Journal of Experimental Child Psychology 217 (2022) 105346

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Auditory hindsight bias in school-age children

Cristina Gordo [a,*], Sergio Moreno-Ríos [a], Hartmut Blank [b]

[a] *Department of Developmental and Educational Psychology, University of Granada, 18071 Granada, Spain*
[b] *Department of Psychology, University of Portsmouth, Portsmouth, Hampshire PO1 2UP, UK*

ARTICLE INFO

Article history:
Received 16 March 2021
Revised 1 December 2021
Available online 17 January 2022

Keywords:
Auditory hindsight bias
Children 's cognitive biases
Hypothetical design
Memory design
Priming
Fluency

ABSTRACT

We report two experiments investigating hindsight bias in children, focusing on a rarely studied age range of 8–13 years. In Experiment 1, we asked children to complete both an auditory hindsight task and a visual hindsight task. Children exhibited hindsight bias in both tasks, and the bias decreased with age. In Experiment 2, we further explored children 's auditory hindsight bias by contrasting performance in hypothetical and memory designs (which previous research with adults had found to involve different mechanisms—fluency vs. memory reconstruction). Children exhibited auditory hindsight bias in both tasks, but only in the hypothetical design was the bias magnitude modulated by a priming manipulation designed to increase fluency, replicating and extending the pattern found in adults to children.

Introduction

On March 13, 2020, the World Health Organization (WHO) declared COVID-19 a pandemic. During the following months, citizens and political leaders criticized the WHO for having acted too slowly given that the likely outcomes of COVID-19 had been predictable months earlier. But were they predictable? Thinking that oneself (or another person) would have been able to predict an outcome (e.g., of COVID-19) can also be due to hindsight bias (Fischhoff, 1975)—people 's tendency to believe, once they know the outcome, that they were able to predict it, claiming that they "knew it all along" (e.g., Bernstein, Atance, Meltzoff, & Loftus, 2007).

* Corresponding author.
E-mail address: gordogordo@urg.es (C. Gordo).

https://doi.org/10.1016/j.jecp.2021.105346
0022-0965/

Hindsight bias has been documented across cultures (Pohl, Bender, & Lachmann, 2002) and in a large variety of judgment contexts, including medical diagnoses (Arkes, 2013; Arkes, Wortman, Saville, & Harkness, 1981; Dawson et al., 1988), sport events (Blank, Diedenhofen, & Musch, 2015; Gray, Beilock, & Carr, 2007; Leary, 1981), legal decisions (Harley, 2007; Hawkins & Hastie, 1990; Kamin & Rachlinski, 1995), election outcomes (Blank, Fischer, & Erdfelder, 2003; Blank & Nestler, 2006; Leary, 1982), and consumer satisfaction surveys (Zwick, Pieters, & Baumgartner, 1995). In addition, hindsight bias has been obtained with different stimuli, including verbal (e.g., Fischhoff, 1975; Nario & Branscombe, 1995; Nestler & von Collani, 2008; Roese & Olson, 1996), visual (e.g., Bernstein, Atance, Loftus, & Meltzoff, 2004; Harley, Carlsen, & Loftus, 2004), gustatory (Pohl, Schwarz, Sczesny, & Stahlberg, 2003), and auditory (Bernstein, Kumar, Masson, & Levitin, 2018; Bernstein, Wilson, Pernat, & Meilleur, 2012; Higham, Neil, & Bernstein, 2017). Hindsight bias has been studied in both adults and children (see below) using different types of materials but, in the case of children, never auditory stimuli. As in adulthood, communication in childhood is based on oral exchanges. In this context, hindsight bias could lead to errors in oral communication; for example, children could overestimate the clarity of their messages for speakers. Although overconfidence in communication has been widely studied in adults (e.g., Chang, Arora, Lev-Ari, D ‘Arcy, & Keysar, 2010; Keysar, 1994, 2000; Keysar & Henly, 2002; Moreno-Ríos, Rodríguez-Menchen, & Rodríguez-Gualda, 2011), little is known about it in children. In a recent study involving written communication, Gordo and Moreno-Ríos (2019) showed that 8- to 13-year-olds overestimate the ability of a naïve addressee to understand the writer‘s intended message. However, it remains unclear whether children would overestimate the intelligibility of an auditory message, that is, whether children would display auditory hindsight bias. Our aim in the current work was to test whether children exhibit auditory hindsight bias and, furthermore, whether its magnitude changes with age.

Assessing hindsight bias

Two main experimental designs have been used to investigate hindsight bias: memory designs and hypothetical designs. In memory designs, participants first answer questions such as “How tall is Mount Kilimanjaro?” Later, they receive feedback about the solution (e.g., the height of Mount Kilimanjaro is 5895 m). At a third point in time (often directly after receiving feedback), they are asked to remember their foresight judgments. Typically, participants ‘ recollections of their foresight judgments are biased toward the solution feedback they received earlier. By contrast, participants in hypothetical designs are asked to make a hypothetical judgment after having been provided with the solution (“The height of Mount Kilimanjaro is 5895 meters. What would have been your estimate had I not told you?”). In a control condition, participants answer the same questions without solution feedback. Here again, the (hypothetical) hindsight estimates are biased by the solution feedback. Typically, the effects are larger in a hypothetical design than in a memory design (e.g., Fischhoff, 1977; Wood, 1978).

Of particular interest in the context of the current research, there is a social version of the hypothetical design in which participants are not being asked to make hindsight judgments about themselves (i.e., their naïve “prior” self) but rather are being asked about the extent to which naïve others (typically peers) would have known the correct answer to a knowledge question (e.g., “Out of 100 of your peers, how many would have known the correct answer?”). This design variant was first introduced by Fischhoff (1975), who found the magnitude of hindsight bias to be very similar to the one obtained in the traditional hypothetical design. It has been used particularly in research with children because it is arguably more intuitive for them than hypothetical judgments given that it eliminates the introspective demands required in judgments about their naïve “prior” self (Bernstein et al., 2004).

Auditory hindsight bias

In adults, auditory hindsight bias has been tested mainly using the social version of the hypothetical design. Different studies have found that individuals overestimate their peers ‘ ability to identify an auditory target when they receive feedback about the auditory target ‘s identity. For example, Epley et al. (2004) told half of their participants that, in a song by the rock band Queen played backward, it is possible to identify the message "it is fun to smoke marijuana." Informed participants predicted that a higher percentage of their naïve peers would identify the message than uninformed participants did. More recently, several studies assessed auditory hindsight bias using muffled words (e.g., Higham et al., 2017) or sentences (Bernstein et al., 2012). Again, results showed that participants are unable to discard the provided feedback when asked to predict how many of their naïve peers would identify the distorted auditory stimuli (Bernstein et al., 2012, 2018; Higham et al., 2017).

Hindsight bias in children

Hindsight bias research in children has so far used knowledge questions or visual materials as stimuli. For example, Bernstein, Erdfelder, Meltzoff, Peria, and Loftus (2011) asked children to identify, as quickly as possible, blurred objects that progressively became clearer. Thereafter, children were asked to estimate at what point a puppet named Ernie (the naïve other) would be able to identify the same degraded objects. Children claimed that Ernie was able to identify the same objects at a more degraded level than they themselves had been able to do previously. More recently, Ghrear, Fung, Haddock, and Birch (2021) presented children aged 4–7 years with several factual questions (e.g., "Which kind of bird can fly the highest?") and asked them to indicate, on a 5-point visual scale, how many children "about their age" would know the answer. For half the questions, children were informed about the correct answer before making their estimates. Children gave higher estimates in this condition compared with when they were not given solution feedback (Experiments 2 and 3), thereby showing hindsight bias.

Children also showed the bias in memory designs. In these studies, children 's task was to answer several numerical knowledge questions (e.g., "How many countries are there in Africa?"). After receiving solution feedback, they were asked to recall their previous answers. Results showed that children 's recollections of their previous foresight ratings were biased toward the provided feedback (e.g., Bernstein et al., 2011; Pohl, Bayen, Arnold, Auer, & Martin, 2018; Pohl, Bayen, & Martin, 2010). In terms of developmental differences, these and other studies suggest that the magnitude of hindsight bias decreases from 3 to 5 years of age (Bernstein et al., 2004, 2007, 2011; Ghrear et al., 2021, Experiment 2; Pohl et al., 2010). Little is known, however, about the precise development of the bias during middle childhood, the period covered in the current research in 1-year increments. In the case of hypothetical designs, only two studies have explored the bias development during this period and had slightly inconsistent results. Whereas in one study the bias was stable after 6 years (Bernstein et al., 2011), a recent study found a decrease in bias magnitude from 3 years well into adolescence (Bernstein, 2021).

Experiment 1

The goal of the current work was to investigate auditory hindsight bias in schoolchildren and to find out whether the bias magnitude changes (or not) with age. To this end, we created a task involving songs that seemed to contain "hidden messages." Such hidden messages are sound patterns resembling sentences that (particularly with information about the supposed content of the "sentence") can be "heard" when a song is played backward, for example (see Epley et al., 2004). In some trials, the songs were played without information about the content—the foresight judgments (FJ) condition. In others trials, children were informed about the message content (e.g., "There are no tomatoes in your garden") before playing the song—the hindsight judgments (HJ) condition. Like Ghrear and colleagues (Ghrear et al., 2021; Ghrear, Chudek, Fung, Mathew, & Birch, 2019), we asked children to make predictions about their peers ' performance. Specifically, in all conditions the children 's task was to estimate how many members of a group of six naïve same-age peers would be able to identify the hidden message in each song.

To allow comparisons with the only study that explored the bias in this age range using a hypothetical design (Bernstein et al., 2011), we also included a visual hindsight bias task. Children were shown pictures of celebrities and were asked to estimate how many members of a group of six naïve peers would recognize these celebrities. For half the pictures, children made their judgments without identity information (FJ condition); for the other half, they received feedback about the celebrities ' identities before making their judgments (HJ condition). Previous visual hindsight bias tasks used (a) visual images and (b) visual outcome feedback, whereas auditory hindsight bias tasks used (a) auditory stimuli but (b) propositional/verbal outcome knowledge (e.g., distorted words ' identity). To directly compare the two biases in children, we used visual images and auditory stimuli but always provided propositional/verbal outcome knowledge. Unlike in previous research on visual hindsight bias, therefore, there was no need to degrade or distort the visual stimuli in our tasks.

We tested children from third grade (~8 years of age) onward for several reasons. First, although it seems clear that hindsight bias decreases from 3 to 5 years (Bernstein et al., 2004, 2007, 2011), the bias trajectory during middle and late childhood using a hypothetical design needs further exploration (cf. Bernstein et al., 2011, vs. Bernstein, 2021). Second, although metacognitive skills develop during early childhood, one aspect takes longer—source monitoring, or the ability to accurately attribute the origins of one 's memories, knowledge, and beliefs (Johnson, Hashtroudi, & Lindsay, 1993; Lindsay, 2008). This skill is crucial in the current study because the question is whether children will attribute their recognition of the hidden messages to the information provided by the experimenter or to their own unaided understanding. Several studies indicate that there is an increase in this skill from about 4 to 8 years of age (Drummey & Newcombe, 2002; Ruffman, Rustin, Garnham, & Parkin, 2001; Sluzenski, Newcombe, & Ottinger, 2004), but little is known about its later development. Third, before 7 years of age, children 's judgments of the frequency of events are poor (Sharman, Powell, & Roberts, 2011). Given that we asked children about frequencies (how many peers?), we needed to ensure that children had a basic grasp of frequency judgments.

Based on the available previous research (e.g., Bernstein et al., 2004, 2007, 2011), we expected that children aged 8–13 years would exhibit both auditory and visual knowledge hindsight bias and at a relatively stable level (Bernstein et al., 2011), but in light of the sparsity of research on the development of hindsight bias and source monitoring over this age range, we kept an open mind.

We included a further experimental condition in the auditory task as a test of the robustness of auditory hindsight bias in children. In research with adults, Bernstein et al. (2018, Experiment 2) found that providing participants with an initial unaided identification trial before they made their hindsight judgments successfully reduced auditory hindsight bias. Similarly, we included a condition where children listened to the same song twice (two-hearings condition), first without knowing the message content (two-hearings foresight judgments [Two-FJ] condition) and then for a second time after being informed about it (two-hearings hindsight judgments [Two-HJ] condition). Although children 's ability to predict the knowledge of other, less informed persons is limited compared with adults (Hayashi & Nishikawa, 2019), it has been shown that children 's empathy increases as a result of personal experience (Chambers & Davis, 2012; Gerace, Day, Casey, & Mohr, 2015). Thus, personally experiencing the difference in detection difficulty between the foresight (Two-FJ) and hindsight (Two-HJ) hearings might promote children 's perspective taking and perhaps subsequently reduce hindsight bias. On the other hand, other research in adults has shown that auditory hindsight bias and hindsight bias in general persist despite instructions or opportunities to avoid it (Bernstein et al., 2012; 2018, Experiment 3; Harley et al., 2004; Pohl & Hell, 1996); thus, we treated this issue as exploratory.

Method

Both our studies (Experiments 1 and 2) were approved by the university 's ethical review board (Comité de Ética en Investigación Humana de la Universidad de Granada).

Participants

A total of 99 schoolchildren (46 girls and 53 boys) aged 8–13 years completed the auditory and visual identification tasks (third grade: $n = 27$, $M = 8.60$ years, $SD = 0.51$; fourth grade: $n = 23$, $M = 9.70$ years, $SD = 0.70$; fifth grade: $n = 23$, $M = 10.43$ years, $SD = 0.51$; sixth grade: $n = 26$, $M = 11.70$ years, $SD = 0.70$). All the participants were native speakers of Spanish. One participant was excluded from the visual identification task sample for not answering all items. Therefore, the visual identification task sample consisted of 98 participants (46 girls and 52 boys).

Participants were recruited from two schools in the province of Granada. Each school had one class of about 25 pupils per grade. All third- to sixth-grade children and their parents were invited to participate (consent by both children and parents was required for participation). We carried out a sensitivity power analysis using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) to determine the minimum hindsight bias effect size required for statistical significance. Given the sample size of 99 children, an alpha level of .05, and minimum power of .95, there is a 95% chance of detecting an effect size of f = .213 (η^2 = .028), assuming statistical significance and that such an effect size actually exists.

Design

For both tasks, we used a 2 (Knowledge: foresight or hindsight) × 4 (Grade: third, fourth, fifth, or sixth) mixed design, with the first variable manipulated within participants and the second one manipulated between groups. In the auditory task, the design included an additional variable, namely the type of measure: traditional (FJ and HJ ratings) or two-hearings (Two-FJ and Two-HJ). Accordingly, the design in this task was 2 (Measure: traditional or two-hearings) × 2 (Knowledge: foresight or hindsight) × 4 (Grade: third, fourth, fifth, or sixth), with the first two variables manipulated within participants and the third one manipulated between groups.

Materials

We briefly pilot-tested both the auditory and visual task materials (using the exact same procedure) with adults (N = 22, 8 men and 14 women) before applying them to children. The main purpose of this was to pretest the relative difficulty of the materials and check that the selected excerpts of songs met Epley et al.'s (2004) criterion (see below). In both tasks, the outcome feedback was provided by the experimenter; hence, the tasks differed only in the stimuli used (auditory or visual).

Auditory task. A total of 21 excerpts of songs with a "hidden message" served as auditory stimuli. Songs were selected following Epley et al. (2004): "The selection played for participants is sufficiently unclear to ensure that very few (if any) of those who were not told about the critical phase would hear it on their own, but virtually everyone told about the phrase in advance would have no difficulty detecting it" (p. 333). Of these 21 songs, 13 were in Spanish and 8 were in English. The hidden message in the Spanish songs could be heard when the song excerpt was played backward (see https://www.youtube.com/watch?v=TvhCThWWy3Q for an illustrative English example). Conversely, in the English-language songs, the hidden message could be heard when the song excerpt was played forward.[1] See https://osf.io/a76ct/?view_only=e18b8871c6d44e2c9473505ef065c96a for an example of the materials used in this experiment.

On the basis of the pilot study, we arranged the auditory stimuli into three sets of 7 songs according to the difficulty of identifying the hidden message (based on adults ' responses in the FS judgment condition of the pilot study). Because information about the hidden messages will have more impact in songs with harder-to-detect messages (as compared with songs with easy-to-detect messages), it was necessary to match the difficulty of the songs across conditions. To this end, we counterbalanced the assignment of the three song sets (7 songs per set) to experimental conditions, resulting in three different slideshow presentations (A, B, and C). Specifically, in the FJ condition, the song excerpts were played and children provided their estimates after each song without hidden message information. In the HJ condition, children were given hidden message information before each song and then provided their estimates. Finally, in the two-hearings condition, children listened to the same song excerpt twice: first without being informed of the message (Two-FJ) and second after being informed (Two-HJ) (see Fig. 1). Thus, in this condition, children provided two estimates concerning the same song: one without (Two-FJ) and one with (Two-HJ) hidden message information.

[1] This made use of a popular Spanish pastime—discovering Spanish-sounding phrases in English-language songs. For example, the line "Their innocence will pull me through," appearing at 1:17 in the song *De Do Do Do, De Da Da Da* by The Police, sounds to Spanish ears like "Bebiendo Schweppes, como mejor" ("Drinking Schweppes, I eat better"). We leave it to the readers to decide whether such misperceptions reflect poor language skills of Spanish listeners or poor articulation by British singers. The main point for our purposes is that listeners can clearly detect the Spanish sentence once they are informed about it.

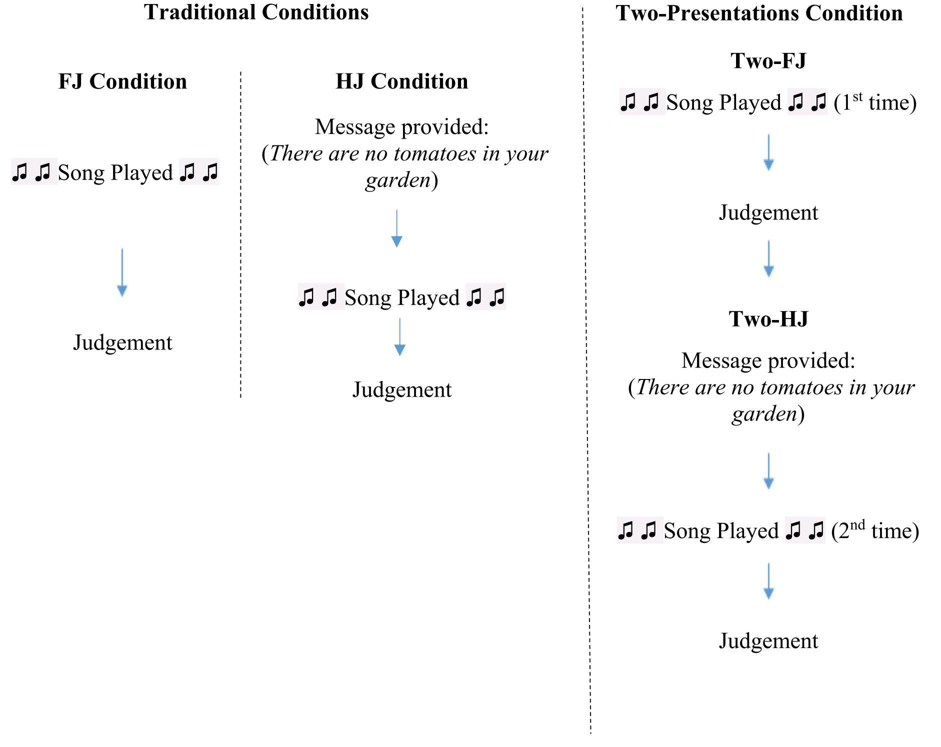

Fig. 1. Auditory hindsight bias task: Experimental procedure per condition—foresight judgments (FJ), hindsight judgments (HJ), and two-hearings conditions. The English translation of the message in the example is "There are no tomatoes in your garden."

In each slideshow presentation, the song excerpts appeared in random order. In noninformation trials (FJ and Two-FJ), the slides contained only the trial number (e.g., Song 3). In information trials (HJ and Two-HJ), the slides further included the sentence that seemed to be included in the specific song (the hidden message). Children were assigned to one of the slideshow presentations (A, B, or C) sequentially following the order of arrival to the experiment. They provided their answers in a booklet containing 21 scales from 0 to 6 by circling the respective number. Each scale was preceded by a song number (e.g., Song 3).

Visual identification task. A total of 24 pictures of celebrities from politics, music, sports, and literature were selected (e.g., Margaret Thatcher, Keith Richards) and combined into two slideshow presentations. The selected celebrities were famous enough for children to have heard of them but were sufficiently unfamiliar to rule out the possibility that all same-age peers would immediately recognize them (which might have been the case with, say, Hannah Montana or Sponge Bob).

In each presentation, we provided children with feedback about the identity of 12 celebrities (HJ stimuli). No information was provided about the identity of the 12 remaining pictures (FJ stimuli). Each slideshow included six blocks composed of 4 pictures each (e.g., George Bush, Angela Merkel, Cristina Kirchner, and Tony Blair). In each block (see Fig. 2), children received information about the identity of two celebrities (e.g., Angela Merkel and Tony Blair), whereas no information was provided about the remaining celebrities (e.g., George Bush and Cristina Kirchner); this assignment was counterbalanced across participants. A detailed instruction sheet ensured that all groups received the same instructions and the same amount of information for each celebrity (e.g., "This is George Bush. He was president of the USA").

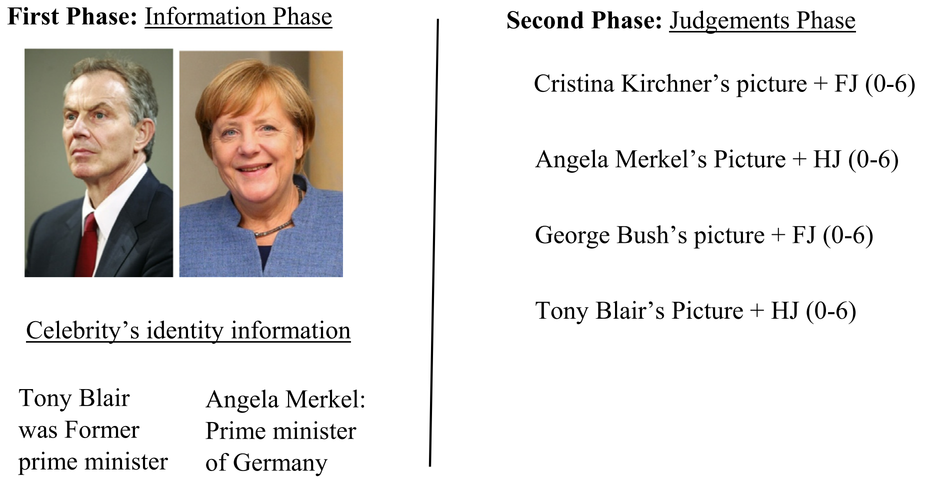

Fig. 2. Visual task: Experimental procedure per trial in the information and judgment phases. FJ, foresight judgments; HJ, hindsight judgments.

Procedure

The two tasks were applied in the same experimental session in a counterbalanced order. Children were tested in a quiet room in groups of 3–5. We started each experimental session explaining the task and the meaning of the scale: "Your task is to indicate, on a scale like this one, how many of a group of six naïve same-age peers would identify the 'hidden message ' in the songs (or recognize the celebrity 's identity)." We defined naïve peers as "classmates who are not present in the room and who therefore do not have the information about the message that I will give you." In both tasks, before completing the experimental trials, children completed two practice trials in order to check whether they had understood the meaning of the scale. The practice trials involved questions with clear and unambiguous answers (e.g., "How many of your same-age peers would recognize Dani [the principal of their school]?"). Once all children had answered the practice trials satisfactorily (partly after having received further explanation and two more practice trials as necessary), the main task started.

Auditory task. The task began with the following instructions: "Now, we will listen to some songs. Some people say there are 'hidden messages ' in these songs. In some cases, I will tell you the message people say can be heard, whereas in other cases I will not tell you anything about the content of the message. Moreover, there will be some cases in which I will play the same song twice. In these cases, in the first playback I won 't tell you the content of the message, but I will do before playing the song for the second time." Thereafter, children completed the experimental trials.

In traditional FJ trials, the song (excerpt) was played once and children provided their ratings (by circling a number on the scale) without receiving any information about the content of the hidden message. In the traditional HJ trials, the experimenter told children about the content of the hidden message before playing the song ("In this song, some people say you can hear 'There are no tomatoes in your garden '"). The message also appeared written on the screen while the song was played. Once children had heard the song, the experimenter asked them to provide an estimate of the number of peers who would identify the hidden message in the song. Finally, in the two-hearings condition trials, the same song excerpt was played twice. After the first time, children provided foresight ratings without any information about the message content (Two-FJ). Then the experimenter told children about the content of the hidden message and the song was played again, after which children provided their hindsight ratings (Two-HJ). As in the traditional HJ trials, the message also appeared on the screen while the song was played. Before each hindsight rating, we reminded children that they should think of same-age peers who do not have any information about the content of the message.

Visual identification task. Like the auditory task, this task started with a general task explanation before completing the experimental trials: "Now I will show you two pictures of celebrities. I will introduce them to you first, and then these celebrities and two additional celebrities will appear on the screen one by one. Your task will be to circle on the scale the number of classmates who would be able to recognize each celebrity. Remember that you should think of classmates who were not present in the room and, therefore, did not receive the information about the celebrities that I will give you." After that, children began the experimental trials.

As mentioned above, each presentation included six blocks, each of which comprised 4 pictures. At the beginning of each block, 2 pictures of celebrities appeared on the screen and were introduced to the children (e.g., "This is George Bush. He was president of the USA"). Presenting the pictures in pairs minimized the length of each block. After that, in the second phase of the block, 4 pictures (these and 2 others) were presented to children one by one on-screen and they made their judgments. Before each judgment, the experimenter reminded children that they should ignore the identity feedback received at the beginning of the block when making their judgments.

Results

Auditory task

As explained above, children provided four different judgments: the two traditional hindsight judgments (FJ and HJ) and the two judgments in the two-hearings condition (Two-FJ and Two-HJ). For each type of auditory judgment (traditional and two-presentations), we created a magnitude of bias score for each child by subtracting his or her average score in the foresight trials (FJ or Two-FJ) from the respective average in the hindsight trials (HJ or Two-HJ) (Bernstein et al., 2011). Thus, we obtained two different hindsight bias measures: a traditional bias measure and a two-presentations bias measure.

The judgments were submitted to a 2 (Measure: traditional or two-hearings) × 2 (Knowledge: foresight or hindsight) × 4 (Grade: third, fourth, fifth, or sixth) mixed analysis of variance (ANOVA), with the first two variables being manipulated within participants. This overall ANOVA revealed main effects for measure, $F(1, 95) = 4.28$, $p = .041$, $\eta^2 = .04$, knowledge, $F(1, 95) = 599.22$, $p < .001$, $\eta^2 = .86$, and grade $F(3, 95) = 9.72$, $p < .001$, $\eta^2 = .24$. Interestingly, the interaction between measure and knowledge was not significant, $F(1, 95) = 0.04$, $p = .836$, $\eta^2 = .01$, meaning that the bias magnitude did not differ between the two measures. We also obtained a significant three-way interaction among these factors, $F(1, 95) = 4.29$, $p = .007$, $\eta^2 = .12$; therefore, we subsequently analyzed participants ' responses in the traditional hindsight and two-hearings conditions separately.

Children 's estimates of the numbers of same-age peers who would identify the message in the traditional conditions (FJ and HJ) were submitted to a 2 (Knowledge: foresight or hindsight) × 4 (Grade: third, fourth, fifth, or sixth) mixed ANOVA. Results are shown in Table 1. The analysis revealed a strong main effect for knowledge, $F(1, 95) = 475.84$, $p < .001$, $\eta^2 = .83$; participants stated that a higher number of peers would identify the hidden message when they were informed about its content in advance. This is the *traditional hindsight bias effect.* The interaction with grade was also significant, $F(3, 95) = 8.43$, $p < .001$, $\eta^2 = .21$. Further analysis of the interaction showed a significant cubic trend, $M = 0.67$, 95% confidence interval (CI) [0.22, 1.11], reflecting different amounts of hindsight bias across the age groups. Post hoc comparisons (using Bonferroni correction for multiple comparisons, resulting in an adjusted alpha of .008) revealed that third graders and fourth graders exhibited more bias than sixth graders, $F(1, 52) = 10.21$, $p = .002$, $\eta^2 = .17$ and $F(1, 48) = 20.71$, $p < .001$, $\eta^2 = .31$, respectively. In addition, fourth graders showed more bias than fifth graders, $F(1, 44) = 12.67$, $p = .001$, $\eta^2 = .22$. No other significant differences were found.

The same analysis was performed on the ratings in the two-hearings condition (see Table 2) and revealed main effects for knowledge, $F(1, 95) = 427.88$, $p < .001$, $\eta^2 = .82$, and grade, $F(3, 95) = 8.99$, $p < .001$, $\eta^2 = .22$. Again, children exhibited hindsight bias; after being told about the content of the hidden messages, they thought a higher number of their peers would be able to identify these. Unlike

Table 1
Auditory task: Mean ratings (and standard deviations) in the traditional foresight and hindsight judgment conditions and bias magnitudes (and standard deviations) per grade.

	FJ condition	HJ condition	Bias magnitude
Third grade	2.29 (1.16)	4.93 (1.02)	2.64 (0.98)***
Fourth grade	2.07 (0.99)	5.19 (0.59)	3.12 (1.12)***
Fifth grade	2.24 (1.13)	4.09 (1.28)	1.85 (1.30)***
Sixth grade	3.57 (0.22)	5.39 (0.69)	1.82 (0.88)***
Total	2.56 (1.26)	4.92 (1.04)	2.35 (1.19)***

Note. FJ, foresight judgments; HJ, hindsight judgments.
*** $p < .001$.

Table 2
Auditory task: Mean ratings (and standard deviations) in the two-hearings foresight and hindsight judgments conditions and bias magnitudes (and standard deviations) per grade.

	Two-FJ condition	Two-HJ condition	Bias magnitude
Third grade	2.88 (1.39)	5.23 (0.95)	2.34 (1.11)***
Fourth grade	2.42 (1.02)	5.01 (1.00)	2.60 (1.35)***
Fifth grade	2.05 (1.02)	4.26 (1.16)	2.21 (1.07)***
Sixth grade	3.31 (1.10)	5.51 (0.40)	2.20 (0.94)***
Total	2.69 (1.23)	5.02 (1.01)	2.33 (1.12)***

Note. Two-FJ, two-hearings foresight judgments; Two-HJ, two-hearings hindsight judgments.
*** $p < .001$.

in the previous ANOVA, however, there was no interaction with age here (although descriptively the pattern of bias magnitudes was the same; in fact, there is a perfect rank order correlation of the bias means in Tables 1 and 2).

Visual identification task

The findings obtained in the visual identification task were submitted to a 2 (Knowledge: foresight or hindsight) $\times$ 4 (Grade: third, fourth, fifth, or sixth) mixed ANOVA and are shown in Table 3. Furthermore, as in the auditory task, we created a magnitude of bias score by subtracting each child 's average score in foresight trials from the average in hindsight trials (Bernstein et al., 2011). There was a main effect for the knowledge factor, $F(1, 98) = 327.48$, $p < .001$, $\eta^2 = .78$; children 's ratings were higher for introduced celebrities than for celebrities whose identity had not been explained. This is the hindsight bias effect. The interaction with grade was also significant, $F(3, 94) = 13.82$, $p < .001$, $\eta^2 = .31$, and included a significant quadratic component, $M = -0.69$, 95% CI [-1.13, -0.24]. Post hoc comparisons (using the same Bonferroni correction and adjusted alpha of .008 as in the auditory task) revealed that all other age groups showed more bias than sixth graders: third graders, $F(1, 52) = 35.61$, $p < .001$, $\eta^2 = .41$, fourth graders, $F(1, 47) = 34.44$, $p < .001$, $\eta^2 = .43$, and fifth graders, $F(1, 47) = 28.32$, $p < .001$, $\eta^2 = .38$. Finally, again the rank order of bias magnitudes was the same as in Tables 1 and 2.

Table 3
Visual identification task: Mean ratings (and standard deviations) in the foresight and hindsight judgments conditions and bias magnitudes (and standard deviations) per grade.

	FJ condition	HJ condition	Bias magnitude
Third grade	2.07 (1.23)	4.56 (1.28)	2.49 (1.26)***
Fourth grade	2.38 (1.30)	5.02 (1.15)	2.65 (1.41)***
Fifth grade	2.37 (0.85)	4.45 (1.04)	2.08 (0.97)***
Sixth grade	3.36 (1.45)	4.21 (1.22)	0.85 (0.62)***
Total	2.55 (1.32)	4.55 (1.20)	1.99 (1.30)***

Note. FJ, foresight judgments; HJ, hindsight judgments.
*** $p < .001$.

Relations between measurements

Three indexes of hindsight bias were computed for each child: a *visual identification* index, a *traditional auditory* index, and a *two-hearings* index. These indexes (each reflecting the difference between children 's ratings in the respective foresight and hindsight judgments conditions) were used to determine whether there were similarities among the three different bias measures. Only children who completed both the auditory and visual tasks (n = 98) were included in this analysis. Results showed a strong positive relation between the traditional auditory index and the two-hearings index (r = .51, p < .001), a moderate relation between the traditional auditory index and the visual identification index (r = .28, p < .001), but no significant relation between the visual identification index and the two-presentations index (r = .17, p = .095).

Discussion

In Experiment 1, we found that auditory hindsight bias (in both conditions: traditional and two-hearings) is present during childhood like other types of hindsight bias (e.g., Bernstein et al., 2004, 2007). Children aged 8–13 years claimed that a higher number of their same-age peers would identify the hidden message when they had been informed about its content previously. Similarly, in the visual identification task, children claimed that more same-age peers would recognize the celebrities when they had received feedback about their identity in advance. Furthermore, it seems that in childhood, as much as in adulthood, hindsight bias is a phenomenon that is hard to eliminate or even reduce. In fact, hindsight bias was present even when children experienced how difficult it is to identify the message without outcome feedback (two-hearings condition). Thus, it seems that letting children personally experience the difficulty of detecting a specific auditory message does not make them attribute the same difficulty to other children.

In addition, in general agreement with a recent study that assessed the bias in this age range using hypothetical designs (Bernstein, 2021), we found that hindsight bias decreased over the age range we observed. Specifically, in all three tasks, hindsight bias peaked in fourth graders (∼9 years of age) and then declined. This result is consistent with Lagattuta, Sayfan, and Blattman 's (2010) finding that from 6 to 9 years of age children tend to overly rely on their own previous personal experiences when asked to predict or explain behaviors or mental states. Thus, younger children 's larger bias may reflect this tendency to base judgments of others ' mental states on their own personal experiences.

Returning to the two auditory biases (traditional and two-hearings), although the pattern of findings was largely similar in these conditions, it remains an open question whether the underlying processes are comparable. Relevant clues to answering this question come from auditory hindsight bias research with adults linking different hindsight designs (hypothetical and memory) to different underlying cognitive processes. Specifically, hindsight bias in hypothetical designs (corresponding to our traditional auditory hindsight condition) has been linked to misattributed processing fluency (e.g., Bernstein et al., 2018; Higham et al., 2017); target knowledge facilitates processing of the auditory target (creating subjective fluency) and in turn leads to overestimating target identifiability (fluency misattribution). By contrast, hindsight bias in memory designs more strongly depends on how the pre-feedback judgments are recollected (if possible) or reconstructed (e.g., Higham et al., 2017).

Our two-hearings condition can be seen as a hybrid between a hypothetical design and a memory design. On the one hand, as in the traditional (social) hypothetical task, participants made hypothetical judgments about a group of peers, unlike in a memory design where participants are asked to *remember* their first judgments. On the other hand, the intended effect of the first, unaided listening experience should depend on participants ' ability to remember/reconstruct it, and in this respect the two-hearings condition resembles a memory design. It is possible that this hybrid design then produces a hybrid auditory hindsight bias that depends on both fluency and memory processes. We designed Experiment 2 to follow up this question and learn more about the involved cognitive mechanisms by contrasting a (slightly modified but conceptually equivalent) two-hearings condition with a proper memory design and using a priming procedure to assess the role of processing fluency. It was also of interest to see whether the hindsight bias age trajectory observed in Experiment 1 would replicate in a different sample of children.

Experiment 2

In recent research, fluency misattribution has been suggested as a mechanism underlying auditory hindsight bias in hypothetical designs (Bernstein et al., 2018; Higham et al., 2017). The idea is that outcome knowledge facilitates the processing of a distorted auditory target, creating subjective fluency. This subjective fluency makes participants think that the auditory target is easier to identify than it really is and, therefore, that others should also be able to identify it. Researchers used either *conceptual priming* (Higham et al., 2017) or *repetition priming* (Bernstein et al., 2018) to demonstrate the role of fluency based on the following logic. Both priming and outcome knowledge are known to facilitate the processing of the auditory stimulus and create subjective fluency. However, their effects are not additive; there is little or no benefit of using both priming and outcome knowledge in terms of fluency (Bernstein et al., 2018). That is, increases in fluency due to outcome knowledge (leading to hindsight bias) should be less pronounced if fluency has already been heightened by priming (Higham et al., 2017) or repetition priming (Bernstein et al., 2018). As a consequence, the (auditory) hindsight bias should be smaller in a priming (vs. no-priming) condition, which would indirectly confirm the dependence of hindsight bias on fluency.

In their research, Higham et al. (2017) presented participants with semantically related (e.g., nurse–high fluency) and unrelated (e.g., grass–low fluency) prime words before playing muffled versions of target words (e.g., "dtr" for doctor). In the hindsight phase, participants heard a clear version of a target word before hearing the prime word (related or unrelated) and the muffled version of the target word. Their task was to estimate how many of their naïve peers would be able to identify the muffled words without target knowledge. Results showed that prime relatedness interacted with auditory hindsight bias; whereas the bias was found for related and unrelated prime trials, the effect was smaller in the related prime trials than in the unrelated ones. Crucially, Higham et al. also used the same procedure to test priming effects in the memory design (with otherwise identical materials) but found only two independent main effects for priming and knowledge. By implication, this confirms the unique role of fluency in auditory hindsight bias according to the logic set out above.

Higham et al. (2017) further argued that, in the memory design, (auditory) hindsight bias can be compared with memory distortion phenomena such as the *misinformation effect* (Loftus, Miller, & Burns, 1978; Pohl & Gawlik, 1995) in that both effects crucially rely on memory reconstruction processes. Thus, priming does not moderate the bias in these designs because it arises from memory reconstruction rather than fluency; in turn, this reinforces the idea that different processes underlie hindsight bias in memory and hypothetical designs.

More recently, Bernstein et al. (2018) further studied the role of fluency in hypothetical designs and found that (a) repetition priming (i.e., priming the target word by itself) produced similar effects to conceptual priming (i.e. through related words) and (b) the modulating effect of repetition priming was independent of the number of repetitions (one, three, or six). Because conceptual priming would be difficult to realize for the "hidden messages" that we used in Experiment 1 (and that we wanted to keep for reasons of comparability), we used repetition priming for our priming manipulation in Experiment 2. Before providing foresight and hindsight judgments, children heard a recording that contained clearly spoken versions of some of the target messages that seemed to be included in the songs, increasing processing fluency for those targets.

Overall, the procedure in Experiment 2 was conceptually similar to the two-hearings condition in Experiment 1 with some necessary adaptations due to the new priming manipulation and memory design. First, in the hindsight phase, children provided hypothetical judgments (as in Experiment 1) for only half the trials. In the remaining trials, they were asked instead to *recall their foresight ratings.* That is, the two-hearings condition from Experiment 1 was split into two versions differing only in the nature of the hindsight task; hypothetical (i.e., estimating how many peers would recognize the hidden message without outcome knowledge) versus memory (i.e., remembering one 's own foresight judgment). Second, to accommodate priming phases and to provide meaningful retention intervals for the memory design, the foresight and hindsight phases of the auditory task were implemented as separate blocks (not immediately following each other for a given song/message as in Experiment 1). Third, the priming procedure also required some necessary minor adaptations of the stimulus materials (see Method section for details). Lastly, we asked questions probing the understanding of task instructions and the identification of the messages as a check of the priming manipulation (Bernstein et al., 2018; Higham et al., 2017).

If different processes underlie hypothetical and memory auditory hindsight biases not only in adulthood but also in childhood (and if our two-hearings condition in Experiment 1 otherwise "behaves" like a traditional hypothetical design), then we should expect to find a similar pattern of effects as in the research above, that is, two independent main effects for priming and knowledge in the memory design and an interaction between these two factors in the (two-hearings) hypothetical design, specifically in the form of a smaller hindsight bias effect for priming messages as compared with no-priming messages (Higham et al., 2017).

Regarding developmental trajectories, we expected to find, as in Experiment 1, a decrease starting around fifth grade for the hypothetical design. Regarding the memory design, results from previous research are contradictory. Whereas in some studies the bias was stable during middle and late childhood (Bernstein et al., 2011; Pohl et al., 2010), a recent study found a decrease in the magnitude of the bias from 9 to 12 years of age (Pohl et al., 2018). Therefore, we did not make any specific prediction for the developmental trend in these designs. Finally, we expected that in both hypothetical and memory tasks the number of hidden messages identified would be higher for priming songs than for no-priming songs (Higham et al., 2017).

Method

Participants and design

A total of 197 children (103 boys and 94 girls) aged 8–13 years participated in the study. All of them were native speakers of Spanish. Of this original sample, 19 children were excluded from analysis for answering comprehension questions incorrectly. Thus, our final sample consisted of 178 participants (94 boys and 84 girls) (third grade: n = 35, M = 8.49 years, SD = 0.51; fourth grade: n = 45, M = 9.47 years, SD = 0.50; fifth grade: n = 52, M = 10.54 years, SD = 0.58; sixth grade: n = 46, M = 11.43, SD = 0.54). Two other schools in the province of Granada (with one and two groups per grade, respectively) were invited to participate in the study. As in Experiment 1, all children who wanted to participate and obtained their parents ‘ agreement were included in the study. Again, we carried out a sensitivity power analysis (assuming an alpha level of .05 and minimum power of .95). With our sample size of 178 children, we had a 95% chance of detecting an effect size of f = .157 (η^2 = .043).

Within each grade, children ‘s participation followed a 2 (Knowledge: foresight or hindsight) × 2 (Task: hypothetical or memory) × 2 (Priming: no-priming or priming). All these factors were manipulated within participants.

Materials

In this experiment, we used only English-language songs in order to avoid lexical interference between the (English) lyrics and the (Spanish) primes. Thus, the auditory stimuli consisted of 12 English-language songs that seemed to contain a message; these were the 8 English-language songs from Experiment 1 and 4 new songs of the same kind. The songs were randomly split into four sets of 3 and were assigned to the four experimental conditions and phases of the experiment as illustrated in Table 4. As shown in the table, 6 songs were used in the hypothetical task (3 with priming and 3 without priming), and the other 6 songs appeared in the memory task (3 with priming and 3 without priming). These stimulus sets were combined into four different counterbalanced presentations to ensure that each set of materials was used equally often in each task and condition.

Each task involved four phases: a foresight phase, a hindsight phase, and two priming phases. Like Higham et al. (2017), we aimed to increase the fluent processing of the auditory targets in both foresight and hindsight judgments. However, our repetition priming did not allow us to present the primes *immediately* before each foresight and hindsight judgment as in Higham et al. (2017); this would have practically eliminated the difference between prime and target knowledge. Therefore, we included two separate priming phases to ensure that the expected priming effect was present while children made both foresight and hindsight judgments.

Table 4
Assignment of stimulus materials to hindsight tasks and conditions across phases in Experiment 2.

Task/condition	Phase 1 (priming)	Phase 2 (foresight judgments)	Phase 3 (priming)	Phase 4 (hindsight judgments)
Hypothetical/priming	3 sentences (e.g., Set A)	3 songs (e.g., Set A)	3 sentences (e.g., Set A)	3 songs (e.g., Set A)
Hypothetical/no-priming	–	3 songs (e.g., Set B)	–	3 songs (e.g., Set B)
Memory/priming	3 sentences (e.g., Set C)	3 songs (e.g., Set C)	3 sentences (e.g., Set C)	3 songs (e.g., Set C)
Memory/no-priming	–	3 songs (e.g., Set D)	–	3 songs (e.g., Set D)

Note. The hypothetical and memory hindsight bias tasks were run consecutively (in counterbalanced order). Orthogonal to this, the assignment of stimulus sets to tasks and conditions was also counterbalanced (by rotating through the scheme). The materials in each set consisted of songs played backward, each of which supposedly contained a "hidden message" that corresponded to the sentences used in the priming phases.

For the priming phases, we created four different recordings (corresponding to the four stimulus sets above) that included spoken versions of the hidden messages for half the target songs in a clear female voice. In each recording, the hidden message (a sentence) was repeated three times for three of the targets. Thus, each recording included a total of nine sentences. The sentences were separated by 1-s breaks and appeared in random order but with the restriction that the same message must not appear consecutively. In the foresight phase, the songs appeared one by one together with a song number (e.g., Song 1). In the hindsight phase, the slides also included the sentence (the hidden message) that could be "heard" in each song.

For both the hypothetical and memory tasks, children provided their answers in a booklet similar to the one used in Experiment 1. The booklet also included a message identification question after each foresight judgment ("Did you hear a message in the song? If so, write it down") and two instruction comprehension questions at the end of each hindsight phase: (1) "In this activity, your task was (a) to remember your ratings from Activity 1 [i.e., the foresight ratings], (b) to guess how many of your peers would identify the 'hidden message ', (c) I can 't remember" and (2) "When answering the questions where you were asked to think of six of your peers—did these peers receive any information about the content of the 'hidden message '? Yes/No."

Procedure

Children were tested in a quiet room in groups of 3–5. Both hindsight task conditions were applied in the same experimental session in a counterbalanced order. The session started with explaining the tasks and the meaning of the response scale to the children.

Unlike traditional priming manipulations, in which the prime (the message) is presented immediately before the target (the song), we presented all primes in separate independent phases. With this "unspecific" priming method, participants listened to all messages together before starting the foresight and hindsight phases of the hypothetical and memory tasks. Crucially, this method allowed us to differentiate the identity priming from target knowledge, which appeared linked to a specific target.

The procedure was the same in the hypothetical and memory task conditions. Both conditions started with a priming phase in which children listened to the clear spoken version of three of the hidden messages as described above. Children were told, "Now I will play a recording. You should listen to it carefully because it is going to give you some clues about the hidden messages that people say can be heard in these songs." Immediately after the recording, the foresight phase started. Six songs were played one by one, and children provided their estimates. After each estimate, children answered the message identification question (see above). Once they had completed the foresight phase, the second priming phase started with the same instructions as in the first priming phase, and the same priming recording was played again. Immediately thereafter, they completed the hindsight phase.

In the hindsight phase, the same 6 songs were played in a different order. Before playing each song, we informed children about the content of the song 's hidden message (target knowledge). The message also appeared on the screen while the song was played. The instructions differed between tasks.

In the memory task, children were asked to recall their previous foresight estimates. In the hypothetical task, children were asked to estimate—but ignoring the provided target feedback (as well as the "clues" from the priming phase)—how many members of a group of 6 naïve peers would be able to identify the message. At the end of each hindsight phase, children answered the two instruction comprehension questions (see Materials section).

Results

Identification performance

To explore whether priming increased the number of hidden message identifications in the foresight phases (as a check on the effectiveness of the priming procedure), we conducted a 2 (Priming: no-priming or priming) × 4 (Grade: third, fourth, fifth, or sixth) mixed ANOVA. In this analysis, we included only those participants who had given a positive answer to the message identification question and had attempted to write the message down (n = 175; 98% of our sample). Three independent raters then classified these written messages, awarding 1 point for full identifications (e.g., "There are no tomatoes in your garden"), 0.5 points for partial identifications (e.g., "There are tomatoes in your wardrobe"), and 0 points for missing or mistaken identifications (e.g., "He wears jeans"). The internal consistency (Cronbach 's alpha) of the researchers ' classifications was .98. A fourth rater resolved any disagreements.

From these ratings, we created an index of identification performance from 0 to 6 for each participant, where a rating of 6 means that participants identified all six messages in the respective condition. The analysis yielded a strong main effect for priming, $F(1, 171) = 364.23$, $p < .001$, $\eta^2 = .68$. The identification index was much higher for priming songs (M = 1.96, SD = 1.29) than for no-priming songs (M = 0.13, SD = 0.31). Furthermore, the Priming × Grade interaction was significant, $F(3, 171) = 5.01$, $p < .001$, $\eta^2 = .08$. The trend analysis showed a significant linear component, M = 0.66, 95% CI [0.28, 1.05], showing that the number of identified hidden messages in the priming condition increased with age. Nevertheless, in all grades priming increased children 's message identification success.

Hindsight bias

In the memory task, following common procedure, we removed perfect matches between foresight and hindsight ratings given that these cases of veridical recollection distort the memory hindsight bias index (e.g., Erdfelder & Buchner, 1998; Pohl, 2007). Thus, 20% of responses were removed from this analysis. Note that in our study the retention interval was very short; therefore, the large proportion of veridical recollections is not surprising.

Children 's (remembered in the memory task) estimates of the number of peers who would identify the hidden message were submitted to a 2 (Task: hypothetical or memory) × 2 (Knowledge: foresight or hindsight) × 2 (Priming: no-priming or priming) × 4 (Grade: third, fourth, fifth, or sixth) mixed ANOVA. Results are displayed in Table 5 and Fig. 3. The three-way interaction among task, priming, and grade was significant, $F(3, 139) = 4.72$, $p = .004$, $\eta^2 = .10$. Thus, we decided to analyze participants ' responses to each task independently. Furthermore, for each task, we created a magnitude of bias score for each child by subtracting the child 's average estimate in the foresight phase from the average score in the hindsight phase (Bernstein et al., 2011).

Hypothetical task. Participants ' ratings were subjected to a 2 (Knowledge: foresight or hindsight) × 2 (Priming: no-priming or priming) × 4 (Grade: third, fourth, fifth, or sixth) mixed ANOVA. The analysis showed main effects for knowledge, $F(1, 174) = 103.12$, $p < .001$, $\eta^2 = .37$, and for priming, $F(1, 174) = 162.58$, $p < .001$, $\eta^2 = .48$. Participants claimed that a higher number of peers would identify the message when they were informed about the content of the message just before hearing the song (M = 3.54, SD = 1.21) than when no information was provided (M = 2.52, SD = 1.06), showing auditory hindsight bias. Similarly, children provided higher ratings for priming songs (M = 3.62, SD = 1.09) than for no-priming songs (M = 2.44, SD = 1.07). Importantly, the interaction between knowledge and priming was significant, $F(1, 174) = 6.91$, $p = .009$, $\eta^2 = .03$. Further analysis showed that the hindsight effect

Table 5
Mean peer identification ratings (and standard deviations) for nonpriming and priming songs in foresight and hindsight conditions per grade and bias magnitudes (and standard deviations) in the hypothetical and memory tasks.

	Hypothetical					Memory				
	Foresight		Hindsight		Bias	Foresight		Hindsight		Bias
	No-priming	Priming	No-priming	Priming		No-priming	Priming	No-priming	Priming	
Third grade	1.82	3.20	3.90	4.75	1.81***	2.15	3.16	3.13	3.66	0.74**
	(1.23)	(1.83)	(1.60)	(1.21)	(1.69)	(1.41)	(1.16)	(1.27)	(1.26)	(1.30)
Fourth grade	1.48	3.50	2.93	4.27	1.10***	1.60	2.13	2.29	2.72	0.64**
	(1.13)	(1.56)	(1.54)	(1.23)	(1.58)	(1.15)	(1.57)	(1.80)	(1.67)	(1.16)
Fifth grade	1.97	2.58	3.00	3.76	1.11***	1.97	3.01	2.45	3.34	0.40*
	(1.22)	(1.28)	(1.20)	(1.18)	(1.21)	(0.92)	(1.24)	(1.29)	(1.29)	(1.07)
Sixth grade	2.11	3.56	2.52	3.63	0.26	1.86	2.80	1.97	2.92	0.11
	(1.18)	(1.35)	(1.36)	(1.26)	(1.10)	(1.19)	(1.29)	(1.38)	(1.44)	(0.53)
Total	1.85	3.19	3.04	4.06	1.03***	1.89	2.77	2.42	3.14	0.45***
	(1.20)	(1.54)	(1.48)	(1.28)	(1.48)	(1.17)	(1.37)	(1.49)	(1.45)	(1.05)

* $p < .05$.
** $p < .01$.
*** $p < .001$.

was greater for no-priming songs than for priming songs, although both effects were significant on their own, $F(1, 177) = 92.93$, $p < .001$, $\eta^2 = .34$ and $F(1, 177) = 42.42$, $p < .001$, $\eta^2 = .19$, respectively.

The Knowledge × Grade interaction was also significant, $F(3, 174) = 8.53$, $p < .001$, $\eta^2 = .12$. The trend analysis showed a significant linear component, $M = -1.04$, 95% CI [−1.47, −0.61]. With the exception of sixth graders, $F(1, 45) = 2.45$, $p = .124$, $\eta^2 = .05$, all children showed significant hindsight bias. Finally, there was a weak (and rather uninteresting and difficult to interpret) Priming × Grade interaction, $F(3, 174) = 5.85$, $p < .001$, $\eta^2 = .09$, due to larger priming effects in fourth and sixth graders (see Table 5).

Memory task. The same analysis was performed for participants ' ratings in the memory task[2] (see Table 5) and revealed main effects for knowledge, $F(1, 139) = 29.22$, $p < .001$, $\eta^2 = .17$, and priming, $F(1, 139) = 58.65$, $p < .001$, $\eta^2 = .29$. Participants ' (remembered) ratings were higher in hindsight ($M = 2.78$; $SD = 1.24$) than in foresight ($M = 2.33$; $SD = 1.05$), showing auditory hindsight bias in the memory design. Ratings were also higher for priming songs ($M = 2.96$, $SD = 1.27$) than for no-priming songs ($M = 2.15$, $SD = 1.11$). Furthermore, there was a marginally significant interaction between knowledge and grade, $F(3, 139) = 2.52$, $p = .06$, $\eta^2 = .05$. The trend analysis showed a significant linear component, $M = -0.47$, 95% CI [−0.82, −0.11]. Again here, with the exception of sixth graders, $F(1, 37) = 1.64$, $p = .208$, $\eta^2 = .04$, all children showed significant hindsight bias. Post hoc comparisons revealed that third and fourth graders exhibited more bias than sixth graders, $F(1, 66) = 7.30$, $p = .009$, $\eta^2 = .10$ and $F(1, 72) = 6.49$, $p = .013$, $\eta^2 = .08$, respectively. Crucially, the theoretically important Priming × Grade interaction was *not* significant, $F(3, 139) = 1.91$, $p = .316$, $\eta^2 = .02$.

Discussion

In Experiment 2, we investigated whether the differential pattern of cognitive processes linked to the two hindsight bias designs in adults (i.e., processing fluency in hypothetical hindsight bias and remembering/reconstruction in memory hindsight bias) is already present in children aged 8–13 years. Using repetition priming (Bernstein et al., 2018), we manipulated the fluency with which the hidden

[2] Remember that we excluded 20% of cases from this analysis due to veridical recollection. Including all participants, however, produces the main principal pattern of findings: main effects for knowledge, $F(1, 174) = 27.82$, $p < .001$, $\eta^2 = .13$, and for priming, $F(1, 174) = 86.63$, $p < .001$, $\eta^2 = .33$. Importantly, the interaction between these two factors was not significant either, $F(1, 174) = 1.72$, $p = .191$, $\eta^2 = .01$.

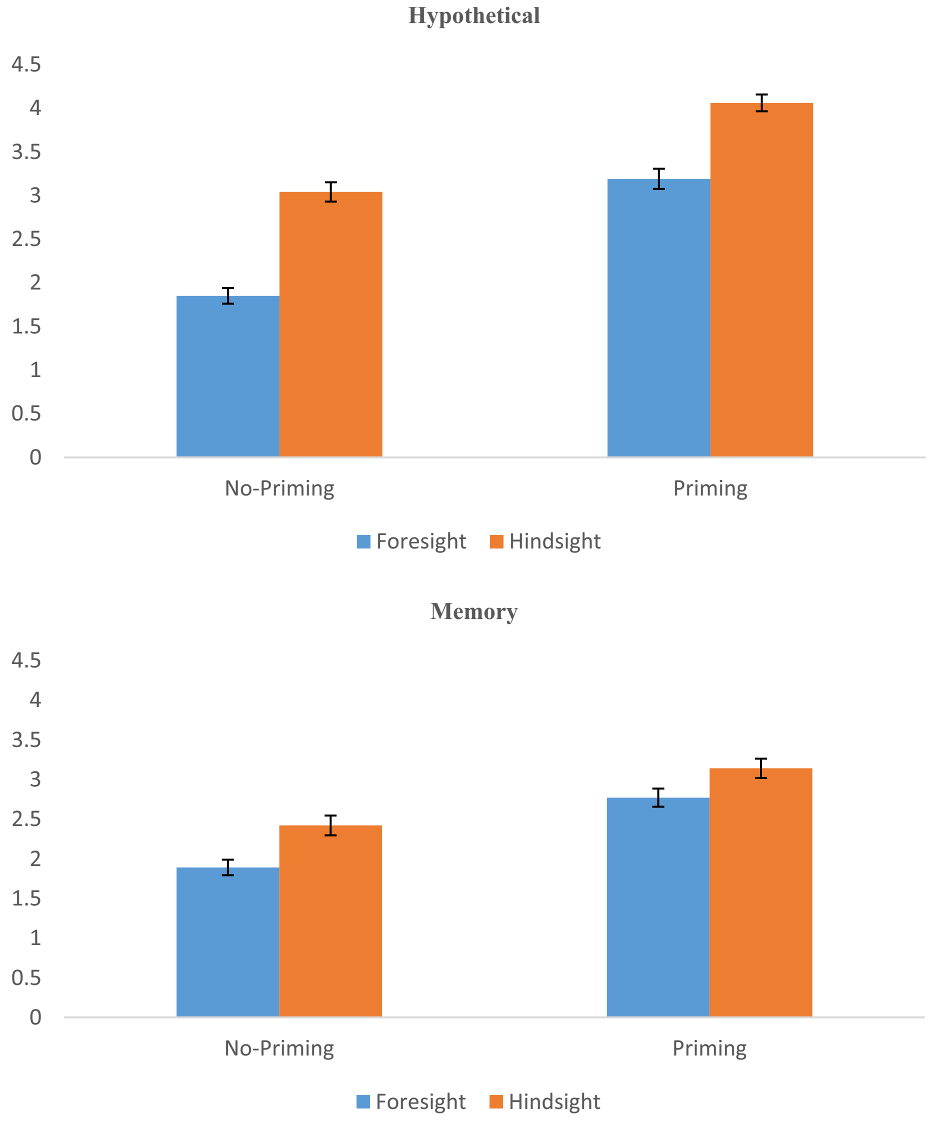

Fig. 3. Mean peer identification ratings in foresight versus hindsight and in the hypothetical task (top panel) versus memory task (bottom panel) for no-priming and priming songs in Experiment 2. Error bars represent standard errors of the mean.

messages were processed and asked children to complete auditory hypothetical and memory tasks. Results showed that only in the hypothetical task was the bias magnitude modulated by priming. In particular, the bias was greater for no-priming songs than for priming songs. This modulation was not present in the memory task. These results are consistent with previous auditory hindsight bias studies in adults (Higham et al., 2017) as well as with research on visual hindsight bias in children (e.g., Ghrear et al., 2021) and in adults (e.g., Birch, Brosseau-Liard, Haddock, & Ghrear, 2017). These latter studies, using visual materials, found that fluency processes are operative in hindsight bias when it is assessed in the context of hypothetical designs.

General discussion

In two experiments, we investigated auditory hindsight bias in children aged 8–13 years using a methodology similar to the one used in auditory hindsight bias research with adults (e.g., Bernstein et al., 2018; Epley et al., 2004; Higham et al., 2017). Results showed that children exhibit auditory hindsight bias in the context of hypothetical (Experiments 1 and 2) and memory (Experiment 2) designs. Children not only provided higher estimates when they were informed about the content of the "hidden message" in advance (compared with when they were not informed about it) but also distorted their recollections of their previous foresight ratings when they had been informed about the message content.

In Experiment 1, we also investigated whether auditory hindsight bias can be reduced by experimental means. For this purpose, like Bernstein et al. (2018), we included a condition where children made *two* hypothetical judgments regarding the same song (two-hearings condition): one in foresight and another in hindsight. Results were consistent with the majority of findings in adults (Bernstein et al., 2012, Experiment 2; Bernstein et al., 2018, Experiment 3)—hindsight bias persisted. Therefore, it seems that during childhood as well hindsight bias is a robust phenomenon and is hard to overcome. Despite largely similar findings in this condition and the "traditional" hypothetical condition (i.e., without foresight judgments), however, there remained a principal ambiguity regarding the cognitive processes involved. The two-hearings condition combines elements from both hypothetical designs and memory designs, and previous research on auditory hindsight bias with adults (Bernstein et al., 2018; Higham et al., 2017) has traced the bias in these designs to different underlying processes—fluency processes in hypothetical designs and memory processes in memory designs.

The goal of Experiment 2, then, was to use the priming methodology of the above research to resolve this ambiguity and contrast the two-hearings condition with a proper memory design. The findings pointed to a role of fluency processes in the two-hearings (hypothetical) task but not in the memory task. Consistent with the idea that priming increases the fluency processing of auditory targets and, in turn, reduces the subjective impact of target knowledge in hypothetical designs (Bernstein et al., 2018; Higham et al., 2017), auditory hindsight bias in the hypothetical task was modulated by priming (paralleling Higham et al., 2017). By contrast, there was no such modulation in the memory task. In turn, this suggests that the two-hearings condition is, on balance, more akin to a hypothetical design than to a memory task.

Developmental trajectories

Our study suggests that auditory hindsight bias decreases with age. Disregarding minor differences between Experiments 1 and 2 in the shapes of the trajectories, we found an overall decline of auditory hindsight bias, in both hypothetical and memory designs, across our age range (8–13 years), with third and fourth graders (8–10 years) showing the strongest bias. Thus, different from some previous research (e.g., Bernstein et al., 2011; Pohl et al., 2010) but in line with recent findings (Bernstein, 2021; Pohl et al., 2018), we could demonstrate that hindsight bias continues to decrease during middle and late childhood. This decrease was also present in our visual identification task in Experiment 1 and suggests that the trend does not depend on the type of material (although further types of stimuli might need to be studied in order to be more confident about this generalization). In any case, it seems clear that children 's ability to make inferences about the perspective of less informed peers increases during middle and late childhood.

There was an important difference, however, between previous research (Bernstein et al., 2004, 2007, 2011) and ours that could explain the different developmental patterns—the bias measure. Those previous studies used a more "implicit" measure of the bias (i.e., the point at which a naïve other would be able to identify a degraded object that progressively becomes clearer). By contrast, we asked children to provide an explicit numerical judgment (i.e., how many peers would identify the hidden message). Children were asked to ignore their actual experience and select from available options (zero peers, one peer, etc.) the one that fits best with their subjective impression. This type of measure may be more sensitive to developmental changes in metacognitive abilities that occur around this age (Flavell, Green, & Flavell, 1995; Flavell, Green, Flavell, & Grossman, 1997; Siegler, 1996).

Our hypothetical task in Experiment 2 also differed from previous research in terms of the salience or identifiability of the source of target knowledge. In previous research target knowledge resulted from foresight experience with the target (e.g., an object that progressively becomes clearer). By contrast, in our study this information was explicitly provided by the experimenter, rendering the source more salient than in previous research. In addition, older children are generally better at accurately attributing the origins of their knowledge (e.g., Drummey & Newcombe, 2002; Ruffman et al., 2001; Sluzenski et al., 2004). In combination, therefore, the developmental trajectory of the bias in our research may reflect improved source attribution ability in older children, facilitated by heightened salience of the source, due to the explicit experimenter provision of target information.

Differential source salience could also explain why, in the hypothetical task, the bias disappeared in sixth graders in Experiment 2, whereas it was present in this grade in Experiment 1. In Experiment 2, the foresight and hindsight judgments were provided in two different phases, making the role of target knowledge in message identification more salient than in Experiment 1. This should have facilitated source attribution for older children, making them less prone to succumb to auditory hindsight bias.

Like Pohl et al. (2018), we found that memory hindsight bias decreases during middle and late childhood. In particular, third, fourth, and fifth graders, but not sixth graders, showed auditory hindsight bias in the memory design. Previous research in adults found that the effect size in memory tasks depends on the retention interval; the longer the interval, the larger the bias (e.g., Blank et al., 2003). In our study, the retention interval was very short: Only a brief priming phase separated the hindsight phase from the foresight phase. Moreover, the number of judgments that children were asked to recall was small (only six), as was the choice of possible answers (a number from 0 to 6). Because older children have better memory skills (e.g., Cowan, 1997; Goswami, 2020; Keil, 1989; Schneider & Pressley, 1997), this might explain the disappearance of the effect in sixth graders in our Experiment 2.

Finally, as mentioned previously, the bias disappeared in sixth graders in both hypothetical and memory tasks in Experiment 2. It is important to note that this does not mean that the hindsight bias effect disappears after this age. The bias is present even in adults. It is possible that the tasks used in Experiment 2 were not sensitive enough to capture the effect in the oldest children and/or the task may have been easier for them. In any case, these results help us to understand what factors are related to hindsight bias during development. In the hypothetical task in Experiment 2, the bias may have disappeared in older children because the source of knowledge was more salient than in Experiment 1. In the memory task, the bias could have disappeared in sixth graders because the retention interval was short and the number of judgments to recall was small. Along these lines, the bias disappearance in older children in Experiment 2 could be taken to indicate that there are developmental changes in source monitoring and metamemory skills that make older children less vulnerable to hindsight bias. Moreover, it is important to note that the differences between the Experiment 1 and Experiment 2 hypothetical tasks did not affect the developmental trend of the bias; it just affected the bias magnitude score (the difference between hindsight and foresight ratings). In both experiments, younger children showed the most hindsight bias and older children showed the least hindsight bias. Although the bias magnitude score was systematically higher in Experiment 1 compared with Experiment 2, the developmental trend was the same in both experiments—the bias decreased with age.

Conclusions

Our two experiments extend previous research on a phenomenon recently discovered in adults, auditory hindsight bias, to school-age children. We established that (a) children of this age show strong auditory hindsight bias and (b) this hindsight bias is as robust against debiasing attempts as in adults. Moreover, (c) the bias shows the same pattern of underlying cognitive processes (fluency and memory processes) as in adults. Finally, and partly different from previous research involving other modalities, (d) auditory hindsight bias declined across our age range. Future research should continue exploring why during development children get better at making accurate predictions about others ‘ limited knowledge. It is possible that improvements in metacognition abilities, reasoning, and/or theory of mind lead to a reduction in this bias.

CRediT authorship contribution statement

Cristina Gordo: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Sergio Moreno-Ríos:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Visualization, Supervision, Project administration, Funding acquisition. **Hartmut Blank:** Methodology, Formal analysis, Writing – review & editing, Visualization, Supervision.

Acknowledgment

This work was supported by the Spanish Government, Ministry of Economy and Competitiveness (PGC2018-095868-B-I00). Funding for open access charge: Universidad de Granada / CBUA. The funders had no role in study design, data collectionand analysis, decision to publish, or preparation of the manuscript.

Data availability

The two experiments in this article earned an Open Data badge for transparent practices. Data for the experiments are available at the Open Science Framework (https://osf.io/a76ct/?view_only=e18b8871c6d44e2c9473505ef065c96a).

References

Arkes, H. R. (2013). The consequences of the hindsight bias in medical decision making. *Current Directions in Psychological Science, 22*, 356–360.

Arkes, H. R., Wortman, R. L., Saville, P. D., & Harkness, A. R. (1981). Hindsight bias among physicians weighing the likelihood of diagnoses. *Journal of Applied Psychology, 66*, 252–254.

Bernstein, D. M. (2021). Hindsight bias and false-belief reasoning from preschool to old age. *Developmental Psychology, 57*, 1387–1402.

Bernstein, D. M., Atance, C., Loftus, G. R., & Meltzoff, A. (2004). We saw it all along: Visual hindsight bias in children and adults. *Psychological Science, 15*, 264–267.

Bernstein, D. M., Atance, C., Meltzoff, A. N., & Loftus, G. R. (2007). Hindsight bias and developing theories of mind. *Child Development, 78*, 1374–1394.

Bernstein, D. M., Erdfelder, E., Meltzoff, A. N., Peria, W., & Loftus, G. R. (2011). Hindsight bias from 3 to 95 years of age. *Journal of Experimental Psychology: Learning, Memory and Cognition, 37*(2), 378–391.

Bernstein, D. M., Kumar, R., Masson, M. E., & Levitin, D. J. (2018). Fluency misattribution and auditory hindsight bias. *Memory & Cognition, 46*, 1331–1343.

Bernstein, D. M., Wilson, A. M., Pernat, N. L. M., & Meilleur, L. R. (2012). Auditory hindsight bias. *Psychonomic Bulletin & Review, 19*, 588–593.

Birch, S. A. J., Brosseau-Liard, P. E., Haddock, T., & Ghrear, S. E. (2017). A "curse of knowledge" in the absence of knowledge? People misattribute fluency when judging how common knowledge is among their peers. *Cognition, 166*, 447–458.

Blank, H., Diedenhofen, B., & Musch, J. (2015). Looking back on the London Olympics: Independent outcome and hindsight effects in decision evaluation. *British Journal of Social Psychology, 54*, 798–807.

Blank, H., Fischer, V., & Erdfelder, E. (2003). Hindsight bias in political elections. *Memory, 11*, 491–504.

Blank, H., & Nestler, S. (2006). Perceiving events as both inevitable and unforeseeable in hindsight: The Leipzig candidacy for the Olympics. *British Journal of Social Psychology, 45*, 149–160.

Chambers, J. R., & Davis, M. H. (2012). The role of the self in perspective-taking and empathy: Ease of self-simulation as a heuristic for inferring empathic feelings. *Social Cognition, 30*, 153–180.

Chang, V. Y., Arora, V. M., Lev-Ari, S., D 'Arcy, M., & Keysar, B. (2010). Interns overestimate the effectiveness of their hand-off communication. *Pediatrics, 125*, 491–496.

Cowan, N. (1997). The development of working memory. In N. Cowan (Ed.), *The development of memory in childhood* (pp. 163–199). London: Psychology Press.

Dawson, N. V., Arkes, H. R., Siciliano, C., Blinkhorn, R., Lakshmanan, M., & Petrelli, M. (1988). Hindsight bias: An impediment to accurate probability estimation in clinicopathologic conferences. *Medical Decision Making, 8*, 259–264.

Drummey, A. B., & Newcombe, N. (2002). Developmental changes in source memory. *Developmental Science, 5*, 502–513.

Epley, N., Keysar, B., Van Boven, L., & Gilovich, T. (2004). Perspective taking as egocentric anchoring and adjustment. *Journal of Personality and Social Psychology, 87*, 327–339.

Erdfelder, E., & Buchner, A. (1998). Decomposing the hindsight bias: A multinomial processing tree model for separating recollection and reconstruction in hindsight. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*, 387–414.
Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175–191.
Fischhoff, B. (1975). Hindsight ≠ foresight: The effect of outcome knowledge on judgment under uncertainty. *Journal of Experimental Psychology: Human Perception and Performance, 1*, 288–299.
Fischhoff, B. (1977). Perceived informativeness of facts. *Journal of Experimental Psychology: Human Perception and Performance, 3*, 349–358.
Flavell, J. H., Green, F. L., & Flavell, E. R. (1995). The development of children's knowledge about attentional focus. *Developmental Psychology, 31*, 706–712.
Flavell, J. H., Green, F. L., Flavell, E. R., & Grossman, J. B. (1997). The development of children's knowledge about inner speech. *Child Development, 68*, 39–47.
Gerace, A., Day, A., Casey, S., & Mohr, P. (2015). Perspective taking and empathy: Does having similar past experience to another person make it easier to take their perspective? *Journal of Relationships Research, 6* e10.
Ghrear, S., Chudek, M., Fung, K., Mathew, S., & Birch, S. A. J. (2019). Cultural variations in the curse of knowledge: The curse of knowledge bias in children from nomadic pastoralist culture in Kenya. *Journal of Cognition and Culture, 19*, 366–384.
Ghrear, S., Fung, K., Haddock, T., & Birch, S. A. J. (2021). Only familiar information is a "curse": Children's ability to predict what their peers know. *Child Development, 92*, 54–75.
Gordo, C., & Moreno-Ríos, S. (2019). Children's illusory transparency of intention: Construal versus pragmatic view. *Discourse Processes, 56*, 331–344.
Goswami, U. C. (2020). *Cognitive development and cognitive neuroscience: The learning brain*. London: Routledge, Taylor & Francis Group.
Gray, R., Beilock, S. L., & Carr, T. H. (2007). "As soon as the bat met the ball, I knew it was gone": Outcome prediction, hindsight bias, and the representation and control of action in expert and novice baseball players. *Psychonomic Bulletin & Review, 14*, 669–675.
Harley, E. M. (2007). Hindsight bias in legal decision making. *Social Cognition, 25*, 48–63.
Harley, E. M., Carlsen, K. A., & Loftus, G. R. (2004). The "saw-it-all-along" effect: Demonstrations of visual hindsight bias. *Journal of Experimental Psychology: Learning, Memory and Cognition, 30*, 960–968.
Hawkins, S. A., & Hastie, R. (1990). Hindsight: Biased judgments of past events after the outcomes are known. *Psychological Bulletin, 107*, 311–327.
Hayashi, H., & Nishikawa, M. (2019). Egocentric bias in emotional understanding of children and adults. *Journal of Experimental Child Psychology, 185*, 224–235.
Higham, P. A., Neil, G. J., & Bernstein, D. M. (2017). Auditory hindsight bias: Fluency misattribution versus memory reconstruction. *Journal of Experimental Psychology: Human Perception and Performance, 43*, 1143–1159.
Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin, 114*, 3–28.
Kamin, K. A., & Rachlinski, J. J. (1995). Ex post ≠ ex ante: Determining liability in hindsight. *Law and Human Behavior, 19*, 89–104.
Keil, F. C. (1989). *Concepts, kinds and cognitive development*. Cambridge, MA: MIT Press.
Keysar, B. (1994). The illusory transparency of intention: Linguistic perspective taking in text. *Cognitive Psychology, 26*, 165–208.
Keysar, B. (2000). The illusory transparency of intention: Does June understand what Mark means because he means it? *Discourse Processes, 29*, 161–172.
Keysar, B., & Henly, A. S. (2002). Speakers' overestimation of their effectiveness. *Psychological Science, 13*, 207–212.
Lagattuta, K. H., Sayfan, L., & Blattman, A. J. (2010). Forgetting common ground: Six- to seven-year-olds have an overinterpretive theory of mind. *Developmental Psychology, 46*, 1417–1432.
Leary, M. R. (1981). The distorted nature of hindsight. *Journal of Social Psychology, 115*, 25–29.
Leary, M. R. (1982). Hindsight distortion and the 1980 Presidential election. *Personality and Social Psychology Bulletin, 8*, 257–263.
Lindsay, D. S. (2008). Source monitoring. In J. Byrne (Series Ed.) & H. L. Roediger, III (Vol. Ed.), *Learning and memory: A comprehensive reference,* Vol. 2: *Cognitive psychology of memory* (pp. 325–348). Oxford, UK: Elsevier.
Loftus, E. F., Miller, D. G., & Burns, H. J. (1978). Semantic integration of verbal information into a visual memory. *Journal of Experimental Psychology: Human Learning and Memory, 4*, 19–31.
Moreno-Ríos, S, Rodríguez-Menchen, M. A., & Rodríguez-Gualda, I. (2011). Bias in perspective-taking during reading: Adjusting the knowledge of characters. *Journal of Pragmatics, 43*(7), 1977–1986. https://doi.org/10.1016/j.pragma.2010.12.013.
Nario, R. N., & Branscombe, N. R. (1995). Comparison processes in hindsight bias and causal attribution. *Personality and Social Psychology Bulletin, 21*, 1244–1255.
Nestler, S., & von Collani, G. (2008). Hindsight bias, conjunctive explanations and causal attribution. *Social Cognition, 26*, 482–493.
Pohl, R. F., Bayen, U. J., Arnold, N., Auer, T. S., & Martin, C. (2018). Age differences in processes underlying hindsight bias: A life-span study. *Journal of Cognition and Development, 19*, 278–300.
Pohl, R. F., Bayen, U. J., & Martin, C. (2010). A multiprocess account of hindsight bias in children. *Developmental Psychology, 46*, 1268–1282.
Pohl, R. F., Bender, M., & Lachmann, G. (2002). Hindsight bias around the world. *Experimental Psychology, 49*, 270–282.
Pohl, R. F., & Gawlik, B. (1995). Hindsight bias and the misinformation effect: Separating blended recollections from other recollection types. *Memory, 3*, 21–55.
Pohl, R. F., & Hell, W. (1996). No reduction in hindsight bias after complete information and repeated testing. *Organizational Behavior and Human Decision Processes, 67*, 49–58.
Pohl, R. F., Schwarz, S., Sczesny, S., & Stahlberg, D. (2003). Hindsight bias in gustatory judgments. *Experimental Psychology, 50*, 107–115.

Roese, N. J., & Olson, J. M. (1996). Counterfactuals, causal attributions, and the hindsight bias: A conceptual integration. *Journal of Experimental Social Psychology, 32*, 197–227.

Ruffman, T., Rustin, C., Garnham, W., & Parkin, A. J. (2001). Source monitoring and false memories in children: Relation to certainty and executive functioning. *Journal of Experimental Child Psychology, 80*, 95–111.

Schneider, W., & Pressley, M. (1997). *Memory development between two and twenty* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Sharman, S. J., Powell, M. B., & Roberts, K. P. (2011). Children's ability to estimate the frequency of single and repeated events. *International Journal of Police Science & Management, 13*, 234–242.

Siegler, R. S. (1996). *Emerging minds: The process of change in children's thinking*. New York: Oxford University Press.

Sluzenski, J., Newcombe, N. S., & Ottinger, W. (2004). Changes in reality monitoring and episodic memory in early childhood. *Developmental Science, 7*, 225–245.

Wood, G. (1978). The knew-it-all-along effect. *Journal of Experimental Psychology: Human Perception and Performance, 4*, 345–353.

Zwick, R., Pieters, R., & Baumgartner, H. (1995). On the practical significance of hindsight bias: The case of the expectancy-disconfirmation model of consumer satisfaction. *Organizational Behavior and Human Decision Processes, 64*, 103–117.