji, Zhang, & Nisbett, 2004; Ross, Xun, & Wilson, 2002). Therefore, Study 2 was done with translated material.

4.2 Study 2

Method overview. One hundred and forty four participants took part in Study 2 (USA: $N = 59$; Vietnam: $N = 85$; $M_{age} = 30.38$, $SD = 8.99$). The design and procedure in Study 2 were identical to Study 1, with the only difference that the Vietnamese participants in Study 2 received the entire survey and the material in Vietnamese language. The Vietnamese experiment was a translation of the English version.

Foreseeability and inevitability impressions were measured with two and six items, respectively. Principal component analysis showed that only two of the inevitability items were universally understood by the participants, hence these two were used for the analysis. Again, measurement invariance analysis yielded a very good fit (for details see Appendix C).

Main results. First, I compared analytic and holistic thinking style between the subsamples. With the translated material, participants from Vietnam showed stronger levels of holistic thinking ($M = 4.91$, $SD = .62$) than US-American participants ($M = 4.64$, $SD = .51$), $F(1, 142) = 7.33$, $p = .008$, $\eta_p^2 = .05$.

I conducted separate ANOVAs for each dependent variable to test for differences between nationalities as well as between article versions. The results showed a significant interaction of nationality and article version for likelihood ratings, $F(1, 57) = 13.96, p < .001, \eta_p^2 = .20$ and (by trend) impressions of foreseeability, $F(1, 140) = 3.48, p = .064, \eta_p^2 = .02$. The expected increase in hindsight bias after reading the hindsight version led to significant increases only in the US American, but not in the Vietnamese subsample. Impressions of inevitability were not affected (means and standard deviations are available in Table 2). As in Study 1, I found that more holistic thinking led to larger hindsight bias, but there were no significant interactions of thinking style and article version, all p 's $> .41$.

Summary. Study 2 provided yet additional support for the hypothesis that reading a biased article increases hindsight bias. Contrary to the initial hypothesis, this effect was not moderated by holistic thinking style. Furthermore, only Americans showed the expected increase in hindsight bias, Vietnamese participants did not.

Table 2

Means and standard deviations of the dependent variables in Study 2 as a function of nationality and article version. Adapted from Table 3 in von der Beck et al. (2017).

		Foresight article <i>M (SD)</i>	Hindsight article <i>M (SD)</i>
Likelihood ratings	US Americans	6.69 (2.27)	7.80 (1.54)*
	Vietnamese	4.88 (2.94)	5.19 (3.31)
Foreseeability impressions	US Americans	2.69 (.78)	3.54 (.98)*
	Vietnamese	3.30 (1.04)	3.43 (1.03)
Inevitability impressions	US Americans	3.04 (.84)	3.49 (.96)
	Vietnamese	3.98 (.86)	3.88 (.89)

Note. * $p < .005$

4.3 Discussion

Taking both studies into account, I replicated the effect that reading biased information can increase hindsight bias beyond the effect of mere outcome knowledge. Participants from six different nationalities read a foresight or hindsight version of the Wikipedia article about the Fukushima nuclear power plant and reported increased impressions of likelihood and foreseeability only after reading the hindsight article. This is especially relevant given that hindsight bias is also linked to wrong guilt or responsibility attributions (Anderson, Jennings, Lowe, & Reckers, 1997; Carli, 1999; Hastie, Schkade & Payne, 1999), which can negatively impact the public image of inculpable but involved agents. Please note, however, that the increase in hindsight bias was limited to the Western sample in Study 2. Hence, the findings must be interpreted with caution.

Vietnamese participants did not show the expected increase in hindsight bias and this finding was stable across both studies and hence not caused by language effects. One reason could be that the text itself might have had characteristics that appeal to a reader from a Western culture, but not so much to a reader from an Asian culture, because the material was a direct translation from the English language version. To my knowledge, there is unfortunately no research on the “persuasive fit” of study material across cultures. However, if this was the case, it would imply that the process of hindsight bias *amplification* is affected by other processes than ‘immediate’ hindsight bias, such as elaboration likelihood models (Petty, Cacioppo & Goldman, 1981) or source credibility (Pornpitakpan, 2004).

Moreover, this result may have been a consequence of the material used. The perception and examination of the Fukushima disaster may have been very different in Vietnam and the US, for example because Vietnam is geographically closer and thus potentially more affected. Hence, participants from Vietnam could have had a more elaborate, and potentially ‘satisfied’, causal model before participation (Pezzo & Pezzo,

2007). A more satisfied causal model could also have been a result of the previously mentioned holistic reasoning style and its influence on hindsight bias immediately after receiving outcome knowledge (Choi & Nisbett, 2000; Yama et al., 2010). In consequence, there may have been no ‘room’ for hindsight bias to increase at a later point in time. However, further research is needed to explore this finding.

This research also teaches a valuable lesson in terms of measurement caveats in cross-cultural research. Whereas I did not find differences in analytic vs. holistic thinking style in Study 1, which was administered in English, I found pronounced differences in Study 2, where material was translated to participant’s mother tongue. This finding is in line with previous research on language effects on participant behavior (e.g. Boucher & O’Dowd, 2011; Ross, Xun & Wilson, 2002) and demonstrates the importance of translations in multicultural studies.

More importantly, I have now repeatedly shown that reading a distorted Wikipedia article can increase hindsight bias, indicating that hindsight bias is a dynamic process which can change as a function of information. Thus, the present findings significantly extend knowledge about consequences of hindsight bias, because previous studies usually ended with the provision of outcome knowledge (Christensen-Szalanski & Willham, 1991; Guilbault et al., 2004). Finally, the findings are relevant to the use of Wikipedia as a knowledge repository and encyclopedia. Wikipedia offers the unique possibility to access foresight knowledge to events, also before something happened (given that an article existed). Hence, it allows access to the pre-event perspective, which previously became unavailable in hindsight. Making readers aware of this feature could help to circumvent or at least decrease hindsight bias in the future. Thinking of possible other event outcomes, which raises awareness for the foresight ambiguity (Dawes, 1993), has been repeatedly shown to decrease hindsight bias (cf. Roese & Vohs, 2012).

5 General Discussion

Hindsight Bias is a ubiquitous phenomenon and human judgment error that distorts memory of earlier predictions and leads to biased perceptions of the foreseeability and inevitability of events (Fischhoff, 1975; Guilbault et al., 2004; Roese & Vohs, 2012). Especially after disasters, people search for an explanation and try to make sense of what happened in order to avoid similar negative consequences in the future (Louie, 1999; Nestler et al., 2008a). In this dissertation, I examined the influence of hindsight bias in different phases of knowledge about what happened. I found that hindsight bias can emerge even when knowledge about what happened is still unclear, extending theoretical assumptions about the prerequisites of hindsight bias. Furthermore, I found that already existing hindsight bias transfers into written artefacts and that reading such distorted material can further increase hindsight bias. An examination of this effect with readers from different nationalities yielded no moderation by cultural differences, in this case different causal reasoning styles. Taken together, these findings broaden the understanding of underlying causal reasoning processes of hindsight bias and its prerequisites and consequences and demonstrate how distorted hindsight perceptions multiply and proliferate.

5.1 On hindsight bias without real hindsight

The studies presented in Chapter 2 investigated hindsight bias in the absence of certain knowledge about an event. I found that participants wrongfully thought to have “conjectured all along”, when their conjectures about what happened changed over time. In other words, I found hindsight bias without real hindsight, demonstrating that an event does not have to have actually occurred to elicit hindsight bias, it just needs a seemingly valid conjecture. Moreover, the findings are the first to show that both conjecture-based

and knowledge-based hindsight bias do not differ from each other with regard to the magnitude of hindsight bias.

These results are relevant to several theoretical explanations of hindsight bias. Sense-making models of hindsight bias argue that it is a result of sense-making processes which are elicited by unexpected events (Pezzo, 2003; Pezzo & Pezzo, 2007). This notion is supported by the present data, because it shows that a plausible conjecture elicits hindsight bias to the same extent as definite knowledge. Research has repeatedly found that hindsight bias is stronger, the more an outcome makes sense (Pezzo, 2003; Roese & Maniar, 1997, Yopchick & Kim, 2012), and, in turn, is decreased or reversed, the more an outcome seems surprising (Ash, 2009; Calvillo & Gomes, 2011; Pezzo & Pezzo, 2007). As described in the introduction, some theories of hindsight bias assume that it is the result of a distorted cognitive model construction process. Based on a constructivist perspective, Nestler et al. (2008a) proposed that individuals develop a cognitive model of any event they would like to understand. However, in hindsight, this model contains more event-consistent than –inconsistent elements, a result of a distorted search for (and evaluation of) antecedents – distorted by one’s outcome knowledge (cf. Hawkins & Hastie, 1990). In the light of the present studies, it is likely that a plausible conjecture can lead to the same distorted model construction process as definite knowledge. Here, the causal model is based on what one considers to be the most plausible option, resulting in distorting ‘filter mechanisms’.

Another theory on hindsight bias assumes that it is the result of anchoring on the current (post outcome) knowledge when reconstructing previous knowledge (Erdfelder & Buchner, 1998; Guilbault et al., 2004; Hawkins & Hastie, 1990). The same processes can theoretically explain hindsight bias from conjectures, too. Focusing on a current conjecture distorts one’s memory for a previous conjecture. Furthermore, Hawkins and Hastie (1990) proposed that participants are more likely to rely on information that fits the known outcome rather than contradicts it, when asked to reproduce earlier judgments (see also

Nestler et al., 2008a; 2008b). Again, the same process might be at work if people base their reproductions on information that fits their current conjecture about what might have happened instead.

General theoretical models of causal reasoning assume that people searching for a causal explanation retrace critical events and evaluate how each event increases the outcome probability (Spellman, 1997). The event that is perceived to raise the outcome's probability the most is selected as the cause. When final clarification is lacking, the explanation receiving the highest likelihood is the best guess in this "probability-updating account", likely functioning as the substitute for definite knowledge. Furthermore, Mandel (2003) proposed that people experience causation through sufficient rather than necessary causes. A plausible conjecture might be such a sufficient argument, at least sufficient enough to appear to have been "clear all along".

In contrast, it could also be plausible to assume that conjectures do not elicit hindsight bias, because they – by definition – include the knowledge that one does not know yet and therefore might raise awareness for alternative possibilities. Thinking of alternatives has been shown to decrease hindsight bias significantly (Hirt & Markman, 1995; Mussweiler, Strack & Pfeiffer, 2000; Nestler & von Collani, 2008; Sanna, Schwarz & Small, 2002). One moderating factor in this case could be the conjecture's *certainty*. In the case of great uncertainty, one is most likely very aware of all the possible alternatives and the causal model is thus much more diverse and less biased (resembling a foresight rather than hindsight state of mind). The more certainty about what happened there is, the more likely it is that the above mentioned processes emerge and the causal model becomes more restrictive. If one considered likelihood ratings as a proxy for certainty, the present findings support the latter approach, because participants in the laboratory study assigned rather high likelihoods to the most plausible conjecture (~75%). However, a more conclusive design would be to ask for likelihood ratings as well as certainty evaluations of

these ratings to test the moderating role of certainty. This could be an interesting path for future research.

An alternative explanation for the present findings could be that the hindsight bias based on conjectures is merely an effect of knowledge updating. One did not know something in the beginning, knows more later and updates one's judgment accordingly. However, the crucial difference between knowledge updating and hindsight bias is that one falsely believes to have had the late information all along, hindsight bias is thus a consequence of knowledge updating (e.g. Fischhoff, 1975). In the laboratory study, participants knew that they received some of the additional information only later, but they still failed to completely reconstruct their initial, more naïve state of mind.

An aspect of particular practical importance, because people make wrong assumptions about what other people know (Bernstein et al., 2016; Blank, Musch & Pohl, 2007), is the relationship of hindsight bias and false attributions of blame and responsibility. When conjectures are sufficient to elicit hindsight bias, this could mean that involved actors could be seen as responsible by the general public, without even knowing if and how they acted. This could for example result in wrong accusations of inertia or even the belief in conspiracy theories ("they did not do ... on purpose although it was obvious all along"). The belief that others acted unreasonably given seemingly obvious knowledge has also been termed tertiary hindsight bias (Kelman, Fallas & Folger, 1998). One future-directed scenario where this could be relevant is risk prevention. Research on risk perception has shown that risk perception is a function of a person's beliefs and not of the actual characteristics of the hazard (Sjöberg, 2000). Furthermore, a study by Fischhoff et al., (2005), demonstrated that hindsight bias can emerge on the basis of changing risk judgments over time. For example, if a person was personally convinced that there is a high terror risk and at the same time has the conjecture that there will be an attack soon (which is falsely perceived as long-lasting), s/he would be ever more convinced of the truth of his/her thoughts and likely approve of unnecessary means to alleviate the

perceived threat or suffer from unnecessary fear (but note that cognitive processes are much more complex and involve other distortions such as confirmation bias, Nickerson, 1999, availability heuristics, Tversky & Kahnemann, 1973, etc.).

Conjecture-based hindsight bias also means that personal convictions are equally powerful as facts when it comes to people's judgments. Especially in the current climate of "post factual" information and "emotional truths", these cases of tertiary hindsight bias based on assumptions are important. Faulty attributions of blame based on mere conjectures of what could have been thus carry an unpredictable risk to injure the public image of any agent involved in negative events. Furthermore, hindsight bias carries the personal risks of myopia and overconfidence, which can lead people to falsely identify the root of a problem or exaggerate their own abilities, respectively, and thus impair future decision making (Roese & Vohs, 2012). This research helps to mitigate these consequences, because it fosters understanding of antecedents, underlying mechanisms and boundary conditions and raises awareness which may help to prevent hindsight bias in the first place. While further research is needed to identify the specific mechanism that is underlying the effects, these two studies are, at least to my knowledge, the first demonstrating that a change in a conjecture about what happened is already sufficient to lead people to believe that they have "believed it all along". They succumbed to hindsight bias in the absence of hindsight knowledge.

5.2 On hindsight bias transfer

Whereas the studies presented in Chapter 2 investigated hindsight *before* learning about the outcome of an event, the studies presented in Chapter 3 and Chapter 4 focused on the consequences of hindsight bias *after* one has initially learned about the outcome of an event. Building on the findings of a previous study showing hindsight bias in Wikipedia articles (Oeberst et al., 2017, Study 1), I found that an author's hindsight bias is carried into (collaboratively) written artefacts. Hindsight bias within the articles was directly related to the author's individual hindsight bias, indicating that bias prevention measures such as a need for a neutral point of view did not prevent hindsight bias transfer. Collaboration did not affect resulting hindsight distortions in the articles.

My findings crucially extend the knowledge about hindsight bias consequences, because the transfer of hindsight bias was not addressed in previous research. Furthermore, the findings support theoretical models of causal reasoning. The central process leading to hindsight bias after events is a distorted information search (Hawkins & Hastie, 1990; Nestler et al., 2008a; Roese & Olsen, 1996). When one is asked to write an (explanatory) article about an event, the first step is also to gather information. And this is of course done in the light of one's aim to provide a conclusive explanation, hence likely following the same process of underweighting inconsistent antecedents and overestimating the importance of consistent antecedents (Nestler et al., 2008a). In a sense, the article thus turns into a written equivalent of one's causal event model, and thus contains hindsight distortions.

In contrast, one can also imagine that the aim to write an informative article leads to considerably wider information search, out of the interest to provide as much information as possible. Considering that hindsight is so pervasive and difficult to overcome (Roese & Vohs, 2012), however, this option is rather unlikely. A better remedy may come from collaboration of multiple authors, as they potentially contribute a more

diverse set of antecedents to the article, which could mitigate hindsight bias. Previous research regarding hindsight bias in groups offers inconclusive findings in this regard (Bukszar & Connolly, 1988; Choi & Choi, 2010; Stahlberg et al., 1995) and none of it examined collaborative effects on hindsight bias transfer. My finding suggests that collaboration does not strengthen, but also not mitigate hindsight bias, but the exact effect of collaboration on bias transfer needs to be examined in future studies

In sum, I demonstrated that hindsight bias can transfer from an author to an artefact, which had not been shown before. Further research is needed to identify which factors contribute to this process and further explore on the role of collaboration. My results also raise another question: What happens after reading such a distorted text?

5.3 On hindsight bias after reading

Following up on the above finding, I tested the influence of reading a distorted article in an online-study. This question is important to consider, because it explores whether hindsight bias can proliferate via means of written artefacts. Hence, the bias of a single author, or group of authors on Wikipedia, can potentially distort the event perceptions of numerous readers, spreading hindsight bias and carrying its negative consequences along.

Hindsight distortion in a Wikipedia article has been defined as the difference between a foresight and a hindsight version of the article in terms of how much it suggests that the event was foreseeable, likely or inevitable (Oeberst et al., 2017). In a first step, it was necessary to establish that reading a distorted article really had an *incremental* effect on hindsight bias, over and above mere outcome knowledge, as this had not been shown before. Besides, reading the article could simply act as a reminder for the event, because it provides surrounding information not influencing hindsight bias. The results confirmed the classic finding that outcome knowledge leads to hindsight bias: Participants who learned about the event judged it to have been more likely and more inevitable in hindsight. The

central finding was that participants who had read the distorted Wikipedia article showed an additional increase in inevitability and (marginally) likelihood perceptions. Thus, this study demonstrated that reading information which in itself contains hindsight distortions can lead to an even further distorted event perception.

In Chapter 4, I replicated the effect of an increased hindsight bias after reading distorted articles in two further studies. Again, I found that reading the distorted hindsight article increased hindsight bias. I had hypothesized that the effect would be more pronounced in holistic thinkers, based on the notion that a holistic world view would simplify the search for consistent antecedents (Choi & Nisbett, 2000), however, this moderating effect of holistic thinking style (as opposed to analytic thinking style) was not supported by the data. In a follow-up study, I replicated the increase in hindsight bias-effect once more, however, only in the US-American and not in the Vietnamese sample (please see the discussion section in Chapter 4 for a detailed examination of this finding). Apart from using a different event (the Fukushima nuclear disaster) than in the previous study, I also compared participants who read a foresight article about the event to participants who read a hindsight article about the event, to rule out that the increase in hindsight bias was merely an effect of salience. In addition, Wikipedia is used worldwide, and therefore having a culturally diverse sample (with participants from Germany, Japan, Sweden, Singapore, Vietnam, United States) increased the ecological validity of my findings. Thus, my findings reliably show that hindsight distortions can be communicated and that individual hindsight bias dynamically changes with more information.

These findings contribute to several theoretical accounts of hindsight bias. In a broad sense, they support the notion that hindsight bias gets stronger the more causal information is available, because the articles provided additional information in this regard. This has also been found by other scholars (Jennings, Lowe, & Reckers, 1998; Roese & Maniar, 1997; Trabasso & Bartolone, 2003; Trabasso & van den Broek, 1985; Wasserman, Lempert, & Hastie, 1991; Yopchik & Kim, 2012). In the sense of Causal

Model Theory (Nestler et al., 2008a), for example, the distorted articles provided additional outcome-consistent model elements, thus tipping the cognitive model into an ever more biased perspective. Already in 1981, Pennington described that more detailed descriptions result in greater hindsight bias. Dougherty, Gettys and Ogden (1999) also showed that likelihood judgments are strongly related to the amount of detail in imagining outcomes that did not happen in a simulated model of hindsight bias. The fewer details the simulated participants knew about potential other scenarios, the greater the hindsight bias. Drawing from this line of reasoning, I argue that reading a Wikipedia article likely caused participants in my studies to have difficulties imagining other outcomes while adding detail to the known outcome, hence also increasing the perceived likelihood of the known outcome. This argument is also related to findings that counterfactual thinking can reduce hindsight bias (Hirt & Markman, 1995; Mandel, 2003; Roese & Olsen, 1996; Williams, Lees-Haley & Brown, 1993).

In the studies on hindsight bias after reading, knowledge updating is an important part of the entire cognitive process and certainly takes place as well, since the main motivation to read a Wikipedia article should be to update one's knowledge. The most important aspect is *how* the knowledge updating takes place and why it contributes to hindsight bias. Based on the theoretical assumptions of Causal Model Theory (Nestler et al., 2008a) and on my findings, it is likely that the knowledge updating process is in itself distorted in direction of what one already knows, because the Wikipedia article can facilitate access to outcome supporting antecedents. Put differently, the knowledge updating process takes place within a hindsight framework and thus leads to an increase in hindsight bias (Slovic & Fischhoff, 1977). In the study where the event was previously unknown, the article provided information that made the event appear even more inevitable, incremental to the effect of mere outcome knowledge. In case of the Fukushima nuclear disasters, which was known to all participants, we do not know if hindsight bias was apparent before reading the articles, but found the same increasing effect, albeit this

time for impressions of likelihood and foreseeability. A more fine-grained examination of which pieces of information are used (or neglected) to upgrade the cognitive model could help to disentangle the two processes of knowledge updating and hindsight bias. This distinction would also help to differentiate between arguments relevant for impressions of inevitability and impression of foreseeability, respectively.

Notwithstanding, the differences between hindsight bias components throughout the studies also support the notion that hindsight bias is not a unitary phenomenon, but an umbrella term describing distinct components: biased perceptions of foreseeability, inevitability, and memory distortions (Blank et al., 2008). Nestler, Blank & Egloff (2010) propose that the components of hindsight bias are related, but rest on different cognitive processes. Impressions of foreseeability are based on subjective considerations of one's own state of knowledge and ability. Hence, in the study which involved a previously unknown accident (Chapter 3), participants reported to not have been able to personally foresee this accident and consequently showed no hindsight bias on the component of foreseeability impressions. But perceptions of inevitability, which are based on judgments about the objective state of the world (Nestler et al., 2008b), were distorted by hindsight, as the information from the text was apparently sufficient to come up with an explanation why the accident happened. This is in line with a study by Yopchick & Kim (2012), who demonstrated that knowledge of a causal antecedent is necessary for hindsight bias to occur and mere outcome knowledge insufficient.

One aspect that might be particularly important with regard to the communication of hindsight bias is source credibility. Wikipedia, for instance, is a very popular and trusted source of information (Flanagin & Metzger, 2011; Shen, Cheung & Lee, 2013), hence biased articles have the potential to reach and influence a vast amount of people. Furthermore, when information is unclear, people rely on social consensus information to make a judgment (Festinger, 1954). Wikipedia, as a collaboratively written encyclopedia, thus likely has a strong persuasive quality. These mechanisms are related to persuasion

research and less important regarding hindsight bias after outcome knowledge, but highly relevant in hindsight bias after reading.

Rouet (2006) lists source credibility as an important external resource of functional document use (Task-based Relevance Assessment and Content Extraction (TRACE) model, see also Rouet & Britt, 2011 for an updated version). Here, the information resource is seen as informative in itself, providing first information about the usefulness of the document for the reader's informational needs. Furthermore, the source of information is relevant to its persuasive character. Generally, the more credible a source is perceived to be, the more persuasive it is (Pornpitakpan, 2004). More specifically, the more trustworthy a source appears and the more expertise a communicator (seemingly) has, the stronger its persuasive influence on people's attitude. However, this effect is moderated by a number of variables, for example message characteristics (e.g. argument quality, Stoltenberg & Davis, 1988) and receiver characteristics (e.g. processing mode, Petty, Cacioppo & Goldman, 1981; Petty & Cacioppo, 1986; Chaiken, 1980; 1987). Under heuristic processing (or *peripheral*, in terms of the Elaboration Likelihood Model, Petty & Cacioppo, 1986), which is typically found under low motivation (Chaiken & Maheswaran, 1994), as potentially in an online study, Wikipedia could be a very valid external cue, given that it is a popular encyclopedia. Furthermore, Ward (2013) argued that people tend to mistake Internet knowledge for their own knowledge. This could lead readers to simply take the information from an article for granted and adjust their cognitive model accordingly, without putting much effort into critical thought about the presented contents. In other media, with lower source credibility, there might be less bias transfer, because readers are more skeptical. However, further research is needed to support these ideas.

Summing up the set of studies from Chapters 3 and 4, I found that hindsight bias can be increased even long after initial outcome knowledge was gained, by reading a distorted media report about the event in question. In the future, an interesting question to pursue would be to test the opposite: If hindsight bias can be increased, can it also be

decreased through similar mechanisms? However, in the present studies, reading the foresight article did not reduce hindsight distortions. This finding is not surprising, given that decreasing hindsight bias has been found a difficult endeavor (Guilbault et al., 2004). The most effective approach so far seems to be a “consider the opposite-technique” (Arkes, Faust, Guilmette & Hart, 1988; Hirt & Markman, 1995; Mussweiler, Strack & Pfeiffer, 2000; Nestler & von Collani, 2008; Sanna & Schwarz, 2007; Roese & Vohs, 2012), but it can also backfire: Coming up with alternatives gets more difficult the more alternatives one tries to generate. This metacognitive experience can make an event appear even more inevitable, because it seems so difficult to generate other outcomes (Schwarz, Sanna, Skurnik & Yoon, 2007). Thus, hindsight bias is difficult to overcome, but raising awareness of the potentially detrimental effects of biased media reports is important to stimulate further applied research how hindsight bias could be diminished.

5.4 Strengths and Limitations

With a combination of quasi-experimental field studies and laboratory / online experiments, and the dual focus on prerequisites and insights into consequences of hindsight bias, this dissertation fills the gap between theoretical considerations surrounding hindsight bias and applied implications of hindsight bias. I could establish my findings in multiple experiments with an adequate number of participants, therefore high testing power, and (partly) across various cultures, yielding improved ecological validity.

Hindsight bias is very difficult to investigate in real life events, especially disasters and accidents, because they never occur with previous warning signs (although the hindsight perspective suggests otherwise). One notable exception are elections (cf. Blank, Fischer & Erdfelder, 2003), but these usually do not qualify as disasters. To my knowledge, there is only one study which examined hindsight bias before and after a real life accident. Verplanken and Pieters (1988) asked participants before and after the Chernobyl nuclear fallout how likely a nuclear accident was. They found a reversal of

hindsight bias. Participants reported that they never would have thought such a devastating nuclear accident would occur (however, this conclusion has been criticized, Arkes, 1988). One insight from the present studies is that using Wikipedia as a means to access a foresight knowledge state is feasible, too. Furthermore, I showed that hindsight bias can be investigated even when definite knowledge about a real life disaster is not yet available, merely based on people's conjectures about what happened.

The role of Wikipedia as a means to influence hindsight bias inspired part of this research. As mentioned above, Wikipedia offers excellent preconditions to investigate hindsight bias, because it provides a record of the foresight state of knowledge. My research profited from these preconditions and I can provide a unique test of theoretical assumptions based on real world events and real material. However, Wikipedia is an unparalleled research environment, but it is by far not the only source of information available today. This notion raises the questions whether or not the present findings generalize to other information sources. Based on the theoretical argumentation above, the answer is yes. Wikipedia has fairly strong principles to prevent bias, but, as the present studies show, hindsight bias enters nevertheless. This is in line with other studies showing that Wikipedia does include bias (as in "incorrect representation of facts", not cognitive bias per se), for example in political articles (Greenstein & Zhu, 2012) and in event descriptions (Rogers & Sendjarevic, 2013). In the case of newspaper articles or TV reports, journalists might follow similar objectives of a neutral coverage, but this norm is potentially less strong as on Wikipedia, since the main goal is often to provide the most important explanation in a brief manner to satisfy consumers' informational needs, while at the same time attending to other news as well. Moreover, it would be unreasonable to assume that a journalist (or any other human producing informative content) is immune to hindsight bias and writes perfectly balanced hindsight accounts of events. Hence, the production of written artefacts and the reception of distorted information should lead to distorted event representations, regardless of the information source. In the studies on

conjecture-based hindsight bias, participants also read bogus newspaper articles, which elicited hindsight bias just as in the Wikipedia studies. Nevertheless, further research on the influence of media reports on hindsight bias could help to define the features of underlying mechanisms such as source credibility, coherence, novelty etc.

To prevent hindsight bias from spreading through Wikipedia, it could be useful to raise awareness among authors and readers, for example by installing warnings of hindsight bias within Wikipedia articles on events, pointing to the fact that earlier article versions are available for comparison. Similar warnings exist in articles violating the principle of objectivity and could help information seekers to understand the ambiguity of the foresight perspective, alleviating hindsight bias (e.g. Dawes, 1993). This idea is supported by studies on visual hindsight bias, which have shown that having insight into the foresight perspective helps to reduce bias (Wu, Shimojo, Wang & Camerer, 2012).

In the face of negative events, it is important to keep in mind that human cognition does not only revolve around causal models, but is much more complex (Williams et al., 1993). Scholars have repeatedly shown that for example counterfactual thinking (Roese & Maniar, 1997; Nestler & von Collani, 2008), attribution (Williams et al., 1993), knowledge (Hertwig, Fanselow & Hoffrage, 2003), individual differences (Musch & Wagner, 2007), surprise, subjective plausibility and defense mechanisms (Pezzo, 2003; Tykocinski, 2001) play an important role as well. However, the present studies are not suitable to provide this integration.

Another important insight results from the differences in holistic-analytic thinking based on a mere translation of materials. This finding demonstrates the importance of considering cultural differences (Henrich, Heine & Norenzayan, 2010). Besides, it is a good reminder not to generalize research findings too quickly and to be aware of methodological caveats. All in all, using participants from various cultures helped to draw more substantial conclusions about the increasing effect media reports on hindsight bias, such as that the effect reliably replicated in Western participants, but not in Vietnamese

participants. This finding also shows, however, that more research is needed to pinpoint divergent underlying processes.

Hopefully, tragedies like the disappearance of flight MH 370 or the Fukushima nuclear disaster never happen again. Fortunately, my studies show that it is feasible to use bogus scenarios to investigate the same phenomena, too. At the same time, investigating these real-life events demonstrated that hindsight bias is not just a bias that affects individual perception. Rather, it can be transferred, communicated back and forth between persons and artefacts, increased, and even develops on the basis of conjectures alone. These findings imply that hindsight bias can easily spread to a wider audience, potentially distorting event perceptions of thousands of readers and thus altering the public perception of events.

These findings are especially relevant in the face of a “post-factual” society, where opinions seem as important as facts (Ribeiro, Calaism, Almeida & Meira Jr. 2017), because hindsight bias can carry negative consequences such as myopia and overconfidence which impair individual decision making (Roese & Vohs, 2012), as well as false and premature attributions of responsibility and blame (Carli, 1999), which can damage public reputation.

This dissertation helps to mitigate these negative consequences by advancing knowledge about the prerequisites of hindsight bias, demonstrating how it is communicated and transferred and raising awareness of hindsight bias as a strong, albeit often unnoticed phenomenon distorting human reasoning.

6 Conclusion

With a hindsight perspective, it is always easy to define exactly where things got off the right track and disaster unfolded. Failure to foresee the future, predict events and prevent tragedy has fascinated observers since ancient times (compare for example the story of Oedipus in Greek mythology, or Shakespearean dramas, e.g. The tragedy of Macbeth) and hindsight bias is still cause for a distorted perception of events today. This dissertation demonstrates that hindsight bias can evolve even without definite knowledge about what happened, on the basis of conjectures, and further shows that hindsight bias is communicated, transferred, and enhanced via written artefacts such as Wikipedia articles. Thus, ultimately, the hindsight bias of a few can become the hindsight bias of many.

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Zusammenfassung

Im Nachhinein erscheinen Ereignisse oft vorhersehbarer, zwangsläufiger und wahrscheinlicher als im Vorhinein. Die Tendenz im Nachhinein zu überschätzen, was man im Vorhinein wusste („Ich habe das ja schon immer gesagt!“), ist ein psychologisches Phänomen namens *Rückschaufehler* (engl. *hindsight bias*). Diese Dissertation befasst sich mit dem Rückschaufehler in verschiedenen Stadien des Wissens um ein Ereignis. Zum einen geht es darum, inwiefern es ohne konkretes Wissen darüber, was passiert ist, einen Rückschaufehler geben kann, und zum anderen inwiefern sich Rückschauverzerrungen (am Beispiel von Wikipedia) verbreiten und verstärken, wenn die Umstände eines Ereignisses längst klar sind. Die hier vorgestellten Studien geben Antworten auf die folgenden Fragen:

Braucht es für den Rückschaufehler zwingend endgültiges Wissen über ein Ereignis? Ist eine Vermutung hinreichend um den Rückschaufehler auszulösen? Antworten auf diese Fragen geben zwei Studien, eine Feldstudie zum vermissten Flug MH370 und eine Laborstudie. Es zeigte sich, dass der Rückschaufehler auch auf Grundlage von Vermutungen entstehen kann, in dem Sinne, dass die Überzeugung entsteht, etwas schon immer vermutet zu haben. Darüber hinaus zeigen meine Ergebnisse, dass ein vermutungsbasierter Rückschaufehler sich in der Ausprägung nicht von einem wissensbasierten Rückschaufehler unterscheidet. Diese neuen Erkenntnisse erweitern den bisherigen Kenntnisstand zum Rückschaufehler und den zugrundeliegenden Prozessen, zum Beispiel zur Relevanz von Sinnzusammenhängen.

Wird der Rückschaufehler in schriftliche Artefakte übertragen? Was sind die Konsequenzen davon, so ein verzerrtes Artefakt zu lesen? Wird der Rückschaufehler des Lesers zusätzlich verstärkt? Diese Fragen habe ich in vier Laborstudien untersucht und gefunden, dass a) Rückschauverzerrungen in Schriftstücken direkt mit dem Rückschaufehler ihrer Autoren zusammenhängen, b) das Lesen solch eines Artikels den individuellen Rückschaufehler verstärkt und c) dieser Effekt nicht durch kulturell bedingte Unterschiede in Denkmustern moderiert wird. Diese Befunde zeigen somit, dass der Rückschaufehler des Einzelnen durch ein Medium unter Vielen verbreitet werden und sich dadurch vervielfachen und verstärken kann.

Summary

In hindsight, events often seem predictable, more obvious, and more likely than in foresight. This tendency of overestimating what one knew before an event happened (“I knew that all along”) is a psychological phenomenon called *hindsight bias*. This dissertation focusses on hindsight bias at different stages of knowledge about an event. On the one hand, hindsight bias may develop even in the absence of definite knowledge about what happened. On the other hand, hindsight distortions may be communicated and enhanced even after clarification of what happened (for example through Wikipedia articles). This dissertation thus answers the following questions:

Do hindsight distortions necessarily require definite knowledge? Is a conjecture sufficient to elicit hindsight bias? Two studies, on field-study surrounding the missing flight MH370 and one laboratory study, provided answers. I found that hindsight bias can indeed develop on the basis of conjectures, as participants were convinced to have ‘conjectured all along’. Furthermore, I demonstrate that the magnitude of the resulting hindsight bias is comparable to hindsight bias based on definite knowledge. These findings are novel contributions to hindsight bias research and provide relevant insights in underlying mechanisms such as sense-making processes.

How does hindsight bias transfer into written artefacts? What are the consequences of reading material that is distorted by hindsight bias? Does the reader’s hindsight bias increase even further? Four studies offer further insights into the answers of these questions. I found that a) hindsight distortions in written artefacts are directly related to the author’s level of bias, b) reading such a distorted article can further increase a reader’s hindsight bias and c) the phenomenon is not moderated by cognitive thinking style due to different cultural backgrounds. These findings demonstrate that the hindsight bias of an individual can be communicated via written artefacts and thus spreads and proliferates among many.

Eigenanteil

Bei den vorliegenden Manuskripten A & C wurden die Forschungsfragen und die Studiendesigns von Ina von der Beck mit Unterstützung von Aileen Oeberst entwickelt und die Studien von Ina von der Beck durchgeführt, ausgewertet und, unter Mitwirkung durch die angegebenen Ko-Autoren, verschriftlicht. In Manuskript B wurden Studien 2 & 3 von Ina von der Beck entwickelt, durchgeführt und ausgewertet, zum Teil unter Anleitung von Aileen Oeberst. Die Verschriftlichung erfolgte durch Aileen Oeberst und Ina von der Beck mit Unterstützung durch die angegebenen Ko-Autoren.

APPENDIX

The manuscripts in the appendix are in the same order of appearance as in the dissertation.

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Oeberst, A., von der Beck, I., Back, M., Cress, U., & Nestler, S. (2017). Biases in the production and reception of collective knowledge: The case of hindsight bias in Wikipedia. *Psychological Research*. [ePub ahead of print]

Appendix C.....179

von der Beck, I., Oeberst, A., Cress, U., & Nestler, S. (2017). Cultural Interpretations of Global Information? Hindsight Bias after Reading Wikipedia Articles across Cultures. *Applied Cognitive Psychology*, 31, 315-325.

APPENDIX A

Running head: HINDSIGHT BIAS WITHOUT HINDSIGHT

Is there hindsight bias without real hindsight?
Conjectures are sufficient to elicit hindsight bias.

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Abstract

After learning about an event, people often mistakenly believe to have predicted what happened all along (hindsight bias). But what if what has happened is not known, but subject to conjecture? Could conjectures, in the absence of knowledge about the event, elicit the same bias and make people believe they “conjectured it all along”, too? We examined this question in two studies. Immediately after the disappearance of flight MH370 in March 2014, we asked $N=432$ individuals about the likelihood of a number of possible events. One year later, $N=100$ of these individuals participated again and were randomly assigned to two experimental conditions. Participants in the *current conjecture group* answered the same questions from their current perspective, participants in the *reproduced conjecture group* were asked to reproduce their earlier estimates. Results show that conjectures had changed over time and affected participants’ reproductions of their earlier estimates. We replicated this finding in a controlled lab experiment ($N=94$) and found a comparable magnitude of conjecture-based and knowledge-based hindsight bias. These findings demonstrate hindsight distortions in the absence of definite knowledge and extend theoretical assumptions about the prerequisites of hindsight bias in the context of events.

Keywords: hindsight bias, conjectures, judgment

Public Significance statement

After learning about an event, people often mistakenly believe to have predicted what happened all along. This psychological effect is called hindsight bias. Our studies show that hindsight bias can also occur when people only hold conjectures, thus only assume what happened, rather than have definite knowledge about an event.

On March 24, 2015, Andreas Lubitz, the co-pilot on a scheduled flight from Barcelona to Dusseldorf, locked himself in the cockpit and crashed the aircraft into a mountain in the French Alps. Two weeks earlier, he had been diagnosed “unfit to work” because he was suffering from a psychotic episode, but he had concealed the diagnosis from his employer. Soon after the preconditions of this fatal catastrophe became known, questions arose: Should this event not have been foreseen, given the pilot’s previously diagnosed depression and suicidal tendencies? Moreover, could this crash have been prevented? However, it is easy to be “wise” after an event has happened. The phenomenon of events seeming inevitable and foreseeable with the benefit of hindsight is termed *hindsight bias* (Fischhoff, 1975). It is a robust and pervasive error in human judgment (Guilbault, Bryant, Brockway & Posavac, 2004; Pohl & Erdfelder, 2017; Roese & Vohs, 2012).

Common to all theoretical accounts of hindsight bias is the idea that current knowledge is proposed to affect *ex-post* estimates of the *ex-ante* perspective. At first glance, this seems to imply that knowledge is a necessary precondition for hindsight bias. However, outcome knowledge is not necessarily a dichotomous feature (present vs. absent). Rather, it can be conceptualized as a continuum, with conjectures of varying degrees of certainty. One might, for instance, already know that *something* happened without yet knowing what exactly. This was the case immediately after the airplane crash in the Alps, and also when flight MH370 disappeared on its way from Kuala Lumpur to Beijing on March 8, 2014. It soon became clear that flight MH370 had not gone as planned, and after the plane had been missing for several days, it seemed likely that *something serious* had happened. A thorough, albeit unsuccessful search for the aircraft and a careful investigation by Malaysian authorities uncovered some pieces of information and rendered some developments more likely than others. However, final clarification is still missing (at the time of publication). Thus, a state of conjecturing, not knowing what happened, persists even if a particular conjecture, for example a technical failure, seems

most plausible. In such a case, we wonder whether a plausible conjecture results in a hindsight bias similar to that arising from definite knowledge. In other words, do people likewise erroneously think that they had a specific conjecture all along?

To date, no study has addressed this question. There is prior research, however, on hindsight bias regarding almanac questions, in which the veracity of feedback has been manipulated: when feedback was labelled as “another person’s estimate” (e.g. Pohl, 1998) and thus could have been wrong, hindsight bias still occurred – as long as the feedback was not highly implausible (Pohl, 1998; cf. Hardt & Pohl, 2003). However, reasoning about almanac questions differs in several aspects from reasoning about events. The most important one in the context of hindsight bias is that events trigger causal reasoning processes – an attempt to understand why something happened (Nario & Branscombe, 1995; Nestler & von Collani, 2008a) – which then result in hindsight bias (see below). These processes do not take place in the realm of almanac questions and therefore, previous findings with knowledge questions cannot be generalized to hindsight bias in the context of events. Moreover, sense-making and causal-modelling approaches of hindsight bias do not allow for a straightforward hypothesis when it comes to conjectures, either, as we will outline in the following.

After learning about an event, people search for explanations, a result of striving to understand the world around them (Nestler, Blank & von Collani, 2008). This is particularly likely after unexpected events, as these are initially surprising and elicit a need for an explanation (Pezzo, 2003; Pezzo & Pezzo, 2007). When retrospectively searching for an explanation, however, people focus on and overweight the relevance of antecedents that are *consistent* with what happened. Inconsistent antecedents, in contrast, are overlooked, ignored or underweighted (Nestler et al., 2008; Nestler, Blank & Egloff, 2010). As a result, if people are able to come up with an explanation for the event (Pezzo, 2003), this explanation is likely biased towards the outcome and this one-sidedness suggests the event to be much more likely and inevitable than in foresight (e.g., Carli,

1999; Fischhoff, 1975; Nestler & Egloff, 2009; Blank & Nestler, 2006). Unless the surprise remains, impressions of foreseeability likewise increase (Müller & Stahlberg, 2007; Nestler & Egloff, 2009; see also Pezzo, 2003). In contrast, if people are unable to come up with an explanation or found that chance played a crucial role, they do not show any hindsight bias (Nestler et al., 2008; Pezzo, 2003; Wassermann, Lempert, & Hastie, 1991; Yopchick & Kim, 2012).

In case of a (negative) event with an unknown ending, sense-making mechanisms should be triggered as well, because one already knows that *something* has happened, which likely elicits attempts to resolve the resulting uncertainty by searching for an explanation of the situation (Bruckmüller et al., 2017; Van den Bos, 2009). But, since what happened is still unclear, the sense-making process can take different forms: On the one hand, sense-making can revolve around the question of *what* happened rather than *why* it happened, for example in a state of merely knowing *something* happened. This process should resemble a true foresight perspective more than a hindsight perspective. After all, in order to clarify what happened, the search for antecedents comes first. Although the search for antecedents might be biased because one focuses on what *is* already known (e.g. a flight's disappearance), it would necessarily be less one-sided as there are many different explanations for what *is* known. Thus, we would expect a much broader and less biased search for antecedents so that a hindsight bias might not necessarily arise or be substantially lower than in the case of definite knowledge.

On the other hand, sense-making may be based on the information *that* something (negative) has happened (e.g., the disappearance of a plane) with a focus on finding out *why* this happened rather than *what exactly* happened. This case is particularly likely if a conjecture has come up immediately, for example because it is mentioned in the initial information source. The subsequent sense-making process could then be distorted by this conjecture and might be similar to the 'classic' knowledge-based hindsight bias (Nestler et al., 2008): The search for antecedents is distorted by what is currently conjectured. In

addition, sense-making in the light of a conjecture could be facilitated because it might be even easier to come up with an explanation of what could have happened without the framework given through definite knowledge, thereby strengthening hindsight bias (e.g. Nestler et al., 2008; Pezzo, 2003; Roese & Maniar, 1997; Yopchick & Kim, 2012). Moreover, while definite knowledge (about something very unexpected) may cause feelings of surprise, which can decrease or even reverse hindsight bias (Calvillo & Gomes, 2011; Pezzo, 2003), conjectures might be much more in line with individuals' expectations – as they result from individuals' reasoning – and thus leave less room for surprise and its resultant attenuating effect on hindsight bias.

In both cases, sense-making in the light of a conjecture still differs substantially from sense-making based on definite knowledge: Conjectures, by definition, merely involve *possibilities* and therefore always implicitly include alternative situations, too. In the past, several scholars have found that thinking about alternative (or opposite) outcomes can decrease hindsight bias (e.g., Arkes, Faust, Guilmette & Hart, 1988; Hirt & Markman, 1995; Mussweiler, Strack & Pfeiffer, 2000; Nestler & von Collani, 2008b; Sanna, Schwarz & Small, 2002). Thinking about alternative outcomes makes the *a priori* uncertainty more salient and thus decreases feelings of inevitability or predictability of the final outcome (Dawes, 1993; Roese & Vohs, 2012).

In sum then, whether or not conjectures regarding events are sufficient to elicit hindsight bias is an open question. This question is particularly relevant in situations in which definite knowledge might never emerge, but also addresses the very nature of hindsight bias and its boundaries. We therefore investigate the impact of current conjectures on the reproduction of earlier estimates in a two-wave study (Study 1) and replicate and extend our findings in a controlled lab experiment (Study 2).

Study 1

On March 8, 2014, flight MH370 disappeared from radar with 239 people on board while flying from Kuala Lumpur to Beijing. Apart from individual pieces of airplane wreckage, the aircraft has not been found (at the time of publication). A year after its disappearance, it was unclear what exactly had happened, but many pieces of information had been gathered that rendered some possibilities more likely than others and various theories about causes leading to the disaster had been developed and were discussed in the media (e.g., Zeit Online, 2015; The New York Times, 2015; tagesschau.de, 2015; The Daily Telegraph, 2015). Hence, it was unknown what exactly had happened, but there was reason to *assume* certain event alternatives. Study 1 made use of this situation to examine conjecture-based hindsight bias and was set in this first year of the planes disappearance.

Method

Immediately after the plane's disappearance, we conducted an online survey which was available from March 17th, 2014 until March 19th, 2014 (t_1). The period of participation was brief to ensure similar levels of information across participants. Within the specified time frame, no substantially new information about the case was published. In a second online survey in March 2015 (t_2), we invited the same participants again and assessed either what they thought most likely happened (*current conjecture group*) or their reproduction of the conjectures they had provided a year earlier (*reproduced conjecture group*). This two-wave design allowed us to assess whether conjectures changed over time and whether reproductions of previous conjectures systematically shifted towards current conjectures at t_2 . This study (as well as Study 2) was approved through an institutional ethics committee.

Participants and design. To be able to detect an effect of small to medium size ($f = 0.2$, derived from the medium effect size $M_d = .33$ for hindsight bias in real world events (Guilbault et al., 2004)), a sample size of $N = 68$ was necessary at t_2 (suggested by

G*Power (Faul, Erdfelder, Lang, & Buchner, 2007); parameters set to $\alpha = 0.05$, $1-\beta = .90$, 2 groups, 2 measurements, ANOVA: repeated measures, within – between interaction). Given low response rates in a two-wave design, we collected a large sample at t_1 , of which a response rate of 15% would be sufficient to achieve $N = 68$ at t_2 .

Participants from various German universities were recruited via e-mail lists and participated online for the chance to win vouchers. Four hundred and thirty-two people (71.8% women, $M_{\text{age}} = 24.63$; $SD = 5.18$) participated in the first wave (t_1) and answered a short survey about the missing plane. Four hundred and six of them agreed to participate again at a later point in time and separately provided their e-mail address for future contact. Of these 406 individuals, $N = 100$ completed the second survey a year later, at t_2 (71.0% women, $M_{\text{age}} = 24.49$, $SD = 4.67$). A post-hoc power analysis with G*Power (Faul et al., 2007; parameters as above) revealed that $N = 100$ participants are sufficient to be able to detect an effect of small to medium size ($f = 0.2$) with 95% power.

The subsample of participants at t_2 did not differ significantly from the entire sample at t_1 with regard to age, $M_{t1} = 24.67$, $SD = 5.33$, $M_{t2} = 24.49$, $SD = 4.67$, $t(429) = .31$, $p = .76$, gender distribution, $X^2(1, N = 432) = .04$, $p = .85$ ($t_1 = 71.8\%$ female, $t_2 = 71\%$ female), or knowledge about the case, $M_{t1} = 2.90$, $SD = .94$, $M_{t2} = 2.94$, $SD = .89$, $t(430) = .54$, $p = .59$.

At t_2 , participants were randomly assigned to one of the two experimental groups (*current conjecture*, $N = 42$; *reproduced conjecture*, $N = 58$). Hence, the study comprised a 2 (point in time: t_1 , t_2 ; within) x 2 (*current conjecture*, *reproduced conjecture*; between) design.

Materials and procedure.

First wave (t_1). After giving informed consent, participants estimated the likelihood of four mutually exclusive potential events regarding the missing flight MH370 – presented in random order: (1) “The plane was hijacked and later crashed because of fuel

shortage” (*hijacking and crash*), (2) “The plane was hijacked and safely landed somewhere else”, (*hijacking and landing*), (3) “The plane crashed because of a technical failure (no human intervention)” (*technical failure*), (4) “The plane was deliberately damaged and crashed (e.g. terrorist attack)” (*deliberate damage*). Participants were instructed to assign percentages to each event that added up to one hundred percent in total. Additionally, there was an open-ended question asking participants to provide their personal conjectures about the event. Their answers indicated that our chosen potential events reflected participants’ own conjectures. Afterwards, participants reported if and how many fatalities they anticipated. 95.4% of the sample expected fatalities, but the numbers they provided indicated that participants did not know how many passengers had been on board altogether. Therefore, we did not analyze these responses.

Next, we asked participants to rate the foreseeability of what happened to flight MH370 with three items (“It has been clear to me all along what happened to flight MH370”, “I find it difficult to predict what happened to flight MH370” (reverse coded), “Overall, it is foreseeable what happened to flight MH370.”) using a Likert scale (1 = *not at all true* to 5 = *very true*, Cronbach’s $\alpha = .69$, and $.76$, for t_1 and t_2 , respectively). The items were averaged into a composite *foreseeability scale*. Initially, we planned to assess all three components of hindsight bias – memory distortions, impressions of foreseeability, and impressions of inevitability (Blank, Nestler, von Collani, & Fischer, 2008). However, we were unable to formulate inevitability items that suited the present case (see Blank et al., 2008, for example items). Therefore, we focused on memory distortions and perceptions of foreseeability.

Finally, participants indicated how much they knew about the case (1 = *I just heard about this for the first time* to 5 = *I am very interested in the event and actively follow most media coverage*). After providing demographic information and an anonymized ID code for later matching, participants were thanked and invited to participate again at a later date, to this end they provided their e-mail address in a separate survey.

Second wave (t₂). One year after the first wave of data collection, participants were randomly assigned to experimental conditions upon starting the online-questionnaire. Participants in the *current conjecture group* were asked the same questions as at t₁, that is, they provided their current likelihood estimates of the four possible events and indicated their current perception of foreseeability of the event. Participants in the *reproduced conjecture group* were asked to reproduce their likelihood and foreseeability estimates from t₁. Instructions clearly stated that participants were to reproduce their earlier judgments and that we were not interested in their current evaluation (“Please try to remember your responses from last year as accurately as possible and try to give your responses today in light of the knowledge you had one year ago. That is, we are not interested in your judgment today. Rather, please remember and repeat your opinion / judgments from a year ago as well as possible.”, translated from German). Accordingly, foreseeability items were formulated in the past tense (e.g. “It was clear to me all along what had happened to flight MH370.”). Thus, impressions of foreseeability also had to be reproduced in the *reproduced conjecture group*. Therefore, this measure assesses the memory distortion component (Blank et al., 2008). Increases in impression of foreseeability can be derived from the *current conjecture group*. Material and data are available at osf.io/9zgxk.

Analyses

There are two necessary preconditions for an examination of conjecture-based hindsight bias: First, current conjectures have to change over time. After all, without a change in conjectures there could be no shift of reproduced conjectures towards current conjectures (cf. Fischhoff, Gonzalez, Lerner & Small, 2005). Second, conjectures at t₁ have to be comparable in both experimental groups, because our argument relies on the generalizability of the (t₂) conjectures from the *current conjecture group* to the *reproduced conjecture group*. We test these preconditions and elaborate on them within the context of our main analyses, while detailed results are reported in the footnotes. Analyses were

conducted with the one hundred individuals who participated at both measurement points. Omitting correct recalls (9.1% of reproductions were correct) did not change the result pattern; therefore all cases are included in the following report.

Results

Likelihood estimates. The measurement procedure for the likelihood ratings resulted in variables that were deterministic linear combinations of each other, because the ratings for the four event alternatives had to sum up to 100 per cent. To resolve this constraint, we only included three event alternatives in the analyses, all except *deliberate damage*. The current conjectures for this alternative did not significantly shift over time ($M_{t1} = 16.90$, $SD = 15.66$, $M_{t2} = 23.31$, $SD = 23.47$), $t(41) = 1.60$, $p = .12$. We adjusted for this constraint in Study 2.

We conducted a mixed-model ANOVA with experimental group (*current conjecture*, *reproduced conjecture*) as between-participant factor and point in time (t_1 , t_2) and event alternative (hijacking and crash, hijacking and landing, technical failure) as within-participant factors and participants' likelihood ratings as dependent variables, including all interactions. This analysis included the test for the first necessary precondition. The test revealed a significant main effect of point in time, $F(1, 98) = 6.67$, $p = .011$, $\eta_p^2 = .06$, no main effect of experimental group, $F(1, 98) = .51$, $p = .475$, a significant main effect of event alternative¹, $F(1.84, 180.53) = 8.13$, $p = .001$, $\eta_p^2 = .08$, and a significant interaction between event alternative and point in time, $F(2, 196) = 56.49$, $p < .001$, $\eta_p^2 = .37$. None of the other interactions were significant, all F s $< .25$, all p s $> .083$ (see Table 1).

To elucidate the interaction of event alternative and point in time, we ran three paired t -tests comparing t_1 to t_2 estimates for each event alternative – collapsed across experimental groups since there was no significant difference between these. The tests showed that likelihood estimates for the given scenarios differed between the two points in

time. Likelihood ratings for a hijacking and crash significantly decreased from t_1 ($M = 31.21$, $SD = 21.74$) to t_2 ($M = 19.73$, $SD = 19.02$), $t(99) = 4.42$, $p < .001$, $d = .44$, $M_{diff} = -11.48$, 95% CI [-16.63, -6.32]. Likewise for a possible hijacking and landing ($M_{t1} = 30.66$, $SD = 24.45$; $M_{t2} = 11.94$, $SD = 14.13$), $t(99) = 7.54$, $p < .001$, $d = .80$, $M_{diff} = -18.72$, 95% CI [-23.65, -13.79]. In contrast, a technical failure was perceived as significantly more likely at t_2 ($M = 45.01$, $SD = 28.34$) than at t_1 ($M = 20.56$, $SD = 21.92$), $t(99) = 8.20$, $p < .001$, $d = .83$, $M_{diff} = 24.45$, 95% CI [18.52, 30.37].

Thus, participants considered both hijacking scenarios as less likely and the technical failure as more likely than before. Hence, conjectures significantly changed over time and the first necessary precondition to investigate whether a conjecture-based hindsight bias exists was fulfilled.² The fact that there was neither a significant main effect of experimental group, nor a significant interaction involving that factor furthermore shows that participants' conjectures at t_1 were comparable³, fulfilling the second necessary precondition. The absence of a significant difference between experimental groups also indicates that we obtained a conjecture-based hindsight bias in its most extreme form: Participants who were asked to reproduce their prior conjectures at t_2 did not only significantly shift their reproductions into the direction of current conjectures, but arrived at reproductions that did not differ from current conjectures anymore. Consequently, participants erroneously believed to have held their current conjectures all along.

Foreseeability rating. Recall that the two experimental groups followed different tasks regarding the foreseeability impressions. Whereas the *current conjecture group* reported their current foreseeability ratings, the *reproduced conjecture group* reproduced their t_1 foreseeability ratings at t_2 . These different tasks tap different components of hindsight bias, namely, foreseeability impressions and memory distortions, respectively (Blank et al., 2008). Therefore, we conducted separate t_1 - t_2 comparisons for each experimental group. Genuine foreseeability ratings in the *current conjecture group* showed no significant change from t_1 to t_2 in a paired t -test, $t(41) = 1.70$, $p = .096$,

$M_{diff} = .22$, 95% CI [-.04, .46] (see Table 1), indicating no increase in perceived foreseeability of the event and thus no hindsight bias regarding the foreseeability component. However, participants' *reproduced* foreseeability ratings were significantly higher than their initial foreseeability ratings at t_1 , $t(57) = -2.86$, $p = .006$, $d = 0.47$, $M_{diff} = .36$, 95% CI [.11, .60] (see Table 1), indicating that participants thought things had been more foreseeable at t_1 than this was actually the case. This distortion is in line with our findings regarding the reproductions of likelihood estimates and further supports the hindsight bias we found with respect to the memory component (Blank et al, 2008).

Table 1

Means and standard deviations for the perceived likelihoods of event alternative and the foreseeability scale as a function of point in time and experimental group.

	Current conjecture		Reproduced conjecture	
	t_1	t_2	t_1	t_2
	$M (SD)$	$M (SD)$	$M (SD)$	$M (SD)$
Hijacking and crash	29.43 (24.61)	15.24 (16.97)	32.50 (19.57)	22.98 (19.89)
Hijacking and landing	35.50 (26.99)	11.28 (15.59)	27.16 (22.02)	12.41 (13.09)
Technical failure	19.95 (22.82)	50.16 (31.06)	21.00 (21.43)	41.26 (25.83)
Foreseeability	1.86 (.73)	2.08 (.87)	1.79 (.67)	2.15 (.84)

Discussion

In a two-wave design, we investigated conjectures regarding flight MH370, and found a distortion pattern comparable to classic hindsight bias research (e.g., Erdfelder & Buchner, 1998; Fischhoff & Beyth, 1975). Reproduced conjectures had significantly shifted towards and were even comparable to current conjectures. Thus, participants failed to ignore their current state of mind when reproducing their earlier, more naïve state of mind. Our results thus suggest a conjecture-based hindsight bias, which, however, was limited to the memory distortions component. Genuine foreseeability impressions, in contrast, did not significantly increase over time. Dissociations between the hindsight bias components “memory distortions” and “foreseeability impressions” have been documented before (e.g., Blank et al., 2008; Nestler et al., 2010). Whether the basis of hindsight bias – conjectures or knowledge – affects dissociations between these components remains to be examined.

Critically, the response rate in this study was quite low. Although there were no substantial differences between the full sample at t_1 and the sample at t_2 , we cannot exclude that factors which caused participants to participate again (or not to do so) may have influenced the results, for example heightened interest in the topic. Such an alternative account was ruled out in Study 2, in which we aimed to replicate our findings under controlled conditions and to directly compare conjecture-based and knowledge-based hindsight bias.

Study 2

We used a fictitious case that suggested a particular conjecture (more than others) at t_1 , but provided more support for another conjecture at t_2 . In line with Study 1, we hypothesized that a change in conjectures (as opposed to gaining knowledge in a knowledge-based hindsight dilemma) is sufficient to trigger hindsight bias. Furthermore, we added an experimental group in which participants received explicit knowledge about

what happened to be able to compare conjecture-based and knowledge-based hindsight bias.

Method

Participants and design. A power analysis suggested a sample size of $N = 75$ to $N = 114$ to be able to detect an effect of small to medium size.⁴ One hundred and thirteen people participated in the first part of the study, $N = 96$ completed both parts, and $N = 94$ response sets (t_1 , t_2) could be successfully matched based on an 8-digit participant code. The two participants with non-matching codes were not included in the analyses. Participants (73 female, 18 male, three without specification) were recruited via e-mail from a large German university and participated for a payment of 8€. They were on average 23.13 years old ($SD = .50$) and were – at t_2 , about five days later – randomly assigned to one of the three experimental groups (*current conjecture*: $N = 34$, *conjecture-based reproduction*: $N = 29$, *knowledge-based reproduction*: $N = 31$). The study thus comprised a 2 (point in time, within) x 3 (experimental group, between) design.

Materials and pretest. Study 2 was designed to resemble Study 1. We used a fictitious scenario about a ferry that went missing in the Philippines and (at t_1) had not been found yet. The text was carefully set up to provide tentative support for the conjecture that the ship sank because it was in poor condition and likely had a technical defect (materials were pretested, see below). In order to simulate delayed information reception and allow for hindsight bias to develop, the second part of the study (t_2) happened roughly five days later. At t_2 , participants received further information according to their experimental group. In the *current conjecture group* and the *conjecture-based reproduction group*, participants received a bogus newspaper article explaining that the circumstances of the ferry's disappearance still remain unclear, but the article included some sources of information suggesting a capacity overload to be the most likely reason for the ship's disappearance. Participants in the *knowledge-based reproduction group* received an article with the information that the ferry was found shipwrecked and that this

was due to capacity overload. All other information was kept identical between the articles. Hence, three different bogus newspaper articles were used in this study: An initial article at t_1 suggesting a technical failure (initial text), which all participants read, and two follow-up articles at t_2 , which were distributed according to the experimental group. Of the latter two articles, one version suggested that the *most likely cause* was capacity overload (conjecture text) and one version *clearly identified* capacity overload *as the cause* for the ferry's disappearance (knowledge text).

All texts were pre-tested in an online study with $N = 71$ participants ($M_{age} = 39.60$, $SD = 13.34$; 45 male, 23 female, 2 unspecified), to test whether the t_2 texts would effectively lead to a shift in current conjectures, the necessary precondition for an examination of hindsight bias. Pretest participants were randomly assigned to read one of the three text versions (initial text, conjecture text, knowledge text, between-participants). A mixed-model ANOVA across the three text versions and the dependent variable likelihood ratings for seven different event alternatives (see below, within-participants), yielded a non-significant main effect of text version, $p = .85$, a significant main effect of event alternative, $F(4.10, 278.85) = 54.84$, $p < .001$, $\eta_p^2 = .45$ and a significant interaction of event alternative and text version, $F(8.20, 278.85) = 12.49$, $p < .001$, $\eta_p^2 = .27$. Follow-up contrast analyses showed that a technical failure was perceived as more likely by participants who received the initial text ($M = 66.52$, $SD = 24.27$) than participants who read the conjectured text ($M = 38.79$, $SD = 27.36$) or the knowledge text ($M = 38.41$, $SD = 35.16$), $F(2, 68) = 8.12$, $p = .001$, $\eta_p^2 = .19$. In turn, a capacity overload was perceived as more likely by participants who had read the conjectured text ($M = 74.67$, $SD = 22.32$) or the knowledge text ($M = 86.77$, $SD = 19.09$) than by participants who had read the initial text ($M = 26.43$, $SD = 26.07$), $F(2, 68) = 46.05$, $p < .001$, $\eta_p^2 = .57$. All other comparisons between event alternatives were not significant, all F s $< .09$, all p s $> .40$. Note that there was no significant difference in the likelihood ratings of a capacity overload between participants who read the conjecture and

the knowledge texts, $t(44) = 1.68, p = .055$. In the main study, however, the experimental groups differed significantly. Furthermore, participants who had received definite information still perceived the likelihood of the event to be considerably less likely than one would expect for *knowledge* (86.77 % vs. 100%), $t(21) = 3.25, p = .004$. We address this issue in the results section, where we present additional analyses that more closely realize the desired constellation of a knowledge-based reproduction as compared to a conjecture-based reproduction. Foreseeability impressions also differed significantly between conditions in the pretest, $F(2,68) = 3.75, p = .029$, with a linear contrast analysis indicating a linear increase from initial ($M = 2.2, SD = .91$) over conjecture ($M = 2.53, SD = .94$) to knowledge text ($M = 3.04, SD = 1.24$), $p = .008$.

Procedure. Participants were instructed to work on the first part of the questionnaire at home (t_1) and to come to the lab a couple of days later to complete the second part of the study (t_2). They were automatically contacted via e-mail 120 hours prior to their lab appointment and received the link to an online survey to be completed as soon as possible. The average time interval between t_1 and t_2 was 4.02 days ($SD = 1.6$ days).

At t_1 , all participants read the initial text about the missing ferry (see above). Next, they were asked to judge the likelihood of seven different situations that might have led to the disappearance of the ferry: 1) a mistake of the captain, 2) a technical failure, 3) a fire in the engine room, 4) generally poor condition of the vessel, 5) a pirate hijacking, 6) capacity overload and 7) an attack. All likelihood ratings were made on a scale of 0 = *highly unlikely* to 100 = *highly likely* with a slider component. In contrast to Study 1, event alternatives were judged without the constraint of a fixed overall sum for all events. The items were presented in fully random order. Participants also provided foreseeability impressions (adapted items from Study 1) at t_1 and t_2 . Internal consistencies for the foreseeability scale at both points in time were good (Cronbach's alphas were .76 at t_1 and .81 at t_2 , respectively) and foreseeability items were therefore averaged into a composite variable.

To distract participants from the missing ferry scenario, we also included a (later irrelevant) second scenario at t_1 , for which participants likewise provided likelihood and foreseeability ratings. Before finishing, participants were reminded to come into the lab a couple of days later.

Upon arrival at the laboratory at t_2 , participants answered a control question to determine whether they had filled out the first part of the study. Two participants failed this question; they had not worked on the t_1 part before coming to the laboratory. They agreed to fill out the t_1 questionnaire in the lab instead of at home and returned five days later to finish the study. Next, participants were randomly assigned to one of the three experimental groups and read the second informative text about the missing ferryboat according to their experimental group. Then, prior to reporting likelihood ratings for all seven event alternatives and foreseeability ratings once more, participants completed a filler task which took approximately 10 minutes and was a pretest for an unrelated study. The likelihood estimates and foreseeability ratings were reported in the following scheme: participants in the *current conjecture group* were asked to state their current judgments, and participants in the *conjecture-based reproduction group* and the *knowledge-based reproduction group* were asked to reproduce their earlier conjectures. Instructions clearly stated to reproduce the previous estimates from t_1 and to ignore the new information (for instruction wording, see Study 1). In a second step, participants in the two reproduction groups were additionally asked to report their current conjectures as well, and in turn, participants in the *current conjecture group* were additionally asked to reproduce their t_1 conjectures, yielding all judgments from all participants. Afterwards, participants were debriefed and thanked.

We expected that participants in Study 2 would shift their current conjectures from t_1 to t_2 (from technical failure to capacity overload). Furthermore, we expected that participants in the *conjecture-based reproduction group* would erroneously believe to have

had the later conjecture all along. Finally, we expected that participants in the *knowledge-based reproduction group* would likewise erroneously believe to have known it all along.

Analyses

As in Study 1, the data has to meet two preconditions to qualify for a test of hindsight bias. First, there must be a change in conjectures over time. Second, conjectures must be comparable across conditions at t_1 . In the following results section, we first inspect whether our data meets the necessary precondition of comparable conjectures at t_1 . Next, we continue to the main analyses and report on the other necessary precondition, a change in conjectures from t_1 to t_2 . All of the analyses are reported for both dependent variables: likelihood estimates and foreseeability ratings. The number of correct recalls was low (6.6%) and did not differ between conditions, $X^2(3, 60) = 3.60, p = .308$. Omitting correct recalls did not change the result pattern, therefore all analyses are reported including correct recalls.

Results

Conjectures at t_1 . A mixed measurement ANOVA with all seven event alternatives (within) and three experimental groups (*current conjecture*, *conjecture-based reproduction*, *knowledge-based reproduction*, between) yielded a significant main effect of event alternative, $f(5.17, 470.56) = 48.35, p < .001, \eta_p^2 = .35$, but all other comparisons were not significant, f 's < 1.04 , all p 's $> .39$. Hence, the necessary precondition of comparable current conjectures across conditions at t_1 was met. There was also no significant difference between experimental groups regarding the dependent variable foreseeability impressions, $F(2, 91) = 3.03, p = .053, \eta_p^2 = .06$.

Likelihood estimates. For the sake of brevity and clarity, the following analyses only contain the event alternatives *technical failure* and *capacity overload*, which were the crucial alternatives involving new information as well as significant changes over time. The result pattern remained the same when the analyses included the other five

alternatives. We conducted a mixed-model ANOVA with experimental group (*current conjecture*, *conjecture-based reproduction*, *knowledge-based reproduction*) as between-participant factor and point in time (t_1 , t_2) and the two relevant event alternatives (technical failure, capacity overload) as within-participant factors, including all interactions, to analyze whether a conjecture-based hindsight bias occurred (as in Study 1) and whether this was comparable to a knowledge-based hindsight bias. There was a main effect of event alternative, $F(1, 91) = 39.44$, $p < .001$, $\eta_p^2 = .30$, an interaction of point in time by event alternative, $F(1, 91) = 69.09$, $p < .001$, $\eta_p^2 = .43$, an interaction of experimental group by event alternative, $F(2, 91) = 10.83$, $p < .001$, $\eta_p^2 = .19$ and a three-way interaction, $F(2, 91) = 11.54$, $p < .001$, $\eta_p^2 = .20$. No other effects were significant, all F 's < 3.58 , p 's $> .062$.

To elucidate the three-way interaction, we conducted repeated measures ANOVAs across point in time (t_1 , t_2) and event alternative (technical failure, capacity overload) within each experimental group. In the *current conjecture group*, this analysis yielded a significant main effect of point in time, $F(1, 33) = 5.34$, $p = .027$, $\eta_p^2 = .14$, a non-significant main effect of event alternative, $F(1, 33) = .005$, $p = .94$, and a significant interaction of point in time by alternative, $F(1, 33) = 72.66$, $p < .001$, $\eta_p^2 = .69$. Follow-up paired t -tests showed the following pattern: Whereas judgments for a technical failure decreased from t_1 to t_2 , $t(33) = 6.13$, $p < .001$, $d = 1.28$, $M_{diff} = -31.59$, 95% CI [-42.06, -21.11], they significantly increased regarding the capacity overload alternative, $t(33) = -8.01$, $p < .001$, $d = 1.90$, $M_{diff} = 45.38$, 95% CI [33.86, 56.91] (see Table 2 for all means and standard deviations). With this change in conjectures over time, the second necessary precondition for the examination of conjecture-based hindsight bias is fulfilled. In the *conjecture-based reproduction group*, there was no significant main effect of point in time, $F(1, 28) = 1.46$, $p = .24$, but a significant main effect of event alternative, $F(1, 28) = 23.94$, $p < .001$, $\eta_p^2 = .46$ and a significant interaction, $F(1, 28) = 10.17$, $p = .004$, $\eta_p^2 = .27$. Paired t -tests revealed that participants' estimates for a technical failure at

both points in time were comparable, $t(28) = 1.12$, $p = .27$, but estimates for the capacity overload alternative at t_2 were significantly higher than at t_1 , $t(28) = -3.07$, $p = .005$, $d = .63$, $M_{diff} = -15.87$, 95% CI [-26.45, -5.27]. Thus, participants' reproductions of their capacity overload estimate shifted towards current conjectures. Finally, in the *knowledge-based reproduction group*, the main effect of point in time was not significant, $F(1, 30) = .02$, $p = .90$, but there was a significant main effect of event alternative, $F(1, 30) = 28.61$, $p < .001$, $\eta_p^2 = .49$, and a significant interaction term, $F(1, 30) = 8.48$, $p = .007$, $\eta_p^2 = .22$. Paired t-tests indicated that participants' reproductions of their technical failure estimate were significantly lower than t_1 estimates, $t(30) = 3.11$, $p = .004$, $d = 0.60$, $M_{diff} = -15.26$, 95% CI [5.25, 25.27], and the reproduced judgments were descriptively higher than t_1 estimates, $t(30) = -2.02$, $p = .053$, $d = 0.48$, $M_{diff} = -14.39$, 95% CI [-28.96, .18]. Thus, again, participants' reproductions shifted towards current conjectures – this time significantly for both event alternatives.

Since all participants provided reproduced and current estimates at t_2 , we were able to test whether participants (somewhat) controlled for their current conjectures during reproduction (note that order of dependent variables differed between groups). A mixed model ANOVA for likelihood ratings with experimental group (*current conjecture*, *conjecture-based reproduction*, *knowledge-based reproduction*) as a between-participant factor, task (t_1 , $t_{2_reproduction}$, $t_{2_current}$) and event alternative (technical failure, capacity overload) as within-participant factors, including all interaction terms, yielded the following results: The main effect of task was significant, $F(2, 182) = 6.27$, $p = .002$, $\eta_p^2 = .06$, the interaction of task and event alternative was significant, $F(2, 182) = 135.77$, $p < .001$, $\eta_p^2 = .60$, but all other effects were not significant, all F 's < 1.32 , p 's $> .30$.

To elucidate the two-way interaction, we compared the likelihood judgments for each event alternative separately – aggregated across experimental groups. For a technical failure, a repeated measures ANOVA (task: t_1 , $t_{2_reproduction}$, $t_{2_current}$; within) revealed a significant main effect of task, $F(2, 92) = 51.76$, $p < .001$, $\eta_p^2 = .53$. Follow-up within-

subject contrast analysis yielded a significant difference between initial t_1 judgments ($M = 66.45$, $SD = 23.27$) and their reproduction at t_2 ($M = 55.89$, $SD = 24.32$), $F(1, 93) = 13.65$, $p < .001$, $\eta_p^2 = .13$, between reproductions and current conjectures at t_2 ($M = 32.51$, $SD = 28.65$), $F(1, 93) = 54.80$, $p < .001$, $\eta_p^2 = .37$, and initial judgments and current conjectures, $F(1, 93) = 102.48$, $p < .001$, $\eta_p^2 = .52$.

Regarding the capacity overload, the same analysis demonstrated a similar pattern: again there was a significant main effect of task, $F(2, 92) = 107.58$, $p < .001$, $\eta_p^2 = .70$. Follow-up within subject contrast analysis showed a significant difference between initial t_1 judgments ($M = 28.79$, $SD = 25.14$) and their reproduction at t_2 ($M = 43.78$, $SD = 28.19$), $F(1, 93) = 21.24$, $p < .001$, $\eta_p^2 = .19$, as well as between reproductions and current conjectures at t_2 ($M = 76.28$, $SD = 23.14$), $F(1, 93) = 103.12$, $p < .001$, $\eta_p^2 = .53$, and initial judgments and current conjectures, $F(1, 93) = 205.77$, $p < .001$, $\eta_p^2 = .69$.

Hence, participants did not only change their mind over time but also partially corrected for this change of mind in the reproduction: Their reproduced conjectures were closer to their initial conjectures than their current conjectures were. This correction was, however, not sufficient to eliminate hindsight bias, since the reproduced conjectures still significantly shifted towards current conjectures (or knowledge).

In sum, we found a conjecture-based as well as a knowledge-based hindsight bias. In order to compare their magnitude directly, we ran a mixed-model ANOVA with point in time (t_1 , t_2) and event alternatives (technical failure, capacity overload) as within-participants factors and experimental group (*conjecture-based reproduction*, *knowledge-based reproduction*) as a between-participant factor. We obtained only a significant main effect of event alternative, $F(1, 58) = 52.24$, $p < .001$, $\eta_p^2 = .47$, as well as a significant interaction of point in time by event alternative, $F(1, 58) = 17.15$, $p < .001$, $\eta_p^2 = .23$. None of the other effects were significant; all F 's < 2.4 , all p 's $> .12$. Consequently, conjecture-based and knowledge-based hindsight bias did not differ from one another.⁵

Foreseeability rating. As in Study 1, the *current conjecture group* provided insight into potential increases in genuine foreseeability ratings (cf. Blank et al., 2008; Nestler et al., 2008), whereas the two reproduction groups provided insight into the memory component of hindsight bias. Therefore, we conducted separate tests for the different tasks. Genuine foreseeability ratings in the *current conjecture group* increased significantly from t_1 to t_2 , $t(33) = 3.14$, $p = .004$, $d = 0.47$, $M_{diff} = .30$, 95% CI [.11, .50] (see Table 2). For the reproduction groups (*conjecture-based reproduction*, *knowledge-based reproduction*; *between*), a mixed measures ANOVA with point in time (t_1 , t_2 ; within) yielded only a significant main effect of point in time, $F(1, 58) = 4.66$, $p = .03$, $\eta_p^2 = .07$. Participants from both conditions reproduced foreseeability ratings which were significantly larger than their initial ratings (see Table 2). No other effects were significant, all F 's < 2.5 , p 's $> .12$.

Thus, genuine foreseeability ratings increased over time, and participants who had reproduced their earlier ratings (regardless of experimental group) erroneously believed that they had foreseen to a greater extent what happened to the ferry than they actually did.

Table 2

Means and standard deviations of the likelihood estimates in Study 2 as a function of event alternative, experimental group, and point in time.

	Current conjecture		Conjecture-based reproduction		Knowledge-based reproduction	
	t ₁	t ₂	t ₁	t ₂	t ₁	t ₂
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Technical failure	67.12 (22.45)	35.53 (27.29)	59.59 (23.35)	53.48 (20.60)	72.13 (23.16)	56.87 (27.58)
Capacity overload	28.91 (25.03)	74.29 (19.89)	25.97 (24.47)	41.83 (25.47)	31.29 (26.39)	45.68 (33.36)
Foreseeability	1.88 (.57)	2.18 (.69)	1.95 (.79)	2.16 (.83)	2.28 (.68)	2.43 (.86)

Additional analyses. Participants in the *knowledge-based reproduction group* still produced estimates significantly different from 100 when asked for their current likelihood judgments regarding the event alternative capacity overload ($M = 85.34$, $SD = 21.91$), $t(30) = 3.6$, $p = .001$, $M_{diff} = -14.16$, 95% CI [-22.19, -6.12]. Hence, even if they assigned significantly higher likelihoods to the “known” event than participants in the *conjecture-based reproduction group* did to the “conjectured event” ($M = 68.38$, $SD = 25.00$), $t(58) = 2.88$, $p = .006$, $d = .74$, $M_{diff} = 17.46$, 95% CI [5.32, 29.60], we did not establish a *definite* knowledge base.

This may be a result of asking for *likelihoods*, which might deter participants from assigning absolute values to the favored alternative, because it indirectly implies that other

things could have happened, too. Thus, we conducted the following analysis in order to provide a more compelling comparison of knowledge and conjectures. We compared those $N = 20$ participants from the *knowledge-based reproduction group* who had reported the highest current conjectures at t_2 ($M = 97.25$, $SD = 3.09$) with those $N = 21$ participants in the *conjecture-based reproduction group* who had reported the lowest current conjectures at t_2 ($M = 58.62$, $SD = 22.62$). In the repeated measures ANOVA, there was a significant main effect of event alternative, $F(1, 39) = 27.13$, $p < .001$, $\eta_p^2 = .41$ and a significant interaction of point in time and event alternative, $F(1, 39) = 14.81$, $p < .001$, $\eta_p^2 = .27$, all other F 's < 2.31 , p 's $> .14$. It yielded the same result pattern as the complete analysis. The experimental groups did not significantly differ in their reproductions. Hence, participants with conjectures compared to (almost) certain knowledge about the event showed similar magnitudes of hindsight bias. This finding supports the idea that knowledge is not a necessary precondition for hindsight distortions in the context of events.

Furthermore, we calculated the mean shift between t_1 and t_2 (absolute difference between t_1 estimate and t_2 reproduction) for the combined relevant event alternatives, which were crucially manipulated by the feedback information (technical failure; capacity overload) and for the combined irrelevant alternatives, which may serve as control (mistake of the captain; fire in the engine room; generally poor condition of the vessel; pirate hijacking; an attack). Comparing these two mean shifts in a dependent t -test showed that there was a significantly higher difference between t_1 and t_2 for the relevant ($M = 25.73$, $SD = 16.55$) than for the irrelevant event alternatives ($M = 15.19$, $SD = 8.03$), $t(59) = 4.93$, $p < .001$, $M_{diff} = 10.54$, 95% CI [6.27, 14.81], demonstrating a clear effect of the knowledge manipulation.

Discussion

Replicating the result from Study 1 under controlled conditions, we found a conjecture-based hindsight bias: People changed their conjecture over time, but were not able to fully control for their knowledge in hindsight and erroneously reported that they

had considered their current conjecture as being more likely all along. Hence, the present paper is the first to document a “hindsight bias” without definite knowledge in the context of a specific event. Additionally, there were no significant differences in memory distortions between the *conjecture-based reproduction* and the *knowledge-based reproduction group*. It must be acknowledged, though, that participants in the *knowledge-based reproduction group* did not seem to possess definite knowledge as their assigned likelihoods to the actual event were substantially lower than 100%. With a subsample of our data, however, we were able to come very close to such definite knowledge and found the same effects. Therefore, our additional analyses provide a valid comparison between the “classic” (knowledge-based) hindsight bias and conjecture-based hindsight bias. Moreover, our analyses documented a hindsight bias even when participants assigned less than 60% likelihood to the current conjecture – which is substantially different from (more or less certain) knowledge.

Contrary to Study 1, we also found that genuine impressions of foreseeability increased over time in Study 2. This could have been due an increase in subjective certainty about learning what happened from t_1 to t_2 . Whereas the whereabouts of flight MH370 remained unclear and resulting conjectures may have seemed very uncertain in Study 1, the informative text in Study 2 provided a conjecture that might have seemed more reliable, for example, because it included witness accounts. Furthermore, these witnesses reported similar problems in previous times, which likely contributed to foreseeability impressions. Thus, participants might have come to the conclusion that the event was more foreseeable to some extent, even though definite knowledge was still missing. There was also a distorted reproduction of initial foreseeability impressions: At t_2 , what happened was reproduced as having been more foreseeable than initially stated.

General Discussion

This is the first set of studies documenting hindsight bias for ongoing events, thus in the absence of definite knowledge about what happened. In fact, one might wonder whether the reported phenomenon still classifies as *hindsight bias* since it does not involve “real hindsight”. Our findings suggest, however, that hindsight bias based on conjectures leads to comparable distortions as hindsight bias based on knowledge. Across two studies we found that current conjectures affect the reproduction of previous conjectures to the same extent as knowledge does: Participants were “unable to access their uncontaminated foresight knowledge state” (Pohl & Erdfelder, 2017, p. 424), thereby demonstrating hindsight bias (cf. Fischhoff et al., 2005). They thought to have had a specific conjecture all along, whereas, in fact, this was not the case. This is remarkable given that conjectures merely involve possibilities and therefore, by definition, include alternative outcomes as well, which are usually considered to decrease hindsight bias (e.g., Davies, 1987; Roese & Vohs, 2012). The decreasing effect of considering alternatives has even been shown to decrease otherwise very robust anchoring effects (Mussweiler, Strack & Pfeiffer, 2000). Our findings thus suggest that participants did not question the provided conjecture and thought about alternatives, but instead, used it as a basis for their reasoning and their judgment. Thus, the conjecture affected their judgments similarly to how knowledge affects ex-post judgments: Making use of a plausible conjecture increased accessibility to conjecture-consistent information and its weight in the process of evaluation compared to conjecture-inconsistent information, leading to a distorted interpretation and reproduction of the past (Blank et al., 2008; Hawkins & Hastie, 1990; Pezzo, 2003; Pezzo & Pezzo, 2007; Nestler et al., 2008) and a reconstruction of one’s earlier predictions that is biased towards the current conjecture (Erdfelder & Buchner, 1998; Hardt & Pohl, 2003; Pohl, 2007; Pohl, Eisenhauer & Hardt, 2003; Stahlberg & Maass, 1997). Although we did not assess the underlying processes directly, there are several arguments for a biased *reconstruction* rather than a biased *recollection* process underlying our results. For

example, the long retention intervals combined with rather complex information and the use of highly differentiated measures (e.g. sliders allowing for 100 different evaluations without providing numerical feedback) likely impeded successful recollection (Hell, Gigerenzer, Gauggel, Mall & Müller, 1988). Furthermore, the generally low rate of correct recollections in our studies argues for a biased reconstruction rather than biased recollection process (Erfelder, Brandt & Bröder, 2007). Thus, it is likely that participants did not rely on memory traces, but tried to reconstruct their judgments based on metacognitive assumptions about what they could have known earlier (Ross, 1989; Stahlberg & Maass, 1997) or inferential strategies (cf. Werth & Strack, 2003). One indicator could have been the heightened processing fluency of the current conjectures, which was misattributed to its likelihood (Harley, Carlsen, & Loftus, 2004; see also Birch, Brosseau-Liard, Haddock & Ghrear, 2017). Our analyses support this reconstructive process as well as the notion that participants were somewhat aware of the fact that they had not precisely held their current conjecture all along, which becomes apparent in the finding that they systematically tried to control for their current conjectures. However, they were only partially successful and thus still exhibited a significant hindsight bias. Moreover, hindsight bias was not only large, but in its magnitude comparable to knowledge-based hindsight bias. The finding also indicates that conjectures did not *facilitate* sense-making to an extent succeeding definite knowledge. This assumption was based on the idea that definite knowledge could also restrain sense-making processes, because it provides concise parameters. However, this should have resulted in a larger hindsight bias in the *conjecture-based* than in the *knowledge-based reproduction group*, as previous studies on hindsight bias have found that the ease of making sense crucially increases hindsight bias (Pezzo, 2003; Pezzo & Pezzo, 2007; Pohl, 1998; Nestler et al., 2008). Still, we did not assess underlying processes directly, hence it might also be the case that different processes worked into contrary directions. Consider, for instance, the possibility that conjectures left participants more open to alternatives to one specific conjecture - more than in the *knowledge-based reproduction condition* - but at the same

time facilitated explaining the current conjecture as they were not bound by definite knowledge. In this case, both processes might level each other out, resulting in the same magnitude of hindsight bias. Then again, it must be acknowledged that the materials in our two reproduction conditions were highly similar and one might wonder whether differential reasoning about events requires more latitude with regard to the background information provided. Essentially, however, these are considerations that need to be addressed and investigated directly in future research.

Related to the question of the underlying processes, it remains to be examined, how conjectures (differentially?) affect the different components of hindsight bias (Blank et al., 2008). We found a consistent hindsight bias on the memory distortion component, but an inconsistent pattern with regard to the foreseeability component (a significant bias only in Study 2). Impressions of inevitability had not been assessed in our studies and might not be affected at all. After all, something that is not definite yet might hardly seem inevitable. On the other hand, this impression might also depend on the subjective certainty of one's conjecture. Thus, exploring the potentially moderating role of (un-)certainty itself might also be an interesting endeavor, given that conjectures likely need some minimum degree of subjective certainty to elicit a hindsight bias. If a conjecture is just mere guess, one would not expect the same bias to occur, because it might likely come along with the metacognition of "I know I am / was just guessing", which would counteract retrospectively increased perceptions of foreseeability. In the same vein, one might not expect systematic memory distortions to occur, either. For example, Hasher, Attig and Alba (1981) found no hindsight bias after outcome information was declared false (see also Erdfelder & Buchner, 1998, Experiment 3). Remarkably, however, the extreme group comparison in our additional analysis of Study 2 revealed no differences in hindsight bias for participants who gave very high likelihood ratings and ratings just below the 60%-rate. If one takes likelihood ratings as a proxy for certainty, our results thus suggest that certainty does not matter within this range – at least not with regard to the memory

distortions component of hindsight bias (note that it was not possible to perform a similar comparison for the foreseeability ratings).

Uncertainty surrounding an event – within the range of our study – does not seem to affect the reconstruction of the earlier state of mind (see also Pohl, 1998, for the context of almanac questions). But many things remain still unclear: Apart from the fact that certainty does not only need to be measured directly, and ideally, also varied experimentally, it would also be particularly interesting to examine hindsight bias in the context of somewhat/very uncertain conjectures and to extend the analyses to all three components of hindsight bias. Within this context, it might also be worthwhile to examine whether fictitious and real-world information generally differ in the certainty they (may) elicit. Furthermore, participants in Study 2 only received fictitious information which participants perceived as knowledge. They did not have genuine, self-acquired knowledge about a real event. These differences should be taken into account in future studies, because factors such as personal involvement could influence the results (Pezzo & Beckstead, 2008; Tykocinski, 2001).

Another interesting question that arises from our research is whether individuals' conjectures might be more important than factual knowledge – in case they differ from one another. When the conjecture makes (subjectively) more sense, this could well be true (cf. Pezzo, 2003). Moreover, research on belief perseverance shows that, once established, beliefs are often maintained even if the initial evidence supporting that belief is disproved (Davies, 1997; see Anderson, 2007, for an overview). Especially with regard to current debates on trustworthiness of information and “post-factual” societies, research examining differential influences of “belief” vs. “knowledge” on individuals' perception of not only the past, but also the present, is increasingly more relevant. In terms of hindsight bias, answers to these questions could increase our theoretical understanding of necessary preconditions and boundaries surrounding hindsight bias.

At the same time, an examination of related lines of research might be beneficial. The present studies resemble investigations of impression or attitude change over time. Analogous to our results, scholars have found that people overrate the similarity between the past and the present when trying to reconstruct past impressions of others (e.g. McFarland & Ross, 1987), their own attitudes (for example Markus, 1986), beliefs (Wolfe & Williams, 2017) or emotions (Levine & Safer, 2002). Two explanations for these misconceptions are that a) people are inclined to view themselves as consistent across time (e.g. Ross, 1989) and b) if something cannot be remembered directly, people use the last currently available mental representation as a judgment basis (Levine & Safer, 2002). It would be interesting for future research to examine the differences or similarities between these processes and the underlying mechanisms of hindsight bias more closely. Possibly, differences that are obvious at first glance – such as the fact that one line of research is about the self, whereas the other is about (external) events – might vanish at closer inspection. After all, participants in hindsight bias studies might also base their reproduction of earlier conjectures on implicit assumptions about themselves – namely on how they derive predictions. In light of this metacognitive process, the content of the reproduced prediction – self-related vs. event-related – might be less relevant.

Conclusion

In past research, hindsight bias has been defined as the distorting effect of knowing what happened on people's perceptions and reproduced predictions, for example resulting in "I knew it all along" thoughts. We offer a novel perspective by questioning the dichotomous nature of knowledge about an event and investigate hindsight bias in the case of conjectures about what happened. Our findings extend previous theoretical assumptions about the prerequisites of hindsight bias and raise novel research questions, for example about the role of certainty of information in hindsight judgments. In conclusion, two studies clearly demonstrate hindsight distortions in the absence of definite knowledge. *Believing* in a certain event sufficed to convince people that they "believed it all along."

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Footnotes

¹ Greenhouse-Geisser correction due to violated assumptions of sphericity was applied whenever required throughout the manuscript.

² For a more direct test, the first precondition should be tested in the *current conjecture group* only. Results for a comparison of t_1 and t_2 using only this group are identical: hijacking and crash, $t(41) = 3.21$, $p = .003$, $M_{diff} = -14.19$, 95% CI [-23.13, -5.25], hijacking and landing, $t(41) = 5.52$, $p < .001$, $M_{diff} = -24.21$, 95% CI [-33.10, -15.35], technical defect, $t(41) = 6.04$, $p < .001$, $M_{diff} = 30.21$, 95% CI [20.11, 40.32].

³ This result holds when comparing t_1 conjectures directly across experimental groups: A repeated measures ANOVA with the likelihood estimates for the event alternatives (hijacking + crash, hijacking + landing, technical failure) as within-participant factor and the experimental groups (assigned at t_2 , *current conjecture* vs. *reproduced conjecture*) as between-participant factor yielded only an expected significant main effect of event alternative, $F(2, 196) = 5.10$, $p = .007$, $\eta_p^2 = .05$, all other F s < 1.58 , all p s $> .210$. An independent t -test comparing the foreseeability impressions of t_1 between the two experimental groups showed likewise no significant differences, $t(430) = -.59$, $p = .55$.

⁴ Although the effect sizes in Study 1 were medium to large ($d = 0.5$ to $d = 0.8$), we wanted to be able to find small to medium effects in this study due to the much shorter time interval and the experimental set up in the laboratory. Therefore, given $f = 0.2$ or $f = 0.25$ and a correlation between repeated measures of $r = .3$ in Study 1, G*Power (Faul et al., 2007) suggested a sample size of $N = 75$ to $N = 114$ (parameters set to $\alpha = 0.05$, $1 - \beta = .90$, 3 groups, 2 measurements, nonsphericity correction $\epsilon = 1$, ANOVA: repeated measures, within – between interaction).

⁵ Comparisons between each reproduction group and the *current conjecture group* are available in the supplemental materials.

APPENDIX B

Running head: HINDSIGHT BIAS IN WIKIPEDIA

Biases in the production and reception of collective knowledge:
The case of hindsight bias in Wikipedia

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Abstract

The Web 2.0 enabled collaboration at an unprecedented level. In one of the flagships of mass collaboration – Wikipedia – a large number of authors socially negotiate the world’s largest compendium of knowledge. Several guidelines in Wikipedia restrict contributions to verifiable information from reliable sources in order to ensure recognized knowledge. Much of psychological research demonstrates, however, that individual information processing is biased. This poses the question whether individual biases translate to Wikipedia articles or whether they are prevented by its guidelines. The present research makes use of hindsight bias to examine this question. To this end we analyzed foresight and hindsight versions of Wikipedia articles regarding a broad variety of events (Study 1). We found the majority of articles *not* to contain traces of hindsight bias – contrary to prior individual research. However, for a particular category of events — disasters — we found robust evidence for hindsight bias. In a lab experiment (Study 2), we then examined whether individuals’ hindsight bias is translated into articles under controlled conditions and tested whether collaborative writing – as present in Wikipedia – affects the resultant bias (vs. individual writing). Finally, we investigated the impact of biased Wikipedia articles on readers (Study 3). As predicted, biased articles elicited a hindsight bias in readers, who had not known of the event previously. Moreover, biased articles also affected individuals who knew about the event already, and who had already developed a hindsight bias: biased articles further increased their hindsight.

Keywords: hindsight bias, causal models, groups, collaborative knowledge building, Wikipedia

Biases in the production and reception of collective knowledge:

The case of hindsight bias in Wikipedia

The World Wide Web has revolutionized our access to information. A myriad of even remote sources are immediately available at our fingertips. However, with the development of Web 2.0 technologies, the production of informational contents is no longer limited to professionals. Rather, any person with internet access can contribute to the informational web content. Laypersons are thus not only receivers of information but also its producers. Interestingly, a large number of these products are the result of *collective* actions as the Web 2.0 enabled people to *collaborate* at an unprecedented level.

By now, much research points to the benefits of mass collaboration. For instance, the collaboration among millions has led to the creation of the largest compendium of world knowledge: Wikipedia. Psychological research with individuals indicates, however, that human information processing is often biased (e.g., Pohl, 2017). For example, we falsely believe in hindsight that we had known all along in foresight what would happen (hindsight bias; Fischhoff, 1975; Roese & Vohs, 2012; Pohl & Erdfelder, 2017). Considering that many of these biases are robust and widespread, the question arises as to whether they extend to a collective level, that is, whether they are mirrored in products of “collective effort” such as mass-collaboration. The aim of the present studies is thus to examine whether these *collective* representations contain traces of *individual biases*.

To investigate this question, we analyzed how representations of events in Wikipedia articles change over time and whether Wikipedia articles show evidence of hindsight bias. For instance, does the article about the nuclear power plant of Fukushima suggest – in hindsight, but not in foresight – that the nuclear disaster was likely? Moreover, we examined whether hindsight bias in Wikipedia articles may in turn affect readers’ perceptions of events (i.e., their hindsight bias). That is, we tested whether hindsight bias is (1) transferred within the course of *producing* Wikipedia articles, as well

as (2) when *perceiving* Wikipedia articles. We chose Wikipedia as it is one of the flagships of mass collaboration (it is among the ten most frequently retrieved pages of the internet, www.alexa.com, and is also increasingly discovered in and for academic circles, e.g., see <http://www.psychologicalscience.org/members/aps-wikipedia-initiative>) and thus likely shapes the representations of a broad audience. Furthermore, Wikipedia comes along with a number of guidelines that aim at preventing bias. Hindsight bias was chosen because it is one of the most robust cognitive biases (see meta-analyses of Christensen-Szalanski & Wilham, 1991; Guilbault, Bryant, Brockway, & Posavac, 2004) and has a number of far reaching consequences such as effects on the attribution of responsibility and guilt (e.g., Carli, 1999; Hastie, Schkade, & Payne, 1999; LaBine & LaBine, 1996; Rachlinski, 1998).

The article is organized as follows. We first turn to Wikipedia and briefly outline its principles and its status as a repository of collective representations. Next, we define hindsight bias and elaborate on relevant research. Subsequently, we turn to the perception of biased Wikipedia articles. We then report two studies that examined whether Wikipedia articles show traces of hindsight bias (production; Studies 1 and 2) and one study that investigated how Wikipedia articles affect readers' biases in the representations of events (perception; Study 3). Finally, we summarize our results and discuss their implications.

Mass collaboration and Knowledge Production in Wikipedia

Mass collaboration involves the activities of a large number of people. It is usually mediated by digital tools (e.g., Web 2.0) and results in (digital) products (Cress, Jeong, & Moskaliuk, 2016a; e.g., mathematical solutions, Gowers & Nielsen, 2009; data for scientific research, Barron, Martin, Mertl, & Yassine, 2016; computer games, Fields, Kafai & Giang, 2016). One of the most prominent results of mass collaboration is the online encyclopedia Wikipedia. By now, it exists in more than 280 different languages. Its largest version alone – the English language version – was authored by more than 26 million users and contains more than five million articles (<https://en.wikipedia.org/wiki/Wikipedia:Statistics>).

In contrast to traditional encyclopedias, Wikipedia is written exclusively by volunteers and is open to anyone. Therefore, the educational background of the authors is very diverse (e.g., Merz & Döring, 2010) implying that many authors do not have a professional education in the topics they write about (e.g., Oeberst, Halatchliyski, Kimmerle, & Cress, 2014). Another difference to traditional encyclopedias is the number of authors: on average, articles in the English Wikipedia are written by 50 different authors (Kittur & Kraut, 2008). This number is easily multiplied when it comes to articles of broad importance and high topicality (e.g., the nuclear disaster in Fukushima, Keegan, Gergle, & Contractor, 2011; Oeberst et al., 2014; the Arab spring, Ferron & Massa, 2011; Massa & Scrinzi, 2012) or highly controversial topics (e.g., Wilson & Likens, 2015).

Wikipedia's content has thus been socially negotiated (by collaborative authoring) and is publicly available. It may therefore be conceived of as a repository for collective representations (Pentzold, 2009; Olick, 1999). Moreover, it is indeed frequently retrieved (www.alexa.com). If Wikipedia articles were biased they could thus likely shape the views of millions.

Unknown to many users, however, Wikipedia operates on a number of basic rules that aim at preventing bias. Most important for the present purpose are the following three rules: (1) verifiability (<http://en.wikipedia.org/wiki/Wikipedia:Verifiability>; http://en.wikipedia.org/wiki/Wikipedia:Verifiability#What_counts_as_a_reliable_source), (2) no original research (http://en.wikipedia.org/wiki/Wikipedia:No_original_research), and (3) neutral point of view (http://en.wikipedia.org/wiki/Wikipedia:Neutral_point_of_view). These rules urge authors (1) to contribute only information that is verifiable and from reliable sources, (2) to contribute *recognized* knowledge (i.e., precluding novel thoughts and theories to be presented), and (3) to use an unbiased language and to include “all significant viewpoints that have been published by reliable sources, in proportion to the prominence of each viewpoint”.

Prior research has shown that norms may indeed decrease bias (Postmes, Spears, & Cihangir, 2001). Moreover, Wikipedia's guidelines, its overall goal to provide access to world knowledge and the fact that the information is publicly available may effectively foster accuracy motivation (Chen, Shechter, & Chaiken, 1996) rather than motivated reasoning (Kunda, 1990). Could this effectively prevent biases to enter Wikipedia articles? Several studies document that Wikipedia's rules guide individual contributions effectively (Forte & Bruckman, 2008; Oeberst, et al., 2014; Viégas et al., 2004; 2007). And even if Wikipedia may not prevent vandalism (e.g., inserting knowingly false information; e.g., Potthast, Stein, & Gerling, 2008) many authors and computer algorithms continuously check and implement Wikipedia's guidelines, which mostly leads to the fast correction of destructive edits (Adler et al., 2011; Potthast et al., 2008; Viégas et al., 2004; 2007). Similarly, errors often get corrected soon after they get published (e.g., Fallis, 2009). Even more importantly, errors do not necessarily occur more frequently than in traditional encyclopedias (e.g., Britannica, Giles, 2005; see also Fallis, 2008; Magnus, 2009) and a balanced presentation of highly political and emotionally laden events has been obtained as well (Oeberst et al., 2014).

Despite these positive demonstrations of Wikipedia's quality, the encyclopedia is not free from errors. For instance, Wikipedia authors often share certain characteristics (e.g., interest in social media), which may result in an "imbalanced coverage of subjects on Wikipedia" (http://en.wikipedia.org/wiki/Wikipedia:Systemic_bias, e.g., Bellomi & Bonato, 2005; Callahan & Herring, 2011; Hecht & Gergle, 2009; 2010; Royal & Kapila, 2009). While Wikipedia's guidelines do not tackle topic coverage, this example perfectly demonstrates that there are biases that are not covered by Wikipedia's guidelines: an article may contain verifiable information from reliable sources and be presented neutrally, but may nevertheless contain bias—merely due to the selective presentation of information that results from the authors' perspective. Another bias that might not be prevented by Wikipedia's guidelines is hindsight bias.

Hindsight Bias as an Individual Bias

Hindsight bias is the tendency to overestimate in hindsight what one has known in foresight. Once an event occurred, people tend to perceive it as more likely, more inevitable or more foreseeable than they had before its occurrence (see Roese & Vohs, 2012, and Pohl & Erdfelder, 2017, for overviews). In his seminal study, Fischhoff (1975) presented participants with a historical event (e.g., the British-Gurkha War) and asked them to estimate the likelihood of possible outcomes (e.g., British victory, Gurkha victory). Crucially, some of his participants were informed about the alleged outcome of the war prior to making their likelihood judgments while participants in a control group did not receive any information about the outcome of the war. Compared to this control group, participants with outcome knowledge systematically overestimated the likelihood of the “actual” event. This biased retrospective evaluation of events even held when participants were urged to ignore outcome knowledge (Fischhoff, 1975) or when they were informed and warned about hindsight bias prior to the experiment (Fischhoff, 1977). Participants were thus unable to ignore outcome knowledge and to put themselves into the foresight perspective.

Since Fischhoff’s experiments, a vast number of studies have investigated hindsight bias and demonstrated its robustness (see Christensen-Szalanski & Willham, 1991, and Guilbault, et al., 2004, for meta-analyses) and pervasiveness (e.g., Pohl, Bender, & Lachmann, 2002). Also, a number of explanations have been put forward (see Roese & Vohs, 2012 for an overview). Concerning events, several researchers identified causal reasoning as a crucial underlying process (e.g., Blank & Nestler, 2007; Louie, 2005; Jennings, Lowe, & Reckers, 1998; Nestler et al., 2008; Nestler & Egloff, 2009; Pezzo, 2003; Roese & Olson, 1996; Yopchick & Kim, 2012). Based on the assumption that individuals are generally motivated to understand the world, it is proposed that they search for antecedents that are causally linked to the outcome and evaluate these antecedents regarding their suitability to explain the outcome’s occurrence. Importantly, as the search

process is biased towards seeking antecedents that may explain the occurred outcome, individuals place more weight on event-consistent antecedents than inconsistent ones (which would have spoken for a different outcome; Nestler et al., 2008; see also Carli, 1999; Fischhoff, 1975), suggesting that the event was more likely to happen.

Hindsight Bias in the production of Wikipedia articles

To date, the vast majority of studies on hindsight bias examined individuals' personal perceptions: participants received background information as well as outcome information and were asked for their personal perceptions regarding the likelihood, inevitability or foreseeability of the outcome. In other words, hindsight research focused on the *reception* of information and how this information is *evaluated*. The question of whether Wikipedia articles contain hindsight bias thus differs substantially from previous studies as it involves the *production* of information. Information production, however, comes along with a number of processes that go beyond the reception of information and which are affected by additional factors (Hayes, 2009; see also Nestler et al., 2017). One of these factors is the context in which information is produced. As we have outlined above, Wikipedia provides a unique context: First, Wikipedia employs several guidelines that explicitly aim at preventing personal opinions and subjective evaluations and demand verifiable contents from reliable sources instead. Second, Wikipedia articles are socially negotiated by many authors – on the basis of Wikipedia's guidelines. Therefore, analyzing Wikipedia articles also differs substantially from previous group studies on hindsight bias. There, individuals or small groups received information (e.g., statements describing psychological research, Stahlberg, et al., 1995, Study 1), half of them also learned about the actual outcome (e.g., that this finding was actually confirmed/falsified by research) and all participants were asked to estimate how likely they would have thought this statement to be true (disregarding outcome knowledge when provided). Participants in the group conditions typically have to discuss the matter for a limited amount of time (e.g., 30-45min) and have to come up with an unanimous judgment (see also Bukszar & Conolly,

1988; Choi & Choi, 2010; Yama et al., 2010). The differences to the context of Wikipedia are evident: first, Wikipedia articles involve many more people than lab groups (typically 2-4 people). Second, Wikipedia authors are much more heterogeneous. Third, social negotiation in Wikipedia takes place via the production of text rather than scales. Fourth, social negotiation in Wikipedia is guided by Wikipedia's guidelines of verifiability, neutrality and recognized knowledge. Fifth, Wikipedia authors are not limited in their amount of time for their social negotiation. Importantly, this may also mean that they do *not* achieve a consensus at a certain point in time (i.e., in an article version that we analyzed in Study 1).

Taken together, Wikipedia is a prominent example of knowledge production in the World Wide Web, which results from collaboration at an unprecedented level. Several studies have documented the positive effects of mass-collaboration and Wikipedia, in particular, has implemented several guidelines to foster the quality of the articles produced. In consideration of psychological research about biases in human information processing, however, the question arises whether the *collective* representations in Wikipedia nevertheless contain traces of *individual* biases – such as hindsight bias. After all, hindsight bias is likely shared among authors: much research has shown how difficult it is to overcome hindsight bias and that individuals do not spontaneously engage in strategies to reduce the bias (e.g., considering how the same circumstances could have led to a different outcome; see Roese & Vohs, 2012). Hence, it can be presumed that the same cognitive processes that underlie hindsight bias occur in all individuals who collaborate. Moreover, studies indicate that hindsight bias does not vanish in groups. It was rather obtained to the same (Bukszar & Conolly, 1988; Stahlberg, et al., 1995, Exp. 1) or even to a greater extent than in individuals (Choi & Choi, 2010). This implies that any correction processes that one may assume occurring at the collective or group level are in fact not taking place (or not so strong to significantly reduce the bias). On the contrary, people become even more extreme in their view when exchanging with others due to the exposure

to novel arguments that are consistent with one's own evaluation (i.e., event-consistent information, Isenberg, 1986) and due to the motivation to present oneself in a socially desirable way (e.g., as highly knowledgeable person who is able to foresee developments (Mark & Mellor, 1991). Hence, hindsight bias is likely shared among all individual authors but unlikely detected and reduced by their collaboration.

A second major argument for why hindsight bias might enter Wikipedia articles is that hindsight bias might circumvent Wikipedia's guidelines. Specifically, if an article contains event-consistent antecedents but not event-inconsistent ones (see above), this biased selection of information may entirely go unnoticed as long as the (outcome-consistent) information included is verifiable, from reliable sources and presented neutrally. Moreover, given the pervasiveness of hindsight bias (Guilbault et al., 2004; Pohl et al., 2002), and the fact that people are mostly not aware of it (Pohl & Hell, 1996) or unable to avoid it (Fischhoff, 1975; 1977), it is unlikely that a non-biased representation of the event is regarded as a "significant" viewpoint that should be included into the article. In sum then, when biased individuals collaboratively construct a representation of an event, this representation is likely biased as well (e.g., Cress & Kimmerle, 2008; Schulz-Hardt et al., 2002).

Hindsight bias in the perception of biased Wikipedia articles

If Wikipedia articles contain a hindsight bias, they would be highly suggestive of the occurrence of an event – after the fact. Interestingly, reading such highly suggestive articles may have the consequence that a participant's perception of the likelihood of an event is even more increased. Note that this question extends prior research on hindsight bias, which was concerned with the *elicitation* of the bias. That is, all participants were presented with the same information and whether they receive outcome knowledge was varied. This proceeding allowed conclusions about how the same antecedents (i.e., the situation at foresight) are evaluated differently once the outcome is known (e.g., Carli, 1999; Fischhoff, 1975). What happens, however, when the information read already

contains a hindsight bias? In this case one would expect biased articles to (1) elicit a hindsight bias in individuals who have not heard of the event beforehand (i.e., as in the standard hindsight paradigm) and to (2) *increase* hindsight bias in individuals who already knew the event outcome. We have obtained some preliminary evidence for the notion that reading biased articles increases hindsight distortions in comparison to when unbiased articles are read (Oeberst, von der Beck, & Nestler, 2014). In this study, participants read either a foresight version of the article about the nuclear power plant in Fukushima (the last one that existed prior to the nuclear disaster) or a hindsight version of the article that existed 8 weeks after the catastrophe began. The hindsight article version had been rated as being highly suggestive of the disaster (i.e., to contain hindsight bias). Reading the hindsight article version increased participants' perceptions of the likelihood, inevitability, and foreseeability of the disaster. Since we had not obtained genuine foresight estimates for the nuclear disaster, however, it remains unclear, whether reading biased articles increases individuals' hindsight bias above and beyond a previously developed "classic" hindsight bias. There are reasons for such an additional effect: reading an article that is biased by hindsight, may, for instance, provide novel outcome-consistent arguments for the event's occurrence (see Isenberg, 1986, for a related effect). But even if the information contained in the article was identical to participants' own information, reading the article may still increase their certainty concerning their perception and evaluation (e.g., Tesser, 1978).

The present research

Taken together, the present paper investigates hindsight bias in the production and reception of Wikipedia articles. With regard to production, we examine, whether we find traces of hindsight bias in Wikipedia articles (Hypothesis 1), or whether Wikipedia's guidelines prevent hindsight bias to enter the articles (Alternative Hypothesis 1). A unique feature of Wikipedia allows us to investigate these hypotheses empirically: as Wikipedia is based on wiki technology, every article version (i.e., every edit) is saved separately, which

enables comparisons of event representations over time (e.g., foresight vs. hindsight article versions). Studies 1 and 2 examine this question in the field and under controlled conditions, respectively.

Concerning reception, we expect biased articles to *elicit* a hindsight bias in readers who were unfamiliar with the event beforehand – which is consistent with prior research on hindsight bias (Hypothesis 2). Above and beyond, we propose that reading has an *additional* effect on readers' hindsight bias beyond their classic individual hindsight biases (Hypothesis 3). Study 3 tests both, Hypotheses 2 and 3.

Study 1

This study investigated whether events in Wikipedia articles are represented as more likely in retrospect. For a total of thirty-three events, we retrieved article versions from the German Wikipedia that existed prior to the event (foresight) or after the event had happened (hindsight) and assessed indicators of hindsight bias in those articles. By comparing foresight and hindsight versions of articles, we were able to examine whether there is evidence for hindsight distortions in Wikipedia articles.

Method

Selection of events and article versions. We made use of 33 events from six different event categories: (1) elections (e.g., President election in Russia, 2008), (2) public / official decisions (e.g., the declaration of independence of Kosovo), (3) personal decisions (e.g., the suicide of Robert Enke), (4) disasters and calamities (e.g., the nuclear disaster in Fukushima), (5) sports events (e.g., winner of the European soccer championship in 2012), and (6) scientific discoveries (e.g., evidence for the Higgs Boson; see <https://osf.io/vsryp/> for the full list of events as well as the data for all studies). Every event category contained five to six events, whereby half of the events in each category were known by the raters and the other half was not. We selected popular and unpopular events to exclude the possibility that the assessments of hindsight indicators are influenced

by coders knowing the event. As expected, knowledge of the event outcome did not influence any of the dependent variables. Hence, we omitted this variable in all further analyses.

For each event, we retrieved three article versions from the revision history: (1) the last article version that existed prior to the event (t_1 version), (2) the first article version immediately after the event happened, which already contained outcome information (t_2 version) as well as (3) the article version that existed eight weeks after the event had happened (t_3 version). Overall, we retrieved $3 \times 33 = 99$ article versions. The study thus comprised a 6 (event category) \times 3 (article version) mixed design with article version varying within events and event category varying between events.

Linguistic hindsight indicators. In order to analyze hindsight bias with a quantitative measure we assessed linguistic markers that reflect indicators of hindsight bias. To this end, we conducted automatic text analyses with the *Linguistic Inquiry and Word Count* (LIWC; Tausczik & Pennebaker, 2010). LIWC counts words that belong to different categories (e.g., positive emotions, cognitive mechanisms) and provides the percentage of words in the whole text that fall into this category. It has been extensively validated (see Tausczik & Pennebaker, 2010) and successfully used in various research contexts (e.g., Küfner, Nestler, Back, & Egloff, 2010; Robinson, Cassidy, Boyd, & Fetterman, 2015; Rodriguez, Holleran, & Mehl, 2010; Schultheiss, 2013). Here, we determined the number of words of the categories “cause” (containing words such as “hence”), “certainty” (e.g., “always”), tentativeness (e.g., “maybe”), “insight” (e.g., “consider”), and “discrepancy” (e.g., “should”), because the hindsight perspective is assumed to be the result of successful causal modeling (cf., Nestler et al., 2008) and thus is characterized by more certainty and insight and perceptions that those, who are responsible *should* have foreseen the event (Pezzo, 2003). For the analysis used the sum of all categories (Cronbach’s alphas were .664, .725, and .714, for the t_1 , t_2 , and t_3 article versions, respectively).

Coded hindsight indicators. Furthermore, we had all Wikipedia article versions rated by ten coders each, who were blind to the specific research questions. The coding scheme developed for this study contained the following main variables: First, raters' evaluation of whether the article version suggested that a particular event was likely to happen was assessed on a 5-point scale (1 = *no particular event is suggested*, 5 = *a particular event is highly suggested*). Second, the number of explicit phrases that are typical for a hindsight bias (e.g., "It was not surprising that [the event] took place.") was scored for each article version. Finally, a number of other ratings were also assessed, including, for example, the number of explanations contained in the article or the valence of the outcome. However, these ratings are not analyzed here (see <https://osf.io/vsryp/> for the entire coding scheme).

All raters were trained with three extra events for which they coded each of the three article versions (t_1 , t_2 , t_3). For each event, raters first coded the t_1 version before receiving article versions t_2 and t_3 . Additionally, they were urged not to search for further information before having coded t_1 . We calculated intra-class correlation coefficients to determine consistency among coders regarding all metric ratings. Inter-rater agreement was $ICC_{t_1} = .71$ for the hindsight rating of the first article version, $ICC_{t_2} = .73$ for the hindsight of the second article version and for the last version it was $ICC_{t_3} = .71$. For the number of explicit phrases referring to hindsight bias we found agreement values of $ICC_{t_1} = .71$ for the first version, $ICC_{t_2} = .54$ for the second and $ICC_{t_3} = .79$ for the final version.

All coded hindsight indicators concern the event that actually occurred. In case of the unknown events we therefore recoded raters' evaluation when they had evaluated the t_1 article version to be highly suggestive of another event (which did not occur). That is, if a rater found an article about an election to be suggestive of a victory of party X and choosing a rating of "5" but actually party Y won the election the rating was recoded to "1" as this indicated that the t_1 article was not at all suggestive of the actual event — the victory of party Y.

Results

Linguistic hindsight indicators. We first ran a mixed measures analysis of variance with event category (elections, official decisions, personal decisions, disasters, sports events, scientific discoveries) as between-event factor and article version (t_1 , t_2 , t_3) as within-event factor. It yielded a significant main effect of article version, $F(2, 54) = 3.52, p = .037, \eta_p^2 = .12$, a significant main effect of event category, $F(5, 27) = 4.36, p = .005, \eta_p^2 = .45$, but no significant interaction, $F < 1$ (see Table 1). There was, an increase in the proportion of hindsight related words across article versions. Specifically, version 3 contained a significantly higher percentage of hindsight related words ($M = 3.49, SD = 1.61$) than article version 1 ($M = 3.15, SD = 1.68$), $t(32) = 2.07, p = .046$, and article version 2 ($M = 3.11, SD = 1.86$), $t(32) = 2.17, p = .038$. The main effect of event category was due to some categories containing a generally higher proportion of hindsight related words (e.g., disasters: $M = 2.87, SD = 1.33$, scientific events: $M = 5.65, SD = 1.33$).

Coded hindsight indicators. We ran the same mixed measures analysis of variance as above with the rating whether the article was suggestive of a particular event (averaged across raters) as dependent variable. It revealed a significant main effect of article version, $F(2, 54) = 3.74, p = .030, \eta_p^2 = .12$, a significant main effect of event category, $F(5, 27) = 3.77, p = .010, \eta_p^2 = .41$, as well as a significant interaction of article version and event category, $F(10, 54) = 2.62, p = .011, \eta_p^2 = .33$. As can be seen in Figure 1, it was the disaster category that showed a distinct pattern of results over time. A separate repeated measures analyses of variance with article version (t_1 , t_2 , t_3) of the disasters category as within-event variable yielded a significant main effect of article version, $F(2, 10) = 5.92, p = .02, \eta_p^2 = .54$. For none of the other event categories we obtained significant differences in this hindsight indicator between article versions, $F_s < 1$. As displayed in Figure 1, the main effect of article version in the disasters category was entirely driven by the t_3 ratings, which were higher than the t_2 , $F(1,5) = 6.42, p = .05$,

$\eta_p^2 = .56$, and the t_1 ratings, $F(1,5) = 7.89$, $p = .04$, $\eta_p^2 = .61$, which, in contrast, did not differ from one another, $F(1,5) = .05$, $p = .83$.

The number of explicit phrases expressing hindsight bias (averaged across raters) was analyzed the same way, but revealed no significant effects, all $F_s < 1.933$. Descriptively, the number of explicit phrases was low for all three article versions, version 1: $M = 0.68$, $SD = 0.84$, version 2: $M = 0.49$, $SD = 0.54$, version 3: $M = 0.51$, $SD = 0.77$.

Relation between linguistic and coded hindsight indicators. Furthermore, we tested whether the linguistic hindsight indicators (i.e., the proportion variable from the automatic text analyses) were predictive of the coded hindsight indicators (i.e., the ratings). We used a multilevel regression approach for this purpose as the hindsight ratings and the proportions of hindsight words (Level-1) are nested within a single article (Level-2). Specifically, we computed a random intercept-random slope model in which the grand-mean centered linguistic hindsight indicators were used to predict coded hindsight indicators. The results of this model showed that higher values in the linguistic hindsight indicators go along with higher values in the coded hindsight indicators, $b = 0.20$, $t(16.55) = 2.322$, $p = .033$. However, this relationship differed considerably between articles, as indicated by a significant between-article slope variance: 0.15 , $\Delta\chi^2 = 6.16$, $df = 1$, $p = .013$. Further analysis showed that part of this variability could be explained by the event category the article belonged to: The relationship between the linguistic and the coded hindsight indicators was marginally significantly different from zero for the disaster category, $b = 0.43$, $t(6.98) = 2.27$, $p = .058$, but not for any other event category, all $t_s < 1$. Therefore, the automatic text analysis indicators are related to the ratings obtained by the ten coders and the relation seems to be stronger for the disaster category.

Discussion

We investigated whether there is evidence for hindsight distortions in Wikipedia articles or whether Wikipedia's guidelines effectively prevent hindsight bias to occur. Our

study provides empirical evidence for both. On the one hand, we found evidence for a hindsight bias on two hindsight indicators we made use of. Hindsight articles – particularly later ones (t_3) – contained a greater percentage of linguistic markers of hindsight bias and were also rated as more suggestive of the event than foresight articles. In other words, they implied to a systematically greater extent that the event was likely to happen. On the other hand, our coded hindsight indicator, which was a more thorough and fine-grained content analysis, revealed that this increase was mainly due to one particular event category: disasters. In other words, the overwhelming majority of articles did *not* show traces of hindsight bias. This is noteworthy in consideration of the fact that hindsight bias has been documented as a robust, widespread and difficult to overcome bias (Guilbault et al., 2004; Roesse & Vohs, 2012). Moreover, in the case of elections it is of particular interest as there are numerous demonstrations of hindsight bias in *individuals* (e.g., Blank, Fischer, & Erdfelder, 2003; Blank & Nestler, 2006; Fischer & Budescu, 1995; Leary, 1982; Powell, 1988). In other words, our findings substantially deviate from prior research on hindsight bias and despite the fact that null-effects should not be over-interpreted, one may question whether research on individual biases may be generalized to Wikipedia articles. We have argued above that Wikipedia differs substantially from usual lab research in that it conceives itself as an encyclopedia, which may potentially prime accuracy motivation in its contributors, and that there are a number of guidelines that aim at preventing bias. In Wikipedia, authors are not asked to freely express their personal evaluations and the demand to insert verifiable information from reliable sources obviously raises the threshold to obtain hindsight bias – given that we did not find strong evidence for hindsight bias for the majority of articles. We will return to this issue – and the question of why articles about disasters contained a hindsight bias nevertheless – in the General Discussion.

In line with this reasoning, the evidence for hindsight bias we found was indirect rather than explicit, which would be typical for hindsight bias (e.g., “It was no surprise

that...”). There were hardly any such phrases found and, more importantly, we did not obtain any increase over article versions. Instead, hindsight bias was evident more subtly by the more frequent use of hindsight-related words as well as by causal elaborations: The fact that a significant increase was obtained only for t_3 article versions is consistent with prior research showing that outcome knowledge alone (here in t_2 article version) does not elicit hindsight bias (Nestler & Egloff, 2009; Yopchick & Kim, 2012). Rather, (one-sided) causal elaborations are a necessary precondition (Nestler et al., 2008; Yopchick & Kim, 2012).

In sum then, our linguistic indicators suggest a hindsight bias in general whereas our coded indicators argue for hindsight bias only in the case of disasters. This is an interesting issue and we will get back to it in the General Discussion. One might question, however, whether the coded indicators truly reflect a hindsight bias in the *article*. After all, one could argue that it is the raters’ own *individual* biases that are reflected in the ratings rather than the article contents themselves. If our coded hindsight indicators were related to the authors’ own hindsight bias, however, it would provide a validation of our measure and ensure that the coded hindsight indicators actually reflect article contents. It is impossible to track this information in Wikipedia. Therefore, we conducted a lab experiment. Additionally, this experiment allowed us to examine the effect of collaboration on the magnitude of hindsight bias in the produced articles. Although the number of authors was not predictive of hindsight bias in Study 1, there was, in fact, no article in which collaboration did *not* take place. In Study 2, we had participants write articles either individually or collaboratively to assess whether collaboration moderates the magnitude of hindsight bias in the resultant articles.

Study 2

In this lab study we presented all participants with identical information about a fictitious dam in Spain. Participants in the hindsight condition additionally learned that the dam collapsed. All of them were then asked to produce a “Wikipedia-like” article about

the dam. Prior to this, we thoroughly informed them about the guidelines operating in Wikipedia. Article writing took place either individually or collaboratively. Additionally, we assessed participants' personal hindsight biases and let blind observers code the resulting articles for hindsight bias.

Participants and Design

One hundred seventy-six participants (141 female, $M_{age} = 22.80$, $SD = 5.32$; range = 18 - 68) were invited to participate in a lab experiment by personal e-mail for monetary reward. Participants were randomly assigned to one of the four experimental conditions that resulted from our 2 x 2 between-subjects design. Participants either received no outcome information (foresight condition) or learned about the disaster (hindsight condition). Additionally, participants authored the article either in groups of three (collaborative writing condition) or alone (individual writing condition).

Materials

In order to ensure that none of the participants had prior knowledge of the event in question, we developed fictitious material about an alleged dam in a touristic region of the Pyrenees, Spain. Participants received eleven bogus articles from Spanish and German newspapers containing information (all in German) of varying relevance to the subject and arguments for and against the alleged event outcome. For example, one article described the state-of-the-art construction of the dam, whereas another one reported public protests against the dam due to safety concerns. Participants in the hindsight conditions were additionally informed that this dam collapsed in 1993 and the consecutive flooding caused severe devastation in neighboring villages.

Pilot study. In order to test whether the material elicited a hindsight bias, we conducted a pilot study with $N = 56$ people (40 female, $M_{age} = 27.07$, $SD = 9.16$, range 19-60), who read the same materials. Some participants of the pilot study were informed about the collapse (i.e., hindsight condition) and some were not. All participants then

estimated the likelihood of four different, mutually exclusive events (including the actual outcome) in percent (hindsight participants were urged to ignore their outcome knowledge), their impressions of foreseeability (seven items, e.g., “I would have foreseen, that this accident was going to happen”, 1 = *not at all* to 5 = *very much*; Cronbach’s $\alpha = .764$) and their impressions of inevitability (four items; e.g. “Sooner or later there had to be an accident”; 1 = *not at all* to 5 = *very much*; Cronbach’s $\alpha = .815$). A MANOVA with all three dependent variables (likelihood of the actual event, foreseeability, inevitability) yielded a significant effect of condition, Wilk’s $\lambda = .718$, $F(3, 52) = 6.801$, $p = .001$, $\eta^2 = .282$. There was a significant hindsight bias with regard to likelihood ratings ($M_{hindsight} = 15.59\%$, $SD = 11.11$, $M_{foresight} = 6.07\%$, $SD = 6.48$), $F(1, 54) = 15.012$, $p < .001$, $\eta^2 = .218$, and with respect to impressions of inevitability ($M_{hindsight} = 2.96$, $SD = 1.03$, $M_{foresight} = 2.13$, $SD = .57$), $F(1, 54) = 13.788$, $p < .001$, $\eta^2 = .203$. Descriptively, differences in foreseeability impressions were into the same direction ($M_{hindsight} = 2.95$, $SD = 0.73$, $M_{foresight} = 2.63$, $SD = 0.74$), but failed to reach significance, $F(1, 54) = 2.626$, $p = .111$. Note, that impressions of foreseeability and inevitability do not necessarily work in parallel (e.g., Blank et al., 2008; Nestler et al., 2010; Nestler & Egloff, 2009). Given the significant and large hindsight bias for likelihood and inevitability ratings, we regarded the materials as suitable for our main study.

Procedure

After acknowledging legal information and agreeing to voluntarily participate, all participants received a booklet containing eleven alleged newspaper articles about a lake in the Pyrenees. Information was given in short, stand-alone articles in non-chronological order, resembling a collection of cut out newspaper articles from various sources. Participants in the hindsight condition received an additional short article informing them about the outcome. Next, participants received detailed instructions about characteristics of Wikipedia articles and were asked to write such an article on the basis of the information from the newspaper articles. The writing process was realized with the online

collaboration tool (www.etherpad.com) on laptop computers. The tool enabled simultaneous writing by participants in the group condition and contained basic text format editing options and a chat function. Writing time was set to 35-40 minutes. Afterwards, participants filled out an online questionnaire and were asked to rate the likelihood of four mutually exclusive events (same as in pretest), their impression of foreseeability and their impression of inevitability (same items as in the pretest with Cronbach's $\alpha = .761$ and Cronbach's $\alpha = .692$ for foreseeability and inevitability, respectively). Analogous to the pretest procedure, participants in the foresight condition gave these ratings for two different events, one being the actual outcome. Finally, there were some questions regarding prior knowledge of the event, general trust in Wikipedia, Wikipedia engagement and basic demographic information. After debriefing participants were paid and thanked.

Article Analyses

For analyzing the produced articles, we made use of the same hindsight indicators as in Study 1. First, we had three independent raters who were blind to the experimental conditions of the articles rate each article according to a shortened version of the coding scheme used in Study 1. The main dependent variable was – identical to Study 1 – the extent to which the articles suggested that a disaster at the dam was likely, inevitable, and foreseeable (1 = not at all, 5 = very much). Coders were trained on a subset of 20 articles (ICC = .864) and yielded an acceptable agreement (ICC = .712). Second, we conducted an automatic text analysis of the articles with LIWC and measured the percentage of hindsight-related words of the LIWC categories “cause”, “insight”, “certainty”, “tentativeness”, and “discrepancy” as in Study 1.

Results

Individual perceptions. We first analyzed individuals' perceptions to ensure that they actually exhibited a hindsight bias – before analyzing whether their bias translated

into articles. To this end, we conducted a multivariate ANOVA with likelihood, inevitability, and foreseeability ratings as dependent variables and information condition (foresight, hindsight) and writing condition (individual, collaborative) as independent between-subjects factors. It yielded only a significant main effect of information condition, Wilk's $\lambda = .631$, $F(3, 84) = 16.393$, $p < .001$, $\eta^2 = .369$. Neither writing condition, Wilk's $\lambda = .975$, $F(3, 84) = .709$, $p = .549$, $\eta^2 = .025$, nor the interaction were significant, Wilk's $\lambda = .995$, $F(3, 84) = .151$, $p = .929$, $\eta^2 = .005$. The effect of information condition was due to significant differences in all dependent variables (see Table 2), $F_{likelihood}(1, 86) = 28.651$, $p < .001$, $\eta^2 = .250$, $F_{inevitability}(1, 86) = 40.476$, $p < .001$, $\eta^2 = .320$, $F_{foreseeability}(1, 86) = 6.501$, $p = .013$, $\eta^2 = .070$. Outcome knowledge thus had large effects on participants' individual perceptions. With the benefit of hindsight, they perceived the collapse of the dam to be more likely, more inevitable, and more foreseeable than participants without outcome knowledge (foresight condition). Did this translate into more biased articles?

Article analyses.

Coded hindsight indicator. An ANOVA with the averaged hindsight ratings of all three raters as dependent variable and with information condition (foresight, hindsight) as well as writing condition (collaborative, individual) as between-article factors yielded only a significant main effect of information condition, $F(1,86) = 12.298$, $p = .001$, $\eta_p^2 = .125$. The main effect of writing condition, $F(1,86) = 0.064$, $p = .800$, as well as the interaction, $F(1,86) = 0.002$, $p = .967$, were not significant. Trained observers thus judged the articles in the hindsight condition to be significantly more suggestive of a disaster ($M = 2.49$, $SD = 0.75$) than the articles from participants of the foresight condition ($M = 1.92$, $SD = 0.78$).

Linguistic hindsight indicator. An analysis of the percentage of words related to the hindsight perspective with information condition (foresight, hindsight) and writing condition (individual, collaborative) as between-article factors yielded no significant effects at all, $F_s < 1.12$, $p_s > .290$.

Article ratings and individuals' evaluations. In a further step we examined directly, whether participants' individual biases translated into the article by examining whether individuals' evaluations regarding the likelihood, inevitability, and foreseeability of the disaster were related to the article ratings. To this end, we estimated a multilevel model accounting for the partial nesting of individuals in groups in the group condition (see Bauer, Sterba, & Hallfors, 2008, or Sterba, in press, for a description of the adapted multilevel model for partially nested designs).

In the model, we used article ratings to predict each individual measure (likelihood, inevitability, foreseeability). Results of the multilevel model showed that article ratings were significantly associated to individual likelihood ratings, $b = 6.41$, $t(96.09) = 4.69$, $p < .001$, inevitability ratings, $b = 0.17$, $t(110.08) = 2.80$, $p = .006$, but not foreseeability ratings, $b = 0.06$, $t(111.13) = 0.99$, $p = .32$. Finally, the LIWC measure of the article was also significantly predicted by the article ratings, $b = 0.22$, $t(154.89) = 2.42$, $p = .017$.

Discussion

In this study we sought to replicate the effect of Study 1 under controlled conditions and to validate our coded hindsight indicators. Having provided participants with the exact same information we found the classic hindsight bias: Participants with outcome knowledge perceived the event – the collapse of the dam in this case – as more likely, inevitable, and foreseeable than participants in the foresight condition. More importantly, however, individuals' hindsight bias entered their articles. Articles about the dam, which had been authored by participants with outcome knowledge, were significantly more suggestive of a disaster than were articles that had been written by participants without outcome knowledge. Furthermore, the hindsight bias present in the articles was clearly linked to the authors' individual biases, which does not only validate our coded hindsight indicators, but also provides direct evidence for the translation of individual biases into article biases. This is remarkable in consideration of the fact that we had urged participants to follow Wikipedia's guidelines and several indices indeed show

their compliance: For instance, participants frequently inserted references to the sources of the information they contributed. Also, they mostly used a very neutral language for their presentation. Interestingly, writing condition had no substantial impact on this process – collaboration neither reduced nor increased the resultant hindsight bias in the articles. This is consistent with Study 1 as well. Recall, that Study 2 made use of a disaster – the only category of events, for which we had obtained evidence for a hindsight bias in Study 1.

In sum then, the findings of this study validate the hindsight effects we found in Study 1. The fact that we did not obtain any effects with our objective hindsight measure needs to be discussed, though. Due to the fact that participants in our lab study had much less time for their article construction than actual Wikipedia authors do, the articles produced in this study differ from actual Wikipedia articles in several dimensions: they are shorter, less elaborated and of lower quality. Therefore, the chance to detect differences is lower than for actual Wikipedia articles. Also, one might conclude from our findings that the coded hindsight indicators are actually the more sensitive ones. Having provided evidence for their validity in Study 2, the event-specific pattern of the coded hindsight indicators obtained in Study 1 argues for this notion. We will return to the event-specific hindsight bias in Wikipedia articles in the General Discussion. There is one aspect in which Study 1 and Study 2 differ from one another, which might argue for the notion that our lab results even underestimate the effects that might be obtained in Wikipedia – at least in the special case of disasters. As outlined above, disasters and calamities are characterized by their unexpectedness. At the same time, this sort of event often attracts a large number of authors – many of whom have not already previously contributed to the article or not even contributed to Wikipedia at all beforehand (Keegan et al., 2011; Oeberst et al., 2014). In other words, these are – also – people who are attracted to the topic only after the fact and who therefore have retrieved and searched for information exclusively with the benefit of hindsight. In our lab experiment, we first presented all participants with the same information and then informed some of the collapse. The real-world equivalent,

however, would be that they first hear of the disaster and then read the information that is available. It is reasonable to assume that hindsight bias would be much greater in this case because all information is already perceived and evaluated in the light of the outcome.

Study 3

Having provided evidence that Wikipedia articles about disasters contain a hindsight bias, we now turn to an article's effects on readers' personal perceptions regarding the event in question. It suggests itself that reading Wikipedia articles that contain a hindsight bias might increase readers' subjective perceptions of likelihood, inevitability and/or foreseeability of past events whereas the reception of unbiased Wikipedia articles should not. Specifically, we propose biased articles to (1) elicit a hindsight bias in people who have not heard of the event beforehand and to (2) *increase* hindsight bias in people who already knew of the event — and may even have already developed a hindsight bias prior to reading the biased article.

Method

Participants and Design. Altogether 135 participants (106 female, $M_{age} = 24.99$, $SD = 6.90$) completed our online experiment in return for the chance to win vouchers for online stores. None of them had heard of the unknown event prior to the study. They were randomly assigned to one of three experimental conditions – the *foresight condition* ($N = 53$), the *hindsight condition* ($N = 44$) and the *hindsight plus article condition* ($N = 38$).

Materials and Procedure. Participants were invited via mailing lists to an online study on the perception of events. After agreeing to participate in the study and acknowledging legal and ethical information participants were randomly assigned to one of the three conditions (see above). On the next page participants read that we were interested in their perception and evaluation of an event and were asked to carefully read the presented material.

Participants in the *foresight* and *hindsight condition* received general information about the Shushenskaya hydroelectric power station in Siberia. Participants in the *hindsight condition* additionally received outcome information. Specifically, they were informed of the accident that took place on August 17, 2009, in which 75 people died (“On August, 17th, 2009, there was an accident with 75 deaths at the Sayano-Shushenskaya hydroelectric power station. It was caused by the flooding of the engine house after several pipes broke due to high water pressure.”). Participants in the *hindsight plus article condition* read the t_3 article version about the hydroelectric power station, which we had used in Study 1. This article version contained detailed information about the accident on August, 17th, 2009 and potential causal antecedents. In Study 1, our indicators of hindsight bias had revealed that the article was highly suggestive of the event – in hindsight, but not in foresight.

Next, participants in all experimental conditions were asked for their personal likelihood estimates of four alternative events including the original accident (in percent, summing up to 100% for all 4 events). Participants in the hindsight conditions were urged to ignore their outcome knowledge when answering this question. The alternative events were phrased to be mutually exclusive. Afterwards, participants answered six items rating their personal impressions of inevitability (see Blank et al., 2008 for item wordings; 1 = *disagree*, 5 = *agree*) and another three items tapping their personal impression of foreseeability on a 5-point scale (1 = *disagree*, 5 = *agree*). For the foreseeability scale, Cronbach’s alpha was .67. The six items of the inevitability scale, in contrast, proved to be inconsistent (Cronbach’s alpha = .40). We therefore ran a factor analysis and aggregated the three items with the highest loadings on the first factor (explaining 25% of the variance; Cronbach’s alpha = .63).

Subsequently, participants were asked whether they had heard of the event before, whether they knew about its causes and whether they had been familiar with the original Wikipedia article before participating in our study. After providing information about their

general trust in Wikipedia, Wikipedia engagement and basic demographic information, participants were debriefed and informed about the fact that the article they had read was old.

Results and Discussion

Hindsight Bias. Given that we expected a linear increase in participants' perceptions of likelihood, inevitability, and foreseeability (foresight < hindsight < hindsight plus article), we computed linear contrasts for all three dependent variables with foresight condition coded as $c = -1$, hindsight condition coded as $c = 0$, and hindsight plus Wikipedia article condition coded as $c = 1$ (see Table 3 for descriptives). All three contrasts yielded significant linear increases for each of the three dependent variables, $F_{likelihood}(1,132) = 5.08, p = .03, \eta_p^2 = .03$, $F_{foreseeability}(1,132) = 4.53, p = .04, \eta_p^2 = .03$, $F_{inevitability}(1,132) = 35.83, p < .001, \eta_p^2 = .21$. Additionally, we compared the hindsight condition and the hindsight plus Wikipedia article condition directly in order to inspect the additional effect of reading more closely. There was a significant difference with regard to perceived inevitability, $t(80) = 2.85, p < .01, d = 0.62$, and a marginally significant difference into the predicted direction with regard to perceived likelihood, $t(80) = 1.73, p = .09, d = 0.38$. The difference with regard to perceived foreseeability was likewise into the predicted direction, however, fell short of significance, $t(80) = 1.44, p = .15$. Taken together, we found the perceived likelihood, inevitability, and foreseeability for the Shushenskaya disaster to increase with outcome knowledge – the classic hindsight bias – but also and in addition to the classic hindsight bias we found perceptions of likelihood and inevitability to increase with the perception of the t_3 Wikipedia article version.

General Discussion

Web 2.0 enables laypersons to collaborate with others at an unprecedented scale. Such mass collaboration has numerous benefits as documented in a number of studies (see Cress, de Jong, & Moskaliuk, 2016). Moreover, mass collaboration comes along with a

certain context, such as rules and norms that guide collaboration. In case of Wikipedia, several norms aim at the prevention of personal evaluations in order to ensure the construction of recognized knowledge, which is the ultimate goal of any encyclopedia. It is for this reason that we chose to examine Wikipedia articles with regard to hindsight bias: although prior research has documented the robustness and pervasiveness of hindsight bias, it has solely been investigated in terms of individuals' subjective perceptions and evaluations – that is, in reception – but never in production in a context like Wikipedia. Another reason was Wikipedia's popularity. If Wikipedia articles were biased, this would likely shape the views of millions.

Hindsight bias in the production of Wikipedia articles

With regard to Wikipedia articles, we found evidence for hindsight bias only in one particular category of events, namely disasters, but not in other event categories. We will first discuss the absence of hindsight bias in the majority of articles and then turn to the disasters category.

The absence of hindsight bias in the majority of articles is of great interest and importance as it stands in stark contrast to prior research with individuals. Although great caution is warranted when interpreting null-effects, it is noteworthy that research with individuals has documented hindsight bias as highly a robust and pervasive error (e.g., Guilbault et al., 2004; Pohl et al., 2000). Therefore, it seems unlikely that we simply might have accidentally selected events for which no hindsight bias had occurred. For instance, with regard to elections, our finding lacking evidence of hindsight bias in Wikipedia articles contrasts a substantial body of research documenting hindsight bias in individuals (e.g., Blank, Fischer, & Erdfelder, 2003; Blank & Nestler, 2006; Fischer & Budescu, 1995; Leary, 1982; Powell, 1988).

A potential explanation for our results is that Wikipedia's authors may have – personally – succumbed to hindsight bias but that their hindsight bias did not enter the

article. One reason for this could be Wikipedia's request for verifiable and reliable information. Consequently, if individuals' hindsight bias was based on information that is not verifiable and from a reliable source, it should not be inserted into a Wikipedia article or be deleted by others if someone included it nevertheless (e.g., Oeberst et al., 2014). Hence, if individual's biases are based on personal opinions or speculations about why the event has happened one would expect a contrast in the results of research with individuals and research with Wikipedia articles. In the case of the marriage of Prince William and Kate Middleton, for instance, this might be possible, but this information cannot be verified by reliable sources, and is therefore not be included into the article. Wikipedia's rules might thus possibly heighten the threshold for biases to enter and effectively lead to fewer instances of hindsight bias – even if they may not entirely preclude it as we saw for the disasters category.

Only with regard to disasters we found that later articles suggested to a greater extent that the disaster was more likely, more inevitable, and more foreseeable compared to earlier (foresight) articles. Interestingly, disasters have hardly ever been used in hindsight bias research (see Verplanken & Pieters, 1988, for an exception), presumably, because they pose methodological challenges for hindsight researchers (e.g., Hawkins & Hastie, 1990). With the benefit of hindsight, it is plausible why it was particularly the category of disasters that exhibited a hindsight bias: usually, disasters are not initially expected and thus surprising. They are also negative and mostly consequential by causing death, injuries or damage, thereby eliciting a particular need to explain how it could happen which, in turn, fosters hindsight distortions — at least if one can come up with an explanation (Ash, 2009; Guilbault et al., 2004; Musch, 2003; Pezzo, 2003; Schkade & Kilbourne, 1991). From this perspective, it becomes clear how an article may be highly suggestive of the event (in hindsight) even though it does not contain any explicit phrases expressing hindsight bias (e.g. “It was clear that...”). If the article contains an explanation that suggests that all antecedents spoke for the occurrence of this event (as post hoc

explanations lack the appreciation of event-inconsistent antecedents) the article itself becomes highly suggestive of the event. Thus, one might expect a pronounced hindsight bias in the case of disasters, which, might, in turn, transfer to a “collective” hindsight bias in Wikipedia articles, as Wikipedia’s norms may heighten the threshold for hindsight bias but not prevent it all along. Recall, that we have argued that hindsight bias is not per se in conflict with Wikipedia’s guidelines and the results of our lab study (Study 2) corroborate this notion. As long as verifiable information from reliable sources is available and presented neutrally, it may go unnoticed that it is biased by the fact that it focuses on event-consistent information and underweights or ignores event-inconsistent information, which is characteristic for hindsight bias (Carlie, 1999; Nestler et al., 2008). In sum then, we suggest that Wikipedia’s norms contribute to an unbiased presentation of events (see also Postmes et al., 2001), but may not prevent any bias to occur. Although this interpretation has to be tested in future research, it raises an exciting novel possibility to reduce or prevent hindsight bias.

Despite the fact that we found evidence for hindsight bias in only one out of many different event categories the relevance of our results should not be underestimated for at least two reasons: First, disasters and calamities usually attract a particularly broad audience (e.g., Keegan et al., 2011). The Fukushima article, for instance, was retrieved more than 100,000 times in May 2011 alone (the time frame into which our t_3 article version falls: www.stats.grok.se; this number includes the traffic to the article regarding the nuclear power plant as well as the newly created article “Nuclear disaster of Fukushima-Daiichi” to which the elaborations regarding the disaster were migrated). In other words, even if only certain Wikipedia articles might be biased by hindsight, our results indicate that these could likely reach a great number of people.

A second aspect that speaks to the same argument is that highly negative events such as disasters are closely linked to questions of responsibility and guilt (e.g., Harley, 2007; Rachlinski, 1998). Particularly if a damage or harm seems to be foreseeable in

hindsight and thus as preventable accusations of negligence come to mind and are frequently voiced. This may not only result in broadly shared—but biased—attributions of guilt but even in juridical affirmations of negligence that are biased by hindsight (e.g., Hastie, Schkade, & Payne, 1999; LaBine & LaBine, 1996; Smith & Greene, 2005).

Elicitation and Increases of Hindsight Bias Through Reading Wikipedia articles

In consideration of the fact that we did find some articles to contain traces of hindsight bias, we further examined their impact on readers. The present findings show that reading biased Wikipedia articles elicits a hindsight bias in readers who are unfamiliar with the event. In addition, and beyond prior research, we also found that hindsight bias further increased readers' already existent hindsight bias when they knew already about the event. The latter result is interesting as we provided a cause for the event outcome in all hindsight conditions. Informing vs. not informing about a cause for the accident (Yopchick & Kim, 2012) hence cannot explain these findings. However, we believe that causal modeling could be otherwise involved: Wikipedia articles could (1) add new knowledge (i.e., causes) to participants' existing causal model, (2) reactivate participants' existing causal model, or (3) provide a coherent presentation of the causal information, which participants had previously lacked. The first aspect might explain the results of our Study 3 as the Wikipedia article had contained more information than what had been presented to participants in the classic hindsight condition. The second and third explanation may be particularly relevant in real world settings: When time between learning the outcome and reading about it has passed, it is possible, that reading the article reactivates the causal model which in turn contributes to participants' evaluations of the event. Moreover, we usually learn of real-world events by receiving information that is distributed over time (e.g., news-ticker) and/or sources (e.g., news reports). If an article then provides readers with a single coherent presentation of the entire event, it may foster comprehension and a coherent causal model (Pennington & Hastie, 1986; see also McNamara & Kintsch, 1996; McNamara, Kintsch, Songer, & Kintsch, 1996).

Limitations and future prospects

To examine the occurrence of hindsight bias in Wikipedia articles, a foresight article version of that article was necessary. Hence, the present results are limited to events for which articles existed before the event took place (e.g., the power plant article before the Fukushima disaster). Therefore, we cannot exclude selection effects. Presumably, the existence of an article about a topic in Wikipedia likely depends on the relevance of the topic. Thus, it remains unclear whether our results are generalizable to rather irrelevant topics. Recall, however, that we had also included unfamiliar events, but popularity of the event did not affect the results. Also, we have included events from various different event categories, which clearly extends prior research, which typically focused on one event or a particular category of events (e.g., elections).

Concerning future prospects, we believe that it might be interesting to investigate whether hindsight bias is present in other collaborative products as well. We have argued that biases will enter collaborative products if they are widely shared and when there are no guidelines effectively preventing their occurrence. This reasoning implies that our findings should not be limited to Wikipedia articles but the bias is likely to be present in other media as well, as long as the production rules will not prevent it. Especially for disasters, one often finds post hoc articles claiming that a disaster was inevitable and foreseeable (e.g. The Telegraph, 2011; The Express Tribune, 2011), whereas foresight articles warning about the upcoming disaster (which should be possible if it was indeed foreseeable) are missing. Second, our reasoning could well extend to other biases (e.g., descriptions favoring the own group in inter-group conflicts, see Oeberst, Cress, Back, & Nestler, 2016). Again, we believe that this is an interesting endeavor for future research.

Implications for the production of collective knowledge

With regard to the accuracy of Wikipedia it has been repeatedly documented that Wikipedia articles are comparatively accurate (e.g., Giles, 2005). Also, research showed

that there is a positive relationship between the number of authors and the quality of an article (Kittur & Kraut, 2008). Interestingly, however, we obtained evidence for bias particularly in the category of articles that usually attracts an extraordinary high number of authors (e.g., Keegan et al., 2011; Oeberst et al., 2014). More authors, hence, do not automatically lead to less biased articles. Probably, it is not the number of authors that is decisive, but rather the heterogeneity of the authors involved (Schulz-Hardt, Frey, Lüthgens, & Moscovici, 2000; Schulz-Hardt, Jochims, & Frey, 2002). And while a larger number of authors increases the likelihood of a heterogeneous perspective (e.g., in a controversy), it may be of no effect in cases of widely shared and potentially large biases such as the hindsight bias in the context of disasters.

Conclusion

To conclude, the present studies extend prior research on hindsight bias in individuals to a collective level and point to interesting differences between varying types of events as well as the potential power of guidelines, such as present in Wikipedia, on the prevention of hindsight bias. Moreover, our findings indicate that biased Wikipedia articles may, again, nourish hindsight bias in individuals who read those articles. As this paper has hopefully shown, the use of a highly ecological setting led to empirical and theoretical advances and identified several questions for future research, which, in the long run, may foster a more elaborated understanding of biases in the real world.

Compliance with ethical standards

This research was funded by the German Research Foundation (grant numbers OE 604/1-1 and NE 1485/5-1). All authors declare that they have no conflicts of interest. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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Figure 1

Average coded hindsight indicators (error bars are SEs) as a function of article version and event category

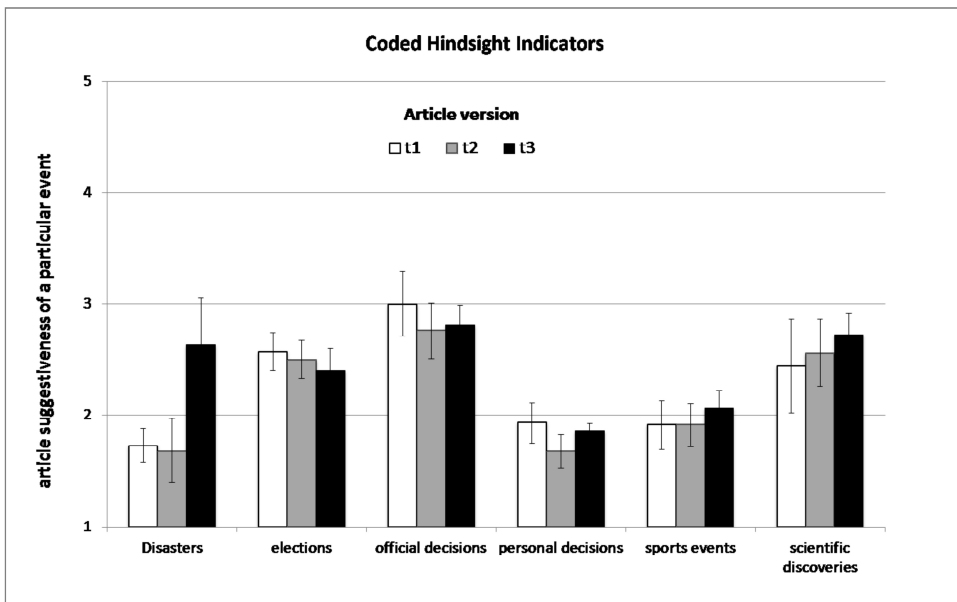


Table 1

Means and Standard Deviations (in Parentheses) of the Linguistic Hindsight Indicator in Study 1 Depending on the Article Version (t_1 , t_2 , t_3) and the Event Category

Event category	LIWC t_1	LIWC t_2	LIWC t_3
Elections	2.71 (1.76)	2.72 (1.84)	3.47 (1.25)
Public / official decisions	2.90 (1.37)	2.48 (0.93)	3.17 (0.88)
Personal decisions	3.32 (2.09)	3.30 (2.08)	3.60 (2.40)
Disasters	2.88 (1.56)	2.60 (1.17)	3.12 (1.10)
Sports events	2.18 (0.91)	2.08 (0.79)	2.11 (0.60)
Scientific discoveries	5.25 (0.99)	5.89 (1.81)	5.81 (0.66)

Table 2

Mean personal evaluations (SDs) in Study 2 as a function of outcome knowledge

	foresight	hindsight
Likelihood	7.14 (8.36)	21.71 (16.57)
Inevitability	2.53 (0.45)	3.25 (0.61)
Foreseeability	2.56 (0.44)	2.84 (0.59)

Note. Since the 11-point likelihood scale reflected percentages (0-100%) we present likelihood estimates as percentages.

Table 3

Mean hindsight evaluations (SDs) of Study 3 as a function of outcome knowledge and article reading

	foresight	hindsight	hindsight + article
Likelihood ^a	17.47 (14.23)	18.47 (18.85)	25.82 (19.60)
Inevitability	2.36 (0.70)	2.82 (0.63)	3.27 (0.83)
Foreseeability	1.96 (0.83)	2.08 (0.71)	2.32 (0.85)

^aNote. Since the 11-point likelihood scale reflected percentages (0-100%) we present likelihood estimates as percentages.

APPENDIX C

Running head: HINDSIGHT BIAS AFTER READING

Cultural interpretations of global information?
Hindsight bias after reading Wikipedia articles across cultures.

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Summary

Hindsight bias is the mistaken belief that an outcome could have been foreseen once it is known. But what happens after learning about an event? Can reading biased media amplify hindsight distortions? And do people from different cultural backgrounds – with different cognitive thinking styles – draw equal conclusions from equal media reports? We report two studies with Wikipedia articles and samples from different cultures (Study 1: Germany, Singapore, USA, Vietnam, Japan, Sweden, $N=446$; Study 2: USA, Vietnam, $N=144$). Participants read one of two article versions (foresight, hindsight) about the Fukushima Nuclear Plant and estimated the likelihood, inevitability and foreseeability of the nuclear disaster. Reading the hindsight article increased individuals' hindsight bias independently of analytic or holistic thinking style. Having excluded survey language as potential impact factor (Study 2), this result remains. Our findings extend prior research on hindsight bias by demonstrating the amplifying effect of additional (biased) information on hindsight bias.

Keywords: hindsight bias, causal models, analytic-holistic thinking, cross-cultural research, Wikipedia

In 2011 an earthquake and a tsunami hit the nuclear power plant of Fukushima, Japan, with devastating consequences. The news spread around the world and the public quickly blamed the operating company, TEPCO, for having failed to use adequate security measures, claiming they should have foreseen the catastrophe (e.g. *The Telegraph*, 2011; *The Express Tribune*, 2011). It is, however, easy to be wise after the event and people have a tendency to overestimate in hindsight what they knew in foresight (Roese & Vohs, 2012). That is, they are convinced that an event is more foreseeable and inevitable — once it took place. This phenomenon is called hindsight bias and prior research on this phenomenon was – by definition – concerned with the effect of outcome knowledge on perceptions of likelihood, foreseeability and inevitability. In the case of Fukushima, however, learning about the event was only the beginning of a long public engagement with the disaster. In the hours, days and months afterwards, an extensive search for information was triggered and resulted in broad media coverage (Friedman, 2011). As all of this happened with the benefit of hindsight, media reports might have been biased as well. Thus, the question arises how this affects recipients of such media reports: Could reading biased articles increase individuals' hindsight bias that is their perceptions of the disaster's likelihood, inevitability, and foreseeability?

Moreover, in today's world, information can be accessed globally via the Internet. For instance, the English Wikipedia is frequently retrieved and edited from all over the world (Wikimedia Foundation, 2011). Global access, however, does not necessarily imply global interpretations. Research has documented cross-cultural differences in cognitive thinking styles, which — among other things — may affect hindsight bias (Choi & Nisbett, 2000). Could they also influence the effect of biased articles on readers' hindsight distortions? In other words, do we find cultural differences in perceptions of the past? The present research examined this question by using Wikipedia articles in two online-experiments with cross-cultural samples. The paper is structured as follows: We first describe hindsight bias in general and then turn to hindsight bias in Wikipedia.

Subsequently, we elaborate on cross-cultural differences in cognitive thinking style and its relation to hindsight bias, present our studies and discuss the findings.

Hindsight Bias

Since Fischhoff's (1975) seminal work, numerous studies have demonstrated the tendency to overestimate in hindsight what was known in foresight (see Guilbault et al., 2004 for a meta-analysis; Pohl & Erdfelder, 2017; Roese & Vohs, 2012 for overviews). In past years, causal reasoning processes have been identified as a crucial factor for the occurrence of hindsight bias for events (e.g., Carli, 1999; Nario & Branscombe, 1995; Nestler & von Collani, 2008; Roese & Olson, 1996; Yopchick & Kim, 2012). According to Causal Model Theory (CMT, Nestler, Blank & von Collani, 2008) hindsight bias results from a one-sided post hoc sense-making process. CMT presumes that people are generally motivated to understand the world. Once an event happened, they strive to understand the causes and therefore search for and evaluate antecedents. This post hoc search, however, is biased in the direction of outcome knowledge: antecedents consistent with the actual outcome are favored and weighted more important, whereas inconsistent antecedents, which would have spoken for a different outcome, are perceived as irrelevant or are underweighted (e.g., Blank, Nestler, von Collani & Fischer, 2008; Carli, 1999; Fischhoff, 1975; Nestler et al., 2008). Consequently, the actual event appears to be the final episode of a straightforward chain of antecedents (Dawes, 1993) that clearly and inevitably led to the specific outcome. This results in the impression that this event could (and should) have been foreseen by the agents involved (Pezzo, 2003).

By definition, prior research on hindsight bias was concerned with the effect of outcome knowledge on the perception of the outcome. Research about the temporal development of hindsight bias after learning about an outcome and the effect of media consumption on individuals' hindsight bias, in contrast, is sparse (e.g., Bryant & Brockway, 1997; Roese, Fessel, Summerville, Kruger, & Dilich, 2006). There are, however, first results pointing to the direction that hindsight bias can further increase when

people are exposed to media contents that contain hindsight bias themselves (Oeberst, von der Beck, & Nestler, 2014). We aim to replicate this finding and examine whether the effect generalizes to individuals from different cultures.

Hindsight Bias and Analytic vs. Holistic Thinking

People from different cultural backgrounds differ on a variety of psychological constructs, one of them being cognitive thinking style. Numerous studies have shown that people from East and South East Asian countries tend to think in a more holistic manner whereas people from Western countries tend to think in a more analytic manner (e.g. Choi & Nisbett, 2000; Masuda & Nisbett, 2001; Norenzayan, Choi & Peng, 2007; Peng & Nisbett, 1999). Analytical thinking is characterized by formal logic (e.g. that opposing propositions can never be true at the same time), causality being attributed to an agents' dispositions rather than the situation, and an overall belief in a linear structure of events. In contrast, holistic thinking is characterized by dialectical logic (meaning opposing propositions can be equally true), and causality is attributed to an interaction of the situation and the agents' dispositions. It is based on the belief that the world is complex and everything is interconnected (Nisbett, Peng, Choi & Norenzayan, 2001). Consequently, analytic and holistic thinkers focus on different pieces of information or aspects about events (e.g. Choi, Dalal, Kim-Prieto, & Park, 2003).

Analytic vs. holistic thinking may affect hindsight bias in two ways (Choi & Nisbett, 2000). First, a holistic thinking style entails a large pool of potential causal antecedents for an event: if everything is connected, it is easier to come up with an explanation (i.e., a causal model) for an outcome. Furthermore, the acceptance of contradictory statements being true simultaneously may lead to the notion that antecedents which appear event-inconsistent for analytic thinkers are perceived as event-consistent antecedents for holistic thinkers. Hence, a holistic thinking style may facilitate generating a plausible chain of antecedents leading up to the actual outcome, which is crucial for hindsight bias, as we outlined above. Second, a holistic mindset leaves less room for

surprise, which, in turn, could likewise result in a greater hindsight bias (Choi & Nisbett, 2000). If an event seems little surprising, it ought to have been foreseeable or due to happen from a hindsight perspective (Ash, 2009; Calvillo & Gomes, 2011; Pezzo, 2003). Taken together, these two aspects argue for a larger hindsight bias in holistic thinkers. Indeed, two studies found a larger hindsight bias in Asian cultures compared to Western cultures (Choi & Nisbett, 2000; Yama et al., 2010). However, there are also findings showing a smaller hindsight bias in Asian cultures (Heine & Lehman, 1996) and no cultural differences at all (Pohl, Bender & Lachman, 2002). However, both these latter findings were obtained assessing hindsight bias with Almanac questions rather than events, which is fundamentally different because it is based on other mechanisms than causal modeling (Hoffrage, Hertwig & Gigerenzer, 2000; Pohl, Eisenhauer & Hardt 2003).

Whether rather analytic or holistic thinking also moderates the effect of reading biased articles on individuals' hindsight distortions is still an open question. The only study that addressed this question surveyed German and Vietnamese participants, who showed comparable effects of reading biased Wikipedia articles on their own perceptions (Oeberst, et al., 2014). Unfortunately, however, they also did not differ with regard to analytic vs. holistic thinking, which might have been because participants lived in Germany when taking part in the study. Hence, a test of whether analytic vs. holistic thinking moderates the effect of biased media contents on readers' individual biases is still pending. The two studies presented here aim to close this gap. To this end we (1) invited a broad sample from different cultures (Study 1) and (2) used translated materials to account for possible language effects (Study 2). The participants were presented with one of two Wikipedia article versions (foresight, hindsight) about the nuclear power plant of Fukushima and were asked for their perceptions of the likelihood, foreseeability and inevitability of the nuclear disaster. We expected the hindsight article version to increase readers' hindsight bias (i.e., impressions of likelihood, foreseeability and inevitability of

the event). Furthermore, we tested whether this effect was more pronounced for holistic thinkers (Choi & Nisbett, 2000).

Study 1

Method

Participants and design. We invited people from Germany, Japan, Singapore, Sweden, the United States and Vietnam for participation. These countries were selected as they cover a large variance in analytic vs. holistic thinking style, based on previous studies with the Analysis-Holism Scale (AHS; Choi, Koo & Choi, 2007): whereas participants from Germany, Sweden and the US should display a more analytic thinking style, participants from Japan, Singapore and Vietnam should display a more holistic thinking style. Overall, four hundred and seventy people (144 women) completed our online experiment. Nineteen people (seven participants from Vietnam and the US, resp., three from Sweden and two from Singapore) were excluded, because they had not heard of the nuclear disaster in Fukushima before taking part in our study. In the remaining sample of 446 participants (Germany, $N = 108$, Japan, $N = 20$, Singapore, $N = 32$, Sweden, $N = 88$, the United States, $N = 106$ and Vietnam, $N = 92$),¹ the mean age was 32.41 ($SD = 11.24$). There was a significant age difference between Eastern ($M = 27.05$, $SD = 6.70$) and Western ($M = 34.94$, $SD = 12.05$) participants, $t(433) = -8.86$, $p < .001$, $d = 0.81$. Age, however, did not correlate with scores on the AHS, r 's < 0.08 , p 's $> .09$. Nevertheless, we have run all analyses with and without age as covariate and it did not change the main results. In the following, we report the analyses without age as covariate². Participants were randomly assigned to read one of the two Wikipedia article versions (foresight, vs. hindsight; between subjects).

Materials and procedure. We invited registered users from crowdflower.com to participate for US \$1 each. The entire study was conducted online and in English. After agreeing to participate in the study, the first question asked for nationality. Next,

participants learned that the study was about the nuclear disaster in Fukushima and were asked to rate the likelihood of the Fukushima nuclear accident (“What is your personal opinion: How likely was this accident?”) on an 11-point scale from 1 (*very unlikely*) to 11 (*very likely*). In line with prior research, they were instructed to ignore their knowledge of the outcome when making the likelihood judgment. Next, everybody read one of the two versions of the original English Wikipedia article about the Fukushima I Nuclear Power Plant. The foresight article version consisted of the last version of the English Wikipedia article that existed prior to the nuclear disaster on March 11, 2011.³ The hindsight article version was available online eight weeks after the event unfolded.⁴ In comparison to the foresight version, the hindsight article version contained detailed information about the nuclear disaster and potential causal antecedents. Interestingly, however, this was mostly information that had been known and was publicly available in advance, but had not been included in the foresight article version (e.g., risks of this type of reactor). Even more importantly, one previous study (Oeberst, Cress, Back, & Nestler, 2016; Oeberst et al., 2017) demonstrated that the hindsight article version was significantly more suggestive of the nuclear disaster than the foresight article version. In other words, in this Wikipedia article, the nuclear disaster was presented as more likely, inevitable and foreseeable – *after* it had taken place. Prior studies therefore indicated that the hindsight article version used here was indeed biased by hindsight.

After reading, participants estimated the likelihood of the accident again. Please note that they were *not* instructed to reconstruct their previous estimates, but just asked to rate the likelihood of the Fukushima nuclear disaster a second time. Additionally, they rated perceived inevitability and foreseeability of the nuclear disaster on a 5-point Likert scale from 1 (*disagree*) to 5 (*agree*). We used six items to measure inevitability impressions. These, however, yielded a low internal consistency. We therefore ran a principal component analysis and aggregated the three items with the highest loadings on the first component into an *inevitability scale* (explaining 55.18 % of the variance;

Cronbach's alpha = .61; e.g. "Under the given circumstances, the event had to happen"), which was then used for all further analyses. Foreseeability impressions were measured with two items (e.g., "It was clear all along that an accident had to happen"). These items yielded an acceptable internal consistency of Cronbach's alpha = .65 and were therefore aggregated into a *foreseeability scale*.⁵

Subsequently, all participants answered the Analysis-Holism Scale (AHS, Choi, Koo & Choi, 2007) to assess analytic vs. holistic thinking. This scale consists of the four subscales *causality*, *attitude toward contradiction*, *perception of change*, and *locus of attention* with 6 items per subscale, adding to a total of 24 items (Cronbach's alphas ranged between .69 – .79). Responses are made on a 7-point Likert scale, a higher score indicates holistic thinking (see Choi, Koo & Choi, 2007 for further details). Afterwards, participants indicated their prior knowledge of the Fukushima nuclear disaster on a 5-point scale, sectioned into 1 (*Nothing – I heard about it for the first time*), 2 (*A little – I have heard about it*), 3 (*Average – I read some articles or watched some of the television coverage*), 4 (*A lot – I read several articles or watched most of the television coverage*), 5 (*Everything – I am very interested in the event and read the majority of media coverage*). Self-reported knowledge about the disaster did significantly differ between nationalities (Japan: $M = 3.50$, $SD = .95$; German: $M = 3.33$, $SD = .68$; Vietnamese: $M = 3.24$, $SD = .88$; Singaporean: $M = 3.22$, $SD = .61$; U.S. American: $M = 2.85$, $SD = .71$; Swedish: $M = 2.80$, $SD = .59$), $F(5, 440) = 9.86$, $p < .001$, $\eta^2 = .10$. These differences in knowledge did not influence the main results when included as a covariate and never had a significant impact, p 's $> .18$. Next, participants rated text comprehension difficulty on a scale from 1 (*easy to understand*) to 5 (*hard to understand*) and we asked for their general attitude towards nuclear energy. Finally, demographic variables were gathered before participants were fully debriefed and thanked.

Results

Analytic vs. holistic thinking style. We first compared analytic vs. holistic thinking style between participants from Asian vs. Western countries. Contrary to our expectations and prior findings we did not find any significant difference on the *AHS total score* between the Western sample ($M = 4.82, SD = .57$) and the (South) East Asian sample ($M = 4.76, SD = .63$), $F(1, 444) = 1.352, p = .24$. An additional MANOVA with all AHS subscales as dependent variables (*causality, attitude toward contradictions, perception of change and locus of attention*) and culture (Asian vs. Western) as between-subjects factor revealed differences into the opposite direction to what was expected. It yielded a significant effect of culture, Wilk's $\Lambda = .96, F(4, 441) = 4.16, p = .003, \eta_p^2 = .04$. On the level of the subscales this effect was significant for *attitude towards contradiction*, $F(1, 444) = 7.25, p = .007, \eta^2 = .02$. As can be seen in Table 1, Westerners were on average *more* holistic than East Asian participants. Despite this unexpected direction of difference, the variation in analytic vs. holistic thinking style may nevertheless be used to test whether it moderates the influence of biased information on readers' hindsight distortions.

Hindsight Bias after reading. We used the PROCESS macro (Hayes, 2013) in SPSS (IBM SPSS for Windows, Version 20.0. Armonk, NY: IBM Corp.) for all moderator analyses. The moderating variable consisted of participants' scores on the *causality* subscale because hindsight bias is based on causal reasoning (Nestler et al., 2008) and the hypothesized effect of analytic vs. holistic thinking style on hindsight bias is based on differences in causal reasoning and the resultant surprise (Choi & Nisbett, 2000). Nevertheless, we ran all moderator analyses with the scores of the *attitudes towards contradiction* subscale (where we found the surprising differences) and the overall AHS scale as moderating variables, too. The result patterns of these moderation analyses regarding our hypotheses, however, were identical in all cases and we therefore report the analyses with *causality* as moderating variable.

Likelihood. We assessed whether reading the hindsight article version led to increased likelihood ratings when compared to reading the foresight article version, and whether individuals would significantly change their ratings after reading the hindsight article. To this end, we conducted a mixed model ANOVA with time of judgment (before vs. after reading) as within-participants variable and article version (foresight vs. hindsight) as between-participants factor. There was a significant main effect for time of judgment, $F(1, 444) = 18.91, p < .001, \eta^2 = .04$ and a significant main effect of article version, $F(1, 444) = 6.89, p = .009, \eta^2 = .01$. Furthermore, the interaction of time of judgment and article version was significant, $F(1, 444) = 24.56, p < .001, \eta^2 = .05$. Before reading, likelihood ratings did not differ between conditions ($M_{foresight} = 6.08, SD = 3.18, M_{hindsight} = 6.31, SD = 3.16$), $t(444) = .78, p = .44$. After reading, however, participants who read the biased hindsight article version gave higher likelihood ratings ($M = 7.23, SD = 2.95$) than participants who read the foresight article version ($M = 6.02, SD = 3.08$), $t(444) = 4.23, p < .001, d = .40$. As expected, only participants who read the biased hindsight article version showed a significant increase in their likelihood ratings for the nuclear catastrophe. This result pattern clearly confirms that reading biased materials enhances hindsight distortions.

In a second step we conducted a moderator analysis to test whether analytic vs. holistic thinking moderated the effect of article version on likelihood estimates. We entered likelihood ratings after reading as dependent variable, article version as independent variable and the AHS subscale *causality* as moderator variable. The overall model was significant, $F(3, 442) = 9.23, p < .001, R^2 = .06$. Both, the *causality* subscale of the AHS and the article version had independent effects on likelihood ratings, $b = .37, t = 2.53, p = .012$ and $b = 1.21, t(442) = 4.24, p < .001$, respectively. The interaction between the two predictors, however, was not significant, $b = .29, t(442) = 1.01, p = .31$. Hence, analytic or holistic thinking style did not moderate the effect of article version on

likelihood ratings. It did, however, affect likelihood ratings independently: more holistic causal reasoning was generally associated with higher likelihood ratings.

Foreseeability. Since we obtained measures of foreseeability and inevitability only after reading, we tested the impact of the biased hindsight article within the conduction of the moderator analysis. With foreseeability perceptions as dependent variable, it yielded a significant overall model, $F(3, 442) = 8.99, p < .001, R^2 = .06$. Again, both main effects reached significance (article version: $b = .27, t(442) = 2.83, p = .005$; analytic vs. holistic thinking (*causality* subscale): $b = .20, t(442) = 4.17, p < .001$), whereas the interaction did not, $b = .05, t(442) = .47, p = .64$. The effect of article version was as predicted: Participants who read the hindsight article felt to a greater degree that the nuclear disaster was foreseeable. Beyond that, more holistic thinking was, again, associated with higher foreseeability ratings. Holistic thinking did not, however, moderate the effect of article version on the perceived foreseeability of the disaster.

Inevitability. The model of the moderator analysis with inevitability ratings as dependent variable was, again, significant, $F(3, 442) = 4.06, p = .007, R^2 = .03$. This time, however, there was only a significant main effect of the *causality* subscale, $b = .155, t(442) = 3.45, p < .001$. Neither the main effect of article version, $b = .022, t(442) = .255, p = .80$, nor the interaction were significant, $b = .01, t(442) = .07, p = .95$. Contrary to likelihood estimates and foreseeability impressions, inevitability perceptions were not significantly higher after reading the hindsight article version compared to the foresight article version. Higher inevitability perceptions were, however, associated with more holistic causal reasoning.

Discussion

Consistent with our hypothesis, we did find an effect of article version on readers' perceptions with the hindsight article leading to increases in likelihood and foreseeability (but not inevitability) perceptions. Although we found holistic thinking to be generally

associated with greater perceptions of likelihood, foreseeability, and inevitability than analytic thinking, we did not find the hypothesized moderation of thinking style on hindsight distortions.

In consideration of the surprising differences that we obtained between Western and Eastern participants in analytic vs. holistic thinking – the participants from Western countries reported more holistic scores than the participants from Asia – one might question the validity of these findings. One possible explanation for this surprising finding is survey language. In the study of Klein et al. (2008), which we had turned to in order to select reasonably different countries, participants had received and answered the AHS in their respective mother tongue. Bui and Flicker (2013), in contrast, who had conducted a survey in English, did not find any differences in the AHS between Western and Asian participants, and concluded that a translation might have been useful. Thus, the study that resembled our proceeding also failed to find the typical cultural differences in analytic vs. holistic thinking.

One reason for this finding might be that English may have triggered analytic thinking. Effects of language on cognitive processes have been demonstrated in multiple studies (e.g. Boucher & O’Dowd, 2011; Ji, Zhang & Nisbett, 2004; Ross, Xun & Wilson, 2002). For example, Boucher and O’Dowd (2011) found strong effects of language priming in bilingual Chinese. Participants from Hong Kong answering questions about tolerance of contradiction, holistic beliefs and self-concepts in Chinese showed greater dialecticism, which is characteristic for holistic thinking, than participants answering the same questions in English. Moreover, if the survey was answered in English, participants showed as much (non-) dialectical (i.e., analytical) thinking as Europeans and Americans. Hence, our result pattern could be a result of English as the survey language. To address this possibility we conducted a second study in participants’ mother tongue, this time comparing US-American and Vietnamese participants.

Study 2

Method

The procedure of Study 2 was identical to Study 1 except for two aspects. First, only participants from Vietnam and the US were invited to participate. Second, the entire material was presented in participants' mother tongue, that is, in Vietnamese or in English, respectively. For this purpose, instructions, questions and the Wikipedia articles were translated from English to Vietnamese. Hence, as in Study 1, participants read one of two Wikipedia articles about the nuclear power plant of Fukushima (foresight vs. hindsight article version) and were asked for their own perceptions of the likelihood, foreseeability and inevitability of the nuclear disaster. We expected to replicate the earlier finding that reading the biased hindsight article increases the readers' impressions of likelihood, foreseeability and inevitability of the event. Furthermore, we tested again whether this effect was more pronounced for participants from an East Asian culture that emphasized holistic thinking (Choi & Nisbett, 2000).

Participants and design. Participants were recruited from Vietnam and the U.S. via crowdflower.com in their respective language. Overall, 162 participants (41.1% female) completed our online experiment. Eighteen people from the US sample were excluded from the analyses, because they had not heard of the nuclear disaster in Fukushima before participation. In the remaining sample of 144 participants (United States, $N = 59$ and Vietnam, $N = 85$), mean age was 30.38 ($SD = 8.99$). Mean age was significantly different between the samples, the US-American sample ($M = 33.44$, $SD = 11.01$) being significantly older than the Vietnamese sample ($M = 28.25$, $SD = 6.53$), $t(86) = 3.248$, $p = .002$, $d = 0.57$. Participants' age, however, was not correlated with analytic or holistic thinking style, all r 's $< .10$ and all p 's $> .22$. Nevertheless, as in Study 1, all analyses were repeated including age as a covariate. This procedure, however, did not change the pattern of results. We therefore report results without the covariate *age* here.

Participants were randomly assigned to one of the two Wikipedia article versions (foresight, hindsight; between subjects).

Materials and procedure. Except for the study language (Vietnamese for Vietnamese participants) the materials and procedures resembled Study 1. Again, participants rated the likelihood of the accident before and after reading and rated perceived inevitability and foreseeability of the nuclear disaster in Fukushima only after reading on a 5-point Likert scale from 1 (*disagree*) to 5 (*agree*). The two items measuring foreseeability (“It was clear all along that an accident had to happen.” and “Overall, the accident was foreseeable.”) yielded an acceptable internal consistency (Cronbach’s alpha = .69). A third item measuring foreseeability had to be discarded because of a translation error. As the overall internal consistency of the six items measuring inevitability was low, we ran a principal component analysis and aggregated the two items with the highest loadings on the first component in both samples (explaining 52.58 % of the variance; Cronbach’s alpha = .58).^{6,7} The subscales of the AHS (Choi, Koo & Choi, 2007), *causality*, *attitude toward contradiction*, *perception of change*, and *locus of attention* yielded acceptable internal consistencies (Cronbach’s alphas were .85, .67, .67, and .75, respectively). Self-reported knowledge about the disaster was by trend higher in the Vietnamese sample ($M = 3.14$, $SD = .83$) than the US-American sample ($M = 2.88$, $SD = .79$), $t(142) = 1.88$, $p = .06$, $d = .31$. When controlling for this variable, however, it did not change the main results and did not have any significant impact itself, p ’s > .13.

Results

Analytic vs. holistic thinking style. As in Study 1, the first step was to compare the subsamples regarding an analytic vs. holistic thinking style. The *AHS total* score differed significantly, $F(1, 142) = 7.33$, $p = .008$, $\eta^2 = .05$, between Vietnamese and US-American participants. In line with previous findings in the literature and contrary to the findings of Study 1, Vietnamese participants showed stronger levels of holistic thinking ($M = 4.91$, $SD = .62$) than US-American participants ($M = 4.64$, $SD = .51$). An additional

MANOVA with all AHS subscales as dependent variables (*causality, attitude toward contradictions, perception of change and locus of attention*) and nationality (US-American vs. Vietnamese) as between-subjects factor yielded a significant effect of nationality, Wilk's $\Lambda = .84$, $F(4, 139) = 6.55$, $p < .001$, $\eta^2 = .16$. This difference was significant for the subscale *causality*, $F(1, 142) = 22.16$, $p < .001$, $\eta^2 = .13$. Again, Vietnamese participants answered in a more holistic manner (see Table 2). The same trend was found for the subscale *locus of attention*, $F(1, 142) = 2.93$, $p = .089$.

Hindsight Bias after reading. Given the significant differences in analytic vs. holistic thinking style between the two subsamples, we tested our hypotheses by comparing participants from both countries. Additionally, we ran the same moderator analyses (using PROCESS; Hayes, 2013) with individuals' score from the *causality* subscale and the *AHS total score*, which we will report subsequently.

Likelihood. We first conducted a mixed model ANOVA with time of judgment (before vs. after reading) as within-participant factor and article version (foresight vs. hindsight) and nationality (US-American vs. Vietnamese) as between-participant factors. It yielded a significant main effect of nationality, $F(1, 140) = 22.81$, $p < .001$, $\eta^2 = .14$, but neither a significant main effect for time of judgment, $F(1, 140) = 1.16$, $p = 0.28$, nor a main effect of article version, $F(1, 140) = .08$, $p = .77$. The interaction of time of judgment and article version was significant, $F(1, 140) = 10.59$, $p = .001$, $\eta^2 = .07$. The interaction of time of judgment and nationality was not significant, $F(1, 140) = 1$, $p = .32$. Finally, the three way interaction of time of judgment, article version and nationality was significant, $F(1, 140) = 5.16$, $p = .025$, $\eta^2 = .04$, meaning that depending on being asked before or after reading and depending on which article version they had read, Vietnamese and US-American participants answered differently. To elucidate this interaction we ran separate mixed-measures ANOVAs with time of judgment and article version for US-Americans and Vietnamese:

For the US-American sample neither main effect was significant, time of judgment: $F(1, 57) = 1.97, p = .16$; article version: $F(1, 57) = .06, p = .80$. But there was a significant interaction between article version and time of judgment, $F(1, 57) = 13.96, p < .001, \eta^2 = .20$. Post-Hoc t -tests showed the expected pattern: likelihood ratings increased only when participants read the hindsight article, $t(29) = 4.23, p < .001, d = .69$, but not when participants read the foresight article, $t(28) = 1.46, p = .16$ (see Table 3).

For the Vietnamese sample, in contrast, there were no significant effects at all. Neither the main effect for time of judgment, $F(1, 83) = .56, p = .95$, nor the main effect of article version, $F(1, 83) = .04, p = .84$, nor the interaction reached significance, $F(1, 83) = .56, p = .46$. As can be seen in Table 3, Vietnamese participants' likelihood ratings after reading were not significantly different from those prior to reading – regardless of the article version read.

Foreseeability. Next, we analyzed whether Vietnamese and U.S.-American participants differed with regard to perceived foreseeability of the event after reading the different Wikipedia article versions. An ANOVA with nationality (US-American vs. Vietnamese) and article version (foresight vs. hindsight) as between subject factors and foreseeability as dependent variable yielded the following results: The main effect of nationality was not significant, $F(1, 140) = 1.67, p = .20$. There was, however, a significant main effect for article version, $F(1, 140) = 6.15, p = .014, \eta^2 = .04$. Consistent with the hypothesis, participants who read the foresight article version rated the event as having been less foreseeable ($M = 3.09, SD = .95$) than participants who read the hindsight article version ($M = 3.44, SD = 1.03$). The interaction between article version and nationality was close to significance, $F(1, 140) = 3.48, p = .064, \eta^2 = .02$. Again, article version made a difference in the U.S.-American sample with higher ratings after reading the hindsight article ($M = 3.50, SD = .96$) than the foresight article ($M = 2.78, SD = .73$), $t(57) = 3.25, p = .002, d = .85$. For the Vietnamese participants, in contrast, article version

did not affect foreseeability ratings, $t(83) = .44$, $p = .66$. This pattern resembles the previous findings regarding likelihood ratings.

Inevitability. Analyzing inevitability ratings with an ANOVA including nationality (US-American vs. Vietnamese) and article version (foresight vs. hindsight) as between subject factors revealed only a significant difference regarding the main effect of nationality, $F(1, 140) = 23.71$, $p < .001$, $\eta^2 = .145$. Neither the main effect of article version, $F(1, 140) = 1.17$, $p = .28$, nor the interaction reached significance, $F(1, 140) = .136$, $p = .24$. The main effect of nationality resulted from generally higher inevitability impressions in the Vietnamese ($M = 3.98$, $SD = .84$) than in the US-American sample ($M = 3.27$, $SD = .91$). Nevertheless, reading the different article versions did not influence participants' perceptions about the inevitability of the event.

Moderator analyses. We conducted moderator analyses with the *causality* subscale of the AHS⁸ for each of the three dependent measures (likelihood, foreseeability, inevitability) separately. There were no significant interactions between article version and analytic vs. holistic thinking, p 's $> .41$. Significant main effects of the *causality* subscale indicated that more holistic thinking predicted generally higher likelihood ratings, $b = .47$, $t(159) = 2.15$, $p = .033$, as well as higher inevitability ratings, $b = .26$, $t(159) = 2.88$, $p = .004$, foreseeability ratings were not related with holistic thinking, $b = .13$, $t(159) = 1.4$, $p = .16$. More holistic thinking did not, however, moderate the impact of article version on participants' hindsight distortions.

Discussion

Conducting the study in participants' mother tongue led to pronounced changes in Vietnamese AHS scores. Descriptively comparing AHS scores between both studies showed more holistic scores on three of the four subscales in Study 2. Most importantly, Vietnamese participants thereby displayed more holistic thinking than did U.S. Americans, which is consistent with the prior literature (for an overview, Norenzayan, Choi, & Peng,

2007). Interestingly and more importantly, however, we did not find the same effect of the article version on hindsight distortions in both samples. That is, the Vietnamese' impressions of the likelihood, inevitability and foreseeability of the Fukushima disaster were not affected when reading the hindsight article version, which was highly suggestive of the disaster (and thus biased by hindsight). For the U.S. Americans, in contrast, we did find an increase in participants' impressions of the disaster's likelihood and foreseeability (but not inevitability) when they read the (biased) hindsight rather than the foresight article version. Hence, our hypothesis that the effect of biased articles on participants' hindsight distortions is pronounced for holistic thinkers was not supported by the data. Furthermore, the moderator analyses did not provide empirical support for the hypothesis that a holistic thinking style affected the impact of article version on readers' impressions.

General Discussion

In today's world, everybody with Internet access has virtually unlimited opportunities to find information online. Especially after accidents and disasters, people search for information. One such source of information could be the online encyclopedia Wikipedia, one of the most frequently retrieved websites worldwide (alexa.com). We examined the effects of (biased) Wikipedia articles on readers from different cultures around the world. Specifically, we investigated a) whether reading a hindsight Wikipedia article increases readers' hindsight bias and b) whether this effect holds for people from different cultural backgrounds or whether it is moderated by an analytic vs. holistic thinking style.

In Study 1 we found that reading the Wikipedia article increased participants' impressions of likelihood and foreseeability of the disaster and analytic vs. holistic thinking did not moderate the influence of the article on hindsight distortions. Further examination of this finding with translated material in Study 2 revealed that only Western participants (from the US) showed the predicted increase in hindsight bias: reading the biased hindsight article version (vs. foresight article version) increased their impression

that the nuclear disaster was likely and foreseeable. Vietnamese participants, in contrast, were not affected by the biased hindsight article. These findings extend prior research in several ways:

First, starting where most hindsight bias research ends, we could show that further reading biased information may increase hindsight distortions above and beyond the effect outcome knowledge has. Although all participants knew that the event happened, participants perceived this event as even more foreseeable and more likely if they had read the hindsight article version. This is particularly interesting given the fact that the hindsight article did not contain any explicit wording expressing hindsight bias, such as “The nuclear disaster could have been foreseen”, but still fostered this judgment in it’s readers. This is relevant because disasters often elicit a particular need for information and explanation as they unfold unexpectedly and come along with several negative consequences. In other words, in case of disasters, information search essentially takes place with the benefit of hindsight and is because of that likely biased (Nestler et al., 2008). Moreover, as hindsight bias is also linked to guilt or responsibility attributions (Anderson et al., 1997; Carli, 1999; Hastie, Schkade & Payne, 1999), it is likely that the effects of reading the hindsight article also influence peoples’ opinion about guilt or responsibility for a (negative) event.

Second, we did not find this effect across samples as Vietnamese participants showed no increase in their hindsight distortions after reading the biased article in Study 2. In fact, additional analyses of only the Vietnamese sample of Study 1 yielded the same result.⁹ Therefore we can exclude that language moderated the effect of material on Vietnamese participants. Nevertheless, this was contrary to what we had expected. Based on the hypothesis from Choi and Nisbett (2000; see also Yama et al., 2010) that a holistic thinking style fosters hindsight bias, we had proposed that the same might hold for the effect of further reading biased materials. A more holistic thinking style was generally associated with greater perceptions of likelihood, inevitability, and foreseeability;

however, it did not lead to pronounced effects of article version on readers' perceptions. This raises the question about underlying mechanisms.

Underlying mechanisms

Recall, that Causal Model Theory (CMT, Nestler et al., 2008) hypothesized that classic hindsight bias results from one-sided causal reasoning: if one searches for an explanation for a known event, one focuses on event-consistent antecedents and ignores or underweights event-inconsistent antecedents. And holistic thinkers were proposed to find even more event-consistent antecedents as they see many more connections between events. The argumentation from a CMT perspective is as follows: When reading biased material after an event (and one may have developed hindsight bias already), one could still expect people to focus on event-consistent information, which would further strengthen their causal model and thus could increase the perception that an event was likely and foreseeable. In this case, the hypothesis that holistic thinking leads to pronounced effects is a valid assumption. It could also be the case, however, that there are different mechanisms at work for the elicitation of hindsight bias and its increase after reading biased materials.

Note that our studies resemble the typical experimental paradigm in persuasion research, where changes in evaluation after exposure to persuasive messages are assessed. From this line of research, we know that source credibility affects attitude change (Petty & Cacioppo, 1986; for a review see Pornpitakpan, 2004). Could this explain our results given that Wikipedia is much less frequently retrieved in Vietnam compared to Western countries (www.alexa.com)? After all, it might indicate that Wikipedia is not perceived as a credible source in Vietnam, therefore having less impact on Vietnamese readers. However, participants from all nationalities reported similarly high levels of trust in Wikipedia in our studies.¹⁰ Moreover, levels of engagement with the article were equal across nationalities, as reading times and text comprehension did not differ significantly.¹¹

Another possible mechanism that has been proposed in the persuasion literature and that is potentially at play here might be an advanced version of the “mere thought effect” (Tesser, 1978): merely thinking about an object for which one holds a certain attitude can lead to more extreme attitudes because the thoughts alone have a directive influence. In this sense, reading the Wikipedia article would strengthen an already existing hindsight bias, because existing schemas (hindsight bias) are strengthened by the article’s information, producing greater schematic consistency (Tesser, 1978) and therefore stronger hindsight distortions. To the best of our knowledge, there are – unfortunately – no cross-cultural studies examining this effect.

Finally, maybe the “persuasive fit” between readers and content matters. Recall that we used a translated version of the original English Wikipedia article in Study 2 to keep article content constant across languages. This article might have had characteristics that influence readers from a Western culture, but not from an East Asian culture like Vietnam, regardless of the language adaption. Whereas one finds several studies speaking to the effect of study language on participants’ perceptions and behaviors (e.g., Boucher & O’Dowd, 2011; Ji, Zhang, & Nisbett, 2004; Ross, Xun, & Wilson, 2002) we are not aware of any research tackling the cultural “fit” of study materials in this field of research. Our own studies document an effect of survey language on participants’ responses. Vietnamese scores on the AHS showed marked differences when administered in English (Study 1) or in Vietnamese (Study 2): responses in English led to more analytic scores than Westerners’ responses, whereas responses in Vietnamese showed the expected pattern of greater levels of holistic thinking (Choi, Koo & Choi, 2007). Hence, study language influenced participants’ responses to the AHS but it did not impact the main findings. Whether this is a result of different underlying mechanisms or a differential fit between participants and study materials, will have to be clarified in further studies.

Limitations and future prospects

A clear limitation of the presented studies is that our findings cannot be generalized to holistic thinkers of other East Asian cultures, mainly because it proved rather difficult to gather sufficient sample sizes in Study 1. Beyond that, deductions and generalizations across these East Asian cultures remain difficult, because the nations in question are similar with regard to a strong Confucian tradition, but also very different on a variety of other variables.

Previous studies (e.g. Choi & Nisbett, 2000; Yama et al., 2010) have often used nationality as a proxy for analytic vs. holistic thinking style. Our research suggests, however, that holistic thinking does not necessarily go along with East Asian nationality, especially when answering questionnaires in English. But even if administered in participants' mother tongue one may not equalize nationality with thinking style. In Study 2 participants from the U.S. and from Vietnam differed both in analytic vs. holistic thinking style as well as in the main dependent variables. When analyzed directly, however, we did not find an impact of an analytic or holistic thinking style on our main dependent variables. This might also be a result of measurement. The AHS has yielded acceptable reliability in various previous settings (e.g. Korea & USA: Choi et al., 2007; Taiwan: Jen & Lien, 2010; China, Japan & Malaysia: Klein et al, 2008), but marked differences in scores between Eastern and Western participants are not always obtained (see for example Bui & Flicker, 2013). Therefore, it might be worthwhile to use alternative instruments to measure analytic vs. holistic thinking (e.g. by more implicit measures such as attention to stimuli, Masuda & Nisbett, 2001), although the predictive validity of the AHS was successfully tested in the original study (Cho, Koo & Choi, 2007).

It must also be acknowledged that our studies do not specify whether the increase in participants' hindsight distortions took place in addition to a previously developed (classic) hindsight bias or not. In other words, the effect of reading biased information could either add to the effect of outcome knowledge (i.e., further increase a previously

elicited classic hindsight bias) or lead to hindsight distortions in cases when participants did not exhibit a hindsight bias before. The only study so far which investigated hindsight bias related to a nuclear accident (Verplanken & Pieters, 1988), found a reverse hindsight bias (participants reported they never would have foreseen such a catastrophe as the Chernobyl Fallout; but see Hawkins & Hastie, 1990 for methodological critique). Since the present studies did not examine the effect of outcome knowledge (i.e., the classic hindsight bias), but the effect of further information after outcome knowledge, our results are not inconsistent with those of Verplanken & Pieters, 1988). Rather, it is possible that participants of our study also initially showed a reverse hindsight bias after learning about Fukushima (e.g., because they immediately experienced how surprised they were, Müller & Stahlberg, 2007) but that reading articles about the nuclear power plant, which were biased by hindsight still increased their perceptions of likelihood and foreseeability. In a related study with an unknown disaster we found that perceptions of likelihood, inevitability, and foreseeability did not only increase after outcome knowledge (i.e., the “classic” hindsight bias) but were additionally enhanced by reading a biased article about the event (Oeberst et al., 2017).

As another limitation, it must be noted that we cannot exclude that the repeated measurement of likelihood estimates affected the results. Possibly, the first estimate before reading geared participants’ attention towards this issue and made them particularly sensitive to information regarding the likelihood of the disaster (which was certainly more present in the hindsight article version). Note, however, that we also obtained effects of article version on participants’ foreseeability impressions, which had been assessed after reading only, and which are presumed to be based on other processes than likelihood judgments (e.g., Blank et al., 2008; Roese & Vohs, 2012). Nevertheless, it would be desirable to replicate the results without the prior likelihood estimate.

Another limitation worth considering are potential effects of the material used. The Fukushima nuclear disaster happened in Asia and articles about it could therefore affect

Asian participants differently than participants from more distant nations. We have not tested whether participants felt more or less threatened by this disaster. It would be possible, however, that Vietnamese participants were more motivated to explain why the disaster took place (Pezzo & Pezzo, 2007). As a consequence, their causal model might have been more accessible, which, in turn, might have prevented a further increase by reading a biased article. Note, however, that this does not explain the results regarding our main research objective – the fact that analytic vs. holistic thinking style did not moderate the effect of biased articles on readers' hindsight distortions. Nevertheless, it is desirable to replicate our findings with different materials.

Conclusion

We set out to examine whether reading a biased Wikipedia article influences readers' perceptions of the event in different cultures. Our findings suggest that reading a biased Wikipedia article strengthened people's conviction that the event was likely and foreseeably. In Study 2, this effect was limited to participants from a Western culture, however, and was not obtained for Vietnamese participants. The reasons for this differential pattern need to be identified in future studies and such research might benefit from a consideration of theories from various lines of research (hindsight bias, persuasion). The impact on Western readers nevertheless emphasizes the relevance of going beyond the classic hindsight bias paradigm. After all, information reception rarely ends with mere outcome knowledge. In the case of a disaster, the outcome might rather be the beginning of it all.

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Table 1.
Means and standard deviations from the four subscales of the Analysis-Holism Scale (Choi, Koo & Choi, 2007) in Study 1.

	Germany		Sweden		USA		Western countries total		Japan		Singapore		Vietnam		Asian countries total		Full sample	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Attitude towards contradiction	4.96 (.97)	5.10 (1.02)	4.81 (.93)	4.95 (.97)	4.52 (1.07)	4.91 (1.03)	4.64 (.84)	4.67 (.92)	4.86 (.96)									
Locus of control	5.08 (.89)	4.98 (.98)	4.78 (.79)	4.94 (.89)	4.88 (.92)	4.98 (1.03)	4.92 (.99)	4.93 (.98)	4.94 (.92)									
Causality	4.91 (.98)	4.85 (1.07)	5.01 (1.05)	4.93 (1.03)	4.85 (1.32)	5.39 (.94)	5.00 (1.32)	5.07 (1.25)	4.97 (1.11)									
Perception of change	4.49 (.78)	4.44 (.91)	4.49 (.90)	4.48 (.86)	4.14 (.73)	4.43 (1.12)	4.38 (.97)	4.34 (.98)	4.43 (.90)									
Total Scale	4.86 (.56)	4.77 (.57)	4.85 (.57)	4.82 (.57)	4.59 (.62)	4.93 (.64)	4.73 (.63)	4.77 (.63)	4.80 (.59)									

Note. Lower scores indicate a preference for analytic thinking, higher scores for holistic thinking.

Table 2.

Means and standard deviations from the four subscales of the Analysis-Holism Scale (Choi, Koo & Choi, 2007) in Study 2.

	US participants	Vietnamese participants	Full sample
	Mean (<i>SD</i>)	Mean (<i>SD</i>)	Mean (<i>SD</i>)
Attitude towards Contradiction	4.70 (<i>1.02</i>)	4.89 (<i>.79</i>)	4.81 (<i>.91</i>)
Locus of Attention	4.63 (<i>.87</i>)	4.97 (<i>.95</i>)	4.81 (<i>.93</i>)
Causality	4.95 (<i>1.05</i>)	5.69 (<i>.96</i>)	5.35 (<i>1.07</i>)
Perception of change	4.33 (<i>.86</i>)	4.07 (<i>1.03</i>)	4.19 (<i>.96</i>)
Total Scale	4.65 (<i>.58</i>)	4.91 (<i>.62</i>)	4.79 (<i>.62</i>)

Note. Lower scores indicate a preference for analytic thinking, higher scores for holistic thinking.

Table 3. Means and standard deviations of the dependent variables likelihood (by time of judgment), foreseeability and inevitability by article version and nationality in Study 2.

		foresight article	hindsight article	Total
		Mean (<i>SD</i>)	Mean (<i>SD</i>)	Mean (<i>SD</i>)
Likelihood before reading	U.S.A.	7.31 (1.89)	6.43 (2.43)	6.86 (2.21)
	Vietnam	5.05 (3.01)	5.00 (3.12)	5.03 (3.06)
	Total	6.18 (2.45)	5.71 (2.77)	5.94 (2.62)
Likelihood after reading	U.S.A.	6.69 (2.27)	7.80 (1.54)	7.24 (1.90)
	Vietnam	4.88 (2.94)	5.19 (3.31)	5.03 (3.12)
	Total	5.78 (2.60)	6.49 (2.45)	6.13 (2.52)
Foreseeability	U.S.A.	2.69 (.78)	3.54 (.98)	3.10 (.98)
	Vietnam	3.30 (1.04)	3.43 (1.08)	3.37 (1.06)
	Total	3.01 (.97)	3.24 (1.03)	3.24 (1.03)
Inevitability	U.S.A.	3.04 (.84)	3.49 (.96)	3.25 (.92)
	Vietnam	3.98 (.86)	3.88 (.89)	3.93 (.87)
	Total	3.54 (.97)	3.70 (.94)	3.62 (.96)

Note. Likelihood was measured on a scale from 1 (*very unlikely*) to 11 (*very likely*), whereas foreseeability and inevitability were measured on a Likert-scale from 1 (*disagree*) to 5 (*agree*).

Footnotes

- ¹ The original sample included $N = 5$ participants from South Korea. This sample was dropped due to the low number of participants.
- ² Entering age as covariate only led to minor changes regarding the main effects on the dependent variable likelihood: The main effect time of judgment in the mixed model ANOVA became marginally significant, $F(1, 443) = 3.42, p = .065, \eta^2 = .008$. More importantly, the interaction between time of judgment and article version remained significant, $F(1,443) = 24.64, p < .001, \eta^2 = .05$. In the corresponding moderator analysis for the likelihood ratings, the main effect of article version became marginally significant, $b = 2.61, t(441) = 1.95, p = .0513$ when including age as a covariate. Again more importantly, the non-significant interaction of the *causality* subscale and article version remained non-significant. Results regarding the other dependent variables inevitability and foreseeability remained the same.
- ³ https://en.wikipedia.org/w/index.php?title=Fukushima_Daiichi_Nuclear_Power_Plant&oldid=396253422
- ⁴ https://en.wikipedia.org/w/index.php?title=Fukushima_Daiichi_Nuclear_Power_Plant&oldid=427595027
- ⁵ Foreseeability impressions were originally measured with three items. However, measurement invariance analysis suggested that the three items were not invariant across countries. This result was caused by one of the three items. Therefore, we decided to exclude this item and to rerun all analyses. The result pattern of Study 1 remained largely the same. As a confirmatory factor analysis model with two items is not identified and hence not estimable, we fit a constrained model to the data in which the factor loadings and the item intercepts were set to equal values across nations. This model agrees with a strong measurement invariance model and showed a good fit to the data for foreseeability, $X^2(2) = 4.75, CFI = .981$,

RMSEA = .078. Likewise, a strict measurement model (in which the factor loadings, the item intercepts and the residual variances were set to equal values) showed a very good fit to the three items used to measure inevitability impressions, $X^2(7) = 9.09$, CFI = .987, RMSEA = .037. Hence, measurement invariance was fulfilled for the measures used in Study 1.

- 6 Inevitability was originally measured with six items. However, principal component analysis of the data within the subsamples indicated that only two of these items were universally understood by all participants (loading strongest and positive on the first component in both the Vietnamese and the US-American sample). Therefore these two items were used in the analysis.
- 7 Foreseeability and inevitability were both assessed with two items. As a confirmatory factor analysis model with two items is not identified and hence not estimable, we fitted a highly constrained model for both measures to the data in which the factor loadings, the item intercepts and the residual variances were set to equal values across participants. This model agrees with a strict measurement invariance model and showed a very good fit to the data for foreseeability, $X^2(3) = 2.92$, CFI = .999, RMSEA = .001, as well as inevitability, $X^2(3) = 1.59$, CFI = .999, RMSEA = .001. From these results we conclude that measurement invariance was fulfilled for the measures used in Study 2.
- 8 The same moderator analyses with the *AHS total score* as moderating variable yielded an identical pattern of results regarding our hypotheses, the interaction terms were not significant, t 's < .34, p 's > .73.
- 9 In Study 1, a repeated measurement ANOVA for the variable likelihood in the Vietnamese sample yielded no significant main effect of time of measurement (before, after) or article version (foresight, hindsight), likewise, the interaction was not significant, all F 's < .29, p 's > .59. Furthermore, independent t-tests (foresight vs. hindsight article version) for the Vietnamese sample showed no difference

between experimental groups regarding foreseeability, $t(90) = .55$, $p = .56$, and inevitability impressions, $t(90) = .42$, $p = .68$.

- ¹⁰ In both studies, trust in Wikipedia was fairly high and did not differ between the subsamples. It was measured with 4 items on a scale of 1 (*not at all*) to 5 (*very much*), yielding a high internal consistency of $\alpha = .84$ and $\alpha = .87$, respectively. In both studies, comparisons between subsamples were achieved using a *t*-test for independent samples. Study 1: $M_{East} = 3.81$, $SD_{East} = .72$; $M_{West} = 3.85$, $SD_{West} = .71$, $p = .62$. Study 2: $M_{US} = 3.34$, $SD_{US} = .67$; $M_{VIET} = 3.51$, $SD_{VIET} = .99$, $p = .40$.
- ¹¹ Reading time in both studies did not differ between Eastern / Western participants (Study 1, $t(392) = .56$, $p = .57$) or languages (Study 2, $t(141) = .10$, $p = .92$). As expected, there was a significant difference in reading duration for the article versions: reading the shorter article version took less time than reading the longer version (Study 1: $t(392) = 6.48$, $p < .001$; Study 2: $t(141) = 4.43$, $p < .001$). Text comprehension did not differ significantly across nationalities and article versions in both studies, all F 's < 2.85 , p 's $> .09$; F 's $< .53$, p 's $> .47$, respectively.

