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Young Children's Predictions of Illness: Failure to Recognize Probabilistic Causation

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Abstract

In this study preschool-aged children made predictions for a set of salient probabilistic causes. Of interest was whether they viewed outcomes of familiar causes of illness as definite or as probabilistic. In Experiment 1, children judged that a common cause would affect all members of a group in the same way. In Experiment 2 children believed they could definitely predict illness outcomes in a single case. These judgments contrasted with adults' variable and uncertain predictions. Children did recognize uncertainty in outcomes dependent on voluntary choices. A third experiment presented both high and low potency causes of illness. Children treated all causes of illness as non-probabilistic. These results are discussed in the context of children's understanding of causal relations and the sources of variability.

There is now intense interest in young children's beliefs about causal relations (see Wellman & Gelman, in press, and 1992, for reviews). Representations of causal relations are thought to provide orderly and stable knowledge and promote powerful inferences. One implication of a causal relation is that we expect some outcomes rather than others. A particular cause (e.g., one object hitting another) will lead to some effects (movement) but not others (color change). This is more than just a statistical expectation. "Cause" implies some necessary connection between one thing or event and another. Thus when we know one thing causes another we expect a regular succession; we feel we know what will (must) happen next and what is ruled out. In this way cause is "the cement of the universe" (Mackie, 1974). It provides the structure that keeps experience regular and predicable.

However, causal regularity is something of a fiction, or at least an idealization. In fact, most commonsense causal knowledge is heuristic and uncertain. For example, pushing one block into another causes the second to move, usually. Dropping a glass on a hard floor causes it to break, often. Offspring resemble their parents, to some degree. While we have many means for coping with the uncertainty of causal relations (see General Discussion below), the important point is that we do recognize this uncertainty. Our notion of "cause" is still an important one, but the power of causal relations is tempered by our recognition that most causal knowledge is only probabilistic and (to some degree) unreliable. Though this aspect of causal knowledge is familiar enough, the uncertainty of causal knowledge presents some interesting developmental questions. In particular, do young children treat cause-effect relations as certain and reliable, or do they too recognize that commonsense knowledge is only approximate?

The purpose of this paper was to explore young children's intuitions about reliability in one particular domain: causes of illness. Would preschoolers see the effects of causes of illness as probabilistic-uncertain or deterministic-certain? Most familiar sources of illness have probabilistic effects; no simple set of initial conditions actually determine whether a person will get sick or not. Yet, parents and teachers regularly instruct children about the causes of illness. Children know many circumstances that are said to lead to illness (e.g., playing with a sick friend, eating dirty food, Kalish, 1996a; Siegal, 1988; Springer & Ruckel, 1992). However, they must also have experience that the causal generalizations about illness do not always hold (e.g., people do not always get sick after eating dirty food). Thus causes of illness present an interesting test case of children's appreciation of probabilistic causality. If children do see some causal outcomes as probabilistic we might expect illnesses to be among those recognized. Conversely, they may have a bias towards viewing causes as deterministic. Such a bias would be apparent in predictions of illness. There are also important practical implications of views about the reliability of causes of illness (see General Discussion).

We know little about children's judgments of probabilistic causation. Research on conceptions of probability/uncertainty and conceptions of causality has been marked by an interesting dichotomy. Studies of probability have been conducted in non-causal contexts (e.g, randomizing devices). Studies of causal reasoning have been conducted in non-probabilistic contexts (e.g, deterministic physical interactions such as colliding blocks). The purpose of this study of reasoning about illness was to begin to assess whether this disciplinary dichotomy is actually characteristic of the way children think about probability and causality.

Research has demonstrated that preschool-aged children understand both uncertainty and causality. At least to some degree, young children can identify ambiguous statements (see Byrnes & Beilin, 1991 for review). Studies with randomizing devices (e.g., spinners, dice) suggest that children understand the ideas of chance (Kuzmak & Gelman, 1986) and odds (e.g., Fischbein, 1975). The literature on the development of causal reasoning demonstrates that young children expect uniform, reliable cause-effect relations (Bullock, 1985; Bullock, Gelman, & Baillargeon, 1982; Shultz, 1982). Cause is an important organizing principle in children's cognition (for review see Gelman & Kalish, 1993). A sensitivity to, and appreciation of, causal relations seems to be present quite early in development (see chapters in Sperber, Premack, & Premack, 1995).

Although young children may understand both causality and uncertainty, it is unclear whether they see any intersection between the two concepts. Although children seem to have some understanding of the probabilistic nature of randomizing devices (e.g., spinners, dice) these devices are explicitly non-causal. Their behavior does not allow causal inferences (at the level of description of interest). That is, although we can state causal "laws" of illness (e.g., "Contact with a sick person makes you sick."), the point of randomizing devices is the absence of such "laws" (e.g., it is a mistake to believe, "Getting a number on spin 1 makes a different number come up on spin 2). Uncertainty is effectively divorced from causation. If this division is mirrored in children's thought they may believe that probabilistic outcomes occur if (and only if) causal relations are absent.

In the literature on causal reasoning, most studies have presented children with deterministic scenarios in which secure causal inferences may be made.[i] Even in relatively complex multi-factorial contexts tasks have been structured to support strong causal inferences. The causal relations are determinate (a given cause-effect relation always holds) and exhaustive (the behavior of the system is completely predictable). In some sense the causal inferences available are too powerful-- at least compared to the heuristic and partial knowledge that often characterizes common sense. Again, causation is divorced from uncertainty. Children may believe that causal relations occur if (and only if) probabilistic outcomes are absent.

Accounts of the development of causal reasoning are unclear about the status of probabilistic or uncertain cause. On the one hand there may be evidence that a strict distinction between causal and probabilistic phenomena becomes blurred with increasing age. Frye and colleagues (Frye, Zelazo, Brooks, & Samuels, 1996) argued that young children see causal relations in simple "if...then" terms. For example, in predicting the path of marbles rolled through a box, 3-year-olds inferred single condition rules (e.g., that starting position determines path). This seems to imply that causal relations were thought to be unexceptionless-- a given cause would always produce a particular effect. For these children there were no "unknown" factors that might produce variability in outcomes. Slightly older children (4-year-olds) were able to learn two condition rules; for example, that starting position and state of a light (on/off) jointly determined path. Recognizing multiple conditions for effects would seem to allow some recognition of probability or uncertainty in causation. If two factors combine to cause an effect, but only one is known (e.g., starting position but not light-state) then inference must be uncertain. Presumably three-year-olds did not recognize that the relation between starting position and ending position is indeterminate (in the absence of knowledge about other conditions). Alternatively, older children's more complex inferences may have reflected an increased drive for definite and exhaustive causal knowledge. Four-year-olds might have expected determinate knowledge since behavior of the marble is non-random (caused). Three-year-olds may have been quite satisfied with the uncertain success of their single condition rule because they expected only approximate knowledge.

A traditional perspective on the development of causal reasoning has been that caused and random phenomena are initially undifferentiated. Piaget (Piaget & Inhelder,

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[i] One notable exception is Schauble's (1996) studies of scientific reasoning. These tasks involved "noise" in the data (measurement error was often large relative to the size of causal effects). Participants (fifth- and sixth-grade children and adults) tended to interpret error in ad hoc and unsystematic ways. Unexpected (or dis-favored) results may have been attributed to error, but the notion of approximate or uncertain effects was not directly incorporated into causal hypotheses.

1951/1975) argued that young children do not distinguish random from non-random events. For them a causal relation may carry no implication of necessity or reliability (Eisert & Kahle, 1986; Sedlak & Kurtz, 1981). For example, Siegler (1976) found that an imperfect correlation did not discourage five-year-olds from identifying a relation as causal. In contrast, eight-year-olds only saw causality when there was a regular correlation between antecedent and outcome. Thus young children may be quite comfortable with the idea of a probabilistic and uncertain causal relation.

From our adult perspective, commonsense knowledge of the causes of illness involves a mixture of causation and probability. We have (important) causal knowledge yet we also recognize the uncertain status of that knowledge. From the above discussion of causal reasoning it is unclear how preschool-aged children might view causal relations in the domain of illness. On the one hand, three-year-olds may see causal relations as definite and un-exceptionless. On the other hand they may be satisfied with rough estimates of causes and effects. Older preschoolers seek out exhaustive knowledge of causes (Frye, et. al, 1996), but they are more accepting of imperfect correlations than are older children (Siegler, 1976). It should be noted that these interpretations and results are not mutually exclusive, and may be quite consistent with one another. However, they do not give an unequivocal sense of whether young children view causal and probabilistic phenomena as strictly distinct or not.

The current study investigated children’s understanding of a set of causal relations that are also probabilistic (at least from a lay adult perspective). Is commonsense knowledge about the causes of illness thought to be definite and reliable (akin to the knowledge of causal relations available in experimental contexts) or is that knowledge understood to be approximate and heuristic? If children see a dichotomy between random and caused events they may disregard the evidence of variability and treat the effects of causes of illness as deterministic. If children see no special inevitability to cause-effect relations their understanding of the causes of illness should reflect the probabilistic nature of their experience.

Since much of the current research on domain specific causal reasoning also focuses on the preschool years (Wellman & Gelman, in press, for review) these children's intuitions were particularly interesting. There has been significant debate regarding young children's understanding of biological causal relations (including causes of illness; Kalish, 1996; Keil, 1992, Solomon & Cassimatis, 1995; Springer & Ruckel, 1992). Young children's views about the reliability of causes of illness will provide more information about their conceptions of causal relations in general and biological relations more particularly.

Experiment 1

One way to assess appreciation of probabilistic causality is to examine beliefs about distributions of outcomes in a population. If the same cause acts on several members of group will all members show the same outcome? A deterministic, reliable cause will produce the same outcome in all cases. For example, if a group of people all jump up into the air, we predict they will all experience the same outcome (i.e., all come back down). A probabilistic, uncertain event will produce a distribution of outcomes. For example, if each member of a group rolls a die, we expect a range of outcomes (e.g., some will get a "six," some will not). In Experiment 1, participants were asked to make predictions about outcomes of groups involved in illness causing events. The judgment of interest was whether or not all members of the group were predicted to experience the same outcome.

Although the main focus of Experiment 1 was on judgments about causes of illness, other items were included as controls against possible response biases. A set of deterministic causes were included; for example, a group of people all playing in the rain and getting wet. Also included were events predicted to have variable outcomes. The literature on children's developing theory of mind suggests children should know that people can differ from each other in their beliefs and desires (see Wellman, 1990 for review). Differences in desires may lead to different behaviors in the face of the same stimuli.

Methods

Participants. Twenty-two children participated. Eleven children were in a younger group (3:6 to 4:6, Mean = 4:3). Eleven children were in an older group (5:0 to 6:2, Mean = 5:6). All children were recruited from daycare centers in a mid-sized midwestern city. Approximately equal numbers of boys and girls participated at each age. Twenty-seven undergraduate students from an introductory educational psychology class at a large midwestern university also participated. Approximately 75% of the adults were female. Participants were predominantly white and middle-class.

Design & Materials. Stimuli were eleven stories describing a group of children all engaging in some activity. Each story was approximately three sentences long and was accompanied by two colored line drawings (one showing the group before the event, one showing the causal agent. See Appendix for stories). Stories were of three types. Three "definite" stories described events that should affect all participants equally (e.g., all members skipping lunch and feeling hunger). Three "variable" stories described events based on intentional decisions (e.g., individuals choosing a color of balloon). These stories were predicted to yield a distribution of outcomes. Finally, five "illness" stories described all members of a group exposed to causes of illness (e.g., all members eat cookies contaminated with germs). Illness items used in this experiment were drawn from existing literature describing children's beliefs about the causes of illness (e.g., Kalish, 1996a; Perrin & Gerrity, 1981).

Procedure. Children were interviewed individually in quiet rooms in their day care centers. Interviews lasted approximately 10 minutes. Adults were tested in groups using micro-computers (and did not see pictures). Participants first heard (or read) a description of the procedure. Children heard the following description: "Today I am going to tell you some stories about some groups of kids doing different things. These kids are all doing things and I want you to help me figure out what will happen. Ok? I'm going to tell you about a bunch of kids who do some thing and we'll try to figure out whether the same thing will happen to all the kids or not. I'll tell something that might happen and then ask you whether that would happen to all of the kids in the story, just to some of the kids in the story, or it wouldn't happen to any of the kids in the story? Ok? Let's start." Adults received the following instructions: "This experiment asks you to judge how many people in a group will experience some particular outcome or can be characterized as having some property. You'll see a brief description of a situation involving a group of children. For example, something like: 'One day a teacher asked each child in her class whether he/she had a brother or a sister.' Then you will see a question asking how many children will have some trait. In this example the question would be: 'How many children do you think will answer that they have a brother?' You'll make your response by clicking on one of three buttons labeled 'all,' 'some,' and 'none.'" Participants then heard/read each story one at a time in random order. Each story ended with a question of the form, "How many of the kids will ... (get sick, buy blue balloons, etc.)? all of them, some of them, or none of them?" Order of alternatives was maintained across questions.

Results

Responses were coded into three categories--all, some or none. However, since the data of interest were the proportions of probabilistic ("some") and reliable predictions ("all" or "none"), responses were recoded into these two categories. Analyses below used the dichotomous coding. Figure 1 presents the proportions of judgments that outcomes would be reliable. Proportions of specific reliable judgments (all or none) are also indicated. Figure 1a presents the data from children broken down by age group. The two groups of children are combined and compared with adults in Figure 1b.

Preliminary analyses revealed no differences between children in the two age groups in their proportions of probabilistic responses for the three kinds of questions (illness items: $t(19) = .76$, variable items: $t(19) = .78$,

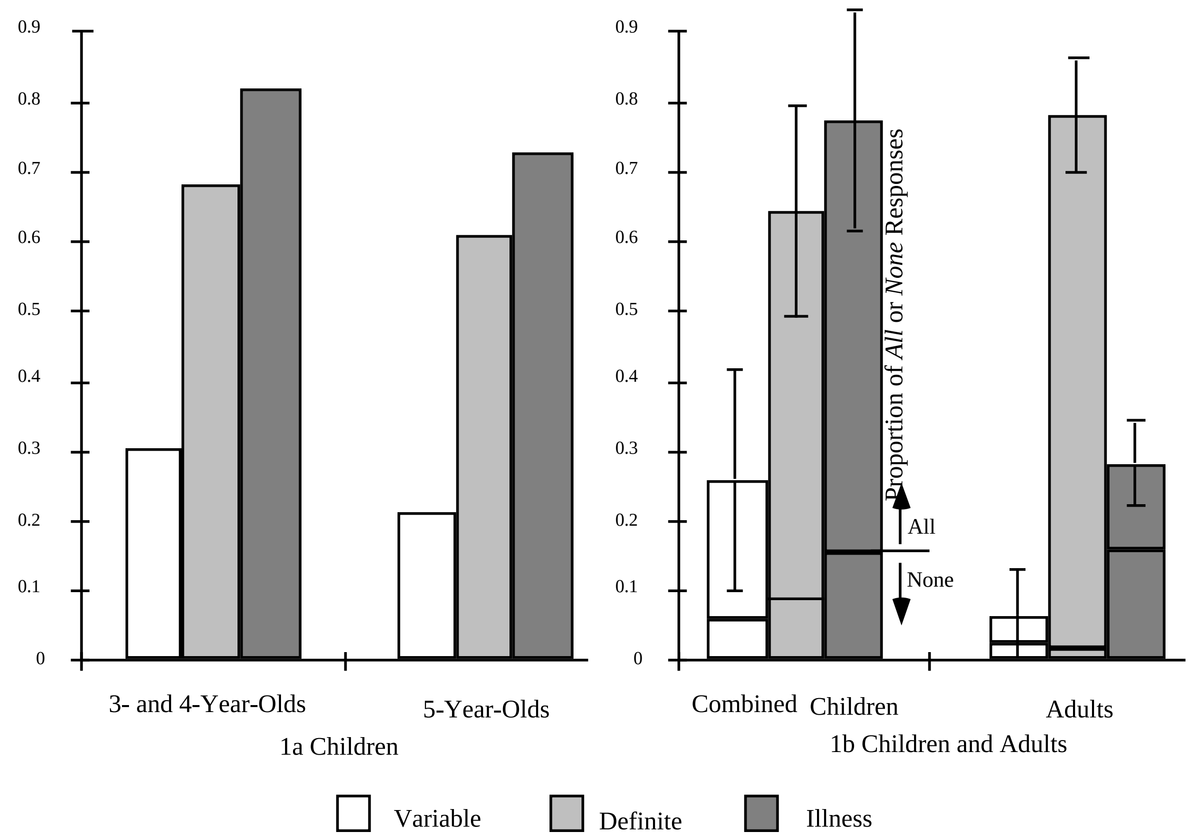

Figure 1. Proportion of responses that predictions will be consistent across group members (Experiment 1). Children's data are shown both separated by age (Figure 1a) and combined (Figure 1b). Error bars represent 1 Standard Deviation. Horizontal lines within bars of Figure 1b indicate proportions of "all" (above line) and "none" (below line) responses.

definite items: $t(19) = -.45$, all tests not significant at $p<.05$). As the age ranges of children within a group were very large, age was also analyzed as a continuous variable. Two sets of rank order correlations were calculated. Age was not well correlated with number of correct responses ($r_s = .07$, correct defined as probabilistic responses for illness and variable items, but reliable responses for definite items). Neither was age correlated with the total number of reliable responses given by a child (across items, $r_s = -.01$). For these reasons the two age groups were collapsed and all children were considered as a group.

The primary purpose of variable and definite items was to serve as controls against possible response biases (answering "some" to all questions or all-or-none to all questions, respectively). Seventy-four percent of children's judgments for variable items were that only some of the group would experience the outcome. This represented a greater than chance rate of probabilistic responding ($T(22) = 253$, $p<.001$[ii]). Sixty-four percent of responses

[ii]Because there were three possible response options the probability of a probabilistic response will be treated as .33. Chance comparisons were also made with a .5 probability of probabilistic responding. Unless otherwise indicated, both comparisons yielded the same results.

Numbers reported in parentheses for Wilcoxon tests represent the number of cases included in the test. These numbers vary for definite items were "all" or "none." This rate of reliable responses was significantly greater than would be expected by chance, if chance is taken to be 50% ($T(22) = 63$, $p<.05$).

Children made significantly more reliable judgments for illness items than for variable items ($T(21) = 1.0$, $p<.001$). There was no difference between illness and definite controls ($T(19) = 47.0$, ns). The proportion of reliable predictions for illness items was greater than would be expected by chance (p(chance) = .67, $T(22) = 60$, $p<.05$). This comparison reflects an underestimation of the difference between observed and chance responding. Children were clearly not answering randomly as may be seen by the large disparity between "all" and "none" responses (80-20, these predictions should be divided 50-50 by chance). For adults, causes of illness were seen as more reliable than variable items ($T(19) = 0.0$, $p<.001$) but less reliable than definite controls ($T(26) = 328$, $p<.001$). Adults made fewer reliable predictions for illness items than would be expected by chance ($T(27) = 372$, $p<.001$). A direct comparison between children's and adults' predictions for illness items shows the same effect. Children saw more reliable outcomes than did adults ($U(22,27) = 314.5$, $p<.001$, Mann-Whitney)

As some causes of illness may be more certain and reliable than others it was important to consider the possibility of item differences. Mean responses for each item are provided in the Appendix. To test for item effects, two Friedman's tests were calculated with responses to illness items 1-5 as repeated measures (children's and adult's responses were analyzed separately). Results suggest that children treated all items similarly ($\chi^2(4) = 5$, ns) whereas adults made distinctions between various causes of illness ($\chi^2(4) = 25$, $p<.001$). Individual participants were also consistent in their predictions for illness items. Eighteen of the 22 children responded the same way (either reliable or "some") for four or more of the five illness items. Of these, 16 saw four or more as reliable. Even assuming the conservative probability of chance (.67 for a reliable response), this level of consistency is significant (consistent pattern = p(4 or 5 reliable) = .47, p(16 or more consistent patterns) = .01). Sixteen adults answered illness items consistently. Of these, all but one showed a pattern of answering "some" to four or five illness items. In this case the individual pattern is significantly different from chance (with p("some") = .33, p(4 or 5 "some") = .04).[iii]

One striking result was the relatively large number of probabilistic ("some") responses children gave for definite items. Post hoc examination of definite items revealed the majority of "some" responses were made for one item (how many children playing in the rain would get wet)-- fifteen (or 68%) for this item versus 9 (or 20%) for the other two definite items combined (see Appendix A). Obviously something about this item was ambiguous for children (though not for adults). Without the rain item, the proportion of reliable responses was slightly, but not significantly, greater for definite than for illness items ($T(15) = 56.5$, ns).

Discussion

The results suggest that children do not see causes of illness as probabilistic. When a group of individuals experience some cause, all are expected to show the same effect. If the students in a classroom play with a sick visitor, all will get sick. Adults, in contrast, expect some variability in outcomes. Moreover, adults distinguish between various causes of illness--some are seen as more reliable than others. Predicting uniform outcomes does not seem to be a general bias on children's part. They judge that the

from test to test because tied scores are not considered in the analyses. Unless otherwise indicated, all tests were 1-tailed and corrected for familywise error using Holm's procedure.

[iii] If the more conservative (in this case) estimate of the chance probability of answering "some" of .5 is used, the second-order binomial probability is different from chance. [p(4 out of 5) = .19, p(15 out of 27 @ .19) < .05]

outcomes in cases of individual choices will be variable. For example, children do predict variable outcomes when members of a group are asked to choose either cookies or cake.

Before considering some alternative explanations, it is worthwhile to attempt to replicate the findings of Experiment 1 using a different paradigm. Expectations of variable outcomes in a population are only one sign that a cause is seen as probabilistic. Another measure of probabilistic causality involves confidence in predictions about the outcome in any single case. Experiment 2 explored children's and adults' ratings of certainty for predictions of different types of causal events.

Experiment 2

When predicting the outcome of a reliable causal event we feel we know for sure what will happen; in cases of uncertain causes we are closer to guessing. For example, people might predict that a person rolling a die will get a "six," but they would be unlikely to express much confidence in this prediction. In contrast, they would presumably express high certainty in the prediction that the die will fall (rather than float) when dropped. Participants in Experiment 2 were asked to predict whether or not individual characters would get sick in a variety of circumstances. After predicting outcomes, participants were asked whether they "knew for sure" that would happen, or "just thought maybe" that would happen. Previous research (e.g., Moore & Furrow, 1990) has established that young children understand the relative certainty of different mental state descriptors (e.g., "think" vs. "know"). If causes of illness are seen as reliable and deterministic, people should have confidence in their predictions. If causes of illness are seen as probabilistic, people should feel less certain.

The two age groups of children participating in Experiment 2 were more highly differentiated than those in Experiment 1. A group of three-year-olds and a group of five-year-olds were tested. This differentiation allows for a stronger test of age differences in judgments.

Method

Participants. Twenty-four children recruited from local preschools participated. Twelve children were in a younger group (M= 3:5, range 3:1-3:10). Twelve were in an older group (M= 5:4, range 4:11-5:7). Twenty-six undergraduate students recruited from an introductory educational psychology class also participated. Approximately equal numbers of male and female children were included. Adults were predominantly female.

Design & Materials. Stimuli were thirteen stories describing individual characters engaging in some activity. Five stories described (potential) causes of illness. These stories were identical in content to those used in Experiment 1 with the exception that only one character was involved. For example, rather than hearing about a group of children who all ate snack without washing their hands, participants heard about a single child who failed to wash before eating. Four stories presented characters involved in situations with variable outcomes. Finally, four stories involved events with definite outcomes. A complete list of items is presented in the Appendix. Stories averaged three sentences in length and were read aloud to children. Each story was accompanied by a colored line drawing depicting the event. Adults did not see pictures.

Procedure. Children were interviewed individually in quiet rooms in their day care centers. Adults were tested in groups using micro-computers. Participants first heard (or read) a description of the procedure. Children heard the following description: "Today I am going to tell you some stories about some kids doing different things. These kids are all doing things and I want you to help me figure out what will happen? Ok? I'm going to tell you about a some kids who do some things and we'll try to figure out what will happen. Ok? Let's start." Adults received the following instructions: "This experiment asks you to judge how certain we can be about outcomes of various events. You'll see a brief description of a situation involving a child. For example, something like: 'One day a teacher asked a boy in her class whether he had a brother.' Then you will see a question asking what will happen. In this example the question would

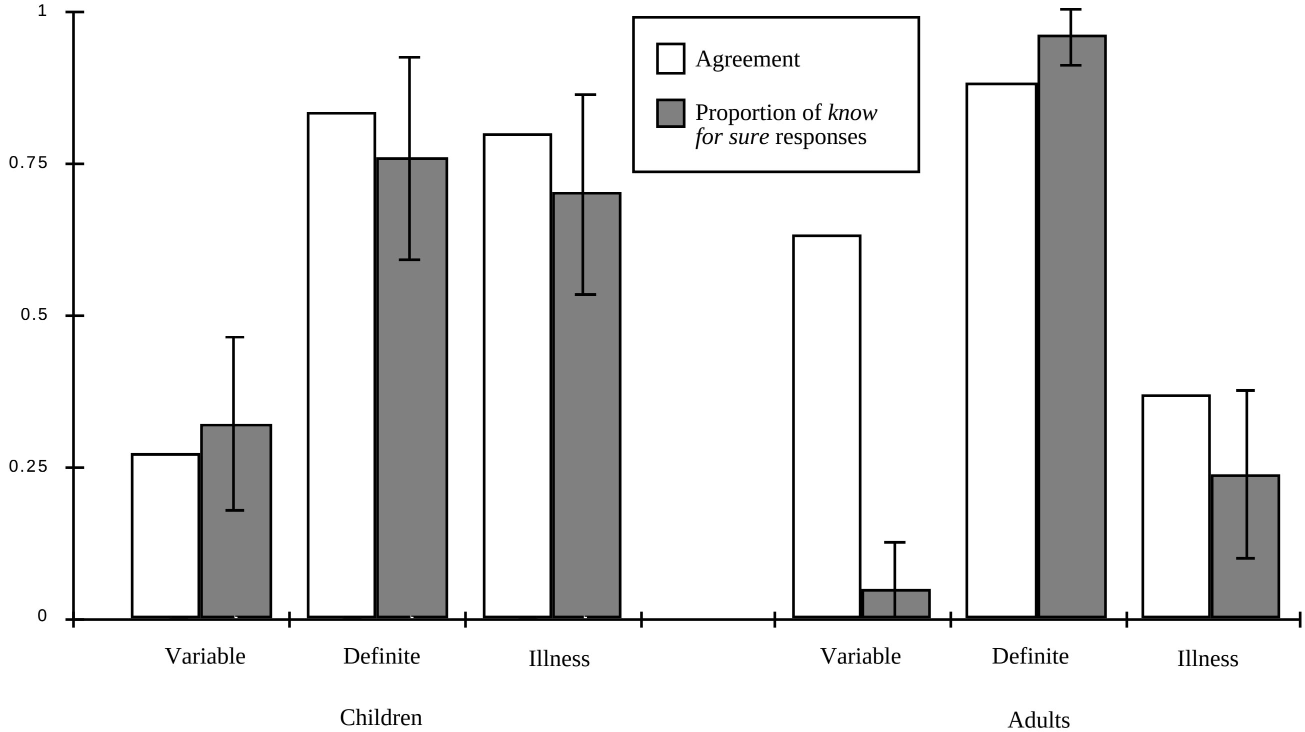

Figure 2. Results from Experiment 2: agreement and mean proportion of "know for sure" responses. Error bars represent 1 Standard Deviation. Agreement = [(proportion of modal responses) - .5]/.5

be: 'Do you think the boy will answer that he has a brother?' Then we'll ask you whether you know for sure or just think maybe. That is, can you be pretty certain what will happen or are you closer to guessing. Don't try to think of any wild 'science-fiction' type scenarios. We'd like to know whether you can be reasonably certain or not. You can think of 'know for sure' as meaning you would be pretty surprised if the event didn't happen the way you predicted. (Answering 'maybe' means you wouldn't be too surprised to be wrong.)" Participants then heard/read each story one at a time in random order. Each story ended with two questions. First a participant was asked to predict the outcome of the event (e.g., whether the person would get sick, choose a red balloon, get hungry). Following this prediction, he or she was asked about certainty-- did he or she "know for sure" or "just think maybe." For example, if a participant predicted a character (named Jimmy) would get sick he or she was asked, "Do you know for sure that Jimmy will get sick, or do you just think maybe Jimmy will get sick?" Order of alternatives was randomized across questions for children but not adults.

Results

The first step in data analysis was to compare the responses of children from the two age-groups. No differences were found in the number of certain responses for illness items ($t(22) = 1.24$, ns) or in overall number of correct responses (uncertain for illness and variable items, certain for definite items, $t(22) = -.24$, ns). There was also no relation between age (as a continuous variable) and responses (correlation between age and certainty for illness $r_s = .25$, $z = 1.19$, age and total correct $r_s = -.07$, $z = .3$). Data from the two age-groups of children were combined in the following analyses. Figure 2 displays judgments of certainty and degree of inter-participant agreement on predictions for children (collapsed across age-group) and for adults.

Variable items were rated as certain at below chance levels ($T(16) = 20$, $p<.05$). Children rated predictions for definite items as certain at greater than chance levels ($T(22) = 215$, $p<.005$). Certainty ratings for illness were greater than chance ($T(24) = 240.5$, $p<.01$). Ratings for illness did not differ from definite items ($T(16) = 47$, ns) but did differ from variable items ($T(22) = 247$, $p<.001$). Adults also rated definite items as certain and variable items as uncertain ($T(26) = 351$, $p<.001$ and $T(26) = 2.0$, $p<.001$, respectively). However, adults' certainty for illness items was intermediate between these two (less than definite items, $T(26) = 0$, $p<.001$ but more than variable, $T(16) = 121$, $p<.01$) and was below chance ($T(26) = 38$, $p<.005$). Finally, children were more certain of illness predictions than were adults ($U(24,26) = 832$, $p<.001$) even though children were less certain of predictions for definite items ($U(24,26) = 505$, $p<.05$).

In addition to exploring mean judgments of illness, data were also analyzed for item differences. Children were equally certain about their predictions for all illness items (no difference in median certainty by item; $\chi^2(4) = 1.55$, ns, Friedman's test). Adults' certainty did vary across items ($\chi^2(4) = 21.37$, $p<.001$). Furthermore, children showed high levels of inter-participant agreement for their predictions of illness (whether the character would get sick or not) for all items. For each item, 18 or more of the 24 children agreed on their predictions ($p<.05$)[iv]. However, adults showed less agreement-- only one item (number 2) showed significant consensus regarding the outcome (19 or more out of 26, $p<.05$). Thus children tended to treat all illness items the same way-- each was seen as having a reliable and known outcome. Adults saw variation among the items and were generally less certain (and less in agreement) about outcomes.

Patterns of individual's responses also revealed that children saw illness predictions as certain, whereas adults viewed the predictions as often uncertain. Sixteen children rated their predictions of four or five of the five illness items as certain (p(4 or 5) = .19, p(16 or more of 24 at .19)<.001). Five children rated four or more items as uncertain (p(5 or fewer of 24 at .19) = .48). Of these five, three seemed to show a probabilistic response bias-- rating only one or fewer predictions as certain across the entire task. Only two adults were certain of 4 or more illness predictions ($p = .1$) whereas 17 were uncertain of four or more ($p<.001$).

Discussion

The results of Experiment 2 are consistent with the findings of Experiment 1. Children felt very certain of their predictions regarding causes of illness. Children saw the consequences of not washing hands before eating as just as certain as the consequences of jumping up in the air (getting sick and coming back down, respectively). This was not a simple response bias on children's part; they did indicate significant uncertainty about some predictions. For example, children indicated they were not sure of their predictions about a character's food preference. Adults did feel uncertain about predictions of illness. Their ratings varied by item. Some events were seen as more reliable causes of illness than others. Children did not make this distinction; all causes of illness were seen as equally potent and reliable.

One possible explanation of the findings from Experiments 1 and 2 is that children have a bias to treat (physical-biological) causal relations as reliable and deterministic. However, an alternative is that children simply have different evaluations of the probabilities associated with particular causes than do adults. From an adult's perspective, the items included in Experiments 1 and 2 represent causes with intermediate probabilities of leading to illness (intermediate potency). Children may recognize that causes of illness are probabilistic, but may believe the probabilities associated with the items from Experiments 1 and 2 are relatively high. For example, adults view some causes of illness as highly potent (e.g., injection with a virus one lacks immunities to). Presumably predictions of illness given high potency causes would be rated as certain and would be consistent across members of a group. If children did see the particular items used in Experiments 1 and 2 as highly potent, a

[iv]The probability of 18 or more "sick" predictions = .01, of 18 or more "not sick" predictions = .01 (Binomial theorem). Thus the probability of 18 or more subjects agreeing = .01 X 2.

different set of items might yield different results.

Experiment 3

The conclusion that children view causes of illness as deterministic clearly depends on the particular causes children are asked about. Perhaps children viewed the stimuli from Experiments 1 and 2 as instances of highly potent causes of illness. Thus the purpose of Experiment 3 was to present children with a set of less potent causes of illness. Two types of stimuli were included in this experiment: a set of strong causes of illness (events or actions that would seem to lead to illness with a high certainty) and a set of weak causes. Weak and strong items involved the same mechanisms of illness causation but at different levels or potencies. For example, two items involved germs as agents of illness: a strong item described a character coming into contact with "a lot" of germs, a weak item described contact with "a few" germs.

If children view causes of illness as deterministic, the reduction in potency from strong to weak items should have an all or none effect. Weak items either do not differ from strong, or weak items are not seen as causes of illness at all; predictions will be highly certain in either case. In contrast, with a probabilistic conception, predictions for weak items may be uncertain. If the items used in Experiments 1 and 2 were too strong to reveal uncertainty in predictions, that uncertainty should be evident for weak items in Experiment 3.

Methods

Participants. Twenty-seven children recruited from local preschools participated in the experiment. Two age-groups were represented: 10 younger (M = 3:7, range 3:5-4:0) and 17 older (M = 4:11, range 4:5-5:4) children. Twenty undergraduate students drawn from an introductory educational psychology class also participated in the experiment. Approximately equal numbers of males and females were included in the child groups. Adults were predominantly female.

Design & Procedure. Experiment 3 was identical in design and procedure to Experiment 2 except for the items used. Ten of the fourteen items involved illness. Five items described strong causes of illness. These items were based on stories from Experiment 2 with the additional information that the causes involved were very potent (e.g., intense in number, duration, or strength; see Appendix for a complete list of items). Five items described weak causes of illness. These items were nearly identical to a corresponding strong item but the causes involved were described as less powerful (e.g., attenuated in number, duration, or strength). Two definite items and two variable items (akin to those used in Experiment 2) were also included.

Results and Discussion

The three-year-old children performed quite poorly on this task. They tended to make positive predictions for all items at about the same rate. Strong and weak causes were both predicted to lead to illness (87% and 89% positive predictions, respectively). However, these children also made positive predictions for definite items (83%); characters were predicted to shrink themselves and to float in the air. Similarly, younger children tended to answer "know for sure" at about the same rate for all items: 68% and 56% for strong and weak items, but also 72% for variable items. Because of this undifferentiated pattern of responding, and because children were answering incorrectly for the variable and definite "control" items, no further analyses were conducted for young children's responses. The added complexity of the illness stories (e.g., information about number and strength of germs) may have confused children. Alternatively, or in addition, the large number of illness items may have caused children to fall into a response strategy of answering "yes" and "know for sure."

Figure 3 presents the mean proportions of positive predictions and mean proportions of "know for sure" responses for both older children and adults. Older children did not seem to distinguish between strong and weak causes. There was no significant difference in their rates of prediction of illness for these two types of items, $T(7) = 25$, ns. Neither was there a significant difference between the

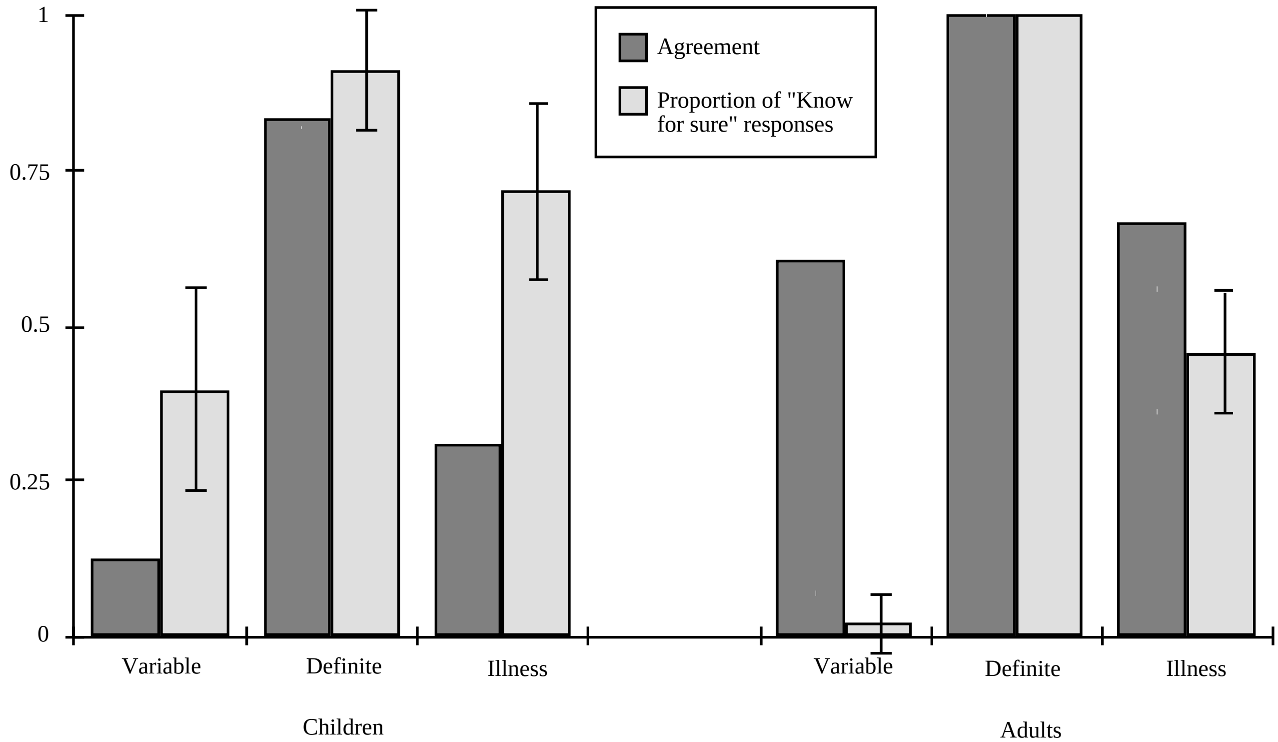

Figure 3. Results from Experiment 3: positive predictions and mean proportion of "know for sure" responses. Error bars represent 1 Standard Deviation.

proportions of "know for sure" responses, T(8) = 10.5, ns. In contrast, adults predicted illness more often for strong items than for weak items, T(17) = 153.0, p<.001. Adults were more certain of their predictions for weak items, T(11) = 9.0, p<.05. They were relatively sure that weak items would not lead to illness. Thus, at least by adult standards, the weak items were less potent causes of illness. However, this difference in potency did not seem to affect children's judgments.

Children did make some distinctions between the various illness items. In particular, predictions of illness for one of the weak items (waving to a sick child) were significantly lower than predictions for the other items (52% of the children predicted illness for this item vs. a mean of 93% for all other illness items, T(10) = 52.0, p<.05). It is important to point out that children do not believe any action remotely associated with illness will lead to illness with high certainty. Eleven of the older children at least once predicted that a character would not get sick.[v]

Comparisons between illness and variable and definte items revealed patterns similar to those observed in Experiment 2. Children were more certain of their predictions for illness than for variable items: strong vs. variable, T(13) = 91; weak vs. variable, T(13) = 91, both p<.01. There was no difference between certainty for illness and definite items: strong vs. definite, T(10) = 14; weak vs. definite, T(10) = 21, both p>.1. Children's responses were generally consistent across particular instances of strong and weak causes of illness. Every illness item was rated as certain by more than 10 of the 17 children. Six illness items (4 weak and 2 strong) received "know for sure"

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[v]In a related study (Kalish, 1997) preschool-aged children reliably judged that actions such as eating the same kind (but not sample) of food as a sick child would definitely not lead to illness. Thus, it is not the case that preschool-aged children view all activities as potential causes of illness.

ratings from 13 or more children (p(13 or more out of 17) = .025, binomial theorem). This pattern contrasted with that of adults. Although adults were more certain of predictions for weak than for variable items, $T(17) = 130.0$, $p<.05$, the difference between strong and variable items was not significant, $T(16) = 96.0$, ns. Finally, adults were significantly more confident in their predictions for definite items than for either type of illness item: vs. strong, $T(20) = 0$; vs. weak, $T(19) = 0$, both $p<.001$.

Four- to five-year-old children generally rated their predictions of illness outcomes as highly certain. They saw causes of illness as akin to more deterministic causal forces (e.g., gravity); both types of causes were thought to lead to their effects with high certainty. Especially important was that children's data revealed no difference in predictions for strong and weak causes of illness. This suggests that the results from Experiments 1 and 2 were not due simply to the selection of highly potent instances of illness causation. Rather, children seem to have a general belief that causes of illness operate in a deterministic manner.

General Discussion

Preschool-aged children tended to view the outcomes of causes of illness as deterministic and reliable. They judged that all members of a group would respond the same way to a (potential) cause of illness. For example, if all the children in a classroom played with a sick child all (or none) would get sick. This belief in the reliability of illness causes was also demonstrated in predictions for individual cases. Children felt certain of their predictions for illness events. For example, children said they knew for sure that a character who played with a sick friend would get sick (or were sure he would not). Although adults sometimes gave these deterministic responses, they also judged many causes of illness to be probabilistic. That is, adults expected that group members would experience a variety of outcomes and often felt unsure about their predictions in individual cases.

In Experiments 1 and 2 participants were asked to make predictions about familiar causes of illness. Examples used were drawn from the existing literature on children's understanding of the causes of illness (e.g., Kalish, 1996a; Kister & Patteson, 1980). Children judged all of these familiar causes to be deterministic (little variability, high certainty). This was not a simple response-bias. Children did recognize a set of events with probabilistic outcomes--notably events dependent on intentional decisions. In Experiment 3, participants were asked to make (and rate) predictions about stories in which the potency of the cause of illness was explicitly manipulated. These stories were created to represent both high and low potency causes of illness (e.g., hugging vs. waving to a sick friend). This manipulation seemed to confuse three-year-olds . These children no longer treated variable and definite control stories as different. Five-year-olds continued to respond as predicted for variable and definite items. Moreover, their performance in Experiment 3 was consistent with the results of Experiments 1 and 2. Children treated causes of illness as definite. Potency manipulations had no observable effect on their judgments.

The results of the experiments reported above raise a number of questions. Clearly at some point in development people (in modern, western, cultures) come to recognize familiar causes of illness as probabilistic. The restricted age-range of children included in this study limits what can be said about these developments. To begin to address the question of how (and when) children might come to the adult view, it important to consider what is involved in understanding probabilistic causal relations. However, before considering some of the possible explanations for children's judgments it is worthwhile to point out some of the direct implications of a tendency to view causes of illness as deterministic and reliable.

Adults recognize different degrees of risk with regards to health behaviors. One dimension of risk is severity of illness (e.g., catching a cold vs. cholera). Another dimension is probability of illness. For example, we may judge that it is less risky to shake hands with a sick friend than to share food. This evaluation of risk may lead us to engage in some "low risk" behaviors but avoid "high risk" behaviors (cf. The Health Belief Model, Becker, 1974). However, if young children do not see causes of illness as probabilistic, they will not be able to evaluate the relative probability of illness associated with various behaviors. All risk behaviors are equally dangerous--or safe. They may be equally disposed to engage in high risk behavior and low risk behavior. When children experience a failure to get sick after engaging in some low risk behavior (either in their own experience or watching others) they may generalize that experience to some high risk behaviors. An assumption that causes of illness are deterministic may be behind the finding that young children are relatively unconcerned about the possibility of getting sick (e.g., Gochman & Saucier, 1982). If there are a limited set of deterministic rules for avoiding illness, all one need do is follow the rules (avoid the causes) to avoid illness. In contrast, much of our adult sense of vulnerability comes from the recognition that our understanding of illness causality is unreliable. Finally, failure to recognize causes of illness as probabilistic may make it difficult for children to understand variability in illness outcomes (i.e., the evidence of the actual probabilistic nature of illness). As adults our understanding of the uncertain nature of illness causation provides us some account of why one person gets sick rather than another in the same situation. Children may fall back on magical, personalistic, or self-blaming explanations for this unaccountable experience (cf., Kister & Patterson, 1980).

In assessing the implications of the belief that causes of illness are non-probabilistic it is important to understand the source of that belief. What leads children to this view? The experiments reported above only begin to address this question. The following discussion of why children view causes of illness as definite, and when they might recognize uncertainty in causal relations, is necessarily speculative and is intended to suggest avenues for future research.

There are several reasons children may view causes of illness as deterministic. One possibility is that they just place too much faith in causality. The developmental literature emphasizes that children use causal relations to structure experience (Carey, 1985). It is an appreciation of causality that allows children to see experience as more than just random co-occurrences of features. Some events and relations are not accidental but are necessary. For example, claims that children are essentialists regarding categories imply they see attributes of category members as causally connected to an underlying essence (Gelman & Coley, 1991). In reasoning about experience, cause seems to be a more important organizing principle for children than for adults (Gelman & Kalish, 1993). Because of its utility, children may over-estimate the reliability of the causal relation. For example, they may assume there is a clear distinction between random and caused phenomena. This would suggest that causal relations are always reliable and stable. The experiments above examined intuitions only about causes of illness. Thus assumptions of deterministic causality may be domain specific (to illness) rather than representative of a general bias. Clearly, studies of children's views of other probabilistically causal phenomena are necessary to asses the generality of their beliefs.

Another way to address the question of why children fail to treat illness outcomes as probabilistic is to consider why or when they might view a causal relation as uncertain. Even though children seem to view causes (of illness) as deterministic they must sometimes face the fact that causal generalizations are not certain. For example, children did treat some of the causal relations in the above experiments as probabilistic and uncertain (e.g., stories involving choices). There seem to be three possibilities: causation may be uncertain because of contingency, because of intention, or because of chance.

A causal relation may be viewed as contingent-- some conditions have to be in place for a cause to lead to an effect. Even young children would seem to recognize this source of variability. Four-year-olds recognize embedded, or two-condition, causes (Frye, et al. 1996). As mentioned above, this raises the possibility of uncertain outcomes if only one of the conditions is known. Events involving intentional decisions were judged to be variable in the above experiments. One explanation for these judgments is that children recognize that people differ in their beliefs and desires and that those differences lead to variable outcomes (cf. Wellman, 1990). This explanation would also seem to apply to reasoning about illness. For example, preschool-aged children know that eating food from the garbage makes you sick, but only if some other conditions hold (e.g., the food has germs on it; Kalish, 1996b). Contingency might be the primary way children account for variability in causal outcomes. If so, we would expect that when children are aware of only one causal condition in a domain (either because of lack of knowledge or because alternative conditions are not salient in the context) they may view that condition as a determinate and exhaustive cause. Causal relations would be seen as probabilistic in contexts where multiple conditions are made explicit (e.g., when reasoning about both causes of illness and sources of resistance).

A second source of variable outcomes is human intention--voluntary action is never deterministic. Mental states do not deterministically cause intentional behavior (White, 1995; Flew, 1985). For example, given that a person wants a cookie and believes cookies are in the cupboard it remains uncertain ("up to" the actor) whether he or she will act to get the cookie (even in the absence of countervailing desires, such as the desire to remain slim). Although preschoolers do understand intentional causes (Shultz, 1980), whether they recognize the indeterminate nature of voluntary action has not been well studied. Such an understanding would be consistent with the probabilistic predictions children made for items involving individual choice in Experiments 1-3. Similarly, one explanation for the results of the experiments is that children judge situations in which people are agents (e.g., they choose to do things) to have uncertain outcomes. Events in which people are patients or recipients of action (e.g., they get sick) are judged to have determinate outcomes. This would be consistent with a view of mental causes as voluntary and indeterminate. It is possible that children interpret variation in illness outcomes as intentionally mediated. For example, some have argued children see illness as punishment (Kister & Patterson, 1980). Punishment is intentionally, and so probabilistically, applied or withheld. If children see intentionality as the main (sole) source of uncertainty in causal outcomes we may expect them to treat human behavior as probabilistic but view natural causal relations as deterministic.

The third source of variability is randomness. Somewhere in the chain of events linking a cause to an effect there may be an element of chance. At least in the context of explicit randomizing devices, children seem to have some understanding of chance outcomes (Kuzmak & Gelman, 1986). What is less clear is whether they extend the idea of chance to contexts where they also know causal relations. However, it is also unclear whether adults ascribe uncertain, probabilistic outcomes to irreducibly random processes. One commonsense principle is that everything must have a cause (the principle of determinism, Bullock, 1985). We may ascribe all probabilistic outcomes to contingencies. Even if we do not know, or expect to be able to know, all the factors that affect an outcome we may assume the outcome is some determinate result (e.g., see outcomes as chaotic but not random). Bullock has argued that children subscribe to the principle of determinism. Alternatively, this faith in the ultimate lawfulness of the world, in the "bureaucratization of nature" (Gellner, 1973), may not characterize children's thinking.

How children interpret variability in causal outcomes (as always contingent or ever random or intentional) is an important question for future research. Although such variability must be an important component of children's actual experience with the world, the experiments described in this study suggest that children may discount this variability in their interpretations or understandings of that experience. Although adults recognize that many of our commonsense beliefs about causal relations are rough heuristics, children may interpret them as absolute laws. Young children seem to expect cause-effect relations to be reliable and deterministic. Whether this represents a general bias, or is a particular interpretation of some domain-specific experience, is also a matter for future studies.

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Appendix

Items Used in Studies 1-3

Items Used in Experiment 1 (and Mean Proportions of "Some" Responses)

1. Illness The kids at school all ate cookies for snack. This day the cookies fell in the garbage and got germs all over them. The kids ate the cookies with germs. How many will get sick? (Children, .36 Adults, .74)

2. Illness One day the kids in a school were all playing outside in the dirt. The kids got hungry. They were so hungry that when they came inside they didn't wash their hands. The kids ate lunch with dirty hands. How many will get sick? (Children, .14 Adults, .59)

3. Illness A group of kids who all hung around together decided they would only eat candy and sweets. They refused to eat any fruits or vegetables. The kids ate candy and sweets all the time. How many will get sick? (Children, .23 Adults, .44)

4. Illness There are a bunch of kids who all go to school together. One day a sick kid came and played in their classroom. The classmates all played with the sick kid. How many will get sick? (Children, .23 Adults, .96)

5. Illness A group of children were all playing outside at school. None of them wore their coats outside and it got really cold. The kids played outside and they all

got really cold . How many will get sick? (Children, .18 Adults, .85)

6. Definite The children at a school eat lunch at school everyday. One day the school ran out of food. The kids didn't have any food to eat for the whole day. How many will get hungry? (Children, .18 Adults, .18)

7. Definite One day a group of kids played outside in the cold. None of the kids wore a coat or mittens. They were outside for the whole day and it was very cold. How many would get cold? (Children, .23 Adults, .26)

8. Definite One day a group of friends was playing outside. They were playing a game when it started to rain. They didn't want to stop playing so they just played outside in the rain. How many would get wet? (Children, .68 Adults, .04)

9. Variable A child invited a lot of friends over to play. After they had played a while it was snack time. The kids could have either cake or ice-cream for snack. How many will choose cake? (Children, .73 Adults, .89)

10. Variable A group of children were all playing together after school one day. A man selling balloons came buy. He had green and blue balloons. Each kid decided to buy a balloon. How many will buy blue balloons? (Children, .68 Adults, 1.0)

11. Variable After their school day ended all the kids at school went home for dinner. During school they had all talked about how much they liked spaghetti. How many will have spaghetti for dinner? (Children, .82 Adults, .93)

<u>Items Used in Experiment 2 (and Mean Proportion of "Know for Sure" responses)</u>

1. Illness One day a sick kid came and played in Tony's classroom. Tony played with this sick kid. What do you think, will Tony get sick? (Children, .71 Adults, .04)

2. Illness One day the Julie's cookies fell in the garbage and got germs all over them. Julie ate the dirty cookies. What do you think, will Julie get sick? (Children, .63 Adults, .23)

3. Illness Jason was outside playing in the dirt and mud. He played a long time, until lunch. He were so hungry that when he came in for lunch he didn't wash his hands. So Jason ate their lunch with dirty hands. What do you think, will Jason get sick? (Children, .71 Adults, .23)

4. Illness Beth only eats candy. She doesn't eat any fruits or vegetables or other good stuff like that. Instead Beth eats candy and sweets all the time. What do you think, will Beth get sick? (Children, .71 Adults, .50)

5. Illness Nathan was playing outside. He went outside without a coat on. It was really cold outside. So Nathan was outside playing with no coats or gloves on. He got really cold. What do you think, will Nathan get sick? (Children, .75 Adults, .19)

6. Definite Brian was playing outside. It started to rain. Brian was playing outside in the rain. What do you think, will Brian get wet? (Children, .79 Adults, .88)

7. Definite Sally always eats her lunch at school . Today the school ran out of food. Sally didn't get to eat any food the whole day. What do you think, will Sally get hungry? (Children, .71 Adults, 1.0)

8. Definite Steve jumped off of is chair. He jumped up into the air. What do you think, will Steve come down to the ground or will he stay up floating? (Children, .75 Adults, 1.0)

9. Definite Pam wants to wear these tiny doll clothes. She wants to shrink herself down really small so she can wear the clothes. What do you think, will Pam get really small? (Children, .79 Adults, .96)

10. Variable One day Paul was at school for snack. The teacher said he could either have cake or ice cream. What do you think, will Paul choose cake? (Children, .42 Adults, .04)

11. Variable Sharon's mom took her to the store. Sharon got to buy a balloon. There were all different colors. What do you think, will Sharon choose a red balloon? (Children, .46 Adults, .04)

12. Variable Patrick was getting some gum out of a gumball machine. There were blue gumballs and green gumballs. He really wanted a green one. He put in his money and turned the handle. What do you think, will a green gumball come out of the machine? (Children, .17 Adults, .08)

13. Variable Peggy got a present from her grandma. Peggy hoped it was a doll. She opened up the package. What do you think, will Peggy get a doll? (Children, .25 Adults, .04)

Items Used in Experiment 3 (and Mean Proportions of "Know for Sure" Responses)

1 Strong. One day a sick kid came into Jimmy's classroom. Jimmy touched and hugged this sick kid. What do you think, will Jimmy get sick? (Older Children, .82, Adults, .20)

1 Weak. This is Sol, he is sick. Jordan walked by and waved to Sol from outside. What do you think, will Jordan get sick? (Older Children, .82, Adults, .80)

2 Strong. Jennifer only eats candy. She don't eat any fruits or vegetables or other good stuff like that. Instead Jennifer eats candy and sweets all the time. What do you think, will Jennifer get sick? (Older Children, .71, Adults, .65)

2 Weak. Last night, Julian ate candy for dinner. He didn't eat any meat or vegetables, just candy. What do you think, will Julian get sick? (Older Children, .77, Adults, .30)

3 Strong. Here is Sally. She ate an apple that had germs on it. The germs on Sally's apple were really strong. So she ate these really strong germs. What do you think, will Sally get sick? (Older Children, .65, Adults, .05)

3 Weak. Cathy was eating some soup. She didn't know it but there were germs in her soup. The germs in Cathy's soup were weak, not very strong. So Cathy ate these weak germs. What do you think, will Cathy get sick? (Older Children, .94, Adults, .15)

4 Strong. Bill was playing on the playground when a sick kid came up an sneezed on him. The sick kid sneezed and lots and lots of germs got on Bill. Bill got lots and lots of germs on him. What do you think, will Bill get sick? (Older Children, .71, Adults, .05)

4 Weak. Karl went to the store and while he was there this sick kid coughed on him. The sick kid coughed and a few germs got on Karl. Karl got a few germs on him. What do you think, will Karl get sick? (Older Children, .88, Adults, .10)

5 Strong. Alice had a piece of toast that had germs all over it. Alice ate up the toast. She chewed and swallowed the whole piece of toast. She ate the germs. What do you think, will Alice get sick? (Older Children, .71, Adults, 0)

5 Weak. Linda had a cracker that had germs all over it. Linda took a little lick of the cracker. She didn't eat anything. Linda had a little lick of the germy cracker. What do you think, will Linda get sick (Older Children, .77, Adults, .20)

6 Variable. Peggy got a present from her grandma. Peggy hoped it was a doll. She opened up the package. What do you think, will Peggy get a doll? (Older Children, .41, Adults, .05)

7 Variable. Patrick was getting some gum out of a gumball machine. There were blue gumballs and green gumballs. He really wanted a green one. He put in his money and turned the handle. What do you think, will a green gumball come out of the machine? (Older Children, .47, Adults, .10)

8 Definite. Steve jumped off of is chair. He jumped up into the air. What do you think, will Steve come down to the ground or will he stay up floating? (Older Children, .94, Adults, 1.0)

9 Definite. Sharon wants to wear these tiny doll clothes. She wants to shrink herself down really small so she can wear the clothes. What do you think, will Sharon get really small? (Older Children, .77, Adults, 1.0)