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Hindsight bias in judgments of the predictability of flash floods: An experimental study for testimony at a court trial and legal decision making

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Abstract

As part of the first author's expert testimony at a court trial, we investigated hindsight bias in perceptions of the predictability of a real flash flood. Participants were presented with pictures taken before the flash flood and asked to rate the muddiness of the water and judge the likelihood of flooding in Experiment 1. Participants who were informed that a flash flood had occurred perceived the river as muddier and judged a flood to be more likely than control participants. Their judgment was biased by hindsight. The results of Experiment 2 revealed that when the causality from muddiness to flooding was instructed, participants judged the river as muddier. These results were interpreted as top-down perception being implicitly adjusted by outcome information and causality information. The judges decided that the defendants had no responsibility to predict the flash flood, taking the hindsight bias into consideration.

KEYWORDS
court trial, hindsight bias, perceptual judgment, probability judgment

1 | INTRODUCTION

Impartial legal decisions are very important at a court trial. However, judges, prosecutors, attorneys, jurors, and witnesses are often susceptible to various kinds of cognitive biases. Hindsight bias, also known as the knew-it-all-along effect, is one of the biases that can affect judgments made under conditions of uncertainty. This is the inclination, after an event has occurred, to see the event as having been predictable. Hence, even if the event is unexpected, people often believe that they could predict it.

If judges and prosecutors are biased by hindsight at a court trial, they are very likely to overestimate the defendant's responsibility to predict and avoid a negative consequence in which the defendant was involved. Although many studies (e.g., Berlin & Hendrix, 1998; Eberwine, 2005; Gilbey et al., 2016; Harley, 2007; Hastie et al., 1999) have pointed out possible biased legal judgments by hindsight at a trial court, very few studies have simulated these judgments (e.g., Roese et al., 2006). This study is one of the few studies. Experiment 1 on perceptual judgment and probability judgment were asked to was conducted in preparation for the first author's testimony at a court trial, and Experiment 2 was its follow-up experiment. The results of partial data of Experiment 1[1] that demonstrated the prosecutors' hindsight bias were reported in the court by the first author, and the judgment was that the defendants had no responsibility for the issue in question.

2 | HINDSIGHT BIAS AND LEGAL DECISION MAKING

Hindsight bias in probability judgments was first reported by Fischhoff (1975). The participants were asked to estimate the probability that an expected outcome would occur from a scenario in the experiment. The participants in the control group were not given any information about the outcome, whereas those in the experimental group were given the information that an unexpected outcome had

occurred, but they were asked to suppose hypothetically that they did not know it. We adopt this paradigm for measuring hindsight bias to simulate a legal judgment. Prosecutors, judges, and jurors should judge the defendant's pre-outcome actions in a fair way ignoring whether a negative outcome has occurred or not. However, legal decision making can be biased by hindsight (e.g., Berlin & Hendrix, 1998; Eberwine, 2005; Gilbey et al., 2016; Harley, 2007; Hastie et al., 1999; Roese et al., 2006). For example, in a trial case where a defendant is accused of negligence in a tragic accident, he or she is tried based on their responsibility to predict and avoid the outcome. The relevant decision makers, including witnesses, prosecutors, judges, and jurors must ignore the negative outcome, and judge the defendant's pre-outcome actions in a fair way. However, they know that the accident did occur. If they are biased by hindsight that the accident was likely to occur, they believe that the defendant could predict the accident. As a result, they are likely to overestimate the predictability and preventability of the negative outcome. This is not fair for the defendant.

In the court case under consideration here, three kindergarten teachers were indicted for causing death and injury through negligence in the pursuit of social activities. When they took their kindergarten children to a riverside, a flash flood occurred and one child drowned and two other children were injured. One of the questions that the trial focused on was whether the defendants could have predicted the flash flood based on the degree of muddiness of the river. People are reminded to look out for sudden muddiness of a river as a cue for a possible flash flood. Therefore, whether the teachers are responsible for the water accident depends on whether they could predict the flash flood based on those signs, and thus, this was one of the focuses of the trial. When people believe that an accident could have been predictable after knowing that the accident occurred, this can cause a detrimental effect of hindsight bias on legal decision making. As a result, the responsibility for the accident is unjustly overrated.

The original motivation to conduct Experiment 1 on perceptual judgment of muddiness and probability judgment that a flash flood occurs was to test if people, including the prosecutors and the witnesses, were susceptible to hindsight bias in this trial case. When we began planning this experiment, the eyewitnesses, who were by the river when the flash flood occurred, had already testified to the fact that the river had turned muddy, and the prosecutors had pointed out the muddiness of the river in the photos, which were taken by the eyewitnesses 30 min before the flash flood and were evidence in the court proceedings at the former hearing of this trial. However, the defendants claimed that the flash flood had been very sudden without any sign of water muddiness and the water of the river had been very clear as it usually is.

Since the witnesses and the prosecutors knew that the flash flood had occurred 30 min after the time when the photos were taken, it is plausible that their perceptual judgment of muddiness and probability judgment of flash flood from the river sceneries in the photos are biased by hindsight. The first purpose of this study was to provide evidence for the judgment in court if the claims of the eyewitnesses and the prosecutors were biased by hindsight. The paradigm of Fischhoff (1975) was adopted in this study. Each of the four photos was presented to the participants, and they were asked to rate the muddiness of water in each photo and estimate the probability that an expected outcome would occur from the scenery of the river in the photo. The participants in the control group were not given any information about the outcome, whereas those in the experimental group were given the information that the flash flood had occurred, but they were asked to suppose hypothetically that they did not know it.

Furthermore, we should point out the cultural differences in hindsight bias between Westerners and Easterners when considering such trial cases, because it has been shown that this bias is greater among Easterners than Westerners (Choi & Nisbett, 2000; Yama et al., 2010). Choi and Nisbett (2000) explain this cultural difference as that Easterners have more complex causal models for events than the Westerners do. Their complex causal models are responsive to an unexpected outcome. Although the explanation is similar, Yama and Zakaria (2019) proposed that Easterners are more dialectical in dealing with an unexpected outcome than Westerners, hence they are more likely to revise the original models using the information of the outcome dialectically than Westerners. We are not very certain which explanation is more valid. But, we are very sure that, since Japanese, as Easterners, are more vulnerable to hindsight bias than Westerners, Japanese have to be especially careful about hindsight bias in a court trial.

3 | THEORIES OF HINDSIGHT BIAS

The second purpose of this study is on theoretical issues. Although several slightly different cognitive theories have been proposed to explain how hindsight bias in probability judgment occurs (e.g., Blank & Nestler, 2007; Roese & Vohs, 2012), we do not intensively discuss which theory is best supported in this study, because the hindsight probability judgment in this trial case, if it had occurred, can be explained by an application of the mechanism, which these theories commonly assume. All the theories focus on the original memory representation constructed by the actual scene, a scenario, or a context and is updated by added information (the outcome information). The basic idea of these theories is causal model theory (CMT; Hawkins & Hastie, 1990; Nestler et al., 2008), which aims to explain hindsight probability judgment for event outcomes. According to this idea, an initial model is constructed when people are given a scenario or a context. The term "model" means a mental representation of a scene or an event that can be operated for a mental simulation of a future event. The initial model is revised when coming across an expected outcome. Hawkins and Hastie (1990) argue that the process in the case of hindsight bias is automatic and implicit: People do not notice the revision consciously, and therefore, hindsight bias occurs. Similar ideas have been proposed with small revisions. For example, agreeing with the idea that the initial model is revised implicitly, Fischhoff (1975) viewed this process as a reconstruction of the prior judgment and Hoffrage et al. (2000) proposed that hindsight bias

could be understood as a by-product of the updating of knowledge after feedback.

In this trial case, the witnesses who were at the riverside just before the flash flood might have constructed an initial model for the prediction that a flash flood would have been very unlikely to occur. Generally, the initial model is just for the most plausible outcome. However, when information that the unexpected outcome occurred is given, people search for causal factors that might explain the unexpected outcome, which they add to the models. It is very likely that the witnesses might change the degree of muddiness of their initial model (memory representation) so that they can predict the unexpected flash flood. If the probability judgment of the witnesses is biased by hindsight, it is very plausible that their memory representation was distorted by the information about the flash flood. If the probability judgment is biased by hindsight, we are assuming that it is perceptual judgment of muddiness of the water for updating the model (e.g., Hoffrage et al., 2000).

However, the possible hindsight bias was not only in the memory representation, but also on the visual perception in this trial case. We do not deal with the problem of the witnesses' memory distortion, but the perception and judgment of the photos of the river. If the prosecutors' perceptual judgment is biased by hindsight, it is probably because they are unable to imagine their judgment of the photos without the information about the flash flood when they visually examine the photos. In other words, the top-down process of perception is biased by hindsight. The prosecutors in effect judged that the river in the photos was slightly muddy and claimed in the court that the defendants should have recognized this as a sign of the flash flood. Their causal model might be that the river was muddy, and therefore, it was probable that a flash flood occurred. However, since they were not at the scene of the accident, it was not their memory representation that was updated. It is plausible they were unable to imagine how they perceive the muddiness in the photos when the unexpected outcome information was not given. This should be investigated for the judgment in the court because a set of photos, which were taken just before the flash flood, was part of the evidence that the defendants could have predicted the flash flood. It is plausible that the prosecutors' perceptual judgment was influenced by the information that the flash flood had occurred.

Hindsight bias related to perceptual cues (sometimes called "visual hindsight bias") has been reported (Arkes et al., 1981; Bernstein & Harley, 2007; Chen et al., 2020; Harley et al., 2004; Muhm et al., 1983). For example, Harley et al. (2004) proposed a fluency-misattribution theory for perceptual hindsight bias. They presented their participants with photographs of celebrities at several levels of blurriness and asked them to identify each photograph in the first phase. After the participants identified all the photographs, they were asked to recall the level of blurriness just when each photograph was identified. The participants chose more blurry photographs than those they originally identified. The explanation was that the photographs were processed with perceptual fluency for the second time, and the participants believed that this was because they had identified the photographs in the first phase. This causes hindsight bias.

However, we are focusing on such another type of perceptual hindsight bias as Muhm et al. (1983) reported in this study. They conducted a screening program for men at high risk of lung cancer and found that the physicians who looked at the previous sets of radiographs could detect the tumor in radiographs of the cases that had initially been interpreted as normal. The physicians knew the outcome that the radiograph was of a lung cancer patient; hence, they were more likely to judge that there is a sign in the radiograph. This is hindsight bias on the top-down processing in perception. Although Muhm et al. (1983) did not refer to CMT (Hawkins & Hastie, 1990; Nestler et al., 2008), it can be applied to the perception of radiographs. In place of an initial model in memory, we can suppose the imagined perception of a nodular shadow in the radiograph. When the outcome information was given, the imagined perception was automatically and implicitly updated so that the physicians could causally explain the outcome that the radiograph belonged to a lung cancer patient. This application of CMT is the same as that to the perception of muddiness in the photos.

However, there are two differences between the study of Muhm et al. (1983) and this study. Muhm et al.'s study shows a case where miss errors decrease, but these decreases may occur due to hindsight bias on the top-down processing in perception. On the other hand, this study deals with possible increase in false alarms: that muddiness in the photos is overestimated. This should be confirmed. The second difference is the strength of causality as mentioned in the next section.

4 | CURRENT STUDY

Two more points to be discussed in this study are ecological validity and causality. First, how can we provide a natural or ecologically valid task to participants to investigate if the judgments of the witnesses and the prosecutors may be biased by hindsight? Since we could not tell the participants the true purpose of this study, we had to conduct deception experiments. We developed the following method with a cover story so that the judgments of both muddiness and probability of a flash flood are necessary for participants in a natural setting in Experiment 1. We let them notice that people must be watchful for the sudden muddiness of a river as a sign of flash flood, and thus, it is necessary to investigate how people judge the muddiness and the probability of a flash flood.

Second, participants were expected to assume causality from water muddiness to flash flood in Experiment 1. In the case of medical diagnosis of X-ray tests, radiologists know that a nodular shadow in a chest radiograph can be a sign of chest cancer (Muhm et al., 1983). In other words, the causality from a nodular shadow to chest cancer is well known. However, it is not certain that everyone knows the causal relation between water muddiness and a flash flood. When this causality is taught by someone, most people may say "Now that you mention it, that is indeed the case." During the trial, both prosecutors and judges knew that muddiness of water could be a cue for a possible flash flood. In effect, when the witnesses were asked to judge the muddiness of water, they were already given the information by the policemen and the prosecutors in this trial case about the causality

that the muddiness was the sign of a flash flood. Hence, the defendants' attorneys (the second and the third authors) claimed that this was a leading question in the court. It is very plausible that the witnesses became more sensitive to muddiness than usual and their perceptual judgment of muddiness could be biased by this causal information. This causality between muddiness and flash flood was also conveyed to the participants in Experiment 1.

Therefore, we focus only on the muddiness judgment and manipulate the causal information in Experiment 2. We set two conditions: a causality condition and a neutral condition. Participants in the causality condition were told that people must be watchful for the sudden muddiness of river as a sign of flash flood, whereas participants in the neutral condition were instructed that the muddiness of river water can be an index of environmental pollution. The neutral condition also provided a natural setting for participants to rate the muddiness of water in the pictures. However, this setting could not be adopted in Experiment 1 where participants were asked to make a probability judgment, because they did not know why they were asked to judge the probability of flash flood.

5 | EXPERIMENT 1

5.1 | Purpose of Experiment 1

Experiment 1 was designed to examine the possibility that people's probability judgment of flash flood and perceptual judgment of muddiness are biased by hindsight for the first author's testimony in this court trial. Our method was to show the pictures that were taken about 30 min before the flash flood and ask participants to make a perceptual judgment of muddiness of the water and make a probability judgment that a flash flood would occur. If the perceptual judgment is vulnerable to hindsight bias, in place of fluency-misattribution, we need an explanation, which supposes top-down processing biased by hindsight. The practical purpose of this experiment is to test if we can find differences in perceptual judgment and probability judgment between those who know the outcome and those who do not and show the results in the court.

The second purpose is to test if CMT (Hawkins & Hastie, 1990; Nestler et al., 2008) can be applied to top-down perception biased by hindsight and the relation between perceptual judgment and probability judgment. CMT supposes that people have implicit access to causal factors in memory representation for an unexpected outcome. If we find a hindsight effect in both perceptual judgment and probability judgment, do people adjust top-down processing implicitly so that they can predict the flash flood? If CMT can be applied to the implicit adjustment, we predict that we would find a correlation between muddiness judgment and probability judgment from this application. In other words, we predict that our participants would revise their probability judgment by implicit updating of the imagined perception so that they can causally explain the unexpected outcome that the flash flood had occurred. This perceptual hindsight bias cannot be explained by the fluency-misattribution theory (Harley et al., 2004), because the outcome information, which is given to our participants, is not visual but in words. This does not mean that the fluency-misattribution theory is rejected, but that the paradigm that we use is different from that of Harley et al. (2004).

Experiment 1 aims to examine if people are susceptible to hindsight bias just by looking at a photo and test if CMT (Hawkins & Hastie, 1990; Nestler et al., 2008) can be applied to top-down perception biased by hindsight and the relation between perceptual judgment and probability judgment.

6 | METHOD

6.1 | Participants

A power analysis for a *t*-test with an estimated effect size of $d = .4$, an α level of 5%, and a power of 80% suggested that we needed 100 participants per condition. One hundred and fourteen undergraduate students of Osaka City University participated in this experiment. Some were taking the class of "Human Behavioral Sciences" and others were taking the class of "Introduction to Psychology." They had not yet learned about human cognitive biases, and we confirmed that no one knew about hindsight bias when debriefing. They were randomly assigned to either the control condition or the outcome condition. Fifty-three (male 19, female 34) of them participated in the former, and 61 (male 28, female 33) participated in the latter (see Footnote 1). The mean age was 19.6 years ($SD = 1.16$).

6.2 | Materials

Materials were a leaflet by the Japanese Ministry of Land, Infrastructure, Transport and Tourism (https://www.mlit.go.jp/river/kankyo/play/pdf/stop.pdf), which advises with some illustrations (no photos) that people have to be watchful for the sudden muddiness of river as a sign of flash flood, four photos of the river which had been taken by eyewitnesses about 30 min before the flash flood, two photos of another river, which were used as fillers,[2] and a booklet in which instructions were printed and participants' responses were recorded. Four photos[3] were chosen by the three authors from some photos that were taken as evidence to ensure that people in the pictures did not influence the judgment of participants and that they included the muddiest and the least muddy pictures. The leaflet and the photos were projected onto a screen, and the participants were asked to rate how muddy the river in each photo was on a 9-point scale provided (from "not muddy at all" to "very muddy") and estimate the probability, in percentage, that a flash flood would occur in about 30 min.

6.3 | Procedure

This experiment was run in two regular classes of "Human Behavioral Sciences" and "Cognitive Psychology" by the first author. Since the

second and third authors were the defendants' attorneys for the defendants, they may have wished that the participants' judgments would be biased by hindsight more strongly than the first author. Hence, they were not present in the class to ensure that the data were not biased by any such desire. Since Experiment 1 was conducted by the first author, who knew the purposes of this experiment, the experiment was not double-blinded. After the participants filled their demographic information in the booklet, the leaflet was projected onto a screen, which the participants were facing toward, using Microsoft Power-point. When presented with the leaflet, the participants were instructed that people should take sudden muddiness of a river as a sign of a possible flash flood, but that, because the Ministry was not certain about how people judge the muddiness and the probability of flash flood, we were gathering the data to investigate these judgments. This reason was a deception. It took about 3 min for this instruction. Secondly, after the experimenter confirmed orally that the participants understood the fake reason, each photo was projected onto the screen and the participants were asked to make a perceptual judgment and a probability judgment. Since it was plausible that the estimated probability could be very low, the participants were instructed that they might answer to express the percent probability as decimal numbers. The participants in the outcome condition were instructed that the flash flood had occurred and three kindergarten children had died, with the information of exact date and location.[4] They were also instructed to judge hypothetically supposing that they did not know the outcome. The participants in the control condition were not given the outcome information. Finally, all the participants were debriefed that the photos were taken about 30 min before the flash flood experiment. None of the participants knew of the water accident and the name of the river. The name of this river is not in popular atlases.

7 | RESULTS AND DISCUSSION

The dependent measures were the rating score of muddiness and the estimated probability of flash flood. Each measure was compared between the two groups: the control condition and the outcome condition.

Since one participant did not respond to all the questions in each of the conditions, the data were excluded from statistical analysis. Each participant's mean rating score of muddiness (9-point scale from "not muddy at all" to "very muddy") and mean estimated probability of four photos (the data of the two fillers were excluded from the analysis) were calculated, and the mean rating score and mean estimated probability of each condition are shown in Table 1.

A *t*-test was conducted to compare the mean rating scores of muddiness. The difference was significant ($t[110] = 2.59$, $p < .05$, $d = .46$). The mean score of muddiness judgment of the outcome condition was higher than that of the control condition. Since the estimated probability data did not have a normal distribution, the mean estimated probability of each participant was converted logarithmically.[5] A *t*-test was conducted on the converted data. The difference was significant ($t[110] = 2.32$, $p < .05$, $d = .44$). The mean estimated probability of the outcome condition was higher than that of the control condition. These differences are as shown in Table 1.

TABLE 1 Mean rating score of muddiness and mean estimated probability of flash flood in each condition

	Visual judgment		Probabilistic judgment	
Control condition (n = 52)	3.14	(.90)	3.59	(8.13)
Outcome condition (n = 60)	3.63	(1.06)	7.43	(10.92)

Note: Mean estimated probability is expressed in percentage.
Note: SD is shown in parentheses.

Correlations between the rating score and the logarithmically converted estimated probability were not significant in the control condition ($r = .16$, *n.s.*) but were significant in the outcome condition ($r = .38$, $p < .01$). Generally, people do not have a strong causal relation in mind between muddiness and flash flood, because the correlation is not significant without the outcome information. However, although the correlation is not very high, the significant correlation in the outcome condition indicates that the participants in the outcome condition used top-down processing to give a causal explanation from the muddiness to the flash flood.

The results of perceptual judgment and probability judgment indicate that both the judgments were biased by hindsight. Therefore, it is very plausible that the judgment of the prosecutors, who knew that the flash flood had occurred, was biased by hindsight. That is, because they knew that the flash flood had occurred, they were more likely to judge that the river water was muddier and the probability of flash flood was higher.

The hindsight bias in the muddiness judgment, which appeared in this study, is not explained by the fluency-misattribution theory (Harley et al., 2004), because we adopted a different method to measure the perceptual hindsight bias from that of Harley et al. (2004). While the outcome stimuli were visual photos in Harley et al., our outcome information was not visual stimuli but the information that the flash flood had occurred. Our participants' perceptual fluency did not increase even when they knew the outcome information. Rather, our participants made a metacognitive judgment considering the outcome to conduct top-down processing so that a slight increase in muddiness could be exaggerated, which is very close to the process of retroactive analysis of the radiographs by Muhm et al. (1983).

The correlation above supports the prediction based on the application of CMT (Hawkins & Hastie, 1990; Nestler et al., 2008). We adopt the explanation of CMT for the results on probability judgment and assume that perceptual judgment of muddiness of the water may be one of the causal factors to implicitly update the original model (e.g., Hoffrage et al., 2000). CMT assumes that what is revised implicitly by unexpected outcome information is the memory representation or the initial model in memory. However, the correlation indicates that it is the top-down visual perception that was revised so that the muddiness could be the sign of the flash flood. In short, the range of application of CMT is enlarged so that the revised representation by

unexpected outcome information is not just in memory but also in perception.

A possible reason why perceptual hindsight bias occurred is that the participants were given the information that muddiness of a river could be a cue for a flash flood. Knowledge of causality enhances the implicit revision of the initial model. This interpretation is compatible with CMT (Hawkins & Hastie, 1990; Nestler et al., 2008). The hindsight bias might not have occurred if this information had not been given to our participants. Therefore, we manipulated the causal information and set two conditions in Experiment 2: a causality condition and a neutral condition. The causality information was given in the causality condition, but it was not given in the neutral condition.

8 | EXPERIMENT 2

The purpose of Experiment 2[6] was to investigate if the perceptual hindsight bias that occurred in Experiment 1 was because the causal information in the leaflet that the muddiness was the sign of a flash flood was given to the participants. This is the practical purpose for legal judgment in the sense that, because the witnesses who were by the river when the flash flood occurred were given the information about the causality by the policemen and the prosecutors in this trial case, if their judgment that the river had turned muddy was biased by hindsight, their bias was likely to be reinforced by the causality information. It is plausible that the causal information enhanced the perceptual hindsight bias in the cases of both Experiment 1 and the trial case.

Hence, in addition to the factor of outcome, we integrate a new factor, causality, into the experimental design in Experiment 2. We set two conditions as mentioned in the section of Current study: a causality condition and a neutral condition. Participants were not asked about the probability judgment in Experiment 2, because it was not natural for them to make a probability judgment in the neutral condition. The method in the causality condition was almost the same as that of Experiment 1, but for that, the participants were not asked about the probability judgment of flash flood. An illustrated figure on the relationship between muddy water and environmental pollution provided by a company was presented in place of the leaflet by the Japanese Ministry of Land, Infrastructure, Transport and Tourism in the neutral condition, and participants were instructed that the muddiness of river water can be an index of environmental pollution. This task is ecologically valid in the sense that participants understand why they need to estimate muddiness. The neutral condition can be a control condition of the causality condition and, furthermore, corresponds to a fictitious case where the witnesses were not given the information about the causality that the muddiness was the sign of a flash flood.

Hence, we propose a working hypothesis that perceptual hindsight bias occurs only in the causality condition if people do not usually recognize that muddiness is the sign of a flash flood. If the hypothesis is supported, CMT (Hawkins & Hastie, 1990; Nestler et al., 2008) proposes that the knowledge of causality enhances the implicit revision of the perceptual top-down processing of the photos. However, if people are already familiar with the causality knowledge that muddiness is the sign of a flash flood, the causality information will not influence their perceptual judgment of muddiness.

9 | METHOD

9.1 | Participants

The design was a fully between 2 (causality: neutral and causal) by 2 (outcome: control and outcome) one. A power analysis for an *F*-test with an estimated effect size of $d = .4$, an α level of 5%, and a power of 80% suggested that the total participants required were 52. Sixty-four undergraduate students of Osaka City University participated in this experiment. They were second-year or higher students of "Cognitive Psychology." They had not yet learned about human cognitive biases, and we confirmed that no one knew about hindsight bias when debriefing. They were randomly assigned to four conditions: 18 (male 10, female 8) in the control-neutral condition, 14 (male 8, female 5, non-response 1) in the outcome-neutral condition, 16 (male 10, female 6) in the control-causality condition, and 14 (male 6, female 8) in the outcome-causality condition[1]. The mean age was 20.5 years ($SD = 1.13$).

9.2 | Materials

Materials were almost the same as those of Experiment 1. We presented the same photos (the four photos and two fillers). We used the same leaflet by the Japanese Ministry of Land, Infrastructure, Transport and Tourism in the causality condition and a figure on muddy water and environmental pollution provided by Geosphere Environmental Technology Corp (https://www.getc.co.jp/ja/service/sediment-transport-2/) in the neutral condition. The leaflet or the figure was printed in each booklet, and the photos were projected onto a screen. The participants were asked to rate how muddy the river in each photo was on a 9-point scale provided (from "not muddy at all" to "very muddy").

9.3 | Procedure

The procedure was almost the same as that of Experiment 1, except that we did not ask the participants to make probability judgments of a flash flood. This experiment was run in a regular class of "Cognitive Psychology." After filling in their demographic information in the booklet, the participants were asked to read the fake reason why this research was necessary. Participants in the neutral condition were instructed that the muddiness of river water could be an index of environmental pollution, but because we were not certain about how people judge the muddiness, we were gathering the data to investigate these judgments. They were not instructed about the relation

TABLE 2 Mean rating score of muddiness in each condition

	Neutral condition		Causality condition	
Control condition	3.42	(.24) (n = 18)	4.22	(.26) (n = 16)
Outcome condition	4.05	(.28) (n = 13)	4.66	(.28) (n = 14)

between water muddiness and a flash flood. Those in the causality condition were given the same instruction as that of Experiment 1. Either of the instructions of the neutral condition or the causality condition was printed in each booklet. After the experimenter confirmed orally that the participants understood the fake reason, each photo was projected onto the screen, which the participants were facing toward, using Microsoft Power-point. The participants were asked to make a perceptual judgment. The participants in the outcome condition were instructed that the flash flood had occurred and a kindergarten child had died, with the information of exact date and location. They were also instructed to judge hypothetically supposing that they did not know the outcome. The participants in the control condition were not given the outcome information. Finally, all the participants were debriefed that the photos were taken about 30 min before the flash flood experiment. None of the participants knew of the water accident or the name of the river.

10 | RESULTS AND DISCUSSION

Each participant's mean rating score of muddiness in four photos was calculated, and its mean score in each condition is shown in Table 2. An ANOVA was conducted using a fully between 2 (causality: neutral and causal) by 2 (outcome: control and outcome) design.

The main effect of outcome was significant (F[1, 58] = 4.18, p < .05, η_p^2 = .067). The scores in the outcome condition were higher than those in the control condition. This means that perceptual hindsight bias occurred, as it did in Experiment 1. The main effect of causality was significant (F[1, 58] = 7.13, p < .05, η_p^2 = .109). The scores in the causality condition were higher than those in the neutral condition. The two-way interaction was not significant (F[1, 58] = .14, *n.s.* η_p^2 = .002). These effects are as shown in Table 2.

It was confirmed that the perceptual judgment was biased by hindsight again. Hence, it is very plausible that the perceptual judgment of muddiness by the witnesses and the prosecutors in this trial case were biased by the outcome information that the flash flood had occurred. This perceptual hindsight bias was not because of the causality information that was given to the participants. The result that the two-way interaction was not significant means that the effect of this outcome information occurred with or without the causality information. Although we proposed a working hypothesis that this perceptual hindsight bias would occur only in the causality condition, it was not supported. Since we found a significant main effect of outcome and a non-significant interaction, although we did not confirm that our participants had already known the causality from muddiness to flash flood, it is likely that the causality information that muddiness is a sign of flash flood was available even if it was not instructed. CMT (Hawkins & Hastie, 1990; Nestler et al., 2008) proposes that the available knowledge of causality enhances the implicit revision of the perceptual top-down processing of the photos, and thus the perceptual hindsight bias occurred.

Furthermore, its effect size of causality was greater than that of outcome. This means that causality information makes people sensitive to the muddiness of water. It does even if people are not given the outcome information. This causality information may have persuaded the participants to have a mental attitude not to miss any sign of water muddiness.

These results have a practical implication for the trial case. The perceptual judgment of muddiness of the water as a sign of flash flood might have been doubly biased independently not only by hindsight but also by the causality information. Therefore, prosecutors and judges must be very cautious not to emphasize causality information between a target sign and a tragic outcome to witnesses when the problem in a trial is whether defendants could predict the outcome from the target sign. The causal information can be a leading question to make witnesses biased by causal inference and this influence may even be greater than that of the outcome information.

11 | GENERAL DISCUSSION

This study had two purposes. The first was to provide evidence for the judgment in court as to whether the claims of the eyewitnesses and the prosecutors were biased by hindsight. The second was to test if CMT (Hawkins & Hastie, 1990; Nestler et al., 2008) could be applied to top-down perception biased by hindsight and the relation between perceptual judgment and probability judgment.

As for the first purpose of this study, the results were that both perceptual judgment and probability judgment were biased by hindsight. Therefore, it is very plausible that the judgment of the witnesses and the prosecutors in this trial case was biased by hindsight. The results of Experiment 2 also indicate that when the causality from muddiness to flash flood is mentioned, people tend to overestimate the muddiness of the water. This study proposes a paradigm, in which participants are given an ecologically valid task, to simulate judgments in a court. As mentioned, although many researchers have argued that hindsight bias can be serious in legal decision making (e.g., Berlin & Hendrix, 1998; Eberwine, 2005; Harley, 2007; Hastie et al., 1999), there is still a lack of empirical studies to simulate legal judgment biased by hindsight (e.g., Roese et al., 2006). This study provides empirical evidence to show that the judgments of witnesses and prosecutors can be biased by hindsight.

The judgment of the first trial at a district court (Japan adopts a three-trial system) was that two of the defendants were found not guilty. This trial was without a jury; hence, the decision was made by the judges. However, one of the three defendants, who was the head of the kindergarten, was found guilty of neglect of both the information that there had been rainfall in the headstream area of the river before the flash flood and her duty to make kindergarteners wear life

jackets. The judges decided that the defendants had no responsibility for judging that the muddiness of the river could be the sign of a flash flood. By the consideration of the first author's testimony on the results of Experiment 1 (the results which were not based on all the data) (see Footnote 1) with the explanation on hindsight bias to the judges, although the witnesses had given the testimony that there was a slight change of color in the river and the persecutors had claimed that the river was muddy in the photos at the former hearing of this trial were not adopted in the judgment of the first trial. Of course, the results of Experiment 1 are not definitive evidence that the river was not muddy, but they were sufficient to demonstrate that people are vulnerable to hindsight bias in both perceptual judgment and probability judgment. Neither the prosecutors nor the defendants appealed anymore; hence, the trial was concluded. In short, this practice that psychologists show evidence of hindsight bias through psychological experimentation is very beneficial for less-biased legal judgment. The results of Experiment 2 conducted in 2018 were not reported at the trial. However, we wish that, if they had been, the judges would have taken the influence of the causality information, which was given to the witnesses by the prosecutors, into consideration more.

The second purpose was the application of CMT (Hawkins & Hastie, 1990; Nestler et al., 2008) to perceptual hindsight bias. Originally CMT assumes that people implicitly revise an initial model in memory so that an unexpected outcome can be predicted. However, the results indicate that it is not only the model in memory but the top-down processing of perception when an outcome is known to people. The updating of this top-down processing is also inferred to be implicit as the revision of an initial model is assumed to be implicit according to CMT (Hawkins & Hastie, 1990).

The paradigm, in which participants are given an ecologically valid task, to simulate legal judgment used in our study is expected to be applied to trial cases in which the defendant's responsibility is to predict and avoid a tragic outcome. However, our results did not show that the defendants were unable to predict the flash flood, but just pointed out the possibility of hindsight bias of the witnesses and the prosecutors. Furthermore, we have not yet confirmed if the judges were persuaded by the first author's testimony because we could not conduct a controlled experiment in which the testimony was not made. A system to evaluate the weight of scientific data to be considered for the judge in trial court may be necessary.

One more limitation of this study is on the difference between this and a similar study by Muhm et al. (1983) on perceptual judgment of X-ray images. We assume that the causality from muddiness to flash flood is not so well known as that of from a nodular shadow to chest cancer. However, this was not confirmed by assessing our participants' prior knowledge about the causality. We are not certain if such causality instruction influences perceptual judgment in the case of medical diagnosis of X-ray tests (Muhm et al., 1983).

In spite of these limitations, this study raises two suggestions. The first is for the purpose of legal decision. The paradigm of ecologically valid task can be used for testimony to be referred to in the light of hindsight bias. The second is the application of CMT (Hawkins & Hastie, 1990; Nestler et al., 2008) to perceptual hindsight bias.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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ENDNOTES

[1] This study was approved by the Ethical Board of Osaka City University since the expected results would be important for the judgment at the court trial and it is beneficial for the students to participate in the experiment to learn psychology. It was approved in the condition that we would gather data in regular classes and would not force the students to participant in the experiment. A priori power analysis for sample size was not required by the Board, but instead, it was required that the experiment should be conducted in the regular class of "Human Behavioral Sciences" and the participants are those who were taking the class. The experiment was conducted in January 2016, which was 1 month before the day when the first author was scheduled to testify the results at the court trial. The reported data in the court were gathered in the regular class of "Human Behavioral Sciences" (N = 64) and show hindsight bias. However, more data were gathered in the regular class of "Introduction to Psychology" (N = 50) in 2018 to examine the correlation between muddiness judgment and probability judgment. The condition for the approval was also applied to Experiment 2, which was conducted in 2018.

[2] The reason why we added two fillers was that the river was so little muddy in the four photos that some students wondered why they needed to rate how muddy the river was in each photo in the pilot experiment. Therefore, the rivers in the two filler photos were muddier than that of photos taken by the witnesses.

[3] The photos were evidence in the court proceedings. According to the Japanese Code of Criminal Procedure (Act No. 281), the defense counsel must appropriately keep safe custody of the copies of evidence and may not entrust custody to others without valid reason. Hence, these photos are not available.

[4] The number of kindergarten children who died was not three but one. The wrong information was due to a mistake by the first author who did not have close contact with the second and third authors when conducting the experiment. The second and third authors did not conduct the experiment themselves because they were the attorneys of the defendants and had a strong desire for the hindsight effects as the results of the experiment. However, we think that this mistake had little influence over the results of this experiment because the results on

muddiness judgment were replicated in Experiment 2. This mistake was reported at the trial court.

[5] The probability of zero cannot logarithmically be converted, because the converted value is negative infinity. Therefore, in place of negative infinity, we assigned −5.55, which is the logarithmically converted value of the second lowest probability estimation .000003.

[6] Experiment 2 was conducted after the judgment of the first trial at a district court. Hence, the results of the experiment were not reported during the trial.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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