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Examining explanatory biases in young children's biological reasoning

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Abstract

Despite the well-established literature on explanation in early childhood, little is known about what constrains children's explanations. State change and negative outcomes were examined as potential explanatory biases in the domain of naïve biology, extending upon previous work in the domain of naïve physics. In two studies, preschool children ($N = 70$, 3- to 5-year-olds) were informed of the distinct health outcomes of characters in four between-subjects conditions (i.e., becoming ill, recovering from illness, continuous health, and continuous illness) and asked to provide explanations. Whereas children in both studies provided relevant information for health outcomes, they more often explained outcomes that included a salient health state change. Presence of a state change also influenced the interpretation of potentially relevant information and improved memory for health outcomes. We discuss how biases in children's explanations constrain children's reasoning and may exacerbate difficulties with reasoning about important health-related topics such as illness prevention.

The development of organized, explanatory systems of knowledge is an integral part of human cognition and a fundamental developmental task. Despite the fact that a well-established, wide-ranging, and influential body of research exists on the development of causal reasoning (Gopnik & Schulz, 2007; Keil, 1992; Kuhn, 1989; Wellman & Gelman, 1992) and on the development of causal explanatory reasoning in particular (Chi, DeLeeuw, Chiu, & LaVancher, 1994; Crowley & Siegler, 1999; Frazier, Gelman, & Wellman, 2009; Gopnik, 2000; Keil, 2006; Keil & Wilson, 2000; Legare, 2012; Legare, Gelman, & Wellman, 2010; Legare, Wellman, & Gelman, 2009; Lombrozo, 2006; Wellman, Hickling, & Schult, 1997; Wellman, 2011), there has been less sustained and systematic research on what constrains children's explanations (Legare et al., 2010).

Causal explanation is a goal-directed cognitive activity that depends on what is relevant or important to the explainer. Given the potentially infinite number of outcomes and events one

could seek to explain, especially for young children early in the process of developing causal knowledge, identifying the specific kinds of events, outcomes, and goals that trigger explanation provides insight into what motivates (and guides) the development of causal cognition (Legare et al., 2010). Although a substantial amount of developmental literature has demonstrated that young children frequently seek (Callanan & Oakes, 1992) and provide explanations (Wellman et al., 1997), little is known about what triggers this childhood explanatory activity. Are there explanatory biases in what children are motivated to explain? Are these biases detectable across multiple domains?

In recent work with preschool children, Legare and colleagues investigated potential biases that prompt explanation: inconsistency with prior knowledge, state change, and negative outcomes (Legare, 2012; Legare et al., 2010). Using a novel “blicket detector” paradigm (Gopnik & Sobel, 2000), children were more likely to first explain an outcome that involved state change (an object activating or deactivating a light) than a non-state change (the light remaining on or off). Thus, in the absence of an inconsistent outcome, state changes systematically triggered children’s explanations. Just as the visual system detects changes (e.g., motion), the causal system may be set up to detect changes, a heuristic for identifying that which needs explanation.

This research provides evidence that state change motivates children’s explanations in the domain of naïve physics, however, no research to date has examined the generalizability of this finding. One possibility is that state change motivates explanatory activity across content domains. For example, children may expect objects to remain in motion or individuals to stay healthy. Therefore state changes, such as contracting illness, may trigger children’s explanations. In the current studies, our objective was to examine state change and negative outcomes as explanatory biases in the domain of naïve biology, using children’s explanations as the primary dependent measure.

There is also some indirect evidence that negative outcomes may motivate explanation. For example, children ask more causal questions about negative emotions than positive emotions, suggesting that negative events may provoke children’s explanations more than positive events or events in which things are functioning as expected (Wellman & Lagattuta, 2004). Additionally, negative events seem to trigger counterfactual thinking as part of the causal reasoning process (German, 1999). Because it is possible that both state change and negative outcomes may provoke causal explanation in children and because these kinds of outcomes are often confounded both in the world and in experimental manipulations, a feature of our study design was to experimentally differentiate the kinds of outcomes that children find noteworthy and feel compelled to explain.

Children have complex beliefs about biological processes at very young ages (Inagaki & Hatano, 2002; 2006; Siegal & Peterson, 1999; Wellman & Gelman, 1992). Even 3-year-olds recognize biological causes (Kalish, 1996) and can use appropriate language to articulate this understanding (Schult & Wellman, 1997; Wellman et al., 1997) by providing explanations that refer to non-obvious properties and entities (Au, Sidle, & Rollins, 1993; Legare et al., 2009). For example, preschool children recognize that germs or contamination are responsible for the transmission of contagious illnesses (Inagaki & Hatano, 2002; Kalish,

1996; Springer & Ruckel, 1992), although this understanding appears to be at a skeletal framework level (Au, Romo, & DeWitt, 1999; Raman & Winer, 2002, 2004; Solomon & Cassimatis, 1999). Other research on the development of biological explanations has demonstrated that even preschool children have sophisticated beliefs about health outcomes (Inagaki & Hatano, 1993; Slaughter & Ting, 2010).

We propose that children's explanations for biological outcomes provide insight into the biases that constrain childhood explanatory activity, as well as provide evidence for the generalizability of previous findings that state change is an explanatory bias in early childhood (Legare, 2012; Legare et al., 2010). The present studies expand upon previous research in three ways by (a) extending the findings from Legare et al. (2010) to a new domain, (b) specifically targeting state change and negative outcomes as additional kinds of explanatory triggers, and (c) investigating explanatory triggers in a knowledge-rich context.

Study 1

In order to isolate state change and negative outcomes as potential explanatory triggers, contrasting scenarios were used. Children in four within-subjects conditions were introduced to two characters and were informed of their health states (see Table 1). One of the characters experienced a change of state in their health condition throughout the day (e.g., going from healthy to sick) and the other character experienced a consistent health state throughout the day (e.g., being healthy in the morning and healthy at night). Condition 1 isolates state change by holding positive valence of outcome constant and testing the contrast between cure and prevention. A character who was sick in the morning and healthy at night (cure) was contrasted with a character who was healthy in the morning and remained healthy at night (prevention). Condition 2 contrasts state change and a negative outcome. A character who was sick in the morning and became healthy at night (cure) was contrasted with a character who was sick in the morning and remained sick at night (remain sick). Condition 3 contrasts negative outcome plus state change to positive outcome plus lack of state change. A character who was healthy in the morning and became sick at night (become sick) was contrasted with a character who was healthy in the morning and remained healthy at night (prevention). Condition 4 isolates state change while holding negative outcome constant. A character who was healthy in the morning and became sick at night (become sick) was contrasted with a character who was sick in the morning and remained sick at night (remain sick). We predicted that in each condition, participants would be more likely to first explain the state change outcome, regardless of the valence of the outcome. Dependent measures include which outcome children explained first and the content of their explanations.

Method

Participants

Twenty-eight preschool children participated (M age 4;3; range 3;1 to 5;2). The sample was recruited from a university town in the American Midwest and was primarily Euro-American.

Materials and procedure

Each participant was presented with two vignettes in each of four within-subjects conditions (eight vignettes total). The vignettes were presented in a separate random order for each participant. In each vignette, two characters (i.e., drawings of young children) were contrasted: one who experienced a health state change and one who did not. The order of the outcomes was counterbalanced. Each vignette was accompanied by two pictures of each character: one of the character in the morning and one of the character at night.

To begin each trial, a yellow poster board representing daytime was placed in front of the participant. Then a picture of the first character was placed on the board followed by a short description of his or her health state. The gender of the characters was always matched to the gender of the participant. The picture corresponded to the character's health state. For example, in Condition 1, children were shown a picture of a child with an unhappy expression and flushed cheeks and were told, "This is Ben in the morning. Ben is sick. He doesn't feel good and his body feels bad." Then a picture of the second character was placed on the board followed by a description of his/her health state. For example, they were shown a picture of a child with a happy expression and no flushed cheeks and were told, "This is Jim in the morning. Jim is healthy. He feels good and his body feels strong."

Subsequently, a dark blue poster board representing nighttime was placed on the table below the daytime board. The experimenter indicated that a whole day had gone by and that now it was nighttime. To represent the state change, two different pictures of the same characters were placed on the nighttime board and short descriptions of their health states were provided. For example, "This is Ben at night. Ben was sick in the morning but now he's healthy. Now he feels good and his body feels strong." After the health states of both characters had been described, children were asked a general explanatory question, "Why is that?" and given the opportunity to explain whichever outcome they chose.

After the participants provided an explanation for the outcome of their choice, they were asked specifically to provide an explanation for each outcome. For example, regarding a character who was sick in the morning and healthy at night, participants were asked, "Why did that happen? Ben was sick in the morning but now he's healthy, why is that? Why is Ben healthy now?" Regarding the character who was healthy in the morning and healthy at night, participants were asked, "Why did that happen? Jim was healthy in the morning and now he's still healthy, why is that? Why is Jim still healthy now?"

Transcription and coding

Interviews were videotaped and transcribed verbatim. As in prior research (Legare et al., 2010), one of the dependent variables was the outcome the child explained first per pair of outcomes in each condition (state change = 1, non-state change = 0, both = 0.5). The other dependent variable was the kind of explanation provided for each kind of health outcome. The content of the explanations for each outcome was coded into five categories: positive action, negative action, absence of positive action, absence of negative action, and non-explanatory. Presence of a specific category of explanation was coded as 1; absence of a specific category of explanation was coded as 0. Explanations were coded as *positive action*

if they referred to a specific health-promoting activity (e.g., eating fruits and vegetables, getting lots of sleep). Explanations were coded as *negative action* if they referred to a specific health-compromising activity (e.g., eating bad food). Explanations were coded as *absence of positive action* if they said that the character failed to engage in a health-promoting activity (e.g., not getting enough sleep). Explanations were coded as *absence of negative action* if they said that the character did not engage in a health-compromising activity (e.g., not eating bad food). Finally, explanations were coded as *non-explanatory* if participants indicated that they could not provide an explanation or did not know.

Inter-rater reliability was established using a randomly selected sample of 25% of the data. Two persons independently coded the reliability sample with 94% agreement. Reliability was calculated for explanatory coding categories for positive action, negative action, absence of positive action, absence of negative action, and non-explanatory categories, with Kappas ranging from .81 to .93. All of the Kappas for this coding fall within near perfect (.81 and above) levels (Landis & Koch, 1977). Disagreements were resolved through discussion.

Composite coding categories—In order to determine if participants generated more relevant explanations for state change than non-state change outcomes, summary scores were computed. Summary score variables were computed based on whether the kind of explanation provided for each kind of outcome was a match, mismatch, or non-explanatory response. Explanations were coded as a match if the kind of explanation given was appropriate and relevant for the outcome. For example, both a negative action and a lack of a positive action were coded as a match explanation for a character who became sick or remained sick. Explanations were coded as a mismatch if the kind of explanation given was inappropriate for the outcome. For example, both a positive action and a lack of a negative action were coded as a mismatch explanation for a character who became sick or remained sick. Finally, non-explanatory responses were included in an additional category for all four kinds of state change and non-state change outcomes.

Summary scores were calculated by adding together match explanation scores for each kind of outcome (state change outcomes, non-state change outcomes, negative outcomes, and positive outcomes). Match explanation scores for cure and becoming sick were summed to calculate a state change score. Similarly, match explanation scores for prevention and remaining sick were summed to calculate a non-state change score. Match explanation scores for cure and prevention were summed to calculate positive outcome scores. Match explanation scores for becoming sick and remaining sick were summed to calculate negative outcome scores. Mismatch scores and non-state explanatory summary scores were calculated the same way. Participants had an opportunity to provide an explanation for each kind of health outcome four times (each outcome appeared in two conditions and each condition had two vignettes). Because two kinds of outcomes were summed together (i.e. becoming sick and cure), scores were out of a total of 8 possible.

Results

Participants' explanations for health state changes were contrasted with their explanations for non-state changes in order to determine whether participants were more likely to first explain health state changes. Conditions 1–4 were designed to test a priori planned comparisons within rather than between conditions. Therefore, *t*-test comparisons to chance were used to calculate which health outcome participants explained first, instead of an omnibus ANOVA. The results of which outcome participants explained first are followed by the content of participants' explanations for the outcomes.

First explanations

In both conditions in which a state change was contrasted with a non-state change outcome and the valence of the outcomes was held constant (both positive or both negative), children were more likely than chance to explain the state change outcome first (Condition 1: $M = 1.32$ out of 2 possible, $SD = 0.5$, $t(27) = 3.3$, $p < .01$; Condition 4: $M = 1.25$, $SD = 0.65$, $t(27) = 2.0$, $p < .05$). If children were merely attending to health outcome, their first explanation for these contrastive events should have been at chance (1.0), given that the outcomes in both conditions were equivalent (e.g., in both cases the character ended up healthy or sick). Additionally, when a state change outcome that coincided with a negative outcome (became sick) was contrasted with a positive, non-state change outcome (prevention), children were more likely than chance to explain the negative, state change outcome first (Condition 3: $M = 1.27$, $SD = 0.57$, $t(27) = 2.5$, $p < .05$). In contrast, when a state change outcome (cure) competed with a negative outcome (remain sick), the first explanation was at chance (Condition 2: $M = 1.14$, $SD = 0.66$, $t(27) = 1.14$, *ns*). This suggests that although state change is an important factor in determining what children explain, other factors, such as negative outcomes (e.g., illness) are also important.

The content of explanations for different kinds of health outcomes

In addition to investigating whether participants were more likely to first explain state change or negative outcomes in contrast to non-state change or positive outcomes, we were also interested in investigating the content of participants' explanations. We predicted that participants would provide more relevant explanations for health state changes than non-state changes. The content of the explanations participants provided for each kind of health outcome was analyzed and the number of explanations that fell into each of the five explanatory categories was calculated. Collapsing across conditions, summary scores for both state change versus non-state change and negative versus positive outcomes were computed. To examine potential effects of state change outcomes on participants' explanations, explanation types for each health-state change (becoming sick and cure) and non-state change (prevention and remaining sick) were compared using paired *t*-tests. Additionally, to examine potential effects of negative versus positive outcomes on participants' explanations, explanation types for each negative outcome (becoming sick and remaining sick) and positive outcome (prevention and cure) were analyzed in the same way.

State change versus non-state change outcomes—Children were significantly more likely to give match explanations to explain state change outcomes (becoming sick and

cure; $M = 5.96$ out of 8 possible, $SD = 2.67$) than non-state change outcomes (staying sick and prevention; $M = 4.39$, $SD = 3.02$), $t(27) = 3.62$, $p < .001$. Nonetheless, children gave significantly more match explanations than mismatch explanations for both state change outcomes, $t(27) = 10.43$, $p < .001$, and non-state change outcomes, $t(27) = 7.69$, $p < .001$, indicating that even young children have access to information about illness and can provide relevant explanations for health outcomes. Additionally, mismatch explanations were very infrequent overall ($M = 0.3$ out of 8 possible for state change outcomes and none for non-state change outcomes). In contrast, children were more likely to fail to generate an explanation (generating a non-explanatory response) for a non-state change outcome ($M = 3.61$, $SD = 3.02$) than a state change outcome ($M = 1.71$, $SD = 2.64$), $t(27) = 4.70$, $p < .001$.

Negative versus positive outcomes—Children were equally likely to give match explanations to explain negative outcomes (becoming sick and remaining sick; $M = 5.32$ out of 8 possible, $SD = 2.78$) as positive outcomes (cure and prevention; $M = 5.04$, $SD = 2.80$), $t(27) = 0.78$, *ns*. Children gave significantly more match explanations than mismatch explanations for both negative outcomes, $t(27) = 9.55$, $p < .001$, and positive outcomes, $t(27) = 9.31$, $p < .001$. This provides further evidence that young children can provide relevant explanations for health outcomes.

Children were also equally likely to fail to generate an explanation (and provide a non-explanatory response) for both a negative outcome ($M = 2.46$, $SD = 2.77$) and a positive outcome ($M = 2.86$, $SD = 2.54$), $t(27) = 1.05$, *ns*.

Discussion

Study 1 provides support for the proposal that non-state change health outcomes motivate fewer relevant causal explanations than state change health outcomes and thus may be less compelling from an explanatory perspective. As hypothesized, preschool children were more likely to first explain and provide relevant explanations for state change outcomes (e.g., cure) than non-state change outcomes (e.g., prevention). Indeed, in three of the four conditions, children were significantly more likely to explain a health state change first. Notably, in both cases when prevention (a non-state change) was contrasted with a health state change (cure or becoming sick), preschool children were more likely to explain the health state change. This would not be anticipated if children were merely attending to the initial health state, which is equivalent in the contrast between prevention and becoming sick. Relatedly, attending to health state outcome also fails to explain this pattern, because in the contrast between curing illness and prevention, health state outcomes are equivalent.

Further support for the special role of state change in provoking causal reasoning was found in the content of the explanations children generated to explain these paired events. Preschool children provided more relevant explanations for health state changes than non-state changes. Additionally, children were less able to generate an explanation (i.e., more likely to provide a non-explanatory response) for non-state changes in health state. Importantly, the fact that preschool children were less able to generate relevant explanations for non-state changes cannot be attributed to a general lack of ability to explain health or illness. For example, preschool children proved to be capable of providing appropriate

explanations for cures or recovery from illness. Given this, the fact that children were more likely to provide relevant explanations for characters that became sick or became healthy (cure) than characters that remained healthy (prevention) is especially important.

The data also indicate that children attend to more than state change when providing explanations for outcomes. Despite the fact that children were more likely to first explain a character who became sick than a character who remained sick, they were equally likely to first explain a character who was cured of illness as a character who remained sick. One possibility for this result is that children are also attending to negative outcomes and inconsistency with prior knowledge. For example, although a cure involves a noteworthy state change, remaining sick is both a highly negative outcome and may violate children's expectations for health outcomes. Alternately, in the case of becoming sick versus remaining sick, because both outcomes are negative, children may attend more to the health state change (becoming sick). However, unlike the results of the analyses of state change versus non-state change outcomes, participants were equally likely to provide relevant explanations for negative health outcomes as for positive health outcomes. These results provide evidence that, relative to state change, negative outcomes may play less of a role in provoking children's explanations.

This study provides important information about explanatory biases in biological reasoning, however, the role prior knowledge may have played in participants' responses is unclear. In order to address this limitation, a second study was conducted that presented children with vignettes featuring novel creatures and novel symptoms. The nature of these novel creatures and symptoms ensured that participants could not entirely rely on prior knowledge and experiences with health outcomes.

Study 2

Study 2 was designed to minimize the effects of prior knowledge on children's explanations for different health states. To this end, children were told of a novel planet inhabited by novel creatures who experienced novel symptoms. Rather than presenting children with familiar characters (e.g., a girl named Sally) and a familiar illness conditions (e.g., tummy ache), children were told about an alien (e.g., Plumin) and a bodily condition that she experienced (e.g., drooping antennae). Half of the vignettes described a state change (e.g., a creature that felt good in the morning but felt bad at night) and a corresponding change of symptoms (e.g., a creature whose antennae went from perky in the morning to droopy at night). The other half of the vignettes described a non-state change (e.g., a creature that felt good in the morning also felt good at night) and did not experience a corresponding change in symptoms (e.g., a creature whose antennae remained perky throughout the day and night).

The objective of this study was to investigate whether participants provided more relevant explanations for health-related outcomes involving state change or negative valence as compared to non-state change and positive valence. Thus, the content of the children's explanations in unfamiliar contexts was of primary interest. In Study 1, children were simultaneously presented with two characters exhibiting different health states. This allowed us to use the order of children's explanations, specifically which character was explained

first, as a measure of explanatory triggers. However, in Study 2, we were interested in assessing the content of children's explanation for each health state without interference from competing (and potentially more compelling) health states. Thus, instead of simultaneously presenting a health state change and a non-state change, each was presented individually.

To illustrate the passing of time, a morning-night metric similar to the experimental paradigm used in Study 1 was used. Four conditions similar to those used in Study 1 were used in this study. Condition 1 represents a cure, or engaging in an action (e.g., taking medication) that could change a health state from illness to healthy (i.e., a character who was sick in the morning became healthy at night). Condition 2 represents an illness-inducing action (e.g., touching an object belonging to a sick individual) that can bring about a change in state from healthy to sick (i.e., a character who was healthy in the morning became sick at night). Condition 3 represents prevention, in which engaging in an action (e.g., eating well) can help maintain a healthy state (i.e., a character who was healthy in the morning remained healthy at night). Condition 4 represents sustained illness in which failing to complete a potential curative action (e.g., not eating well) can be implemented in helping to maintain a state of sickness (i.e., a character who was sick in the morning remained sick at night). These conditions represent two cases of state change (Conditions 1 and 2) and two cases of non-state change (Conditions 3 and 4). We predicted that children would provide more relevant explanations for cases in which state change was prominent (cure and become sick) than cases in which a state change did not occur (prevention and remain sick) and that negative outcomes would elicit more relevant explanations than positive outcomes.

We were also interested in the extent to which children were more motivated to seek out additional, potentially explanatory information for some outcomes than others and whether some outcomes were more memorable than others. To examine this, children were provided with ambiguous information and examined the extent to which they incorporated this information into their explanations. In addition to changing the health state and the valence of the end state, we also informed the participants of an ambiguous action performed by the characters during the time that the state change/lack of state change occurred. These actions (i.e., ate a goz, had a drink of toma, touched a blicket, licked a gaff) were not described as having any relation to the sickness or health state. We predicted that children would be more likely to incorporate the ambiguous actions into their explanations for state change and negative outcomes than non-state change and positive outcomes. A memory task was also included to assess whether some outcomes were more memorable to children than others. We predicted that children would be more likely to remember outcomes in which a state change or negative outcome occurred than outcomes in which a non-state change or positive outcome occurred.

Methods

Participants

Forty-two preschool children participated (*M* age 4;0; range 3;2 to 5;6). The sample was recruited from a university town in the American Southwest, and was primarily Euro-American.

Materials and procedure

Each participant was presented with 4 different vignettes representing the four conditions. They were presented in a separate random order for each participant. The four conditions included four different novel beings, referred to as aliens named Plumin, Tarlin, Kaz, and Dake, who each displayed one of four health conditions: healthy in the morning and sick at night (i.e., become sick), sick in the morning and healthy at night (i.e., cure), healthy in the morning and healthy at night (i.e., prevention), or sick in the morning and sick at night (i.e., remain sick). Additionally, each of the four ambiguous novel actions was associated with a particular alien being (e.g., Tarlin touched a blicket) and had no overt connection to the health state. The kind of alien, condition, and order were randomized across all trials and were presented in a separate random order for all participants. The gender of the aliens was always matched to the gender of the participant.

In each vignette, a novel being was introduced as an alien who lived on a different planet. Each vignette was accompanied by four possible sets of pictures. For the state change conditions, one picture depicted the health state of the character in the morning and one depicted the health state at night. For the non-state change conditions, a mirror image of these healthy/sick drawings was used. A research assistant showed the participant a picture of a ringed planet and said, “This is Zanatar. Zanatar is an alien planet. I’m going to tell you a story about some alien friends of mine on Zanatar and then I am going to ask you some questions.” A single felted poster board with separate yellow and blue sections (representing day and night) was shown to the participant.

Following this introduction, a picture of one of the aliens was placed in the center of the top yellow portion of the board and a short description of his/her health state was described to the participant. The picture illustrated the alien’s health state. For example, in one condition an alien with long tails was placed on the top yellow half of the board. The alien looked happy and his tails were curly (see Figure 1). Children then heard a description of the character and his or her health state. For example, “This is Tarlin. Tarlin is a creature on the planet Zanatar. This is Tarlin in the morning. Look! She has long tails! Tarlin is healthy. She feels good this morning and look! Her tails are squiggly! Look how squiggly they are!” The participant was then informed of an action that the participant completed during the day. For example, “During the day, Tarlin touched a blicket.”

A second picture of Tarlin was then placed on the blue (bottom) half of the board directly beneath the picture already on the yellow (top) half of the board. This second picture represented a state change or a continuation of the health state. For example, the picture of sick Tarlin showed that she was unhappy and that her tails changed shape. In this situation the experimenter told the participant, “Now it is nighttime. Now Tarlin is sick. She doesn’t feel good and look! Her tails are flat! Look how flat they are!” In the case where a state change did not occur, a mirrored copy of the original picture was used to represent that Tarlin was healthy at night. The experimenter then explained, “Now it’s nighttime. Now Tarlin is still healthy. She still feels good and look! Her tails are still squiggly! Look how squiggly they are!” These vignettes were then each followed by the questions, “Why is that?” and “Why is Tarlin healthy/sick now?”

After providing explanations for all of the vignettes and before participating in the memory task, each child participated in a two-minute distracter task. The ‘morning’ version of the novel creature was placed on the top yellow half of the board and the participant was asked to recount her memory of the creature. For example, “This is Tarlin. Do you remember Tarlin? Tarlin was healthy in the morning. Can you tell me, was Tarlin healthy at night, too, or did she get sick? Can you tell me any more about that? Is there anything else you remember about Tarlin?” The order in which the aliens were shown in the memory task was randomized separately from the order they were presented in the first part of the experiment.

Transcription and coding

Interviews were transcribed verbatim. The explanations provided by participants were coded for the same content as in Study 1: positive action (e.g., “he ate healthy food like fruit”), negative action (e.g., “he ate bad food”), absence of a positive action (e.g., “he didn’t get enough sleep”), absence of a negative action (e.g., “he didn’t eat unhealthy food”), and non-explanatory (e.g., “because he’s sick”). Presence of a specific category of explanation was coded as 1; absence of a specific category of explanation was coded as 0.

Explanations for the first question (“Why is that?”) and the follow-up question (“Why is Tarlin sick now?”) were combined to form a composite score for each of the four categories: remain sick, prevention, cure, and become sick. If a child provided at least one explanation of a particular kind in response to either the initial question or the follow-up question, they were given a code of 1 for that explanatory category. If no explanation of that kind was provided they were given a code of 0. For the memory task, we noted whether or not participants recognized the alien and whether or not they identified the alien’s health outcome correctly.

Inter-rater reliability was established using the complete data set. All explanations were independently coded by two people with 92% agreement. Reliability was calculated for explanatory matched coding categories for positive action, negative action, absence of positive action, absence of negative action, and non-explanatory categories, with Kappas ranging from .83–.91. All of the Kappas for this coding fall within near perfect (.81 and above) levels (Landis & Koch, 1977). Disagreements were resolved through discussion.

Composite coding categories—In order to investigate whether participants more frequently provided relevant explanations for some health outcomes than others, summary score variables were once again computed based on whether the kind of explanation provided for each kind of outcome was a match, mismatch, or non-explanatory. Match explanations were coded as 1, mismatch explanations were coded as 0, and non-explanatory responses were coded as 0.5.

As in Study 1, in order to determine if participants generated more relevant explanations for state change and negative outcomes than non-state change and positive outcomes, summary score variables were computed. State change, non-state change, positive outcome, and negative outcome summary scores were also calculated for the memory scores. We calculated both whether the child said that they remembered the character and whether they accurately remembered the character. We also calculated the same summary scores to

examine if children in different conditions were more or less likely to incorporate the ambiguous action into their explanations.

Results

Explanations for health state changes were contrasted with non-state changes, and positive health outcomes were contrasted with negative health outcomes, in order to determine if these outcomes influenced a participant's tendency to provide an explanation. We hypothesized that whereas state changes would be most likely to trigger an explanation, other variables such as negative outcomes might also provoke children's explanations. In order to test these a priori comparisons, we conducted paired *t*-tests between the state change and non-state change, and positive and negative outcomes.

The content of explanations for different kinds of health outcomes

As in Study 1, we predicted that participants would provide more relevant explanations for the vignettes with state changes than the vignettes non-state changes. To examine potential effects of state change outcomes on participants' explanations, summary scores for each health-state change (becoming sick and being cured) and non-state change (prevention and remaining sick) were compared using paired *t*-tests. We analyzed the effects of negative versus positive outcomes on participants' explanations the same way, using paired *t*-tests to compare negative outcomes (becoming sick and remaining sick) and positive outcomes (prevention and cure).

State change versus non-state change outcomes—Participants were significantly more likely to give match explanations to explain state change outcomes (becoming sick and cure; $M = 1.62$ out of 2, $SD = 0.41$) than non-state change outcomes (staying sick and prevention; $M = 1.42$, $SD = 0.40$, $t(41) = 3.42$, $p < .001$). Unlike Study 1, however, participants were not more likely to fail to generate an explanation for non-state change outcomes ($M = 0.45$, $SD = 0.71$ out of 2) than state change outcomes ($M = 0.29$, $SD = 0.60$), $t(41) = -1.42$, *ns*. This indicates that although there were significant differences in the content of the explanations between state change and non-state change outcomes, children were equally likely to attempt to provide an explanation for either outcome. This result likely reflects the method used in Study 2, in which stories were presented one at a time.

Negative versus positive outcomes

Children were marginally more likely to give causal explanations to explain negative outcomes (becoming sick and remaining sick; $M = 1.58$ out of 2, $SD = 0.41$) than positive outcomes (staying healthy and prevention; $M = 1.45$, $SD = 0.42$), $t(41) = -1.92$, $p = .062$. Participants did not give significantly more non-explanatory answers for negative outcomes ($M = 0.36$ out of 2, $SD = 0.58$) than positive outcomes ($M = 0.38$, $SD = 0.62$), $t(41) = 0.27$, *ns*.

Incorporation of the ambiguous action into explanations

As predicted, participants were more likely to incorporate the ambiguous novel action into their explanations in the state change conditions ($M = 0.26$ out of 2, $SD = 0.54$) than the

non-state change conditions ($M = 0.10$, $SD = 0.37$), $t(41) = 2.21$, $p < .05$. This was not the case for negative valence outcomes ($M = 0.17$ out of 2, $SD = 0.44$) as compared to positive valence outcomes ($M = 0.19$, $SD = 0.45$), $t(41) = -0.37$, ns .

Memory task

Children were equally likely to respond to the first question by indicating that they remembered the alien for both the state change ($M = 1.81$, $SD = 0.51$) and non-state change conditions ($M = 1.76$, $SD = 0.53$), $t(41) = 0.63$, ns , and for the negative outcomes ($M = 1.71$, $SD = 0.64$) and positive outcomes ($M = 1.90$, $SD = 0.35$), $t(41) = -1.96$, ns . However, for the second question involving outcomes, children's responses differed significantly. When children were asked to identify whether the health state of the character stayed the same or changed, children were more likely to recall vignettes with state changes ($M = 1.74$ out of 2, $SD = 0.59$) than vignettes not involving state change ($M = 1.43$, $SD = 0.74$), $t(41) = 2.17$, $p < .05$. In contrast, children were equally likely to correctly recall vignettes with positive ($M = 1.55$ out of 2, $SD = 0.59$) and negative outcomes ($M = 1.62$, $SD = 0.54$), $t(41) = 0.77$, ns .

Discussion

The results of Study 2 provide additional support for the proposal that state change triggers children's explanations. As hypothesized, children provided more relevant explanations for health state changes than non-state changes. Children were more likely to provide a relevant explanation for outcomes involving becoming sick or recovering from illness than for outcomes involving the maintenance of health (prevention). In contrast, valence had no measurable effect on the relevance of the explanation given. Children were no more likely to provide a relevant explanation for negative outcomes than they were for positive outcomes.

We also examined the kinds of outcomes that motivated participants to incorporate novel, ambiguous actions into their explanations. As predicted, children were significantly more likely to incorporate the ambiguous information into their explanations for conditions involving state change than for conditions that did not involve state change. In contrast, there was no significant difference in this measure between vignettes with outcomes of different valences. This finding further supports the proposal that state change, but not negative outcomes, serves as an explanatory trigger for information concerning health states.

The data from the memory task also indicate that children attend more to state change than non-state change. Despite the fact that children were equally likely to say that they remembered the aliens from all conditions (prevention, cure, remaining sick, and becoming sick), they were significantly more likely to correctly identify the outcomes of vignettes that included state change as compared to those outcomes that did not include state change. This difference was not seen in comparisons between negative and positive outcomes.

General Discussion

Despite the fact that there is a well-established literature on young children's biological reasoning (Inagaki & Hatano, 2002; Siegal & Peterson, 1999), little is known about what motivates children to construct explanations for biological phenomena and what constrains

this explanatory activity. In the current research, we investigated causal explanatory biases in young children's biological reasoning, specifically targeting state change and negative outcomes.

Our data provide empirical support for the proposal that the presence of a state change serves as an especially powerful trigger for children's explanations in the context of biological reasoning. Consistent with prior research in the domain of naïve physics (Legare et al., 2010), Study 1 demonstrates that children were more likely to first explain state change versus non-state change outcomes. Children were also less likely to explain prevention first as compared to the other health scenarios (becoming sick, being cured, and remaining sick). Additionally, data from both studies demonstrated that participants were better able to generate relevant explanations to interpret state change outcomes in contrast to non-state change outcomes. Participants were more likely to generate causal explanations for becoming healthy (being cured) and becoming sick as compared to prevention and remaining sick.

Study 2 included two additional measures to further investigate the content of children's explanations for state change versus non-state change outcomes. Consistent with our predictions, children were significantly more likely to incorporate ambiguous information into their explanations for conditions involving state change than for conditions that did not involve state change. Children were more likely to search the vignette for a possible explanation when the stories included a character either becoming sick or being cured, but not when the story concerned prevention or remaining sick. Similarly, children were significantly more likely to remember the correct health outcomes for vignettes involving state change as compared to those that did not. Getting sick and being cured were more memorable than simply remaining healthy or sick. Consistent with prior work (Legare et al., 2010), there was little evidence that negative outcomes serve as an explanatory bias in early childhood suggesting that the valence of outcomes seems to play less of a role in provoking children's explanations as compared to state change or inconsistency (Legare et al., 2010).

In addition to providing an ideal context for examining explanatory biases, we propose that studying the influence of state change and negative outcomes on children's explanations may be relevant to understanding reasoning about illness prevention. Despite the substantial amount of research on biological concepts in young children, most cognitive developmental research has focused on children's understanding of the causes and cures of illness (Inagaki & Hatano, 2002; Siegal & Peterson, 1999), and there is surprisingly little research on children's understanding of illness prevention (Piko & Bak, 2006). From an applied perspective, research examining children's understanding of illness prevention could have important educational consequences (Carey, 2000; Schonfeld, Johnson, Perrin, O'Hare, & Cicchetti, 1993).

We propose that examining explanatory biases in early childhood has potential implications for understanding difficulties with reasoning about illness prevention. In particular, we hypothesize that explaining illness prevention may be more challenging for children than explaining why a healthy person became sick, or why a sick person recovered from an illness due to the lack of a state change (i.e., a healthy person remains healthy). Children

understand that certain factors (e.g., germs) can intervene to cause illness and that other factors (e.g., medicine) can intervene to cure illness (Kalish, 1996). In these cases, the intervention of a cause leads to a change of state (e.g., germs lead the individual to change from healthy to sick; medicine leads the individual to change from sick to healthy). The start-state is distinct from the end-state. In contrast, prevention is distinctive in that there is no state change (e.g., medicine results in the individual continuing to display good health). Thus, the desirable outcome is effectively a null or non-effect because a person successfully maintains health by avoiding disease. This lack of state change may make understanding how to prevent illness more difficult than reasoning about how to cure illness. The lack of a perceptible difference or state change in the cause-effect relationship involved in the process of illness prevention may influence the conceptual understanding of biological information. Data from two studies indicate that prevention may be difficult for children to understand because it does not involve a salient state change as can be found in cases of getting sick and being cured. As a result, children may be less compelled to attend to, explain, and reason about prevention.

In sum, our results indicate that regardless of the level of prior knowledge, children are biased to explain state change over non-state change outcomes and are more likely to provide relevant explanations for state-change than non-state change outcomes. This research provides new insight into constraints on children's explanations and into the generalizability of these explanatory biases across domains.

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Figure 1.
Study 2. Stimuli

Table 1

Study 1. Description of conditions, focal contrasts, and predictions for first explanations

Condition	Focal contrast	Prediction: First explanation
1: Positive outcome held constant	State change (cure) vs. non-state change (prevention)	State change (cure)
2: State change and positive outcome compared to non-state change and negative outcome	State change (cure) vs. non-state change (remain sick)	State change (cure)
3: State change and negative outcome compared to non-state change and positive outcome	State change (become sick) vs. non-state change (prevention)	State change (become sick)
4: Negative outcome held constant	State change (become sick) vs. non-state change (remain sick)	State change (become sick)