Journal of Experimental Child Psychology 202 (2021) 105004

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

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

You can['t] catch the sun in a net!: Children's misinterpretations of educational science television

James Alex Bonus *, Judy Watts

School of Communication, The Ohio State University, Columbus, OH 43210, USA

ARTICLE INFO

Article history:
Received 31 October 2019
Revised 26 August 2020

Keywords:
Fantasy
Misconceptions
Television
Refutations
Science education
Learning from fiction

ABSTRACT

Many science television shows feature refutation narratives where characters speculate about the value of scientific misconceptions (e.g., the sun circles the earth) before learning factual information. Previous research suggests that young children misunderstand these stories, and the current study examined whether learning could be improved using interventions previously validated with adults. Children (N = 201) aged 4–7 years viewed a refutation narrative in its original form or in a modified format that lacked misconceptions or that contextualized those misconceptions with additional scaffolds. Although children's comprehension of factual information was high across all conditions, their understanding of misconceptions depended on their prior knowledge. Specifically, children with low prior knowledge mistakenly identified misconceptions as intended factual lessons unless they viewed the story without misconceptions or with two forms of additional scaffolding. Conversely, children with high prior knowledge understood the original story best. These findings suggest that the inclusion of fantasy ideas in children's science programming can disrupt learning for certain children and bolster learning for others.

* Corresponding author.
E-mail address: bonus.1@osu.edu (J.A. Bonus).

https://doi.org/10.1016/j.jecp.2020.105004
0022-0965/

Introduction

Unrealistic material is prevalent in children's television. Recent content analyses have found that the majority of these programs are animated, feature fantastical content, and contain anthropomorphic characters (Bonus & Mares, 2018; Lemish & Russo Johnson, 2019; Taggart, Eisen, & Lillard, 2019). Although this material is undoubtedly intended to entertain (rather than mislead) young audiences, its presence in educational media can impede children's learning (Ganea, Canfield, Simons-Ghafari, & Chou, 2014) and reduce their willingness to transfer factual information gleaned from that content (Bonus, 2019; Ganea, Pickard, & DeLoache, 2008; Richert & Smith, 2011; Walker, Gopnik, & Ganea, 2015). These difficulties arise because children struggle to draw connections across dissimilar sources (e.g., animated representations vs. reality), and they are uncertain about the real-world relevance of information extracted from fantasy worlds (Hopkins & Weisburg, 2017; Strouse, Nyhout, & Ganea, 2018). Accordingly, Woolley and Ghossainy (2013) described children as "naïve skeptics" of fantasy media.

Recently, Hopkins and Weisburg (2017) argued that scholars should move beyond treating fantasy as a unitary construct and instead pursue more fine-grained investigations. One intriguing limitation of prior research is that scholars have primarily examined visual representations of fantasy concepts rather than verbal descriptions of fantasy ideas (Strouse et al., 2018). When both visual and verbal features are independently manipulated, studies suggest that visual cues are more problematic. For example, stories featuring anthropomorphic (vs. realistic) language hinder children's learning only when paired with anthropomorphic images (Ganea et al., 2014), yet children learn equally well from both types of language when realistic images are used (Ganea, Ma, & DeLoache, 2011; Geerdts, van de Walle, & LoBue, 2016). Nevertheless, exposure to anthropomorphic language can also cause children to develop certain false beliefs (e.g., animals make friends) even when paired with realistic images (Ganea et al., 2014). From a theoretical standpoint, this error is reasonable; if children are less likely to quarantine information gleaned from realistic stories (Richert & Smith, 2011), then they should be susceptible to any inaccuracies that those stories verbally communicate. Rather than exhibiting naïve skepticism, children fall victim to erroneous credulity (Woolley & Ghossainy, 2013).

The contemporary media landscape for children's science television embodies unique manifestations of this issue. Indeed, episodes of these programs are frequently structured so that characters pose a science question at the beginning of the story (e.g., "Why does day turn into night?") and proceed to discuss a variety of fantastical possibilities for a substantial portion of the show (e.g., "Perhaps because the sun hides?"). Later, those ideas are refuted (e.g., "Actually, the sun does not hide!") and accurate information is offered at the end of the story (e.g., "The earth rotates"). Presumably, these *refutation narratives* intend to teach children factual science information while simultaneously debunking mistaken ideas that they might already harbor about those topics (Bonus & Mares, 2018). Although a wealth of research suggests that educational texts structured in this way are more effective than nonrefutation texts at imparting scientific knowledge (Sinatra & Broughton, 2011), these improvements have primarily been documented for children in third grade and beyond (Tippett, 2010). The few studies examining younger audiences have identified notable issues. Specifically, Bonus and Mares (2018) found that exposure to a televised refutation narrative had no impact on 4- and 5-year-old children's science knowledge, whereas Mayer (1995) found that exposure to a refutation narrative in a storybook caused some 5- to 8-year-old children to learn new scientific misconceptions (i.e., attitudes, beliefs, or ideas that contradict modern scientific consensus; Tippett, 2010).

The current experiment examined whether children's confusions could be resolved by modifying how misconceptions are presented in a science television show. Specifically, interventions used to debunk misconceptions among adult audiences were adapted for younger viewers and incorporated into a popular science program. These findings highlight unique issues related to children's processing of fantasy material that is verbally (rather than visually) communicated as well as theoretical insights into the obstacles that young viewers confront when debiasing interventions are applied uncritically to the design of children's media.

Theoretical perspectives on children's learning from science television

Young children's confusions about the relative value of factual and fictional information in media narratives are typically understood using Fisch's (2000) capacity model. The model posits that children have limited working memory to devote to making sense of educational programs, which typically embed factual lessons (e.g., the meaning of Spanish words) within entertaining fantasy narratives (e.g., rescuing a talking monkey). Consequently, children learn best when educational material is made central to these narratives and when certain characteristics of the viewer (e.g., personal interest) or of the program (e.g., sound effects) scaffold their understanding. For example, Piotrowski (2014) found that children's learning from an episode of *Dora the Explorer* depended on both the structure of the narrative and their familiarity with the show. Specifically, children who rarely watched *Dora* were confused by segments of the program where characters requested audience participation (e.g., "Count to five with me!"). Although these children learned better when those segments were removed, children who watched *Dora* more frequently learned better when those segments were retained.

With regard to program characteristics, refutation narratives pose a unique set of burdens for young audiences. Indeed, these stories typically adorn accurate scientific information with complex tales of characters speculating about the plausibility of misconceptions. Consequently, children must register the inaccuracy of misconceptions presented early in the story, comprehend factual information presented later, and (when given the opportunity to apply their learning) inhibit their reliance on misconceptions (Brod, Breitwieser, Hasselhown, & Bunge, 2020). Of course, children often fail to integrate related pieces of information into meaningful takeaway messages when that information is presented at disparate points over the course of a televised story (Collins, Wellman, Keniston, & Westby, 1978; Mares & Acosta, 2008). Accordingly, the limited (and sometimes detrimental) effect of exposure to refutation narratives might stem from children's misunderstanding of the overall structure and intent of these shows (i.e., misconceptions are meant to be unlearned or avoided).

With regard to viewer characteristics, both media scholars (Fisch, 2000; Newcomb & Collins, 1979) and refutation scholars (Braasch, Goldman, & Wiley, 2013; van Loon, Dunlosky, van Gog, van Merriënboer, & de Bruin, 2015) suggest that harboring relevant prior knowledge is crucial for understanding educational science messages because it provides a foundation for organizing and interpreting the information contained in those messages. For example, Aladé and Nathanson (2016) found that children learned more about the characteristics of nocturnal animals after exposure to a science television show if they already had some preexisting knowledge about those animals. Of course, children's knowledge is often rife with misconceptions (Pine, Messer, & St. John, 2001), which can make it difficult for children to differentiate between fact and fiction in science media (Fisch, Yotive, Brown, Garner, & Chen, 1997). These inaccurate beliefs can also cause children to ignore factual information in educational stories and to generate invalid inferences as a result of exposure (Tippett, 2010). For example, Vosniadou and Skopeliti (2017) found that children with misconceptions about the day/night cycle recalled fewer facts from a science text about the day/night cycle compared with children with more accurate knowledge. These children also failed to properly integrate new information with their prior knowledge and thus cultivated new misconceptions (e.g., night falls because the earth rotates toward the moon). Consequently, the limited (and sometimes detrimental) effect of exposure to refutation narratives might also stem from children's misidentification or misinterpretation of intended lessons (i.e., facts vs. misconceptions).

One solution is to simply remove misconceptions from this programming. Theoretically, this should free children's cognitive resources and facilitate their comprehension of factual information. Consistent with this idea, Bonus and Mares (2018) compared children's learning from a refutation narrative with their learning from a simpler narrative where characters never discussed misconceptions. Although they found that children who viewed this modified version were more likely to glean factual information from the program and to use this information in their subsequent science explanations, more than half of children in both conditions continued to also mention misconceptions (e.g., day turns to night because the sun turns off). Given that refutation narratives are designed with the intent to correct these mistaken ideas, it is worth considering other modifications that might enhance the effectiveness of these shows.

Enhancing the effectiveness of refutations

It is well established that refutation texts are effective at correcting scientific misconceptions harbored by older children (8 years and over) and adults (Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012; Tippett, 2010). In general, scholars argue that this juxtaposition of accurate and inaccurate information induces a state of cognitive dissonance that encourages knowledge revision (Kendeou & O'Brien, 2014). However, people tend to integrate new information into memory only when it meshes with their prior knowledge and when it is relatively easy to process (Schwarz, Newman, & Leach, 2016). By nature, refutations often conflict with prior knowledge (Ecker, Lewandowsky, Fenton, & Martin, 2013), and the act of revising knowledge is an inherently effortful task that people avoid when less effortful responses are available (Posner, Strike, Hewson, & Gertzog, 1982). Consequently, these interventions sometimes fail among certain subsets of people (Walter & Tukachinsky, 2020), especially those who generate arguments in support of inaccuracies after initial exposure (Chan, Jones, Hall Jamieson, & Albarracin, 2017).

As a result of these limitations, abundant research has investigated strategies intended to improve the effectiveness of debiasing interventions. Two such tactics have been identified (Schwarz et al., 2016). First, warning people to be wary of inaccuracies can enhance their scrutiny of media content, resulting in more careful encoding of that material (Butler, Zaromb, Lyle, & Roediger, 2009; Marsh & Fazio, 2006). For example, Ecker, Lewandowsky, and Tang (2010) had undergraduates read a newspaper article about a bus accident that contained a piece of misinformation (i.e., the passengers were elderly people) that was later retracted. Before reading the article, some participants were cautioned about misinformation (i.e., people often continue believing it even after it is refuted). These warnings reduced participants' reliance on misinformation relative to participants who received no warning, and these effects were stronger when factual information was also presented after the retraction (i.e., "the passengers were actually hockey players").

Second, providing a coherent account about why false information was ever offered can clarify why it should no longer be used (Rapp & Kendeou, 2007). For example, Fein, McCloskey, and Tomlinson (1997) exposed jurors to incriminating evidence in a mock court trial that was later deemed inaccurate and thus was inadmissible in court. Results indicated that jurors exposed to the inadmissible evidence continued to rely on this evidence (and subsequently settled on harsher verdicts) unless they were given additional clarification about why that evidence was originally admitted (e.g., the media fabricated it to sell newspapers, opposing attorneys introduced it with nefarious motivations). In other words, this contextual information provided a new way for participants to encode the misinformation, thereby reducing its overall impact.

Although no studies have incorporated preexposure warnings or justifications into a refutation narrative, there is a rich history of inserting related forms of scaffolding into children's educational television. The capacity model suggests that this material reduces cognitive load by offering a framework for organizing stories (Fisch, 2000) in the form of either plot synopses (before viewing) or summaries of key educational concepts (during or after viewing). In general, children's comprehension improves when programs are augmented with this material even when it increases the length of a show (Calvert, Huston, & Wright, 1987; Jing & Kirkorian, 2020; Neuman, Burden, & Holden, 1990). These modifications have proved to be particularly beneficial for children's understanding of prosocial narratives, which share certain important similarities with refutation narratives. Indeed, these stories typically tell tales of characters who learn a difficult moral lesson (e.g., it is good to share) after committing a series of moral blunders (e.g., greedily hoarding toys; Mares & Acosta, 2008). Given this complexity, younger children often fail to pay attention to implicit aspects of these narratives (e.g., character goals and emotions), and they sometimes devote too much of their attention to less virtuous details (e.g., antisocial behaviors). Although these errors can lead children to behave in ways that are antithetical to intended messages (Ostrov, Gentile, & Mullins, 2013), the inclusion of previews (Cingel, Sumter, Stoeten, & Mann, 2020) and narrative inserts (Mares & Acosta, 2010) helps to minimize these issues.

The current study: Debunking misconceptions in children's television

The current study examined whether the inclusion of additional scaffolding in a refutation narrative would benefit children's learning or whether simply purging this material of fictitious information remains the best strategy (Bonus & Mares, 2018). Specifically, children were randomly assigned to view one of four versions of an educational science television show. Children in the *refutation* condition watched an edited version of the original program where characters posed a science question, tested (and refuted) a series of mistaken hypotheses related to that question, and later learned the correct information. Before viewing this same video, children in the *warning* condition watched a 30-s preview of the episode where a voiceover explained the structure of the narrative and instructed children to watch for the correct information at the end of the show. Children in the *justification* condition viewed the same video as children in the warning condition as well as a 30-s scene (presented later in the program) where characters discussed why it was important to test inaccurate hypotheses (i.e., it is integral to the scientific method). Finally, children in the *factual* condition watched a shorter version of the video used in the refutation condition that did not contain any misconceptions (i.e., after the opening scene, the video transitioned to characters learning correct information).

Consistent with Fisch's capacity model (Fisch, 2000; Fisch, Kirkorian, & Anderson, 2005), three primary outcomes were examined: children's understanding of the overall narrative structure, their comprehension of the underlying educational lessons, and their application of these lessons to a real-world problem, that is, transfer of learning (Barnett & Ceci, 2002). Given the possibility that watching characters test and refute a series of mistaken hypotheses might generate more interest in the narrative or shape children's ideas about the scientific method, additional measures assessed children's enjoyment of the show and gauged their ideas about scientific inquiry.

Predictions for children's understanding of the narrative

As stated previously, children might struggle to learn from refutation narratives because they fail to recognize that inaccurate information is presented in these programs for the purpose of correction. Preexposure warnings might remedy these issues by providing children with the necessary scaffolding to make sense of these stories as they unfold. Similarly, justifying the presence of inaccurate information by explaining its function in a story might provide children with a clearer understanding of the narrative's logic. Accordingly, it was predicted that children in the warning condition (Hypothesis 1a [H1a]) and justification condition (Hypothesis 1b [H1b]) would understand the structure of a refutation narrative better than children in the refutation condition.

Predictions for children's comprehension of the lesson

Bonus and Mares (2018) found that children learned more from a science television program when all misconceptions were removed. Because modifying a refutation narrative to include preexposure warnings and justifications was expected to clarify the structure of these stories, it seemed likely that these modifications might also have the added benefit of helping children to distinguish between accurate and inaccurate information. Specifically, preexposure warnings might do so by labeling information as factual or fictional, whereas justifications might do so by clarifying why inaccurate information is wrong (and accurate information is right). Accordingly, it was predicted that children in the factual condition (Hypothesis 2a [H2a]), warning condition (Hypothesis 2b [H2b]), and justification condition (Hypothesis 2c [H2c]) would comprehend the educational lessons better than children in the refutation condition.

It was less clear whether this additional scaffolding would lead to better comprehension than the video used in the factual condition given that no conflicting information was available in this version to potentially mislead children. Consequently, the following research question was posed: Would children in the warning and justification conditions comprehend educational lessons better than children in the factual condition (Research Question 1 [RQ1])? Because previous research has shown that children's prior knowledge influences their comprehension of science storybooks (Vosniadou & Skopeliti, 2017) and science television (Aladé & Nathanson, 2016), it seemed plausible that children's prior knowledge might moderate the effects of exposure to refutation narratives. Consequently, an additional research question was posed: Would prior knowledge moderate the effect of condition on lesson comprehension (Research Question 2 [RQ2])?

Predictions for children's transfer of learning

Undoubtedly, the ultimate goal of most educational programming is for children to apply what they learn from television shows to relevant real-world scenarios (Fisch et al., 2005). Although children often fail to recognize the real-world applicability of lessons gleaned from television (e.g., Bonus & Mares, 2019), their success in doing so improves when they have a stronger grasp of the intended lesson of these programs (Peebles, Bonus, & Mares, 2018). Because the proposed modifications (i.e., removing misconceptions, adding warnings, and adding justifications) all were expected to improve children's comprehension of intended educational lessons, it seemed possible that these same manipulations might also exert a direct or indirect influence on children's transfer. Accordingly, it was predicted that children in the factual condition (Hypothesis 3a [H3a]), warning condition (Hypothesis 3b [H3b]), and justification condition (Hypothesis 3c [H3c]) would score higher on tests of transfer than children in the refutation condition and that these effects would be mediated by lesson comprehension (Hypothesis 4 [H4]). However, it was unclear whether the warning and justification versions would lead to better (or worse) outcomes than the factual version. Consequently, an additional research question was posed: Would children in the warning and justification conditions score higher on tests of transfer than children in the factual condition (Research Question 3 [RQ3])?

Predictions for children's enjoyment and their perception of science

Although the existing literature casts doubt on the pedagogical value of refutation narratives for young children (Bonus & Mares, 2018; Mayer, 1995), exposure to these stories might have other benefits. On the one hand, children might find these refutation narratives to be more enjoyable than other types of educational stories because they are structured to build dramatic tension (i.e., characters face a problem, try and fail to solve that problem, but eventually prevail). Indeed, there is some indication that students find refutation texts to be more interesting than nonrefutation texts (Broughton, Sinatra, & Reynolds, 2010) and that such interest sometimes enhances the educational effectiveness of these texts (Mason, Gava, & Boldrin, 2008). On the other hand, refutation narratives model some of the essential features of the scientific method (i.e., persisting through trial and error) and thus might contribute to children's early understanding of scientific inquiry. Although the development of this knowledge remains a vital component of children's comprehensive science education (Jirout & Zimmerman, 2015), school-aged children exhibit limited understanding that persistence is a crucial feature of the scientific process (Zhai, Jocz, & Tan, 2014). Consequently, it seemed possible that refutation narratives might impart information about the necessity of making mistakes in science even if children struggle to glean other factual information from these shows. A final research question was posed: Would condition influence children's enjoyment or their perception of science (Research Question 4 [RQ4])?

Method

Participants

Power analyses using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) indicated that a sample size of 180 was required to detect medium effect sizes (analysis of variance [ANOVA] with four conditions, $\alpha = .05$, 80% power). Accordingly, participants were 201 children aged of 4–7 years ($M = 71.77$ months, $SD = 13.32$; 60.2% female) who were recruited and interviewed at a science museum in a large city in the midwestern United States. Parent reports indicated that the majority of children were White (84.08%), whereas the remainder were multiracial (9.95%), Black (3.48%), Asian (1.49%), or other (1%). Many parents (29.4%) had earned a college degree, although there was some degree of variability in education (i.e., 1.5% less than high school, 8.5% high school graduate, 15.9% some college, 13.9% associate degree, 7.0% postgraduate training, 23.9% postgraduate degree). Parents and children did not receive compensation in exchange for their participation, but children received a sticker.

Design and materials

Children were randomly assigned to one of the following conditions: refutation (n = 53), warning (n = 53), justification (n = 49), or factual (n = 46). All children viewed a modified version of the *Ready Jet Go!* episode "Mindy's Bedtime." *Ready Jet Go!* is an animated educational science program for children aged 4 years and over that follows the story of a human-like alien (Jet) and his family who arrive on the earth to learn about the planet. This particular episode tells a story about one of Jet's young human friends, Mindy, as she learns about the cause of the day/night cycle. This particular topic was selected because young children begin to form misconceptions about the day/night cycle very early in life (Saçkes, 2015), and a wealth of research has examined ways to correct these misconceptions in the classroom (e.g., Diakidoy, Vosniadou, & Hawks, 1997; Valanides, Gritsi, Kampeza, & Ravanis, 2000; Vosniadou & Brewer, 1994; Vosniadou & Skopeliti, 2017).

Children in the refutation condition watched an abridged version of the original narrative where Mindy wonders why day turns into night, and she expresses a series of three misconceptions about the subject. First, she wonders whether she can prevent the sun from going down by catching it in a net. Second, she wonders whether daytime will continue if the birds stay awake. Third, she demands to know why the sun will not stop moving around the earth. These misconceptions are refuted by other characters after Mindy tests each possibility (e.g., swiping at the sun with a net, playing kazoos loudly for the birds). Afterward, one of Jet's robots provides Mindy with the correct information. Specifically, the robot uses visual models and realistic depictions of the earth and sun to demonstrate that the earth rotates, whereas the sun is stationary.

Children in the remaining experimental conditions watched manipulated versions of this same video, such that certain segments were removed (i.e., factual condition), replaced (i.e., warning condition), or both added and replaced (i.e., justification condition). Specifically, the video in the factual condition lacked the segment where Mindy expresses misconceptions. The video in the warning condition replaced the theme song with a series of static images from later in the program narrated by a voiceover that previewed the structure of the story. The video in the justification condition included this same warning as well as an additional segment (later in the program) where characters explain how testing predictions—even when they are wrong—is key to the scientific method. These manipulations are summarized in Fig. 1. The scripts used in the warning and justification conditions are available in the Appendix.

Procedure

Parents provided informed consent and permission for their children to participate prior to beginning the study. Children were interviewed individually in a lab space in the science museum while

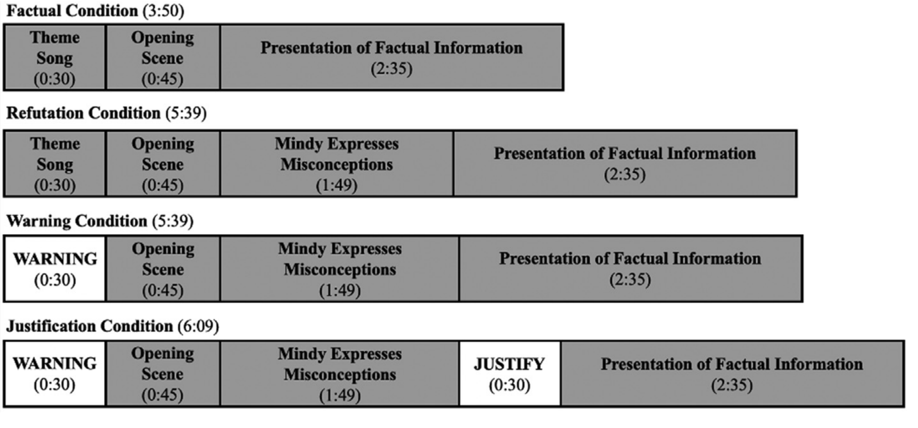

Fig. 1. Structure of experimental clips.

parents completed a demographic questionnaire outside the room. The interview began with a series of questions assessing children's prior knowledge about the earth and sun. Afterward, children watched the clip from their assigned condition and answered questions about it. Finally, children were asked to demonstrate how day turns into night using a model of the earth and sun. The interview lasted 15–20 min.

Measures

Prior knowledge

Eight questions were adapted from Vosniadou and Brewer (1994). Further details about these questions and how they were scored are provided in Table 1. Children's correct responses were summed across all eight questions, with higher scores indicating higher levels of prior knowledge (M = 5.35, SD = 1.50).

Enjoyment

After watching the episode, children were asked whether they liked or disliked the video. After making their selection, children were asked whether they *just* liked or disliked it, *really* liked or disliked it, or *really, really* liked or disliked it. Scores could range from −3 to +3, with higher scores reflecting higher enjoyment (M = 2.05, SD = 1.56).

Narrative comprehension

Three yes/no questions assessed children's narrative comprehension, and children received 1 point for each affirmative response. They were first asked whether any characters expressed inaccurate ideas about the day/night cycle (71% of children said yes). Children who said yes were then shown a picture of Jet, Mindy, and Jet's robot and were asked which of them had an inaccurate idea (82% of these children said Mindy). Finally, they were asked to describe one of those inaccurate ideas. These responses were independently coded by both authors for whether or not they mentioned at least one of Mindy's misconceptions (α = .89), and disagreements were resolved through discussion. Results indicated that 62.68% of these children correctly identified at least one misconception. Children's scores for all three questions were summed (M = 1.73, SD = 1.27). For children in the refutation,

Table 1
Prior knowledge interview protocol.

Procedure and prompt	Scoring
1. Children were shown a realistic picture of the earth and asked, "What is this called?"	Children received 1 point for saying "earth."
2. Children were shown a realistic picture of the sun and asked, "What is this called?"	Children received 1 point for saying "sun."
3. Children were handed a container of blue Play-Doh and asked, "Can you make the earth out of this Play-Doh?"	Children received 1 point for making a spherical shape.
4. Children were handed a container of yellow Play-Doh and asked, "Can you make the sun out of this Play-Doh?"	Children received 1 point for making a spherical shape.
5. Children were asked (in counterbalanced order), "Does the earth move, or does the earth stay still?"	Children received 1 point for indicating that the earth moves.
6. Children were asked (in counterbalanced order), "Does the sun move, or does the sun stay still?"	Children received 1 point for indicating that the sun stays still.
7. Children were asked, "Is it possible to fall off of the earth? Yes or no?"	Children received 1 point for indicating "no."
8. Children were asked, "How does day turn into night?"	Children received 1 point for indicating that the earth rotates.

Note. The experimenter immediately scored all of children's close-ended responses and Play-Doh models. The experimenter typed children's open-ended responses to the final question. These responses were independently coded by both authors after data collection was completed (α = .70); disagreements were resolved through discussion. Although the sun is not actually stationary (i.e., it orbits around the center of the Milky Way galaxy), most teaching interventions for this age group present it as stationary in order to disabuse children of the notion that its movement causes the day/night cycle and to more clearly emphasize the importance of the earth's rotation (e.g., Valanides et al., 2000).

warning, and justification conditions, higher scores on this measure reflected a better understanding of the narrative. Children in the factual condition were expected to score low on this measure given that no inaccurate ideas were presented in that version of the episode.

Lesson comprehension

Children were told that they would hear six statements and that they were to decide whether each statement reflected a scientific fact that Mindy learned on the show. Three statements reflected accurate information that was presented in the program (i.e., the earth is round, the earth rotates, and the sun stays still). The remaining three statements reflected Mindy's misconceptions (i.e., you can catch the sun in a net, daytime comes because birds chirp, and the sun moves). Children could respond verbally or by pointing to a red X (for no) or a green check mark (for yes) depicted on the screen. They received 1 point for each affirmative response, and their scores were added together separately for facts (M = 2.30, SD = 0.76) and misconceptions (M = 0.82, SD = 0.81). Higher scores on the first measure indicated that children correctly identified the factual lessons presented in the program, whereas higher scores on the second measure indicated that children mistakenly believed that Mindy's misconceptions were intended as factual lessons.

Perceptions of mistakes in science

Children were asked a series of three yes/no questions: "Do scientists sometimes make mistakes?"; "Is it OK for scientists to make mistakes?"; and "Is making mistakes part of doing science?" Children received 1 point for each affirmative response, and their scores were summed (M = 2.25, SD = 0.89).

Transfer of learning

Children were presented with six wooden shapes (two spheres, two cylinders, a triangle, and a hemisphere), and they were asked to select the one that was the same shape as the earth and the one that was the same shape as the sun (Valanides et al., 2000). They received 1 point (for each question) for choosing a sphere. Next, they were presented with a large yellow ball and a smaller blue ball with a thumbtack pinned to it (Saçkes, 2015). The experimenter verbally identified the balls as the sun and the earth, pointed to the thumbtack, and said, "This is my friend on the earth, Riley. Using these balls, can you show me how day turns to night for Riley?" For the earth, children received 1 point for rotating the blue ball, 0.5 point for indicating some other type of motion, and 0 points for indicating that it does not move. For the sun, children received 1 point for indicating that the yellow ball does not move and 0 points for indicating some type of motion. If children refrained from moving either ball, they received 0 points for both objects. Finally, the experimenter situated the thumbtack facing away from the yellow ball and asked whether it was daytime or nighttime for Riley. Children received 1 point for indicating nighttime. The experimenter then rotated the thumbtack toward the yellow ball and asked whether it was daytime or nighttime for Riley. Children received 1 point for indicating daytime. Children's scores for all six questions were summed (M = 4.59, SD = 1.38).

Covariates

Three measures were included to control for developmental and individual differences across children. Specifically, parents indicated the highest academic degree they attained (1 = *some high school*, 8 = *postgraduate degree*), the month and year when their children were born, and how frequently (1 = *never*, 5 = *very often*) their children exhibited the following behaviors over the past month: interest in trying new things, eagerness to learn new things, imaginative play, ease in adjusting to new situations, and appropriate use of words to describe their feelings (Shah, Weeks, Richards, & Kaciroti, 2018). Children's age (in months) was used as a proxy for cognitive capacity (Gathercole, Pickering, Ambridge, & Wearing, 2004). Parent education served as a proxy for socioeconomic status (SES), which is positively correlated with children's cognitive capacity (Hackman et al., 2014). The final five questions were averaged (M = 4.41, SD = .052, α = .70) and served as a measure of children's curiosity, which is a stable individual difference variable (Jirout & Klahr, 2012) that is positively correlated with children's intelligence (Alberti & Witryol, 1994) and predictive of their achievement in science (van Schijndel, Jansen, & Raijmakers, 2018).

Results

Analytic strategy

Analyses were conducted in SPSS Version 25 (IBM Corp., Armonk, NY, USA). One-way ANOVAs indicated that children's age, prior knowledge, and curiosity were evenly distributed across conditions. Similarly, chi-square analyses indicated that children's gender and parent education were evenly distributed across conditions. Hypotheses and research questions concerning direct effects of condition were assessed using one-way ANOVAs, and Sidak corrections were used to adjust for multiple comparisons. Conditional and indirect effects were assessed using the PROCESS macro (Hayes, 2018). All analyses were conducted twice: once without covariates and once with three covariates (i.e., children's age, parent education, and children's curiosity). This approach made it possible to examine whether any documented effects of condition were contingent on developmental differences (i.e., age) or individual differences (i.e., SES and curiosity). A correlation matrix is provided in Table 2. Mean comprehension are reported in Table 3. The dataset and syntax used for analyses are available on the Open Science Framework (https://osf.io/mgwc6/).

Narrative comprehension

H1a and H1b predicted that narrative comprehension would be higher in the warning and justification conditions relative to the refutation condition. Although results indicated a main effect of condition, $F(3, 197) = 12.88$, $p < .001$, $\eta^2_p = .16$, this effect occurred because children in the factual condition correctly reported (relative to children in the other three conditions) that inaccurate ideas were not featured in the episode they viewed (all $ps \leq .001$). There were no significant differences across the other three conditions. Because this same pattern emerged when covariates were included in the analysis, H1a and H1b were not supported.

Table 2
Correlation matrix.

Variable	1	2	3	4	5	6	7
1. Age	–						
2. Prior knowledge	.355***	–					
3. Narrative comprehension	.320***	.202***	–				
4. Lesson comprehension (facts)	.005	.165*	.023	–			
5. Lesson comprehension (misconceptions)	−.131	−.255***	−.171*	−.055	–		
6. Transfer	.264***	.396***	.237**	.219**	−.165*	–	
7. Enjoyment	−.073	.090	.098	.220**	−.064	.044	–
8. Perception of science	.381***	.094	.315***	.124	.008	.189**	.073

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

Table 3
Condition comparisons across all dependent variables.

Condition	Narrative comprehension [*M* (*SE*)] Min = 0 Max = 3	Fact comprehension [*M* (*SE*)] Min = 0 Max = 3	Misconception comprehension [*M* (*SE*)] Min = 0 Max = 3	Transfer score [*M* (*SE*)] Min = 0 Max = 6	Episode enjoyment [*M* (*SE*)] Min = −3 Max = 3	Perception of science [*M* (*SE*)] Min = 0 Max = 3
Refutation	1.79 (0.16)	2.40 (0.10)	0.85 (0.11)	4.59 (0.19)	2.11 (0.22)	2.28 (0.12)
Factual	0.87 (0.17)	2.20 (0.11)	0.67 (0.12)	4.29 (0.20)	2.04 (0.23)	2.00 (0.13)
Warning	1.87 (0.16)	2.26 (0.10)	0.89 (0.11)	4.74 (0.19)	1.98 (0.22)	2.25 (0.12)
Justification	2.33 (0.17)	2.35 (0.11)	0.84 (0.12)	4.69 (0.20)	2.06 (0.23)	2.45 (0.13)

Note. The reported means reflect the results of analyses of variance with no covariates included.

Lesson comprehension

H2a, H2b, and H2c predicted that lesson comprehension would be higher in the factual, warning, and justification conditions relative to the refutation condition. RQ1 asked whether comprehension would be higher in the warning and justification conditions relative to the factual condition. Results indicated no effect of condition on comprehension of facts or misconceptions. Because this same pattern emerged when covariates were included in the analysis, H2a, H2b, and H2c were not supported.

RQ2 asked whether these effects would be moderated by prior knowledge. Two PROCESS analyses were conducted: one for comprehension of facts and one for comprehension of misconceptions (Model 1 with 5000 bootstrap simulations). Condition was entered as a multicategorical predictor (with the refutation condition set as the reference group), and prior knowledge was entered as the moderator.

The model predicting comprehension of facts was not significant with or without covariates. However, the model predicting comprehension of misconceptions was significant (overall R^2 = .14, p < .001). Prior knowledge emerged as a negative predictor (B = −.33, SE = .07, p < .001), and the interaction terms explained a significant amount of additional variance (ΔR^2 = .06, p = .003). Specifically, prior knowledge interacted with the factual condition (B = .36, SE = .10, p < .001) and the justification condition (B = .22, SE = .09, p = .018), but not with the warning condition (B = .13 SE = .12, p = .25). These same patterns emerged with covariates; the overall model was significant (R^2 = .15, p < .001), prior knowledge emerged as a negative predictor (B = −.33, SE = .07, p < .001), the interaction terms explained a significant amount of additional variance (ΔR^2 = .07, p = .003), and prior knowledge interacted with the factual condition (B = .38, SE = .10, p < .001) and justification condition (B = .24, SE = .10, p = .015).

Fig. 2 provides a visual representation of these interactions, which were probed using the OGRS (omnibus groups regions of significance) macro (Hayes & Montoya, 2017). This macro applies the Johnson–Neyman technique to identify regions along a moderator variable (i.e., prior knowledge) where a multicategorical predictor variable (i.e., condition) has a significant influence on an outcome variable (i.e., comprehension of misconceptions). Results indicated that condition had a significant effect on comprehension when prior knowledge scores were less than 4.52 or greater than 7.78 (out of 8.00). In other words, children in the factual and justification conditions were less likely than children in the refutation condition to mistake Mindy's misconceptions as factual information when they had low prior knowledge (<4.52), but they were more likely to do so when they had high prior knowledge (>7.78) (see Fig. 2).

Transfer of learning

H3a, H3b, and H3c predicted that transfer would be higher in the factual, warning, and justification conditions relative to the refutation condition. RQ3 asked whether transfer would be higher in the warning and justification conditions relative to the factual condition.

Results indicated no effect of condition on transfer. Because this same pattern emerged when covariates were included in the analysis, H3a, H3b, and H3c were not supported. Although these results suggest that minimal transfer occurred, H4 predicted indirect effects via lesson comprehension. This prediction was tested using PROCESS (Model 4 with 5000 bootstrap simulations). Condition was entered as a multicategorical predictor (with the refutation condition set as the reference group), children's comprehension of facts and misconceptions were entered as mediators, and transfer performance was entered as the outcome.

Results indicated that the model predicting transfer was significant (R^2 = .15, p < .001). Comprehension of facts emerged as a positive predictor (B = .37, SE = .12, p = .003), and comprehension of misconceptions emerged as a negative predictor (B = −.28, SE = .12, p = .017). Condition was unrelated to both mediators, and neither indirect effect was significant. Because this same pattern emerged when covariates were included in the analysis, H4 was not supported.

However, because children's prior knowledge moderated the effect of condition on lesson comprehension in the previous analyses, a moderated mediation analysis was also conducted (Model 7 with 5000 bootstrap simulations). Specifically, children's prior knowledge was entered as a moderator of

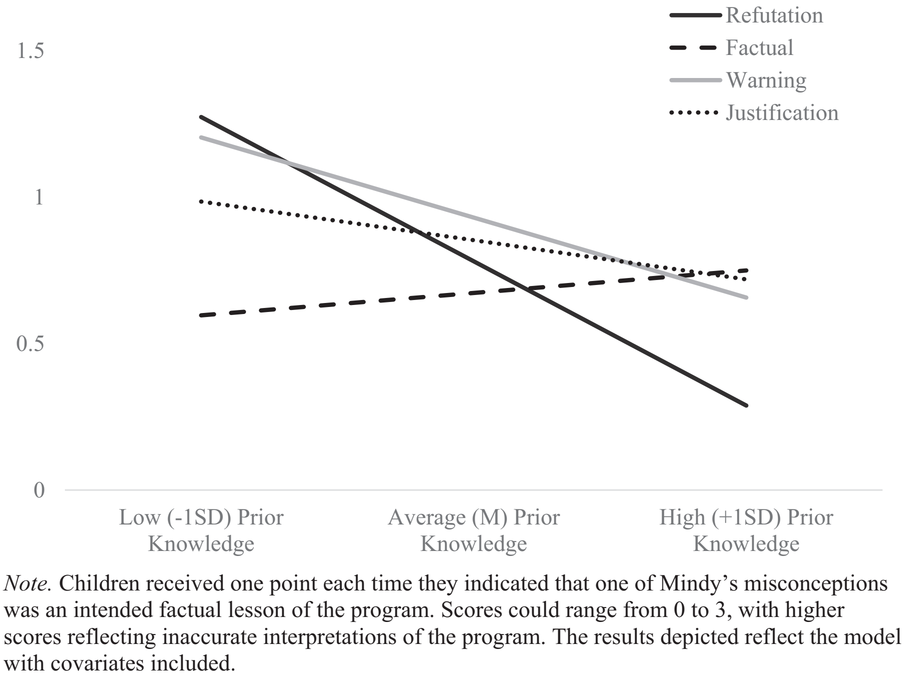

Fig. 2. Statistical interaction between condition and prior knowledge. Children received 1 point each time they indicated that one of Mindy's misconceptions was an intended factual lesson of the program. Scores could range from 0 to 3, with higher scores reflecting inaccurate interpretations of the program. The results depicted reflect the model with covariates included.

the path between condition and lesson comprehension. Consistent with the previous analyses, children in the factual condition with low prior knowledge were less likely than children in the refutation condition to mistake Mindy's misconceptions as factual lessons. Importantly, this effect also improved their transfer performance relative to children in the refutation condition. This indirect effect of condition was significant (effect = .19, *SE* = .09, 95% confidence interval (CI) [.022, .385]), and the index of moderated mediation was also significant (index = −.10, *SE* = .05, 95% CI [−.208, −.014]). These same patterns also emerged when covariates were included in the analysis (indirect effect = .15, *SE* = .09, 95% CI [.002, .330]; index of moderated mediation = −.08, *SE* = .05, 95% CI [−.181, −.002]). There were no significant indirect effects via children's comprehension of facts, and there were no significant effects for children with mean/high prior knowledge or for children in the warning and justification conditions.

Children's enjoyment and perceptions of science

RQ4 asked whether condition would influence children's enjoyment or perceptions of science. Results indicated no effect of condition on children's scores for either outcome, which were high across all conditions. These same patterns emerged with covariates included.

Discussion

Although a wealth of research has examined children's understanding of educational media messages that feature fantasy depictions (Hopkins & Weisburg, 2017; Strouse et al., 2018), fewer studies have investigated realistic stories that verbally communicate fantasy ideas (Ganea et al., 2011, 2014). The current study examined this material as it manifests in refutation narratives on children's science television. In general, these stories align with recommendations from research examining strategies to debunk misconceptions harbored by older children and adult audiences (Tippett, 2010). However, there are many reasons why this approach sometimes fails with adults (Chan et al., 2017; Schwarz et al., 2016), and two prior studies suggested that refutation narratives have either no effect (Bonus & Mares, 2018) or detrimental effects (Mayer, 1995) on younger children's science knowledge. Although research has demonstrated that children learn more factual information from science programs if all misconceptions are removed, these purified versions have no impact on children's belief in misconceptions (Bonus & Mares, 2018).

Accordingly, the current study examined whether learning outcomes could be improved by adopting two strategies deemed to be effective for augmenting these interventions with adults: (a) preexposure warnings about misconceptions and (b) justifying the inclusion of misconceptions. All children viewed an episode of a popular science television show (i.e., *Ready Jet Go!*) about the cause of the day/night cycle. Children in the refutation condition viewed an edited version of the original program where characters expressed a series of misconceptions about the day/night cycle before learning the correct information. Children in the warning condition viewed an audiovisual preview before the show that cautioned about the presence of misconceptions, whereas children in the justification condition viewed this insert in addition to a scene where characters elaborated on why those misconceptions were present (e.g., making mistakes is part of doing science). These three groups were compared with children in the factual condition, who watched the episode without any misconceptions.

Results indicated that children understood the structure and intent of the storyline (i.e., misconceptions are presented for the purpose of correction) regardless of which version of the refutation narrative they viewed (i.e., original vs. warning vs. justification). Their comprehension of the show's factual lessons was also equally high across all conditions. However, there were important differences in their understanding of the misconceptions presented in the show. Specifically, children with low prior knowledge were confused by the original refutation narrative, such that they mistakenly identified the featured misconceptions as factual pieces of information. These errors were mitigated by exposure to the factual and justification versions of the show. Conversely, children with high prior knowledge were *less* likely to make these mistakes when they viewed the original refutation narrative. In other words, the refutation narrative served its intended purpose among children with high prior knowledge but backfired among children with low prior knowledge.

These results for children with low prior knowledge can be understood through the lens of Fisch's (2000) capacity model. Indeed, these children have a weak (and possibly nonexistent) foundation on which to interpret the rather complex stories offered by refutation narratives. Consequently, they were confused by the presence of misconceptions and incorrectly tagged this fictitious information as factual despite comprehending other factual lessons without issue. Purging these narratives of inaccurate information resulted in less confusion. Similarly, the inclusion of two types of additional scaffolding (i.e., preexposure warnings and mid-episode justifications) also reduced confusion. The inclusion of only one type of scaffolding (i.e., preexposure warnings) did not produce the same improvements.

The results for children with high prior knowledge can also be understood through the lens of the capacity model, although certain questions remain. Indeed, these children exhibited the clearest understanding that the misconceptions featured in the story were fictitious—but only when they viewed the original refutation narrative. Considered relative to children in the factual condition, this finding indicates that the story served its purpose for children who had the necessary knowledge to navigate it. However, when considered relative to children in the justification condition, this finding indicates that the inclusion of additional scaffolding actually eliminated what was otherwise a positive effect of exposure to the original narrative. Future research could unpack this finding by considering other types of scaffolding that might be more effective for these children. For example, it might be that children with high prior knowledge naturally make connections between what they see in the show with what they already know and that being exposed to additional content (i.e., warnings and justifications) redirects their attention solely toward deconstructing the narrative. If this were the case, then these children might be better served by narrative inserts that instruct them to focus on making connections with their prior knowledge.

Taken together, these results for children's comprehension indicate that different types of children are best served by different types of science narratives. Specifically, children with low prior knowledge require simpler narratives that deliver direct educational messages without addressing misconceptions or that otherwise contextualize those misconceptions via warnings and justifications. Although children with high prior knowledge are capable of handling stories that attempt to systematically address misconceptions, the inclusion of additional scaffolds hinders their comprehension. Although these conclusions are meaningful in a scholarly sense, they are (perhaps) frustrating in a practical sense. How should producers use this information given that they must design one message for a mass audience?

One way to address this question is to emphasize the results obtained for children's transfer. Although there were no differences across conditions, mediation analyses indicated that the performance of children with low prior knowledge improved when they viewed the factual (vs. refutation) version of the story because they were not exposed to misconceptions that otherwise muddled their comprehension. Meanwhile, the performance of children with high prior knowledge was unaffected despite their improved comprehension in the refutation condition (vs. the factual and justification conditions). Although this latter result might best be attributed to a ceiling effect (i.e., children with high prior knowledge already performed well on the transfer task regardless of the program they viewed), it does indicate that the refutation narrative had no downstream benefits for any children and had downstream detriments for children with low prior knowledge. Accordingly, the current results reaffirm the conclusions of previous studies suggesting that science media geared toward young audiences should be purified of misconceptions (Bonus & Mares, 2018; Mayer, 1995).

Of course, it is worth considering this recommendation in light of the fact that the justification condition operated similarly to the factual condition in all analyses despite failing to improve transfer. Although this difference could be attributed to the varying lengths of the videos used in these two conditions, this explanation seems unlikely. Because transfer was driven by comprehension, one would expect longer videos to inhibit or reduce transfer by interfering with comprehension. However, comprehension of factual information was high across all conditions, and comprehension of misconceptions improved in response to both the shortest video (i.e., factual condition) and the longest video (i.e., justification condition). It is more probable that the justification condition failed to improve transfer simply because the moderating role of prior knowledge was slightly weaker in this condition. Because the indirect effect would likely emerge significant in a larger sample, future research should examine strategies that might strengthen the effects documented here. Indeed, studies of refutation texts have found that it is more effective to use multiple scaffolds than to employ any one strategy in isolation (Ecker et al., 2010; Skopeliti & Vosniadou, 2008). The current results lend support to this notion given that the inclusion of only one scaffold (i.e., warnings) was not as effective as two scaffolds (i.e., warnings and justifications). Incorporating other types of scaffolds (e.g., repeated refutations) or doing so at additional points in the program (e.g., the conclusion) might ensure that more children benefit.

It is also worth considering the types of program modifications that content creators can most realistically pursue. Indeed, the video used in the factual condition was created by removing a key segment that appeared in the original episode. This segment was not replaced with a different "filler" segment (e.g., alternative subplots) because doing so might have confounded the manipulation in more complicated ways. In addition, this approach is relatively common in the narrative insert literature, where treatment and control videos vary in length from 30 s to 2 min (Calvert et al., 1987; Cingel et al., 2020; Jing & Kirkorian, 2020; Neuman et al., 1990). However, existing episodes of *Ready Jet Go!* are 12 min long. If producers simplified these stories by removing segments of the narrative, they would need to fill the remaining time with additional material. Although they might achieve this goal by repeating the same educational messages in new contexts (Fisch et al., 2005), such modifications might not be as feasible or as artistically viable as augmenting existing narratives with additional scaffolding. Consequently, future research should examine interventions that are equally effective for longer episodes and that do not detract from the artistic integrity of this material. Because the modifications applied to the video used in the justification condition seem more suitable for these aims, researchers should continue to investigate similar approaches.

The results obtained for children's enjoyment and their perceptions of scientific inquiry are also supportive of these conclusions. Indeed, these outcome variables were included with the understanding that producers might design refutation narratives because they believe they are more narratively engaging than simpler stories or more honest in their depiction of the scientific process. However, these beliefs did not manifest in children's responses. Regardless of the version of the show that children watched, they all reported high levels of enjoyment and a fairly robust understanding that making mistakes is part of the scientific process. On the one hand, these results suggest that simpler narratives are the better option because they are equally enjoyable and equally efficacious as more complex stories while still providing a slight improvement in learning and transfer for the viewers who stand to gain the most from this programming (i.e., those with the least prior knowledge). At the same time, extra scaffolding does not detract from children's enjoyment. Because neither approach to modifying these narratives (i.e., simplifying or augmenting) appears to have negative ramifications for the viewer experience, researchers and content creators should feel comfortable in pursuing either strategy.

More broadly, future research should examine how these processes apply to children's understanding of other types of science media, especially storybooks. For example, a recent experiment by Venkadasalam and Ganea (2018) investigated 4- and 5-year-old children's learning about physics (i.e., force and motion) from stories where characters initially offered erroneous predictions (e.g., heavier objects reach the ground before light objects) before learning accurate information (i.e., all objects fall at the same rate). Results indicated that children's understanding of physics improved after exposure to these stories, which might suggest that children are less susceptible to misconceptions that are presented in storybooks (rather than television). However, children in that study heard the same story twice, so it might be that refutation narratives are simply more effective after repeated exposures. In addition, children might process refutation narratives differently when those stories are communicated by adults during shared reading rather than by fictional characters on television—especially given that children often watch television alone or with limited input from adults. Consequently, future research should examine whether children's understanding of refutation narratives changes across repeated exposures or in contexts where adults are present to assist with their learning.

Considered within the broader realm of research on children's learning from fantasy, the current study provides a useful complement to the existing literature. As noted in the literature review, much of this research has examined visual representations of fantasy concepts (Hopkins & Weisburg, 2017; Strouse et al., 2018), whereas verbal representations have received less attention. Previous studies suggest that verbal representations (i.e., anthropomorphic language) do not interfere with children's comprehension of educational concepts (Ganea et al., 2011), but they can simultaneously impart inaccurate ideas (Ganea et al., 2014). The current results reaffirm this notion insomuch that children's learning of factual information was high across all conditions, but children with low prior knowledge mistook verbal misconceptions as factual—unless that information was removed or appropriately contextualized. Future research should continue to examine the impact of verbal representations on children's learning by manipulating the types of images paired with this information. Indeed, it might be that certain children were misled in the current study because misconceptions were offered by realistic characters (i.e., humans) and delivered with realistic images (i.e., planetary models). Incorporating additional visual elements of fantasy (e.g., characters successfully capturing the sun in a net) might have cued children to unreality. Of course, such cues might also interfere with their understanding of factual lessons. Consequently, more research is needed to understand how both verbal and visual cues independently contribute to children's comprehension of educational media.

The current study also underscores the importance of directly assessing children's perception of fantasy elements in fictional media. Although this is a common approach in research on science media (Bonus, 2019; Ganea et al., 2011, 2014), research on children's learning from other fictional stories tends to focus on their comprehension of factual (rather than fantastical) elements (Hopkins & Weisburg, 2017; Larsen, Lee, & Ganea, 2018; Richert, Shawber, Hoffman, & Taylor, 2009; Richert & Smith, 2011; Weisburg et al., 2015). Importantly, when scholars have directly assessed children's perceptions of fantasy elements, they have found that they predict children's learning and transfer of factual information (e.g., Richert & Schlesinger, 2016). The current study echoes these results by demonstrating that children's perception of misconceptions (i.e., realistic or fictitious) predicted their transfer of factual information. Consequently, researchers investigating children's learning from fiction in other contexts might consider mimicking the approach of the current study, specifically by assessing children's perception of fantasy elements and analyzing its impact on transfer.

There are many important limitations to consider, the most obvious being the focus on one program (i.e., *Ready Jet Go!*), one subject (i.e., the cause of the day/night cycle), and one domain of knowledge (i.e., science). Future research will need to replicate these results with other programs and topics. In particular, it will be vital for this research to equate the length of stimuli used across conditions to rule out possible confounding effects of length. It would also bode well for this research to examine the role of children's emotions in response to refutation narratives. Indeed, prior research has found that feelings of surprise are central to the process of knowledge revision in response to refutation texts (Muis et al., 2018). Consequently, scholars should examine children's surprise in response to refutation narratives as well as its implications for children's learning. Future research should also seek to examine other variables that are correlated with children's prior knowledge. As discussed in the literature review, this variable was examined as a moderator due to its emphasis in the capacity model (Fisch, 2000) and its importance for children's understanding of science television (Aladé & Nathanson, 2016) and science texts (Vosniadou & Skopeliti, 2017). However, it might be that its impact on children's comprehension is actually reflective of underlying differences in cognitive ability. Although the current analyses sought to account for developmental and individual differences in children by controlling for age, SES, and curiosity, these are imperfect proxies for other variables that are also prioritized by the capacity model (e.g., working memory) and by studies of academic achievement (e.g., intelligence). Future research should directly assess these variables in order to isolate the unique influence of prior knowledge.

Moreover, it is vital to mention that the current sample of children—while relatively large compared with other studies of this nature—was relatively homogeneous in terms of race (i.e., White) and class (i.e., most parents had attained at least a college degree). However, it is worth emphasizing that even in this sample of well-educated families, children with the least prior knowledge benefitted most from the interventions employed. Consequently, it would be reasonable to predict that children from less educated families might benefit even more. That said, these children might also have more difficulty in extracting factual information from science media, especially for longer and more complex lessons. Accordingly, the current study is best viewed as support for this avenue of inquiry with more diverse samples of children.

Conclusions

Undoubtedly, refutation narratives are designed with the admirable goal of educating young viewers. However, the current study indicates that this approach can actually disrupt underlying educational objectives for some children. Although this content should certainly be fun, it is also imperative that it rectifies this amusement with broader educational aims. Failing to do so threatens to undermine the otherwise laudable intentions of these programs.

Acknowledgments

Thanks go to the Center of Science and Industry in Columbus, Ohio, for graciously allowing us to collect data on-site. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix A

Script for the warning segment	
Voiceover:	Do you know why day turns into night? Kids have a lot of different ideas. In this show, you'll learn about why day turns into night. At first, Mindy has the wrong ideas about why day turns into night. Later in the show, she learns the right idea from her robot friend. Make sure to pay attention to the right idea that Mindy learns from her robot friend at the end of the show.
Script for the justification segment	
Sean:	We have to tell Mindy that her ideas are not scientific!
Sydney:	But Mindy is acting like a scientist right now.
Sean:	But her ideas are wrong! She's making mistakes.
Jet:	And that's great because she keeps trying!
Sean:	She's supposed to make mistakes?
Sydney:	Right! Mistakes are fine. They help people know what doesn't work and then figure out what does work.

Note. The warning segment was created by editing together static images from the original episode and displaying them with audio narration recorded by the first author. The justification segment was drawn from an additional scene that was featured in the original episode of *Ready Jet Go!*

Appendix B. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2020.105004.

References

Aladé, F., & Nathanson, A. I. (2016). What preschoolers bring to the show: The relation between viewer characteristics and children's learning from educational television. *Media Psychology, 19*, 406–430.
Alberti, E. T., & Witryol, S. L. (1994). The relationship between curiosity and cognitive ability in third- and fifth-grade children. *Journal of Genetic Psychology, 155*, 129–154.
Barnett, S. M., & Ceci, S. J. (2002). When and where do we apply what we learn?: A taxonomy for far transfer. *Psychological Bulletin, 128*, 612–637.
Bonus, J. A. (2019). The impact of pictorial realism in educational science television on U.S. children's learning and transfer of biological facts. *Journal of Children and Media, 13*, 433–451.
Bonus, J. A., & Mares, M.-L. (2018). When the sun sings science, are children left in the dark? Representations of science in children's television and their effects on children's learning. *Human Communication Research, 44*, 449–472.
Bonus, J. A., & Mares, M.-L. (2019). Learned and remembered but rejected: Preschoolers' reality judgments and transfer from *Sesame Street*. *Communication Research, 46*, 375–400.
Braasch, J. L. G., Goldman, S. R., & Wiley, J. (2013). The influences of text and reader characteristics on learning from refutations in science texts. *Journal of Educational Psychology, 105*, 561–578.
Brod, G., Breitwieser, J., Hasselhown, M., & Bunge, S. A. (2020). Being proven wrong elicits learning in children—but only those with higher executive function skills. *Developmental Science, 23* e12916.
Broughton, S. H., Sinatra, G. M., & Reynolds, R. E. (2010). The nature of the refutation text effect: An investigation of attention allocation. *Journal of Educational Research, 103*, 407–423.
Butler, A. C., Zaromb, F. M., Lyle, K. B., & Roediger, H. L. III, (2009). Using popular films to enhance classroom learning: The good, the bad, and the interesting. *Psychological Science, 20*, 1161–1168.
Calvert, S. L., Huston, A. C., & Wright, J. C. (1987). Effects of television preplay formats on children's attention and story comprehension. *Journal of Applied Developmental Psychology, 8*, 329–342.
Chan, M. P. S., Jones, C. R., Hall Jamieson, K., & Albarracin, D. (2017). Debunking: A meta-analysis of the psychological efficacy of messages countering misinformation. *Psychological Science, 28*, 1531–1546.
Cingel, D. P., Sumter, S. R., Stoeten, E., & Mann, S. (2020). Can television help to decrease stigmatization among young children? The role of theory of mind and general and explicit inserts. *Media Psychology, 23*, 342–364.
Collins, W. A., Wellman, H., Keniston, A. H., & Westby, S. D. (1978). Age-related aspects of comprehension and inference from a televised dramatic narrative. *Child Development, 49*, 389–399.
Diakidoy, I. A., Vosniadou, S., & Hawks, J. D. (1997). Conceptual change in astronomy: Models of the earth and of the day/night cycle in American-Indian children. *European Journal of Psychology of Education, 12*, 159–184.
Ecker, U. K., Lewandowsky, S., Fenton, O., & Martin, K. (2013). Do people keep believing because they want to? Preexisting attitudes and the continued influence of misinformation. *Memory & Cognition, 42*, 292–304.

Ecker, U. K., Lewandowsky, S., & Tang, D. T. (2010). Explicit warnings reduce but do not eliminate the continued influence of misinformation. *Memory & Cognition, 38*, 1087–1100.
Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175–191.
Fein, S., McCloskey, A. L., & Tomlinson, T. M. (1997). Can the jury disregard that information? The use of suspicion to reduce the prejudicial effects of pretrial publicity and inadmissible testimony. *Personality and Social Psychology Bulletin, 23*, 1215–1226.
Fisch, S. M. (2000). A capacity model of children's comprehension of educational content on television. *Media Psychology, 2*, 63–91.
Fisch, S. M., Kirkorian, H. L., & Anderson, D. R. (2005). Transfer of learning in informal education: The case of television. In J. P. Mestre (Ed.), *Transfer of learning from a modern multidisciplinary perspective* (pp. 371–393). Greenwich, CT: Information Age.
Fisch, S. M., Yotive, W., Brown, S. K. M., Garner, M. S., & Chen, L. (1997). Science on Saturday morning: Children's perceptions of science in educational and non-educational cartoons. *Journal of Educational Media, 23*, 157–167.
Ganea, P. A., Canfield, C. F., Simons-Ghafari, K., & Chou, T. (2014). Do cavies talk? The effect of anthropomorphic picture books on children's knowledge about animals. *Frontiers in Psychology, 5*. https://doi.org/10.3389/fpsyg.2014.00283.
Ganea, P. A., Ma, L., & DeLoache, J. S. (2011). Young children's learning and transfer of biological information from picture books to real animals. *Child Development, 82*, 1421–1433.
Ganea, P. A., Pickard, M. B., & DeLoache, J. S. (2008). Transfer between picture books and the real world by very young children. *Journal of Cognition and Development, 9*, 46–66.
Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology, 40*, 177–190.
Geerdts, M. S., van de Walle, G. A., & LoBue, V. (2016). Learning about real animals from anthropomorphic media. *Imagination, Cognition, and Personality, 36*, 5–26.
Hackman, D. A., Betancourt, L. M., Gallop, R., Romer, D., Brodsky, N. L., Hurt, H., & Farah, M. J. (2014). Mapping the trajectory of socioeconomic disparity in working memory: Parental and neighborhood factors. *Child Psychology, 85*, 1433–1445.
Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. New York: Guilford.
Hayes, A. F., & Montoya, A. K. (2017). A tutorial on testing, visualizing, and probing an interaction involving a multicategorical variable in linear regression analysis. *Communication Method and Measures, 11*, 1–30.
Hopkins, E. J., & Weisburg, D. S. (2017). The youngest readers' dilemma: A review of children's learning from fictional sources. *Developmental Review, 43*, 48–70.
Jing, M., & Kirkorian, H. L. (2020). Teaching with televised stories: A story-focused narrative preview supports learning in young children. *Child Development, 91*, e1101–e1118.
Jirout, J., & Klahr, D. (2012). Children's scientific curiosity: In search of an operational definition of an elusive concept. *Developmental Review, 32*, 125–160.
Jirout, J., & Zimmerman, C. (2015). Development of science process skills in the early childhood years. In K. C. Trundle & M. Saçkes (Eds.), *Research in early childhood science education* (pp. 143–165). Dordrecht, Netherlands: Springer.
Kendeou, P., & O'Brien, E. J. (2014). The knowledge revision components (KReC) framework: Processes and mechanisms. In D. N. Rapp & J. L. G. Braasch (Eds.), *Processing inaccurate information: Theoretical and applied perspectives from cognitive science and the educational sciences* (pp. 353–377). Cambridge, MA: MIT Press.
Larsen, N. E., Lee, K., & Ganea, P. A. (2018). Do storybooks with anthropomorphized animal characters promote prosocial behaviors in young children? *Developmental Science, 21* e12590.
Lemish D., & Russo Johnson, C. (2019). The landscape of children's television in the US & Canada [white paper]. Retrieved June 30, 2019, from Center for Scholars & Storytellers, Rutgers University, at https://static1.squarespace.com/static/5c0da585da02bc56793a0b31/t/5cb8ce1b15fcc0e19f3e16b9/1555615269351/The+Landscape+of+Children%27s+TV.pdf.
Lewandowsky, S., Ecker, U. K., Seifert, C. M., Schwarz, N., & Cook, J. (2012). Misinformation and its correction: Continued influence and successful debiasing. *Psychological Science in the Public Interest, 13*, 106–131.
Mares, M. L., & Acosta, E. E. (2008). Be kind to three-legged dogs: Children's literal interpretations of TV's moral lessons. *Media Psychology, 11*, 377–399.
Mares, M. L., & Acosta, E. E. (2010). Teaching inclusiveness via TV narratives in the US: Young viewers need help with the message. *Journal of Children and Media, 4*, 231–247.
Marsh, E. J., & Fazio, L. K. (2006). Learning errors from fiction: Difficulties in reducing reliance on fictional stories. *Memory & Cognition, 34*, 1140–1149.
Mason, L., Gava, M., & Boldrin, A. (2008). On warm conceptual change: The interplay of text, epistemological beliefs, and topic interest. *Journal of Educational Psychology, 100*, 291–309.
Mayer, D. A. (1995). How can we best use children's literature in teaching science concepts?. *Science and Children, 32*, 16–19.
Muis, K. R., Sinatra, G. M., Pekrun, R., Winne, P. H., Trevors, G., Losenno, K. M., & Munzar, B. (2018). Main and moderator effects of refutation on task value, epistemic emotions, and learning strategies during conceptual change. *Contemporary Educational Psychology, 55*, 115–165.
Neuman, S. B., Burden, D., & Holden, E. (1990). Enhancing children's comprehension of a televised story through previewing. *Journal of Educational Research, 83*, 258–265.
Newcomb, A. F., & Collins, W. A. (1979). Children's comprehension of family role portrayals in televised dramas: Effects of socioeconomic status, ethnicity, and age. *Developmental Psychology, 15*, 417–423.
Ostrov, J. M., Gentile, D. A., & Mullins, A. D. (2013). Evaluating the effect of educational media exposure on aggression in early childhood. *Journal of Applied Developmental Psychology, 34*, 38–44.
Peebles, A., Bonus, J. A., & Mares, M.-L. (2018). Questions + answers + agency: Interactive touchscreens and children's learning from a socio-emotional TV story. *Computers in Human Behavior, 85*, 339–348.
Pine, K., Messer, D., & St. John, K. (2001). Children's misconceptions in primary science: A survey of teachers' views. *Research in Science & Technological Education, 19*, 79–96.
Piotrowski, J. T. (2014). Participatory cues and program familiarity predict young children's learning from educational television. *Media Psychology, 17*, 311–331.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*, 211–227.
Rapp, D. N., & Kendeou, P. (2007). Revisiting what readers know: Updating text representations during narrative comprehension. *Memory & Cognition, 35*, 2019–2032.
Richert, R. A., & Schlesinger, M. A. (2016). The role of fantasy–reality distinction in preschoolers' learning from educational video. *Infant and Child Development, 26* e2009.
Richert, R. A., Shawber, A. B., Hoffman, R. B., & Taylor, M. (2009). Learning from fantasy and real characters in preschool and kindergarten. *Journal of Cognition and Development, 10*, 41–66.
Richert, R. A., & Smith, E. I. (2011). Preschoolers' quarantining of fantasy stories. *Child Development, 82*, 1106–1119.
Saçkes, M. (2015). Young children's ideas about earth and space science concepts. In K. C. Trundle & M. Saçkes (Eds.), *Research in early childhood science education* (pp. 35–65). Dordrecht, Netherlands: Springer.
Schwarz, N., Newman, E., & Leach, W. (2016). Making the truth stick & the myths fade: Lessons from cognitive psychology. *Behavioral Science & Policy, 2*, 85–95.
Shah, P. E., Weeks, H. M., Richards, B., & Kaciroti, N. (2018). Early childhood curiosity and kindergarten reading and math academic achievement. *Pediatric Research, 84*, 380–386.
Sinatra, G. M., & Broughton, S. H. (2011). Bridging reading comprehension and conceptual change in science education: The promise of refutation text. *Reading Research Quarterly, 46*, 374–393.
Skopeliti, I., & Vosniadou, S. (2008, August). Categorical information improves the effectiveness of refutational texts. Paper presented at the International Conference on Conceptual Change, Turku, Finland.
Strouse, G. A., Nyhout, A., & Ganea, P. A. (2018). The role of book features in young children's transfer of information from picture books to real-world contexts. *Frontiers in Psychology, 9*. https://doi.org/10.3389/fpsyg.2018.00050.
Taggart, J., Eisen, S., & Lillard, A. S. (2019). The current landscape of US children's television: Violent, prosocial, educational, and fantastical content. *Journal of Children and Media, 13*, 276–294.
Tippett, C. D. (2010). Refutation text in science education: A review of two decades of research. *International Journal of Science and Mathematics Education, 8*, 951–970.
Valanides, N., Gritsi, F., Kampeza, M., & Ravanis, K. (2000). Changing pre-school children's conceptions of the day/night cycle. *International Journal of Early Years Education, 8*, 27–39.
van Loon, M. H., Dunlosky, J., van Gog, T., van Merriënboer, J. J. G., & de Bruin, A. B. H. (2015). Refutations in science texts lead to hypercorrection of misconceptions held with high confidence. *Contemporary Educational Psychology, 42*, 39–48.
van Schijndel, T. J. P., Jansen, B. R. J., & Raijmakers, M. E. J. (2018). Do individual differences in children's curiosity relate to their inquiry-based learning?. *International Journal of Science Education, 40*, 996–1015.
Venkadasalam, V. P., & Ganea, P. A. (2018). Do objects of different weight fall at the same time? Updating naive beliefs about free-falling objects from fictional and informational books in young children. *Journal of Cognition and Development, 19*, 165–181.
Vosniadou, S., & Brewer, W. F. (1994). Mental models of the day/night cycle. *Cognitive Science, 18*, 123–183.
Vosniadou, S., & Skopeliti, I. (2017). Is it the earth that turns or the sun that goes behind the mountains? Students' misconceptions about the day/night cycle after reading a science text. *International Journal of Science Education, 39*, 2027–2051.
Walker, C. M., Gopnik, A., & Ganea, P. A. (2015). Learning to learn from stories: Children's developing sensitivity to the causal structure of fictional worlds. *Child Development, 86*, 310–318.
Walter, N., & Tukachinsky, R. (2020). A meta-analytic examination of the continued influence of misinformation in the face of correction: How powerful is it, why does it happen, and how to stop it?. *Communication Research, 47*, 155–177.
Weisburg, D. S., Ilgaz, H., Hirsh-Pasek, K., Golinkoff, R., Nicolopoulou, A., & Dickinson, D. K. (2015). Shovels and swords: How realistic and fantastical themes affect children's word learning. *Cognitive Development, 35*, 1–14.
Woolley, J. A., & Ghossainy, M. E. (2013). Revisiting the fantasy–reality distinction: Children as naïve skeptics. *Child Development, 84*, 1496–1510.
Zhai, J., Jocz, J. A., & Tan, A.-L. (2014). "Am I like a scientist?": Primary children's images of doing science in school. *International Journal of Science Education, 36*, 553–576.