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Visual hindsight bias, also known as the “saw-it-all-along” effect, is the tendency to overestimate one’s perceptual abilities with the aid of outcome knowledge. The present study investigated visual hindsight bias for facial stimuli. Experiment 1 adopted the visual hindsight bias paradigm from Harley et al. (2004) and replicated their findings with celebrity faces. Experiment 2 examined how emotional valence of facial stimuli (happy, angry, and neutral faces) modulated visual hindsight bias. Results provided evidence of hindsight bias for angry and neutral faces, but hindsight bias for happy faces was only observed in the difficult condition when the degree of emotional expression was varied in Experiment 3. These results suggest that the perceptual difficulty of facial expressions moderates visual hindsight bias. Implications and future directions are discussed.
Visual Hindsight Bias and Emotion Perception

by
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Emily Burgess, Author
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Visual Hindsight Bias and Emotion Perception

Consider the following scenario:

During the night, a woman was approached and attacked by an angry man in a public area with no bystanders to witness the attack. The attacker ran away before police arrived, but footage of the attack was caught on a local shop’s security camera. Although the woman was unable to describe the man to police and the video quality was dark and blurred, police were still able to piece together the man’s angry expression. After some time, a possible suspect from the attack was brought in for questioning. When the woman who was attacked saw the man, she insisted that he was her attacker. She was certain that she had identified him as the same man who first approached her the other night. The police might believe that the woman’s confidence in her ability to identify the man is enough evidence to make an arrest, seemingly forgetting entirely that prior to having seen the man, the woman was unable to describe her attacker at all. Is it possible that, having been given a possible suspect, the woman’s judgment of her ability to identify him under suboptimal conditions was influenced?

This is an example of hindsight bias: individuals have the tendency to believe, once an outcome has occurred, that they ‘knew it all along.’ Unable to disregard their new knowledge state to make accurate cognitive or perceptual judgments about a past state, individuals during hindsight judge events or outcomes as more predictable than they would have in foresight. As in the above scenario, once the woman had seen a possible identity of the angry man, she likely overestimated how easy it had been to identify him in the first place. Hindsight bias is a robust cognitive error that has been observed using basic almanac questions, real-world events, and different perceptual stimuli and has even been displayed throughout history in several judgment and decision-making settings (Arkes, 2013; Bryant & Guilbault, 2002; Harley, 2007;
Louie et al., 2007; for a review, see Roese & Vohs, 2012). The present study examined hindsight bias in the visual domain. It is first imperative to explain the background and history of traditional hindsight bias.

**Traditional Hindsight Bias**

Hindsight bias was first formally demonstrated by Fischhoff (1975), who asked a group of participants to rate the probabilities of four outcomes of a historical or clinical event after being told that one of the four outcomes was “true.” Probability estimates were then compared to participants in the control group, who were not given information regarding whether the outcomes were true or not. Hindsight bias was measured by comparing the probability estimates of both groups; those with outcome information assigned higher probabilities to the true outcomes than those with no outcome information. The pioneered findings from Fischhoff’s studies sparked a large interest in what would soon grow into one of the most studied phenomena both within and outside of psychology. The effect was first termed “creeping determinism” by Fischhoff, but has since evolved into hindsight bias, the curse of knowledge, “knew-it-all-along” effect, and recently in the visual domain, the “saw-it-all-along” effect (e.g., Harley et al., 2004; Wood, 1978).

After these initial investigations, researchers began to examine the bias using real-world scenarios including the outcome of political events (e.g., Bryant & Brockway, 1997; Bryant & Guilbault, 2002; Fischhoff & Beyth, 1975) and self-relevant events such as losing a job or failing an exam (e.g., Blank & Peters, 2010; Melvin & Mellor, 1991). Others used a series of trivia or almanac questions, where participants make a prediction about the answer (e.g., Calvillo, 2013; Edfelder & Buchner, 1998; Hell et al., 1988). For example, participants might respond to a series of chemistry-related questions such as, “How many groups are
included in the periodic table of elements?” to which a participant may respond “12.” Later, they are provided with the correct answer to each question and asked to recall their original prediction. In the case of the periodic table, participants find out that the correct answer is “18 elements.” Hindsight bias is observed when the recalled answer shifts toward the correct answer, such as if a participant recalled his original answer to be “16” when it was really “12.”

**Hindsight Bias Designs**

A hindsight bias paradigm consists of two necessary judgments: a foresight judgment and a hindsight judgment. In foresight, participants provide some sort of prediction or response which may consist of an answer to a question, a likelihood estimate on a continuous or categorical scale, and/or provide a confidence rating (for reviews, see Bernstein et al., 2015; Pohl, 2007; Guilbault et al., 2004). To illustrate: Fischhoff (1977) asked participants to determine whether “absinthe is (a) a precious stone or (b) a liqueur” and rate the probability of them being correct. During hindsight, participants were provided with the correct answer or outcome and asked to recall their original judgment during the first phase (foresight). Participants provided with the correct answer in Fischhoff recalled having assigned higher probabilities to the correct answer. Hindsight bias is then measured as a comparison between the two judgments. The larger the difference between these two judgments, the larger the effect of hindsight bias. A memory design, wherein participants complete both judgments; and a hypothetical design, wherein participants complete one judgment type, are the two main designs for assessing hindsight bias.

**Memory Designs.** Memory designs require the same group of participants to complete both foresight and hindsight judgments. Participants in a memory design provide an initial, foresight judgment, such as an answer to the question, “What is the probability that the Rams will win the Super Bowl?” Because the magnitude of the bias increases with time between the
foresight and hindsight judgments (e.g., Blank et al., 2008), one might ask for the foresight judgment a week prior to the game and the hindsight judgment directly after learning the outcome. After discovering which team won the game, the same group of participants is given a surprise task – they are asked to recall their original probability judgment (hindsight judgment). Hindsight bias is observed when participants recall assigning a higher probability to the winning team than they had originally.

Further, in this design there may also include a control group that would not be told that the Rams won. Thus, we can measure hindsight bias by comparing the hindsight judgments between the group with outcome information and the group with no outcome information. In a memory design, those who receive the outcome tend to systematically shift their responses toward the actual outcome while control group participants (no outcome) are more accurate at recalling their original predictions or estimates.

**Hypothetical Designs.** Unlike memory designs, participants in a hypothetical design are not required to recall their previous judgment. Instead, there are two separate conditions: foresight and hindsight. Those in the foresight condition provide a probability estimate prior to the game. Those in the hindsight condition receive the outcome information (e.g., the winner of the game) and are asked what they (or a naïve peer) would have predicted having not known the outcome of the game. The probability estimates from both the foresight (no outcome) and hindsight (outcome) groups are then compared as a measure of hindsight bias. Evidence of hindsight bias resulting from the use of hypothetical designs has shown that there is more than just a memory component to the bias.

**Theoretical Explanations**

There have been several models and theories proposed to explain the causes of, processes involved, and the conditions necessary for hindsight bias to occur. The principal
explanations that encompass the main traditional hindsight bias theories include both cognitive mechanisms and motivational factors, or a combination of the two (e.g., Hawkins & Hastie, 1990; Hell et al., 1988).

**Cognitive Mechanisms.** Cognitive theories suggest that hindsight bias occurs as a result of the attempts to integrate new knowledge into existing knowledge or to reconstruct one’s memory after having received outcome information (e.g., Fischhoff, 1977; Roese & Vohs, 2012). Outcome information interferes with the search for a previous knowledge state and thus, biases their recollection of a past judgment (e.g., Erdfelder & Buchner, 1998; Hawkins & Hastie, 1990). Further, past information that is consistent with the outcome is activated, leading to its increased perceived foreseeability (e.g., Roese & Vohs, 2012). Using the Super Bowl example: upon learning who wins the game, one might consider only things that led to their success, such as the team’s winning record and MVP players, which gives the impression of knowing all along that they would win.

**Motivational Factors.** Motivational explanations of hindsight bias have also been proposed. In general, motivational theories describe that individuals may be motivated by the need for a sense of predictability and to enhance self-esteem (Hawkins & Hastie, 1990; Roese & Vohs, 2012; Sedikides & Gregg, 2014; Wilson et al., 2003). Because of the need for predictability and order in their complex worlds, people attempt to make sense of outcomes that take place, with the goal likely being to reach a desired state of knowing and assurance (Dijksterhuis, 2010). For example, a negative outcome, such as being fired from a job or losing a family member, may increase hindsight bias such that it serves as a way to reduce uncertainty and protect one’s self-esteem (e.g., Pezzo & Pezzo, 2007). When individuals are presented
with the information regarding an outcome, they are automatically inclined to try and make sense of it (e.g., Pezzo, 2003; Roese & Vohs, 2012; Wilson et al. 2003).

While there may be a lack of unanimity as to exactly why the bias occurs, the consensus remains that hindsight bias happens somewhat automatically and is difficult to eliminate or reduce. Studies have shown that even when educating and warning participants about hindsight bias, they still show a tendency to display the bias (e.g., Bernstein et al., 2012; Guilbault et al., 2004; Harley et al., 2004). These findings suggest that hindsight bias occurs outside of awareness and is perhaps uncontrollable. Most of the literature discussed has been limited to only the verbal domain. Recently, however, hindsight bias has been shown to occur in other modalities including visual (e.g., Harley et al., 2004), auditory (e.g., Bernstein et al., 2012), and gustatory (Pohl et al., 2003), providing converging evidence for the robustness of its effects. As suggested by the scenario provided at the onset of the Introduction, the focus of the current paper will discuss hindsight bias in the visual domain as it relates to emotional faces.

**Visual Hindsight Bias**

Recent studies have now examined the bias using visual perception tasks (e.g., Bernstein et al., 2004; Bernstein & Harley, 2007; Calvillo & Gomes, 2011; Chen et al., 2020; Harley et al., 2004). Harley et al. first studied visual hindsight bias using blurred images of celebrity faces (see Figure 1 for examples). Their paradigm consisted of two trial types that are synonymous with the previously discussed foresight and hindsight judgments: a baseline-identification phase and a “surprise” memory test, respectively. During the baseline-identification (baseline-ID) phase, participants saw a blurred image of a celebrity that gradually became clear and were told to stop the blurring process as soon as they were able to identify the celebrity (see Figure 2A for an example). After completion of all thirty-six baseline-
identification trials, participants were given a “surprise” memory test where the same celebrities were shown in each trial. Each face was first presented at the blurriest level accompanied by the celebrity’s identity (analogous to the outcome). Participants were then to adjust the level of blur of the image until they thought it matched the point at which they stopped the blurring process to identify the celebrity during the baseline-identification phase.

Harley et al. used filter cutoff frequencies ($f_1$) of the images to measure the blur level present at each stopping point. Hindsight bias was calculated as a ratio of the baseline-identification stopping point ($f_1$ value) divided by the memory test stopping point ($f_1$ value), referred to as the hindsight ratio (HR); an HR value larger than one implied hindsight bias. Their results in Experiment 1 produced significant hindsight bias effects: participants were stopping the image at a blurrier level during the memory test compared to the baseline-identification phase. In other words, participants recalled having identified the celebrity when the image was more blurry than it had actually been when they first recognized the celebrity.

Harley et al. (2004) further divided the celebrity faces into four difficulty quartiles based on their mean stopping point during the baseline-identification phase in Experiment 1. Their data illustrated that hindsight bias increased as a function of difficulty. That is, faces which were identified at a later stopping point (assumed to be more difficult to process) produced larger hindsight bias than faces identified earlier in the blurring process (assumed to be easier to process). Harley et al. concluded that like traditional hindsight bias, visual hindsight bias is also sensitive to more difficult tasks.

Harley et al. (2004) observed similar effects even when providing information about hindsight bias and explicit instructions to avoid the bias during Experiment 2. Participants were still unable to accurately recall their foresight judgment blur level, consistently estimating
higher identification performance. In Experiment 3, there was no warning provided. Instead, a hypothetical design was used where participants saw the clear image of celebrities (i.e., outcome stimulus) first then predicted the blurring adjustment performance of a naïve observer. Harley et al. found that participants still consistently overestimated the performance of a naïve peer when identifying celebrities with the aid of outcome knowledge. Taken together, the findings from Harley et al. suggest that the enhanced processing of an outcome stimulus has an influence on one’s perceptual judgment in hindsight.

**Fluency-Misattribution Theory**

Based on the results from the previous experiments, Harley et al. (2004) proposed a fluency-misattribution theory to explain visual hindsight bias and the difficulty effects found. Fluency-misattribution theory suggests that because knowledge of the target identity (or prior exposure) increases the ease of processing of that image, hindsight bias occurs due to the inability to discount that enhanced perceptual fluency. Fluency may be enhanced by factors such as priming, preferences, salience, and familiarity. In the same way that a feeling of déjà vu is evoked when unexpectedly rapid processing of the brain in an unfamiliar area creates an unusual sense of familiarity, so too does the unexpectedly high fluency of identification processing occur in visual hindsight bias, causing the viewer to feel as if they had always been able to perceive the stimulus so clearly.

Individuals might misattribute the enhanced processing to the target identity being *easy* or predictable rather than to the outcome being known or given. Furthermore, to account for the difficulty effects found, Harley et al. (2004) suggested that faces which were more difficult to process during baseline-identification had a larger processing discrepancy to be resolved during the memory test, resulting in more enhanced fluency to be discounted in order to recall how easy (or difficult) it had been to identify the celebrity in the first place.
Evidence for fluency-misattribution theory is also provided in Bernstein and Harley (2007), where hindsight effects were observed for faces that progressed from the traditional blurry-to-clear process, but not when images progressed from clear to blurry. In the backward condition (clear-to-blurry), participants were able to correctly identify the level of blur present during the baseline phase. The authors argued that these results support fluency-misattribution theory as those in the forward condition did not know at the outset which celebrity would be presented and thus, were unaware of the source of enhanced fluency. Participants in the backward condition were presented with the clear stimulus (e.g., celebrity identity) at the outset of both judgments (baseline-ID and memory test) before becoming blurrier, likely making them aware of why fluency had been enhanced. In sum, when a stimulus is processed more fluently and individuals are unaware why, there is a tendency to see it as more foreseeable.

Figure 1
Examples of Celebrity Stimuli used in Experiment 1

Note. Experiment 1 sample stimuli. Left to right: John Cena, Angelina Jolie, Brad Pitt, Zendaya.
Figure 2
Illustration of the Procedure used in Experiments 1, 2, and 3

A

Instructions: Press SPACEBAR as soon as you recognize who the celebrity is. After you press SPACEBAR, type in your guess of the celebrity’s name and press ENTER.

B

Instructions: Use the ‘Z’ and ‘X’ keys to adjust the blurriness of the celebrity until it matches what the celebrity looked like when you first correctly identified him or her during Phase One. Press SPACEBAR when you think it matches the level of blur.

C

Instructions: Use the ‘Z’ and ‘X’ keys to adjust the blurriness of the emotional face until it matches what the image looked like when you first correctly identified him or her during Phase One. Press SPACEBAR when you think it matches the level of blur.

Note. Panel A: Baseline-identification phase. Thirty successively blurred images were created to make it appear as though the celebrity (Experiment 1) or emotional face (Experiments 2 and 3) was gradually becoming clearer. Panel B: Experiment 1 Memory Test. Panel C: Experiment 2 and 3 Memory Test.
The Present Study

A recent conference presentation by Bernstein et al. (2020), who examined visual hindsight bias using several emotional faces, inspired the present study. In their study, participants were shown a blurred image of an emotional face that progressed to clear during the foresight judgment phase. Participants were to stop the clearing process when they were able to identify the emotion displayed in the image. Following all foresight trials, participants completed the hindsight judgment phase, where the clearest image of each face was shown first, and participants had to determine the emotion. They then performed the memory task where they were asked to adjust the blur levels to indicate the point at which they were first able to identify the emotion during foresight (e.g., Figure 2B). They were interested in whether participants stopped the photo at a higher degree of blur during the hindsight trials than they had during the foresight trials (i.e., demonstrated a hindsight bias).

Across four experiments, their results produced hindsight bias for all emotions (angry, disgusted, scared, surprised, sad, ambiguous) except for happy. In other words, participants were able to accurately identify the level of blur at which they were able to identify the happy emotion. This result raises the question: what might explain the lack of hindsight bias effects for happy faces? A possible account is that there is a difference between happy emotions and other emotions in terms of recognition and processing difficulty. Indeed, this is what has been shown in the emotion perception literature.

In order to recognize different emotions, humans generally attend to the most salient features of the face: the mouth and the eyes. The eyes provide a strong attentional cues for angry and other expressions, while the mouth provides stronger cues for happy expressions (e.g., Calvo & Beltrán, 2014; Calvo et al., 2018; Eisenbarth & Alpers, 2011). Therefore, there
may be many shared features across several emotion expressions (i.e., anger and sadness). In contrast, Calvo and Beltrán (2014) suggest that the smile in happy faces is more unique and, as a result, easier to discriminate from other emotion expressions, whose features are more likely to overlap. Additionally, Becker et al. (2011), who found evidence for a happy superiority effect in several visual search tasks, explains that because happy expressions are more common, they are likely processed quicker and more fluently than other expressions.

Importantly, however, many studies have found the opposite effect: an angry superiority effect that suggests processing of angry faces is automatic and quicker than other emotions (e.g., Fox et al., 2000; Shaw et al., 2011). While these contradictory findings can be partially attributed to methodological and stimulus differences (i.e., target amongst distractors; schematic versus real faces), there is evidence that there may be greater variation in the angry emotion, whereas happy emotions can be accurately identified with either a closed- or open-mouth smile (e.g., Calvo & Nummenmaa, 2008). Thus, the features of happy faces may simply be easier to recognize and discriminate than other emotions in the blurry-to-clear paradigm, leading to a reduction in hindsight bias in this case. That is, participants may have identified happy faces sooner than the other emotions used in Bernstein et al. (2020), which would be consistent with task difficulty accounts of hindsight bias: individuals are more accurate at judging their performance for easier tasks than for difficult tasks (e.g., Harley et al., 2004). The present study therefore directly tests this possibility.

The present set of experiments was designed to examine (1) whether visual hindsight bias occurs for emotional faces, and (2) if so, whether it is modulated by the perceptual difficulty of emotions. Experiment 1 adopted Harley et al.’s (2004, Experiment 1) visual hindsight bias paradigm and conceptually replicated their findings with celebrity faces. After
validating the visual hindsight bias paradigm, Experiment 2 then examined how emotional valence of facial stimuli (happy, angry, and neutral faces) moderated visual hindsight bias. Experiment 3 examined the effect of the perceptual difficulty of emotional faces (easy and difficult) in visual hindsight bias.

**Experiment 1**

Experiment 1 adopted Harley et al.’s (2004) paradigm used in their Experiment 1, where participants identified celebrities as their blurred images slowly became clearer. After all identification trials, participants were asked to indicate how blurry the image was when they were first able to identify the celebrity. Hindsight bias was measured as the number of frames (1-30) present between both judgment tasks. Due to the restraints of online data collection, the main purpose of Experiment 1 was to ensure that the modified remote-distributed paradigm could be used to measure visual hindsight bias before replicating Bernstein et al. (2020), using emotional faces as stimuli.

**Method**

**Participants**

A total number of 47 undergraduates (37 females; 10 males) between the ages of 18-45 years old ($M = 23.25$) with normal or corrected-to-normal vision from Oregon State University were recruited through the university’s SONA system and received course research credits for participation. All participants met the inclusionary criteria of being within 2.5 standard deviations of the mean number of frames in each condition. Comparing to the sample size of 42 in Harley et al.’s (2004) study, power analysis using G*Power indicated that the sample size of 47 provides a power of .95 ($\alpha=.05$) to detect the significant difference in the dependent
variable, the level of blur of the image measured as the number of frames, between the two judgment types (hindsight/foresight).

**Materials and Stimuli**

Stimuli were 36 greyscale images of well-known celebrities that measured 175x250 pixels (see Figure 1 for examples). Stimuli were created using MATLAB, where each image was greyscaled using rgb2gray and filtered using the imgaussfilt function. 30 successive blurred images were developed by increasing the standard deviation of the gaussian filter by increments of 1 up to 29. Celebrities were selected based on a familiarity rating survey consisting of 83 celebrities (41 males; 42 females) distributed to a separate group of participants (N = 12) who were asked to rate how familiar each celebrity is from 1 to 4. A rating score of 1 meant “I don’t know his name; I don’t remember where I have seen him; He is not familiar to me”; 2 meant “I don’t know his name; I don’t remember where I have seen him but he looks familiar to me”; 3 meant “I don’t know his name but I remember where I have seen him”; and 4 meant “I know his name,” where participants were then asked to type the name of the celebrity. The top 38 most familiar faces (19 males; 19 females) in ratings were selected for this experiment, with a mean rating of 3.56. The unfamiliar faces, those remaining after selecting the top 38 images, consisted of a mean rating of 2.69, with familiarity ratings being significantly higher for familiar faces ($M = 3.56, SD = .21$) than the unfamiliar faces ($M = 2.69, SD = .26$), $t(81) = 13.242, p < .001$.

**Procedure**

After informed consent, participants first responded to a series of demographic questions on Qualtrics reporting their sex, age, and vision (normal or corrected-to-normal).
Upon completion of the survey, participants were given a URL linked to the experimental trials in PsyToolkit (Stoet, 2010, 2017).

With the exception of online data collection, Experiment 1 closely followed the procedure of Harley et al. (2004), shown in Figures 2A and 2B. Participants first completed 36 trials of baseline-ID, where the image of a celebrity started very blurry and gradually became clear. Once participants were able to identify the celebrity, their task was to press the spacebar to stop the blurring process and type in the name of the celebrity and press ENTER. Participants were told they may identify the celebrity in a number of ways: by any portion of their name, the name of a character he or she plays on television, or the name of a movie in which he or she has starred. Each level of blur was shown for 500 ms until all 30 images were shown to equate the amount of time participants were exposed to the stimulus.

After all 36 baseline-ID trials were complete, participants moved on to the memory test trials. At the start of each memory test trial, participants were shown their response for the celebrity’s identity. Participants were told to use the “Z” and “X” keys to toggle back and forth between blurry and clear until they thought the level of blur present matched when they were first able to identify the celebrity during the blurring process in the baseline-ID phase. Once satisfied with the level of blur present, participants pressed ENTER to move on to the next celebrity face. This task was repeated for all 36 celebrity faces in a random, different order of presentation than baseline-ID. Participants completed two practice trials prior to each phase, which included one male celebrity and one female celebrity that were not presented during the experimental trials. Participants did not receive feedback for their performance.

**Results and Discussion**
Only trials where participants were able to correctly identify the celebrity were included in the final analysis, excluding 23.4% of trials. Trials were coded as accurate if participants were able to identify a portion of the celebrity’s name, character, or a film he or she starred in. Hindsight bias was measured as the mean difference between the number of frames present at the stopping point when participants pressed the spacebar during baseline-ID compared to number of frames present at the stopping point during the memory test. Results from Experiment 1 are shown in Figure 3. There was a significant difference in the mean number of frames between baseline-ID ($M = 19.05$, $SD = 2.43$) and memory test ($M = 17.29$, $SD = 3.29$) phases, $t(46) = 6.390, p < .001, d_z = .932$. During the memory test, participants overestimated their performance in identifying the celebrities during the baseline-ID phase.

Experiment 1 replicated the results of Harley et al. (2004), demonstrating visual hindsight bias for the identification of celebrities. To provide additional support for the hypothesis that the difficulty of the stimulus moderates visual hindsight bias, hindsight ratios (HRs) were also calculated by dividing each stopping point in the blurring process measured as the mean number of frames during baseline-ID by the mean number of frames during the memory test; $HR = 1.12$. Celebrity faces were then divided into four difficulty quartiles based on the mean number of frames present at the stopping point during baseline-ID of each face and comparing to the hindsight ratios; celebrities identified sooner are assumed to be easier than those identified later in the process. As shown in Figure 4, hindsight ratios indeed increased as a function of difficulty.
Figure 3

*Experiment 1 Data*

![Chart showing mean frames comparison between baseline identification and memory test.](chart)

*Note.* Visual hindsight bias is measured as a difference in mean number of frames between the baseline identification phase and the memory test. Error bars represent standard errors.

Figure 4

*Experiment 1 Task Difficulty Effects*

![Graph showing celebrity difficulty quartiles compared to hindsight ratios.](graph)

*Note.* Celebrity difficulty quartiles based on the mean number of frames at the stopping point during Baseline Identification compared to hindsight ratios, calculated as a ratio between the mean number of frames between the baseline identification phase and the memory test.
Experiment 2

After validating the visual hindsight bias design in Experiment 1, Experiment 2 examined whether visual hindsight bias can be obtained using emotional faces. As noted in the Introduction, Bernstein et al. (2020) found hindsight bias for all emotions (angry, disgusted, scared, surprised, sad, ambiguous) except for happy. In this experiment, I included only happy and angry faces as they are highly distinctive and are typical exemplars for positive and negative emotions, respectively. Neutral faces were also included as a baseline emotion to examine the effect of emotional valence on visual hindsight bias between happy and angry.

First, I expect to observe visual hindsight bias for neutral faces and angry faces. If happy faces are easier to process than other emotions, a possibility previously discussed, I predict no hindsight bias for happy faces.

Method

Participants

We conducted an a priori power analysis (G*Power) which showed that a sample size of 32 provides a good chance of detecting a medium effect for the differences between judgment types (power = 95%, $d = .3$, $p = .05$). There were 52 new undergraduates drawn from the same participant pool as in Experiment 1. A total number of 7 participants whose responses were outside of 2.5 standard deviations of the mean frames in each condition were excluded from the overall analyses (Van Selst & Jolicoeur, 1994). For the remaining 45 participants, their mean age was 21.75 years (range: 18-45; 35 females and 10 males). All participants had normal or corrected-to-normal vision.

Materials and Stimuli
Stimuli adapted from the easy condition in Tomasik et al. (2009) were used to develop 36 greyscale images using the same manipulation methods described in Experiment 1. Images consisted of 18 males and 18 females, with each sex split into three groups of six expressing either a happy, neutral, or angry emotion (see Figure 5 for examples), which were made up of 99% of the expression shown.

**Procedure**

The procedure used in the present experiment was the same as Experiment 1 with some exceptions (shown in Figure 2C). Participants completed both the baseline-ID phase and the memory test identifying the emotion present in the images shown. During baseline-ID, participants pressed the “B” key for happy, “N” key for neutral, and “M” key for angry at the point in the blurring process where they first recognized the emotion. At the start of the memory test, participants were shown the clear image of the emotional face first and asked to again respond to the emotion shown. After seeing the clear image, participants used the “Z” and “X” keys to toggle between blurry and clear until they thought the level of blur present matched when they were first able to identify the emotion shown during the blurring process in the baseline-ID phase. Once satisfied with the level of blur present, the point at which participants pressed the spacebar was recorded as the stopping point. After the spacebar was pressed, the next trial began. Participants completed six practice trials prior to each phase, counterbalancing one male and one female expressing each of the three emotions that were not presented during the experimental trials.

**Results and Discussion**

Only trials where participants accurately identified the emotion during baseline-ID were included in the final analysis, excluding 13.9% of trials. Hindsight bias was again
measured as the mean difference in the number of frames between the two phases, which were submitted to a 2 (phase: baseline-ID vs. memory test) X 3 (emotion: happy vs. neutral vs. angry) within-subjects analysis of variance (ANOVA) on mean number of frames. Results show that phase was at the significance level, $F(1,44) = 4.058, p = .05, \eta^2_p = .084$, suggesting a visual hindsight bias. The main effects of emotion were also significant, $F(2,88) = 61.451, p < .001, \eta^2_p = .583$, on the mean number of frames, suggesting that the emotional valence modulated the visual hindsight bias. The analysis also revealed a significant interaction between phase and emotion, $F(2,88) = 7.768, p < .001, \eta^2_p = .150$. Further t-test analyses for each emotion revealed no significant differences in the mean number of frames for happy faces between the memory test ($M = 19.57, SD = 3.20$) and baseline-ID ($M = 19.59, SD = 2.88$), $t<1.0, p = .485$. Angry faces, in contrast, were stopped at a blurrier level during the memory test ($M = 21.01, SD = 3.22$) than baseline-ID ($M = 22.20, SD = 2.84$), $t(44) = 2.420, p = .01$. Similarly, neutral faces were stopped at a blurrier level during the memory test ($M = 20.69, SD = 3.49$) than baseline-ID ($M = 21.96, SD = 3.24$), $t(44) = 2.910, p = .003$, suggesting visual hindsight bias. Results from Experiment 2 (shown in Figure 6) replicated those of Bernstein et al. (2020), demonstrating hindsight bias for angry and neutral faces but no hindsight bias for happy faces.

Experiment 2 provided further evidence for visual hindsight bias for emotional faces with the exception of happy faces. Results show that participants overestimated the level of blur present for angry and neutral faces but were nearly consistent in matching the level of blur present for happy faces, as was found in Bernstein et al. (2020). An explanation for these findings is that happy faces are unique and easier to recognize than other emotions. Evidence from baseline-ID in the present study supports this argument: the number of frames present at
the stopping point for happy faces ($M = 19.59, SD = 2.88$) was significantly lower than both angry faces ($M = 22.20, SD = 3.22$), $t(44) = 9.539, p < .001$ and neutral faces ($M = 21.96, SD = 3.24$), $t(44) = 9.667, p < .001$, suggesting that happy faces were easier to identify than other emotions.

**Figure 5**

*Examples of Emotional Stimuli used in Experiment 2*

![Examples of Emotional Stimuli used in Experiment 2](image)

*Note.* Stimuli adapted from Tomasik et al. (2009) showing happy, neutral, and angry emotions.

**Figure 6**

*Experiment 2 Data*

![Experiment 2 Data](image)

*Note.* Visual hindsight bias is measured as a difference in mean number of frames between the baseline identification phase and the memory test across happy, neutral, and angry faces.
Experiment 3

Visual hindsight bias effects were observed in Experiment 2 for both angry and neutral faces, but not for happy faces. Experiments 1 and 2 have both illustrated that hindsight bias is larger for more difficult faces. As such, it would be expected that emotions that are more difficult to identify would produce a larger hindsight bias effect than easy emotions. It is possible, then, that hindsight bias for happy faces might occur when perceptual processing of the happy emotion is difficult. Experiment 3 examined this possibility by manipulating perceptual difficulty of emotional faces – including easy and difficult conditions for both happy and angry faces using the same paradigm as Experiment 2. Neutral faces were excluded as the difficulty manipulation cannot be easily implemented. For the easy condition, I expect to replicate the results of Experiment 2 where visual hindsight bias was observed for angry faces but was absent for happy faces. For the difficult condition, however, both angry and happy faces should produce the bias.

Method

Participants

An a priori power analysis (G*Power) showed that a sample size of 26 provides a good chance of detecting a medium visual hindsight effect (power = 95%, $d = .3$, $p = .05$). There were 61 new undergraduates drawn from the same participant pool as in Experiments 1 and 2. A total number of 7 participants who were outside of 2.5 standard deviations of the mean number of frames in each condition were excluded from the overall analyses (Van Selst & Jolicoeur, 1994). The remaining 54 participants (42 females; 12 males) were between the ages of 18-45 years old ($M = 20.87$) with normal or corrected-to-normal vision.

Materials / Stimuli
The images were adapted from Tomasik et al. (2009), which contained the same actors as those in Experiment 2 but with easy and difficult manipulations for each emotion (see Figure 7). Faces in the easy condition were made up of 99% of the emotion shown (angry or happy), while faces in the difficult condition were a 50/50 mixture of neutral emotions and the emotion shown (angry or happy).

**Procedure**

The baseline-identification and memory test procedures used in Experiment 3 were the same as Experiment 2, with the exceptions noted below. Participants used the “B” key for happy and the “M” key for angry. Participants completed six practice trials prior to each phase, including one male expressing each of the emotions and one female expressing each of the emotions that were not presented during the experimental trials.

**Results and Discussion**

Results from Experiment 3 are shown in Figure 8. Only trials where participants accurately identified the emotion in the baseline-ID phase were included in the final analysis, excluding 3.6% of trials.

The number of frames at the stopping point was submitted to a 2 (phase: baseline-ID vs. memory test) X 2 (emotion: happy vs. angry) X 2 (condition: easy vs. difficult) within-subjects ANOVA on mean number of frames was conducted. The analysis revealed significant main effects of all three variables: phase, $F(1,53) = 8.617, p = .005, \eta^2_p = .140$, suggesting a visual hindsight bias effect; emotion, $F(1,53) = 10.101, p = .002, \eta^2_p = .160$, which, as in Experiment 2, implies that emotional valence modulates the visual hindsight bias; and difficulty, $F(1,53) = 136.478, p < .001, \eta^2_p = .72$, suggesting that the difficulty manipulation worked.
Critically, the analysis revealed a significant three-way interaction between phase, emotion, and difficulty, $F(1,53) = 4.160, p = .046, \eta_p^2 = .073$. I conducted follow-up analyses for the mean number of frames in each condition. For the easy condition, angry faces produced a hindsight bias effect: the mean number of frames during the memory test ($M = 20.76, SD = 2.13$) was significantly lower than the mean number of frames during baseline-ID ($M = 21.91, SD = 2.25$), $t(53) = 4.546, p < .001$; whereas happy faces produced no hindsight bias as there were no differences in the mean number of frames between the memory test ($M = 20.08, SD = 2.82$) and baseline-ID ($M = 20.30, SD = 2.91$), $t < 1.0, p = .258$. The findings for the easy condition replicated the results in Experiment 2. For the difficult condition, however, both happy and angry faces produced a hindsight bias. For happy faces, the mean number of frames was lower during the memory test ($M = 22.17, SD = 2.66$) than baseline-ID ($M = 22.95, SD = 2.82$), $t(53) = 2.060, p = .02$. For angry faces, the mean number of frames was also lower during the memory test ($M = 22.05, SD = 2.21$) than they had during baseline-ID ($M = 22.89, SD = 2.35$), $t(53) = 2.622, p = .006$.

Experiment 3 produced visual hindsight bias for happy faces when the perceptual difficulty of the emotion was manipulated. There was again a lack of hindsight bias observed for happy faces in the easy condition. These results are consistent with the prediction that hindsight bias increases with increased perceptual difficulty for happy faces. For angry faces, however, there appeared to be a slightly larger bias for easy faces than for difficult faces, although this difference was not significant, $t(53) = 1.185, p = .121$ (see General Discussion).
Figure 7

Examples of Stimuli used in Experiment 3

Note. Stimuli adapted from Tomasik et al. (2009) showing the easy and difficult manipulations: Easy phases (Left) were morphed with 99% of the respective expressions while difficult faces were morphed with 50% neutral expressions (Right).
Figure 8
Experiment 3 Data

Panel A: Visual hindsight bias is measured as a difference in mean number of frames between the baseline identification phase and the memory test for the easy condition. Panel B: Visual hindsight bias for the difficult condition.

Note. Panel A: Visual hindsight bias is measured as a difference in mean number of frames between the baseline identification phase and the memory test for the easy condition. Panel B: Visual hindsight bias for the difficult condition.
General Discussion

The present study examined visual hindsight bias for emotional faces and whether it is modulated by the perceptual difficulty of emotion expressions. The main objective of the present study was to provide a possible account for the findings of Bernstein et al. (2020) that demonstrated visual hindsight bias for several emotions (angry, disgusted, scared, surprised, sad, ambiguous) except for happy. As suggested by Harley et al. (2004), visual hindsight bias is sensitive to task difficulty. It is possible that happy faces are easier to identify than other emotions, which would provide an account for the lack of hindsight bias for happy faces. Consistent with task difficulty accounts, hindsight bias could be observed if the perceptual difficulty of the happy emotion is increased. The present study directly assessed these possibilities.

Summary of Major Findings

Experiment 1 replicated Harley et al. (2004; Experiment 1) and tested the adapted remote-distributed paradigm using celebrity faces. Results showed that participants overestimated their own performance in identifying celebrities under uncertainty. In other words, there was a visual hindsight bias for celebrity faces. Additionally, visual hindsight bias increased for faces that were identified later in the blurring process, or at a clearer state (considered more difficult). Experiment 2 examined the hindsight bias with emotional faces. Results showed evidence of visual hindsight bias for neutral and angry faces, but no hindsight bias was found for happy faces, replicating the findings of Bernstein et al. (2020). Experiment 3 manipulated the perceptual difficulty of the emotions. Results provided evidence for visual hindsight bias for happy faces in the difficult condition and angry faces in both conditions.
Consistent with predictions that the ease of processing of the emotion shown modulates hindsight bias, no effect was found for happy faces in the easy condition.

**Task Difficulty**

The post-hoc difficulty effects found in Experiment 1 provided a critical foundation for the prediction the difficulty of the stimuli would moderate visual hindsight bias in the two experiments that followed. As was done in Harley et al. (2004), celebrity faces were separated into four difficulty quartiles based on the number of frames present at the stopping point during baseline-ID. Faces which had a lower value for the number of frames present at identification were considered easy (because they were identified at a blurrier level), while those with a larger value for the number of frames present were considered more difficult. Hindsight ratios were calculated for each quartile and demonstrated that as difficulty increased, so did visual hindsight bias. Participants indicated having identified difficult faces at a blurrier level than they originally had. The rationale for Experiments 2 and 3, then, was further reinforced by these findings. That is, instead of analyzing difficulty effects post-hoc, the emotion expressions and their perceptual difficulty were manipulated to directly examine the effects. Experiment 2 results demonstrated that across happy, neutral, and angry, hindsight ratios increased respectively (Figure 9A). In Experiment 3, hindsight ratios were compared across both conditions, providing converging evidence a larger visual hindsight bias when happy faces were made perceptually difficult (Figure 9B). Contrary to our hypothesis, however, hindsight ratios for angry faces in the easy condition were slightly larger than those in the difficult condition.

**Emotion Perception**
It has been suggested that happy faces are perhaps easier to recognize in this paradigm due to either the commonality or the uniqueness of a smile in a happy face (e.g., Calvo & Beltrán, 2014), which we predicted would be able to explain the lack of visual hindsight bias for happy faces found in Bernstein et al. (2020) as we have seen that hindsight bias is sensitive to stimulus difficulty. Further, if the perceptual difficulty of the happy emotion is increased, a visual hindsight bias should occur. This is precisely what the results of the present study illustrate.

**Baseline Identification**

The differences in performance across emotions found in the baseline-identification phase are consistent with behavioral and physiological evidence in the emotion perception literature, which have shown that individuals identify happy faces quicker than other emotion expressions (e.g., Batty & Taylor, 2003; Calvo & Nummenmaa, 2008; Tottenham et al., 2009). This was indeed found in the present data: the mean number of frames at the stopping point during the baseline-ID phase in Experiment 2 for happy faces was significantly lower than both neutral and angry faces. These results imply that happy faces were easier to identify than the other two emotions. Experiment 3 further replicated this pattern: in the baseline-ID phase, happy faces were identified at a blurrier level ($M = 21.63$) than angry faces ($M = 22.39$), $p < .001$. Furthermore, people tend to rely on unique perceptual features when identifying emotions (e.g., mouth and eyes). When the perceptual salience of the emotion expression was manipulated for both happy and angry expressions, faces in the easy condition were identified at a blurrier level ($M = 21.11$) than faces in the difficult condition ($M = 22.91$), $t(53) = 10.527$, $p < .001$, suggesting that it took longer to identify less salient emotions.

**Memory Test**
Recall that an overestimation of blur levels during the memory test implies hindsight bias: after seeing the clear image of the emotional face, participants indicated that they identified the emotion sooner than they actually did. The pattern of results here is also consistent with task difficulty accounts of hindsight bias: emotions which were identified at a later stage during baseline-ID produced a larger visual hindsight bias than those recognized earlier, or at a blurrier level. The only exception to this explanation, however, is that angry faces in the easy condition produced a similar bias as angry faces in the difficult condition. It is possible that upon viewing the outcome stimulus of both types of angry faces, participants were motivated to think that they had recognized such an “obvious” emotion sooner, whereas angry faces in the difficult condition were not as obvious.

Along similar lines, happy faces in the easy condition may have been “obvious” (i.e., processed more fluently) during both baseline-ID and the memory test, therefore, demonstrating little to no visual hindsight bias. This explanation is similar to the premises of fluency-misattribution theory (Bernstein & Harley, 2007; Harley et al., 2004), which states that in order to accurately recall the level of blur at which participants first identified the emotion, they must discount the enhanced fluency of the clear outcome image provided. Easy emotions may have had a smaller processing discrepancy to be resolved between the two judgment types in contrast to difficult emotions. Although this may account for much of the data shown in the present study, fluency-misattribution theory is a broad theory that does not include further cognitive and memory processes. In fact, when investigating auditory hindsight bias, Higham et al. (2017) suggested that in a memory design, participants rely less on fluency and more on their own cognitive processes. Therefore, fluency might be playing a role in the present study but may not be the only factor involved.
The possibility remains that there are other cognitive influences also at play such as the reconstruction of a naïve knowledge state. After viewing the clear stimulus for difficult emotions, participants might have attended to the relevant, known features of the celebrity faces (Experiment 1) and emotional faces (Experiments 2 and 3) and reworked them to make sense of how “obvious” they were to recognize initially. For easy faces, the emotion may have actually been *obvious all along*, thus resulting in no new information to be reworked and no hindsight bias. Irrespective of causal mechanisms, visual hindsight bias was moderated by the difficulty of the facial stimuli across all three experiments and consequently may have very important implications for several judgment and decision-making fields.

**Implications**

The study of visual hindsight bias has both theoretical and practical implications. First, there are not nearly as many studies in the visual domain as there are in other domains; as such, the findings in the present study offer an extension of evidence that can aid in theoretical development of visual hindsight bias. Further, the present interaction between emotion perception and hindsight bias offers insight into both how people perceive others and how people *think* they perceive others based on certain factors (e.g., emotional valence), a concept that Harley et al. (2004) referred to as “metaperception.”

Next, the way by which individuals make judgments under visual uncertainty can inform many legal fields (Giroux et al., 2016). In addition to the example presented at the onset of this paper, juries are also at risk of showing the bias due to having knowledge of the outcome (or a possible outcome). For example, imagine that police officers happen to witness to a crime through a low-quality dashboard camera. Aware of the outcome, a jury presented with the footage might overestimate the foreseeability of the crime and indict the officers who
were present at the scene. Researchers must continue educating and warning officials about hindsight bias, as its consequences can lead to misinformation and misconceptions about the predictability of real-world events. Some even speculate that we will begin seeing this judgment error when reflecting on the events leading up to the COVID-19 pandemic (Redelmeier & Shafir, 2020), which could lead to wrongful blame on those who “could have seen it coming.” A critical eye must therefore be placed on any research considering the impact of recalled events, and future designs must be capable of robustness against these types of cognitive errors to avoid drawing inaccurate conclusions about the effects of prior events on current mental states.

Limitations

Because data were collected remotely, I was unable to monitor and assess participant performance during the experiments. While this is a limitation of the study and likely had the benefit of decreasing any demand characteristic confounds, conducting an in-person study decreases participant confusion regarding the instructions of each phase. The blurring methods and stimuli used in the present study were different from either study being replicated; blur levels being captured (i.e., Gaussian filter frames versus $f_i$ values) may have different sensitivities. However, the effect does not appear to be impacted by online data collection after having replicated Harley et al. (2004) in Experiment 1.

Future Directions

Future researchers may wish to implement both memory and hypothetical designs when investigating visual hindsight bias, as the present study only employed the former. Studies using both designs and implementations can assess different, overlapping mechanisms that contribute to the bias. A follow-up study is planned using emotional faces with varying degrees
of emotion in a hypothetical design to evaluate whether there will still be a lack of hindsight bias for happy faces. Another avenue of research could test the effects of both conceptual and perceptual fluency of emotional faces by displaying both upright and inverted faces as was done in Bernstein and Harley (2007). To provide additional insight into underlying mechanisms of the bias, researchers should continue to use a combination of behavioral and physiological measures when studying visual hindsight bias, as this has only been done once using eye-tracking techniques (Wu et al., 2012).

**Figure 9**

*Experiments 2 and 3 Hindsight Ratios*

A

B

*Note.* Panel A: Hindsight ratios, calculated as a ratio between the mean number of frames in baseline identification and the memory test, for each emotion in Experiment 2. Panel B: Hindsight ratios as a function of emotion (angry and happy) and difficulty (easy and difficult) in Experiment 3.
Conclusion

The present study contributes to the growing body of literature examining hindsight bias in the visual domain and provides further evidence that individuals aided with outcome knowledge overestimate their perceptual abilities in hindsight. It is concluded that the perceptual ease in identifying happy faces, as compared to angry and other emotional faces, results in no hindsight bias. The present set of results make it clear that this judgment error is quite universal and is modulated by stimulus factors including emotional valence and perceptual processing. We hope that the present study serves as a catalyst to further investigations of what other perceptual factors might influence visual hindsight bias. To conclude, I must ask: Did you really see it coming?
References


*Hindsight bias for emotional faces.* The 61st annual meeting of Psychonomic Society, Virtual.


