Journal of Experimental Psychology: General

ISSN: 0096-3445

2020, Vol. 149, No. 10, 1935–1949
http://dx.doi.org/10.1037/xge0000751

Children's Beliefs About Causes of Human Characteristics: Genes, Environment, or Choice?

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To what extent do our genes make us nice, smart, or athletic? The explanatory frameworks we employ have broad consequences for how we evaluate and interact with others. Yet to date, little is known regarding when and how young children appeal to genetic explanations to understand human difference. The current study examined children's (aged 7–13 years) and adults' explanations for a set of human characteristics, contrasting genetic attributions with environmental and choice-based attributions. Whereas most adults and older children offered an unprompted genetic explanation at least once on an open-ended task, such explanations were not seen from younger children. However, even younger children, once trained on the mechanism of genes, endorsed genetic explanations for a range of characteristics—often in combination with environment and choice. Moreover, only adults favored genetic explanations for intelligence and athleticism; children, in contrast, favored environment and choice explanations for these characteristics. These findings suggest that children can employ genetic explanations in principled ways as early as 7 years of age but also that such explanations are used to account for a wider range of features by adults. Our study provides some of the first evidence regarding the ways in which genetic attributions emerge and change starting in early childhood.

Keywords: children, conceptual development, genetic attributions, essentialism

Explaining individual differences is an integral component of social cognition. What contributes to variation in personalities, abilities, or behaviors? Are they the product of the choices people make, the accumulation of lived experiences, or the expression of inherent genetic factors? Answering these questions requires making inferences based on incomplete information, as we never have access to a person's entire decision-making process or life history, nor can we precisely or objectively determine the contribution of extrinsic versus intrinsic factors that shape individual differences, let alone which differences (if any) are truly freely chosen. Yet despite such challenges, people readily come up with reasons to explain why people are the way they are. These causal narratives shape how we understand ourselves and others and have the capacity to inform policies in domains as diverse as education, criminal justice, and medicine. In light of the apparent complexity behind creating explanations, and the implications of these explanations, it is important to address the developmental processes that contribute to how we make sense of others.

We focus in particular on how children come to understand the role of genes in explaining human variety. Genetic attributions are unsurprisingly common in adults' explanations for human characteristics. The majority of adults in the United States and other industrialized nations are exposed to information about genes not just in educational settings, but also in popular media and widely available genetic testing kits for home use. Genes are widely understood by both lay individuals and scientists to be biological structures residing within living things, inherited (in the case of sexually reproducing organisms), and responsible for the emergence of outward features. At the same time, however, people vary in how much explanatory power they give to genes (e.g., Carver, Castéra, Gericke, Evangelista, & El-Hani, 2017; Condit, 2010; Dougherty, 2009; Keller, 2005; Lanie, et al., 2004). Nevertheless, genetic attributions have broad conceptual and societal implications. For instance, Dar-Nimrod and Heine (2011) observe that assuming that a particular characteristic is largely caused by genes (which they dub "genetic essentialism") can promote the belief that it is unchanging and less controllable than characteristics that arise from external factors or personal choice. Such beliefs may also motivate the inference that the characteristic being explained is natural, correct, and even more desirable than a freely chosen or

This article was published Online First March 19, 2020.

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This research was supported by NICHD Grant HD-36043 to Susan A. Gelman. We gratefully acknowledge the research assistance of Paulina Bromberg, Kevin Ma, Sarah Romberg, Sarah Stilwell, and Alex Was. Portions of the data reported here were also presented at the Society for Research in Child Development conference in Philadelphia, Pennsylvania.

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environmentally caused outcome (also see Wilson, Dietrich, & Clark, 2003).

Overall, then, endorsing genetic attributions has important implications, making its development a worthwhile topic of investigation. To date, however, most research investigating lay concepts of genes has focused on adults or older adolescents (high school and college age; e.g., Bowling et al., 2008; Smith, Wood, & Knight, 2008; Tsui & Treagust, 2007). Less is known about the development of such beliefs, though it has become an emerging topic of interest. For instance, a couple of studies with children younger than high school age have suggested that by older elementary school age, children possess a rudimentary understanding of genes as being passed down from parents to child and involved in the emergence of physical characteristics. At the same time, however, very few children knew how genes functioned or where they were located, suggesting they did not have elaborated scientific theories regarding genetic mechanisms (Smith & Williams, 2007; Venville, Gribble, & Donovan, 2005). Furthermore, several studies with older children have focused on the social implications of genetic beliefs. For instance, in experimental studies undertaken by Donovan and colleagues with young adolescents, findings suggest that if genetic difference among social categories like race are highlighted, essentialist thinking and racial bias can increase (Donovan, 2014, 2016, 2017), whereas learning about genetic similarity can reduce such inferences and attitudes (Donovan, Semmens, et al., 2019). And in the domain of gender, reading about genetic bases for sex differences has been found to promote endorsement of beliefs in innate gender differences in ability (Donovan, Stuhlsatz, Edelson, & Buck Bracey, 2019).

That high-school-aged and older students have received more attention than younger children most likely reflects that children typically are first introduced to genetic concepts in formal educational settings starting in middle school and continue to receive detailed and mechanistic instruction throughout high school (e.g., Next Generation Science Standards, 2013). Nonetheless, mention of genes, the human genome, and DNA permeates informal instructional contexts in much of the world, even for younger children. News media and popular culture discourse on these topics include programming geared toward young children, such as TV shows, movies, video games, and websites (Donovan & Venville, 2014). For example, both Digimon and Pokémon make reference to DNA and genes, and articles about genes regularly appear in *Scholastic News*, geared toward Grades 1–6 (e.g., "Is there a gene for sports?" (Jones, n.d.)). *National Geographic Kids* links to the National Geographic "Genographic Project" (an initiative analyzing DNA from individuals around the world; "National Geographic Kids: Meet Spencer Wells"; https://kids.nationalgeographic.com/explore/explorers/meet-spencer-wells/) and pbskids.com includes a game about the genetics of dog breeding ("Games: Dog Breeding"; http://pbskids.org/dragonflytv/games/game_dogbreeding.html). Given the ready availability of these concepts, it is perhaps not surprising that one study indicated that 96% of 10- to 12-year-old Australian children had at least heard of DNA or genes (Donovan & Venville, 2012), and another study found that most British 10-year-olds had heard of genes—even though only one third had received formal instruction in the topic (Williams & Smith, 2010). By 9–10 years of age, a subset of U.S. children spontaneously invoked genes on a task asking them to predict characteristics of hypothetical individuals in vignettes in which they had been described as switched at birth and for whom birth versus adoptive parents had different features (e.g., "It will have trouble [being smart]. It's in its genes." [Heyman & Gelman, 2000a])—even though genes were never mentioned by the experimenter. Thus, children in industrialized countries are exposed to concepts of genes well before they receive formal genetic education. Yet currently little is known about these early construals and even less regarding what children younger than 9–10 years of age think.

In the current study, we chose to examine genetic attributions for individual differences. Understanding the extent to which children explain individual differences via genetic explanations can shed light on how children make sense of genes and their role in influencing or causing complex behaviors. Moreover, children's beliefs about genes may be particularly important for inferences about the flexibility of certain behaviors; for instance, believing that genetic differences explain individual differences, such as those involving motivation or intelligence, could encourage the belief that individual differences are "fixed" and not changeable, which could decrease a desire to learn and grow (Dweck, 2006).

When considering the development of genetic attributions, we start by observing that the tendency to attribute outward features to genes—which are internal, inherent, biological, and relatively unchanging—is in keeping with an early emerging set of folk beliefs known as *psychological essentialism*. Psychological essentialism has been extensively documented in both children and adults and includes two broad assumptions: that certain categories are natural kinds with a rich underlying structure and that the members of such categories are believed to share a common causal essence residing inside each (Gelman, 2003, 2005; Medin & Ortony, 1989; Rhodes & Mandalaywala, 2017). Young elementary schoolchildren treat certain categories (e.g., animals, gender) as sharply bounded, natural, and stable, as opposed to graded, culturally invented, and flexible (Rhodes & Gelman, 2009; Rhodes & Mandalaywala, 2017; Taylor, Rhodes, & Gelman, 2009). Young children, and even infants, also rely on internal and inborn aspects of individuals when making judgments about category membership (Gelman & Wellman, 1991; Newman, Herrmann, Wynn, & Keil, 2008; Newman & Keil, 2008; Setoh, Wu, Baillargeon, & Gelman, 2013; Taborda-Osorio & Cheries, 2018) and often draw novel inferences on the basis of category membership over superficial perceptual attributes (e.g., expecting that a leaf bug will have more similarities with a beetle than a leaf it resembles; Dewar & Xu, 2009; Gelman, 2003; Gelman & Coley, 1990; Gelman & Davidson, 2013; Gelman & Markman, 1986, 1987; Gelman & Wellman, 1991; Graham, Kilbreath, & Welder, 2004; Keil, 1989). These findings together suggest that children attribute some kind of internal, unseen causal force to certain natural kind categories and expect such essences to be causally responsible for outward features. As well, children are readily capable of generating explanations consistent with psychological essentialism for a variety of human individual differences, including intelligence and aggression (Dweck, 2006; Gelman, Heyman, & Legare, 2007; Giles, 2003).

As noted above, psychological essentialism and genetic essentialism are similar in that both treat certain features as intrinsic, biological in origin, and relatively unchanging (Dar-Nimrod & Heine, 2011). However, there are differences as well. Most importantly, psychological essentialism need not require any detailed causal theory about the nature of the essence. Instead, psychological essentialism reflects the belief that something internal, inborn, and bodily is responsible for the emergence of a category's features. In this way, psychological essentialism is typically described as involving a placeholder notion of essence; a person can believe that an essence exists without yet knowing what it is (Medin & Ortony, 1989). Genetic essentialism, in contrast, holds that the placeholder is genetic. Genes are an obvious candidate for mapping onto the assumptions of an essence: Genes are found in living organisms, not artifacts, and living organisms are essentialized to a greater extent than artifacts (Keil, 1989). Thus, assumptions regarding the nature, location, and function of genes may become incorporated across development into a preexisting psychological essentialist framework.

The current study examines if and when children provide genetic attributions for human individual differences. Adults' understanding of genes may be explained in terms of two longstanding debates regarding the origins of human characteristics (Jayaratne et al., 2009). The first is the nature versus nurture debate: Are characteristics rooted in our biology, or do they emerge because of how we are raised? From this perspective, genes—as biological and inborn—can be understood as contrasting with environmental factors. The second is the free will versus determinism debate: Are humans able to exercise choice freely over their characteristics and circumstances, or are these outcomes out of their control? From this perspective, genes—as immutable and beyond our control—are contrasted with personal choice. These debates are highly oversimplified, and framing individual differences in such binary, opposing terms is widely acknowledged to be deeply problematic and inaccurate (e.g., Francis & Kaufer, 2011; Moore, 2001; Pinker, 2004). Nonetheless, this historical context suggests that in order to investigate how children understand the role of genetics in explaining behavior, it is also important to ask about their understanding of the role of environment and choice.

The present study is closely based on a prior investigation with adults (Jayaratne et al., 2009), which examined the extent to which people attributed a series of traits and abilities to genes, the environment, and choice. In that study, nationally representative samples of Black and White American adults rated how much these factors explained individual differences in a series of abilities and traits, including athleticism, nurturance, drive to succeed, math ability, tendency toward violence, intelligence, and sexual orientation. Two patterns were noteworthy for our current purposes. First, although most respondents thought most characteristics were due to multiple causes, certain characteristics received higher ratings of genes than others (e.g., intelligence, particularly in the White sample), whereas others received higher ratings of choice (e.g., sexual orientation), and yet others received higher ratings of the environment (e.g., nurturance). Second, the extent to which respondents endorsed genes with a characteristic was negatively associated with their endorsement of choice and also negatively associated with their endorsement of the environment in the White sample. These results suggest that American adults typically assume a complex and multicausal basis for the emergence of human characteristics but that certain characteristics are preferentially attributed to genes, and this endorsement of genes can be associated with lower endorsements of choice and (in some groups) environmental factors.

In the current study, we focused on children ranging from elementary to early middle school age, expecting that children's prior exposure to the concept of genes (both informally and in formal instruction) would be increasing across this time period. We also included a comparison group of adults. As in prior work with adults, we assessed explanations for a series of human characteristics (in this study: intelligence, athleticism, niceness, height, literacy, and food selection; see Table 1). Participants first gave open-ended explanations for the characteristics, which were subsequently coded for endorsement of genes, environment, and choice, as well as causes that would be considered essentialist without making reference to genes (e.g., inborn). Participants were then instructed about the three target explanation types and asked to rate how much each explanation was causally responsible for each characteristic. Instruction on genes was modified from instruction provided in Solomon and Johnson (2000), who found that 6-year-olds were capable of learning several basic features and functions of genes, including that genes were internal, inherited, and responsible for determining species as well as involved in causing the emergence of certain phenotypic features. By eliciting ratings after this brief lesson, we were able to further address three key research questions: a) Will children accept genes as causally involved after learning about their existence and basic function, and if so, how strongly will they do so in comparison to other explanations (i.e. environment and choice); b) do children endorse multiple causes for attributes; and c) do genetic endorsements, if provided, negatively or positively predict other kinds of attributions?

Table 1
Descriptions Provided for Each Characteristic

Characteristics[a]	Description
	Close-transfer
Height (Tall)	is taller than everyone at work, can touch the ceiling, can reach books on the highest shelf
Literacy (Can read)	reads books, understands what s/he reads, can read out loud and silently
Food selection (Picks lemon)	is buying candy to eat later, two kinds of candy are available, lemon and cherry; s/he picks the lemon and not the cherry
	Far-transfer
Intelligence (Smart)	learns new things quickly; is good at solving complicated problems, remembers things well
Intelligence (Not at all smart)	learns new things slowly, is bad at solving complicated problems, has a hard time remembering things
Athleticism (Good at sports)	runs really fast, is good at balancing and throwing a ball, is good at any sport s/he tries
Athleticism (Not at all good at sports)	runs really slowly, is bad at balancing and throwing a ball, is not good at any sport s/he tries
Niceness (Nice)	likes to share, helps if someone is hurt, smiles at people a lot
Niceness (Not at all nice)	hates to share, laughs if someone is hurt, yells at people a lot

[a] Parenthetical text expresses how characteristics were labeled for participants.

Method

Participants

The sample included 71 children between 7 and 13 years (45% = female; M_{age} = 10.08 years, *SD* = 1.94). Four of these children chose not to provide open-ended explanations, or stated they did not know every time they were asked, and thus were not included in that analysis. Other than age, we did not obtain demographic information on the children. There were also 46 adults between 18 and 62 years (50% = female; M_{age} = 33.35 years, *SD* = 9.85). Adults self-reported their race/ethnicity as follows: White (*N* = 41), Asian (*N* = 2), Native Hawaiian (*N* = 1), American Indian/Alaska Native (*N* = 1), and Latino (*N* = 1). Regarding highest educational level attained: 9 graduated high school or had a GED, 16 had some college, 17 had a bachelor's degree, and 4 had an advanced degree. Children were recruited from a database of local families, a local university-affiliated museum, or via emails sent to their parents from a list provided for us by a local middle school. Families resided in university towns in the U.S. Midwest. Adults were recruited via Amazon's Mechanical Turk. Data from six additional adults were discarded due to incomplete surveys. All studies were approved by the IRBs of the two institutions where the authors undertaking data collection were affiliated, and all researchers upheld APA ethical standards in the treatment of our subjects.

Materials and Procedure

Table 2 presents a summary of materials, procedure, and analytical approaches. Participants were presented with a series of short vignettes describing a person with a particular characteristic. Younger children (7–10 years) heard vignettes in a one-on-one interview with an experimenter, whereas older children (11–13 years) participated in groups during school hours, reading the vignettes individually to themselves on a paper-and-pencil version of the measure and hand writing their responses to questions. Adults read the vignettes online in materials presented through Qualtrics and typed their responses. There were six characteristics. Three characteristics were similar to the examples provided during instruction about genes, environment, and choice (see Phase 2, below, for description of instructions provided during close-ended section and the Appendix for full text of instructions), henceforth referred to as "close-transfer" items (height, a visible physical characteristic similar to the visible physical characteristics of eye color and hair color discussed as part of genes instruction; literacy, a skill commonly understood to be learned from adults in the home and school, contexts discussed as part of the environment instruction; and food selection, a choice similar to a color selection described as part of the choice instruction). Another three characteristics were unrelated to the examples provided in the lessons, henceforth referred to as "far-transfer" items (intelligence, athleticism, and niceness, each with both a positive and a negative exemplar—e.g., for intelligence: smart and not smart). Far-transfer characteristics were modeled on a subset of those examined in past research with adults (Jayaratne et al., 2009).

Each vignette started by presenting a fictional individual who was described as having a certain characteristic (e.g., nice), which was elaborated with evidence (e.g., likes to share; see Table 1). For younger children, a drawing of an adult (racially/ethnically ambiguous) accompanied the description, in order to increase their interest and help them pay attention. For the older children and adults, participants were simply told that a series of adults would be described. For all age groups, gender of character was matched to participant gender.

For example, a younger female participant receiving the characteristic of *nice* heard the following while viewing an illustration of an adult woman: "This is Lisa, and she is nice. She likes to share. She helps out if she sees someone get hurt. She smiles at

Table 2
Description of Study Phases and Associated Analyses

Phase	Materials and procedure	Test question/s and response options	Coding and analyses
Phase 1: Open-ended responses	Vignettes describing characters with various traits were presented to participants. Vignettes were read out loud to younger participants (7- to 10-year-olds), along with accompanying character pictures; written text without pictures was presented to older participants (11-year-olds and older). After each vignette, participants provided possible causes for those traits.	What caused [Character] to be [characteristic]? Example: What caused Lisa to be tall? (Response options were open-ended)	Responses coded for endorsement of genetic, environmental, and choice causes, as well as non-genetic essentialist and uncodable
Phase 2: Close-ended ratings	Participants were instructed on what genes, environment, and choice were. For each block (genetics, environment, or choice), they were provided the same set of characters as those presented in Phase 1, and reminded of the relevant characteristics. (Example: Remember Lisa? Lisa is tall.) Younger participants also saw the relevant character picture, while older participants only saw written text.	Do you think [Character's] genes/environment/choices (varied according to block) have to do with why [Character] is [characteristic]? *If no, move to next question and give score of 0. If yes,* How much? Example, for an item presented in the genes block: Do you think Lisa's genes have anything to do with why Lisa is tall? *If yes,* How much? (Response options were Likert-type options ranging 0 = not at all to 10 = completely)	Numerical scores on the three causes were compared to establish relative strengths of ratings; binary patterns of endorsement (i.e., scores of 0 vs. scores of non-zero) were assessed to establish how often multiple causes were endorsed; intercorrelations of ratings were analyzed to establish whether endorsing one cause predicted endorsement of others

people a lot. So, Lisa is nice" (Older children and adults read the same wording, except that the first sentence was replaced by "Lisa is nice," and they did not see any illustrations.) Characters' names (e.g., Lisa) were popular in the United States in 1980 and thus would be common names for adults.

Characteristics were presented in one of two orders that were randomly generated, except that no characteristic directly followed its opposite (e.g., *nice* could not be followed directly by *not at all nice*). The two orders of names and illustrations paired with each characteristic were also randomly generated except that no combination of a characteristic, name, and illustration in the first order could also be featured in the second order. Approximately equal numbers of participants within each age group participated in each of the two orders.

Phase 1: Open-ended responses. After being presented with a person possessing a particular characteristic, participants were first asked to report what caused that characteristic (e.g., "What caused her [Lisa] to be nice?"). We coded each response into one of five categories. The first three of these categories corresponded to our target explanations of interest (with all examples below coming from children's responses): genes (genes or DNA; e.g., "Her mom or dad's genes—she got it from them" [explaining tall]; "Maybe the parents have a certain gene or body type that was passed down" [explaining being good at sports]), environment (external causal factors such as learning or socialization from teachers, parents, friends, or media, or responding to behaviors from these sources; e.g., "His parents might have taught him how" [explaining literacy]; "People used to be mean to him" [explaining being mean]), or choice (choosing, deciding, or wanting, e.g.; "Maybe he just decided to" [explaining being mean]; "Maybe he just doesn't care" [explaining not being good at sports]). We also created a fourth category, *nongenetic essentialist*, to capture responses consistent with essentialism but not referring to genes (inborn, natural, parents, or inheritance, without mentioning environmental mechanisms, e.g., "She was just born to be like that" [explaining being tall], "Maybe her parents were really tall" [explaining tall]). Finally, a fifth category, *other,* was created for uncodable or other kinds of responses. A randomly selected 15% of explanations were coded by a second coder, and Kappas for each of the first four explanation types were excellent, ranging from .93 to 1.0 (average .96).

Phase 2: Ratings of the causal factors. For each causal factor (genes, environment, choice), children (but not adults) received a brief lesson during which the researcher elaborated on what was meant by genes, environment, or choice. For genes, younger children (7- to 10-year-olds) were also first asked if they had ever heard of genes, clarifying that we were talking about genes "like the tiny things in our bodies, not the jeans like what we wear on our legs." If children responded that they had heard of genes, we followed up with a question about what they knew about genes. Older children (11- to 13-year-olds) were not asked these questions, as it was assumed that they had at least heard of genes before, based on confirming biology curricula in the particular school where the participants attended (A. Van Sickle, personal communication, October 14, 2014; Ohio Department of Education, 2011).

The description of genes that all children received was modeled on instruction developed by Solomon and Johnson (2000). Their lesson conveyed basic facts, including that genes come from one's parents, that one gets genes when one is still in the mother's body, and that genes are responsible for the kind of thing one is (e.g., human vs. rabbit) as well as species-specific body parts (e.g., human ears vs. rabbit ears). We additionally mentioned that genes could also be involved in causing an individually varying behavior (i.e. using the right vs. left hand to color). For the environment and choice blocks, similar instructional information was given prior to providing ratings, though the lessons were shorter than for the genes block. For the full text of genes, environment, and choice instructions, see the Appendix.

After instruction, participants provided ratings to indicate how much the relevant cause—genes, environment, or choice (depending on block)—explained each characteristic. Participants provided ratings for each of the nine items (three close-transfer items and six far-transfer items) within each cause block. Gene, environment, and choice cause were presented in all six possible orders across participants, with approximately equal numbers of participants across the child and adult samples participating in the different orders. Characteristics were presented in the same order as in the open-ended response section.

For each characteristic, younger children heard the question in the following form, illustrating with the nice/genes item: "Remember Lisa? Lisa is nice. Do you think Lisa's genes have to do with why she's nice?" If the child responded *no,* a score of 0 was given, and the experimenter moved on to the next characteristic and individual. If a child responded *yes*, the experimenter showed the child a Likert scale consisting of a row of 10 circles of increasing size, and asked, "Can you show me how much Lisa's genes have to do with why she's nice? Just a little bit, like this [pointing to smallest circle], a whole lot like this [pointing to biggest circle], or somewhere in between like one of these [pointing to remaining circles in sweeping gesture]?" Children's selections were then converted into scores ranging from 1 (smallest circle) to 10 (largest circle). Older children and adults used a standard 0 to 10 Likert scale, with 0 corresponding to *not at all* and 10 corresponding to *completely*.

Results

Data analyses proceeded in four phases. First, we examined the open-ended responses, for which participants generated their own causal explanations without specific prompts. Second, we turned to the close-ended ratings of the extent to which each cause (genes, environment, and choice) was rated as explaining the various characteristics (0 = *not at all*, 10 = *completely*) and examined the relative strength of each. This was done separately for close-transfer items and far-transfer items. Third, we examined these close-ended ratings to determine how many of these causes participants at different ages endorsed for any given attribute to determine whether they recognized that a characteristic can be the outcome of multiple causes. Finally, we examined intercorrelations between these close-ended ratings on the different causes (e.g., examining whether ratings of genetic causes negatively correlated with ratings of environment and choice causes). All data are publicly accessible via the Open Science Framework (https://osf.io/38q6w/).

Open-Ended Responses

Table 3 presents the open-ended responses, reporting the percentage of children and adults who used each cause at least once

Table 3
Open-Ended Responses, Percentages of Participants Providing a Given Response Type, Separately by Characteristic and Overall

			Causal factor			
Age group	Transfer	Characteristic	Genetic	Environmental	Choice	Non-genetic essentialist
Adults	Close	Height	43	0	0	24
		Literacy	0	57	4	0
		Food selection	0	0	96	0
	Far	Intelligence	11	13	13	20
		Athleticism	11	4	13	17
		Niceness	0	46	7	9
	Overall		50	67	96	35
Children	Close	Height	15	33	1	45
		Literacy	0	55	21	0
		Food selection	0	1	93	0
	Far	Intelligence	3	43	18	15
		Athleticism	6	18	27	19
		Niceness	3	84	43	13
	Overall		19	99	94	54

for a given characteristic, as well as at least once overall (i.e. across all close-transfer and far-transfer characteristics). Thus, for example, if someone invoked genes for "not smart", they were credited as using genes for the intelligence dimension, as well as overall. Because not all participants provided each response type, we did not make statistical comparisons across them but here provide a few observations.

First, responses that appealed to the environment and choice were provided by the majority of participants (children: 99% and 94%, respectively; adults: 67% and 96%, respectively), whereas those that appealed to genetics and nongenetics were less common. Second, responses that appealed to genetics were more common among adults (50% of whom appealed to genes or DNA at least once, mostly regarding height and occasionally intelligence or athleticism) than children (only 19% of whom appealed to genes or DNA at least once). However, once we broke down the child data further by age (not shown in Table 3), we observed the biggest jump in spontaneous usage of this sort of response was in middle school, with 53% of children from 11–13 years of age ($n = 21$) appealing to genes or DNA, in contrast to only 4% of the younger children (7–10 years of age, $n = 46$). Third, children tended to provide more environmental, choice, and nongenetic essentialist responses than adults. Fourth, both children and adults provided sensible and differentiated responses for all of the close-transfer items: height elicited primarily genetic or nongenetic essentialist responses, literacy elicited primarily environmental responses, and food selection elicited primarily choice responses.

We also examined how often the youngest children (7- to 10-year-olds) said they had heard of genes, and if so, what genes were. (Recall that older children and adults did not receive this question.) Interestingly, even at this young age, children had some exposure to the concept of genes: 43% reported having heard of genes, and of these, most (85%) gave a sensible response as to what genes were or how they functioned. This suggests that even in the early elementary school years, children are hearing about genes and picking up some initial understanding. At the same time, we note that over half the children of this age group did not initially know what genes are.

Ratings Data: Relative Strength of Genes, Environment, and Choice Ratings

We next turn to the ratings of the causal factors that were specifically queried. For each causal factor (genes, environment, and choice), participants rated how well it explained a particularly characteristic (e.g., What caused Lisa to be nice?) from 0 (*not at all*) to 10 (*completely*). To test the relative strength of these ratings, we conducted a series of mixed-effects linear regressions models. We conducted separate models for each of the six outcomes (height, literacy, food selection, intelligence, athleticism, niceness) separately for adults and children. For the adult data, we conducted mixed-effects linear regression models in which cause (genes, environment, choice) was a fixed effect, and participant ID was a random effect. The three-level variable of cause was dummy coded so that genes and environment were the reference groups, thereby allowing us to compare gene ratings to environment ratings, gene ratings to choice ratings, and environment ratings to choice ratings. The dependent variable was the participant's rating of how much a given cause explained the character's attribute (from 0 to 10). For the child data, we conducted mixed-effects models with the same structure as with the adult data, except that age (standardized) and the interaction of age and domain were added as additional fixed effects. Whether the characteristic was present or absent (e.g., smart vs. not smart) yielded no systematically interpretable effects, and all patterns of results reported here are the same as those obtained when the variable was included in the analyses. Presence versus absence is therefore not discussed further.

We first report the results of close-transfer items (height, literacy, and food selection). These were included to confirm that participants could appropriately extend genetic, environmental, and choice causes to characteristics commonly assumed to arise from these sources and similar to those described in the instructional sections. We then report the results of far-transfer items (intelligence, athleticism, and niceness). For each set of analyses, we first present the results for adults, then children. Below, we present only results that were significant at the $<.05$ level. See Table 4 for descriptive statistics and Table 5 for a summary of significant main effects as a function of cause.

Table 4
Ratings Task, Descriptive Statistics for the Various Characteristics (Scores Ranging From 0–10)

Age group	Transfer	Characteristic	Causal factor Genetic M (SD)	Environmental M (SD)	Choice M (SD)
Adults	Close	Height	8.61 (1.39)	0.50 (1.79)	0.07 (0.33)
		Literacy	2.28 (3.01)	4.22 (3.27)	4.48 (3.39)
		Food selection	0.65 (1.79)	1.33 (2.19)	7.91 (2.36)
	Far	Intelligence	5.68 (2.58)	3.27 (2.51)	2.36 (2.09)
		Athleticism	5.48 (2.53)	2.42 (2.52)	3.22 (2.80)
		Niceness	1.66 (2.46)	5.83 (2.11)	7.11 (1.75)
Children	Close	Height	8.51 (2.17)	2.52 (3.63)	2.35 (3.62)
		Literacy	4.42 (3.61)	6.83 (3.12)	6.07 (3.45)
		Food selection	3.01 (3.33)	3.41 (3.54)	8.48 (2.19)
	Far	Intelligence	4.22 (3.03)	5.27 (2.71)	5.64 (2.92)
		Athleticism	4.64 (3.14)	5.14 (3.02)	5.89 (3.13)
		Niceness	3.40 (2.95)	5.87 (3.38)	8.13 (1.98)

Note. Mean values for the far-transfer items reflect the average across both the present and absent items (e.g., for "Niceness", whether the target was nice or not nice).

Height (close-transfer). As predicted, adults indicated that height was rooted more in genes than in choice ($B = -8.54$, $SE = .27$, $t = -31.28$, $p < .001$, 95% CI [−9.08, −8.01]) or the environment ($B = -8.11$, $SE = .28$, $t = -29.69$, $p < .001$, 95% CI [−8.64, −7.57]). Children also reasoned that height was rooted more in genes than in choice ($B = -6.16$, $SE = .49$, $t = -12.61$, $p < .001$, 95% CI [−7.11, −5.21]) or the environment ($B = -5.99$, $SE = .49$, $t = -12.26$, $p < .001$, 95% CI [−6.94, −5.04]).

Literacy (close-transfer). Adults indicated that literacy was rooted less in genes than in choice ($B = 2.20$, $SE = .64$, $t = 3.45$, $p < .001$, 95% CI [.95, 3.44]) or the environment ($B = 1.93$, $SE = .64$, $t = 3.04$, $p = .003$, 95% CI [.69, 3.18]). Similarly, children indicated that literacy was rooted less in genes than in choice ($B = 1.65$, $SE = .53$, $t = 3.13$, $p = .002$, 95% CI [.62, 2.67]) or the environment ($B = 2.41$, $SE = .53$ $t = 4.57$, $p < .001$, 95% CI [1.38, 3.43]). There was also an interaction with child age, revealing that choice attributions, relative to genetic attributions, increased with child age ($B = 1.06$, $SE = .53$ $t = 2.01$, $p = .046$, 95% CI [.03, 2.09]).

Food selection (close-transfer). Adults indicated that food selections were rooted less in genes than in choice ($B = 7.26$, $SE = .43$, $t = 17.02$, $p < .001$, 95% CI [6.43, 8.10]) and less in the environment than in choice ($B = 6.59$, $SE = .43$, $t = 15.44$, $p < .001$, 95% CI [5.75, 7.42]). Like adults, children indicated that food selections were rooted less in genes than in choice ($B = 5.46$, $SE = .48$, $t = 11.36$, $p < .001$, 95% CI [4.53, 6.40]) and less in the environment than in choice ($B = 5.07$, $SE = .48$, $t = 10.54$, $p < .001$, 95% CI [4.13, 6.01]).

Table 5
Summary of Significant Main Effects of Causal Factor

Factor	Adults	Children
Close-transfer		
Height	G > C, E	G > C, E
Literacy	G < C, E	G < C, E
Food selection	G < C; E < C	G < C; E < C
Far-transfer		
Intelligence	G > C, E; E > C	G < C, E
Athleticism	G > C, E	G < C, C > E
Niceness	G < C, E; C > E	G < C, E; C > E

Note. G = genes; E = environment; C = choice.

Summary of close-transfer characteristics. Across all three close-transfer characteristics, results indicated that both children and adults selectively attributed genetic causes. That is, both adults and children attributed height to genes more than to the environment or choice and attributed both literacy and food selection less to genes than to other causes (choice, the environment, or both).

Intelligence (far-transfer). Adults indicated that intelligence was rooted more in genes than in choice ($B = -3.33$, $SE = .39$, $t = -8.55$, $p < .001$, 95% CI [−4.08, −2.56]) or the environment ($B = -2.41$, $SE = .39$, $t = -6.20$, $p < .001$, 95% CI [−3.18, −1.65]) and more in the environment than in choice ($B = -.91$, $SE = .39$, $t = -2.35$, $p = .019$, 95% CI [−1.68, −.16]). Unlike adults, children reasoned that intelligence was rooted less in genes than in the environment ($B = 1.05$, $SE = .38$, $t = 2.79$, $p = .005$, 95% CI [.32, 1.79]) or in choice ($B = 1.42$, $SE = .38$, $t = 3.75$, $p < .001$, 95% CI [.68, 2.15]). There was also an interaction with child age, revealing that choice attributions, relative to environmental attributions, decreased with child age ($B = -.85$, $SE = .38$, $t = -2.25$, $p = .025$, 95% CI [−1.59, −.11]).

Athleticism (far-transfer). Adults indicated that athleticism was rooted more in genes than in choice ($B = -2.26$, $SE = .40$, $t = -5.67$, $p < .001$, 95% CI [−3.04, −1.48]) or the environment ($B = -3.05$, $SE = .40$, $t = -7.66$, $p < .001$, 95% CI [−3.84, −2.27]). Unlike adults, children indicated that athleticism was rooted less in genes than in choice ($B = 1.25$, $SE = .35$, $t = 3.54$, $p < .001$, 95% CI [.56, 1.94]) and more in choice than in the environment ($B = .75$, $SE = .35$, $t = 2.12$, $p = .035$, 95% CI [.06, 1.44]).

Niceness (far-transfer). Adults indicated that niceness was rooted less in genes than in choice ($B = 5.45$, $SE = .34$, $t = 16.09$, $p < .001$, 95% CI [4.78, 6.11]) or the environment ($B = 4.16$, $SE = .34$, $t = 12.30$, $p < .001$, 95% CI [3.50, 4.83]) and more in choice than in the environment ($B = 1.28$, $SE = .34$, $t = 3.79$, $p <$

.001, 95% CI [.62, 1.95]). Like adults, children indicated that niceness was rooted less in genes than in choice ($B = 4.72$, $SE = .33$, $t = 14.17$, $p < .001$, 95% CI [4.07, 5.38]) or the environment ($B = 2.46$, $SE = .33$, $t = 7.38$, $p < .001$, 95% CI [1.81, 3.11]), and more in choice than in the environment ($B = 2.26$, $SE = .33$, $t = 6.79$, $p < .001$, 95% CI [1.61, 2.92]). There were interactions with age, revealing that relative to environmental attributions, genetic attributions ($B = -1.59$, $SE = .33$, $t = -4.76$, $p < .001$, 95% CI [−2.24, −.94]) and choice attributions ($B = -1.23$, $SE = .33$, $t = 3.70$, $p < .001$, 95% CI [−1.89, −.58]) decreased with age.

Summary of far-transfer characteristics. As was the case with the close-transfer items, adults varied in the extent to which they rated the three causes as explaining different characteristics. That is, adults attributed intelligence more to genes than to the environment or choice, attributed athleticism more to genes than to the environment or choice, and attributed niceness less to genes than to the environment or choice. Children responded differently. Specifically, children attributed intelligence, athleticism, and niceness less to genes than to the environment or choice. Simply put, across three distinct characteristics, young children indicated that genes play less of a causal role than other factors.

Ratings Data: Use of Multiple Causal Factors

As in Jayaratne et al. (2009), we investigated whether participants tended to entertain multiple kinds of causes versus selectively endorsing only one cause to the exclusion of others. To do this, we examined participants' close-ended ratings to see how often participants endorsed zero, one, two, or three causal factors for each attribute (see Table 6). There were eight possible patterns: genetics only, environment only, choice only, genetics plus environment only, genetics plus choice only, environment plus choice only, all three causal factors (genetics, environment, and choice), or none of the three causal factors. Each participant's responses to each characteristic (e.g., height, smart, not-smart) were classified in terms of which causal factor or factors were endorsed, in a binary fashion (i.e., A score of 1–10 indicated endorsement, and a score of 0 indicated nonendorsement). For example, a child responding on the "tall" characteristic who gave a score of 9 for genetic causes, a 3 for environmental causes, and a 0 for choice causes would be considered to have endorsed two causes (namely the two nonzero responses for genes and environment). We then calculated percentages of respondents displaying each of the eight possible combinations of patterns. For the far-transfer characteristics, percentages reflect the average of the patterns in the positive and negative versions of each characteristic (e.g., the percentage provided for the "genes only" pattern for intelligence reflects the average of the percentages for genes-only causes for smart and not-smart).

Consistent with Jayaratne et al. (2009), the modal response for many of the characteristics studied was to endorse all three causal factors, and this was particularly true for children. Furthermore, when genes combined with just one other factor, this sometimes was environment and sometimes was choice. Thus, for the most part, neither children nor adults assumed that genes are strictly deterministic or that they exclude the influence of other factors. Notably, however, the modal response for height was to endorse genes only, and a substantial subset of adults endorsed genes-only for both intelligence (23%) and athleticism (34%). Thus, genetic causes do have substantial explanatory power for a subset of participants.

Ratings Data: Relations Among Causal Factors

We next examined relations between and among individuals' ratings of the genetic, environmental, and choice causes. First, we looked at the stability of individual differences in the tendency to endorse genetic causes; for this, we examined relationships in people's ratings of the genetic causes for the three far-transfer characteristics. Second, we looked at whether ratings of the genetic causes negatively predicted ratings of environment- and choice-based causes, patterns that would be predicted by the nature/nurture and choice/free-will debates, respectively, and that were found in past work with adults (Jayaratne et al., 2009). To test

Table 6
Ratings Task, Percentage of Respondents Reporting Zero, One, Two, or Three Causal Factors for Each Characteristic, Presented Separately for Adults and Children

	Causal factor							
Age group	G only	E only	C only	G, E only	G, C only	E, C only	GEC	(none)
Adults								
Height	***89***	2	0	2	0	0	4	2
Literacy	7	9	11	2	4	24	***33***	11
Food selection	0	0	***54***	0	9	24	7	7
Intelligence	23	2	7	24	8	0	***35***	2
Athleticism	***34***	0	7	8	9	8	***35***	1
Niceness	0	3	9	0	3	***54***	30	0
Children								
Height	***41***	0	1	20	11	0	25	1
Literacy	3	3	4	9	3	20	***58***	1
Food selection	1	1	21	0	17	18	***41***	0
Intelligence	4	6	9	4	4	14	***54***	4
Athleticism	5	3	6	4	6	15	***56***	6
Niceness	0	0	12	1	7	25	***54***	2

Note. Participants were categorized as endorsing genetic (G), environmental (E), and/or choice (C) causes if they attributed a non-zero score for that causal factor. Percentages in *bold italics* indicate modal responses.

these two questions, we examined the relevant interrelations separately by adult and child participants, via a series of correlation analyses.

Regarding relationships in genetic endorsements across the far-transfer items, Figure 1 shows the interrelations among ratings for genetic causal factors between the far-transfer items, separated by adult and child participants. Among adults, ratings of the genetic causal factor were positively correlated between the niceness and intelligence traits and between the intelligence and athleticism traits. Among children, ratings of the genetic causal factor were positively correlated between each pair of far-transfer items.

Regarding how genetic endorsements predicted environment and choice endorsements, Figure 2 shows the interrelations among the ratings for genetic, environmental, and choice causal factors for each trait, separated by adult and child participants. Only one negative association was found, namely, in adults' ratings in the domain of athleticism, where genetic explanations were negatively associated with choice explanations. For children, in the domains of intelligence and athleticism, genetic explanations were positively associated with choice explanations and environmental explanations. For both children and adults, environmental and choice explanations tended to be positively associated with one another, with this especially being the case for children across almost all domains. Overall, the links we observed are not nearly as consistent in our dataset as in Jayaratne et al. (2009). Whereas in the prior work, genes showed numerous negative correlations with both choice and environment, here we found only one such association.

General Discussion

In an era in which genes figure prominently in popular culture, education, science, and the news, it is important to understand how children interpret the role of genes and how such interpretations change across development. The current study examined chil-

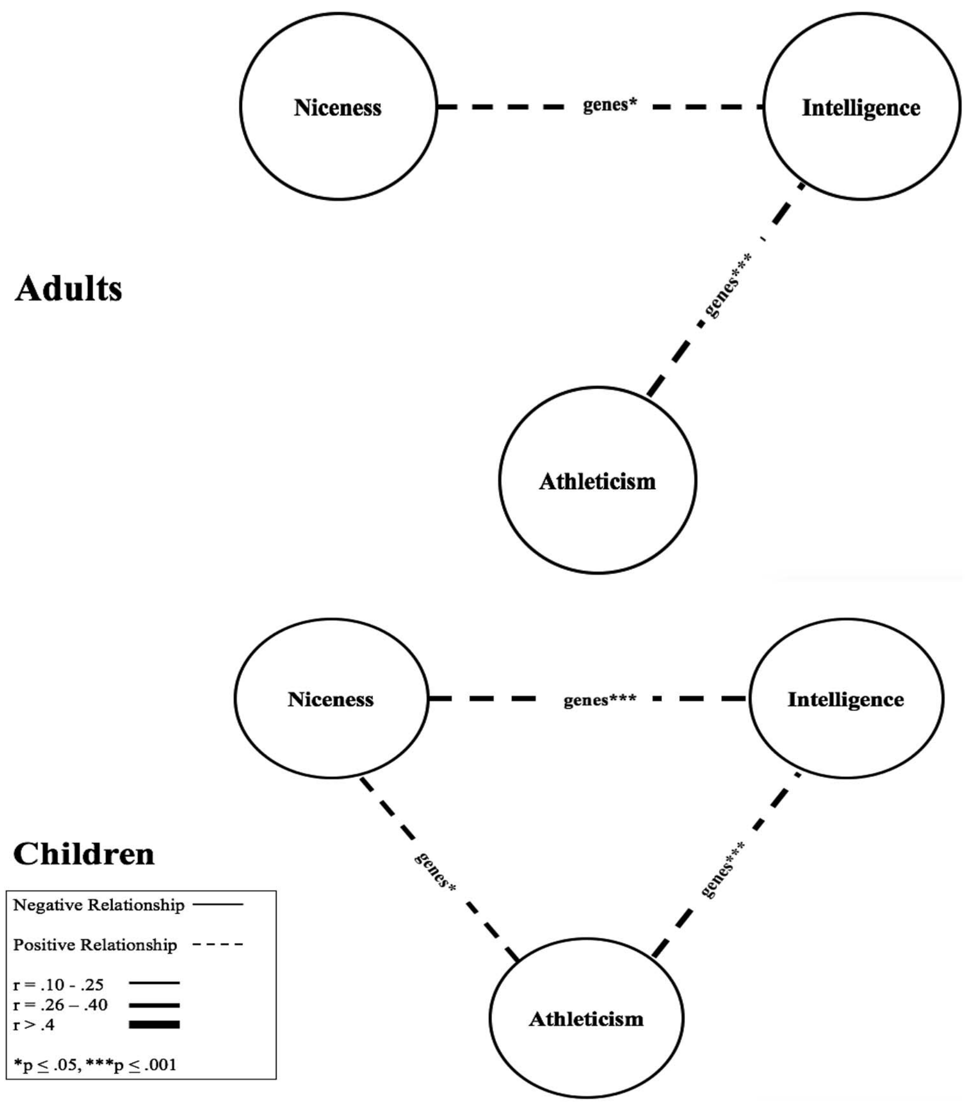

Figure 1. Interrelations in genetic endorsements across the far-transfer items.

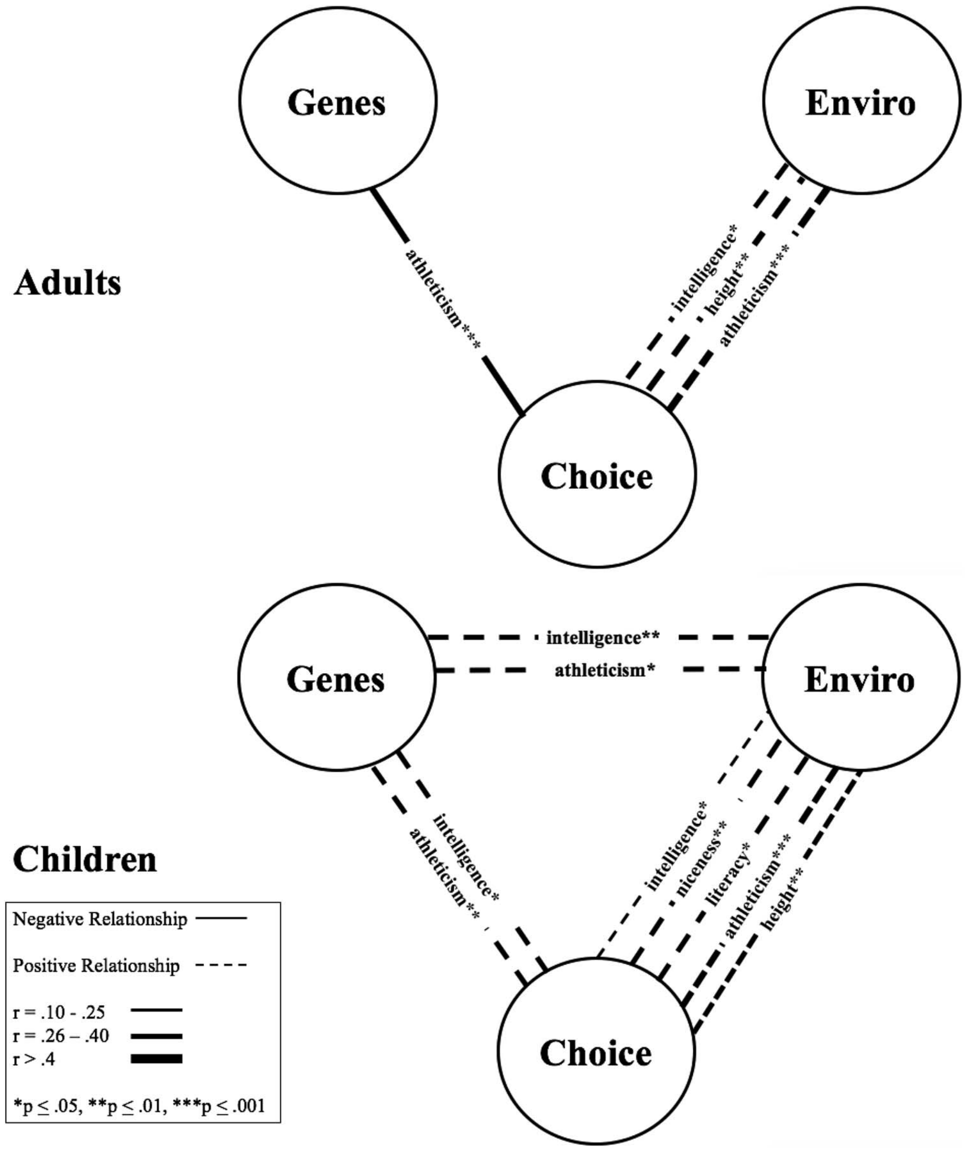

Figure 2. Interrelations among genetic, environmental, and choice explanations. Enviro = environmental.

dren's explanations for a variety of human characteristics, with a particular focus on genetic explanations. We compared children's genetic attributions to other common explanations, most particularly those appealing to personal choice and one's environment, which play an important role in historical debates regarding the basis of human differences (nature/nurture and free will/determinism).

Several main patterns emerged from our findings. First, there was a sharp increase in spontaneous mention of genes starting at 11 years of age on an open-ended explanation task: Children ages 7–10 mentioned genes only 4% of the time, whereas those ages 11–13 did so 53% of the time. Second, spontaneous mention of genes was found primarily for the physical characteristic of height and rarely for the far-transfer characteristics we studied (intelligence, athleticism, and niceness). This suggests that genes may not be particularly salient when crafting explanations for nonphysical characteristics—even among adults.

However, on the ratings task, after describing the function of genes, we found clear evidence that both adults and children endorsed genetic explanations. Both adults and children strongly preferred genetic explanations to explain height—suggesting that children were capable of applying genetic explanations in a systematic and principled fashion. Moreover, both children and adults tended to endorse the involvement of genes to some extent for the majority of characteristics. However, the ways in which children and adults endorsed genes relative to other causes differed strikingly for some domains. Whereas adults favored genetic explanations for intelligence and athleticism, children favored environment- and choice-based factors for intelligence and choice-based factors for athleticism. These differences may arise from multiple noncompeting possibilities, including children's home- and school-based exposure to lessons imparting the importance of effort, practice, and learning, as well as choice and environment providing more salient and concrete examples of influences to which children can easily appeal.

This difference may also relate to how people are employing psychological essentialism. As noted earlier, psychological essentialism holds that for certain natural kinds, there is an intrinsic, internal, and immutable aspect or quality that is responsible for an item's characteristics (Gelman, 2003). Prior work indicates that essentialist reasoning emerges early in childhood and often extends to explanations of individually varying human characteristics, such as intelligence or kindness (Heyman & Gelman, 2000a, 2000b). Consistent with this literature, children in our data spontaneously appealed to nongenetic essentialist explanations fairly frequently to explain human characteristics (56% of the child sample overall, including 47% of those children below age 11). At the same time, prior work also found that essentialism undergoes important developmental change. For example, different components of essentialism become increasingly interlinked with age (Gelman et al., 2007), and experiences with different cultural, linguistic, and environmental contexts influence when and how essentialism is applied, particularly in the social domain (Diesendruck, 2013; McIntosh, 2018; Rhodes & Mandalaywala, 2017; Roberts & Gelman, 2016; Tawa, 2016). Thus, although both children and adults often operate with essentialist beliefs, the nature of these beliefs, and the entities to which essentialist assumptions are applied, undergo considerable change.

We speculate that children's growing exposure to genes may influence their essentialist concepts about individual differences in human characteristics, such as intelligence or athleticism. (Note that we are not the first to propose that exposure to genetics can affect essentialist reasoning, and indeed, there is empirical support for this idea. As a prime example, Donovan, Semmens, and colleagues (2019) showed that an instructional intervention about genetic science can powerfully reduce racial essentialism. Here we consider how even casual exposure to genetic concepts may influence children's essentialism regarding individual differences, as with variation in intelligence, athleticism, or personality.) Specifically, children's increasing exposure to genes may have at least two consequences for essentialist reasoning about individually varying properties. First, it is generally recognized that essentialism starts out as a "placeholder" notion—that is, an unspecified belief that there is some sort of causal essence but the details are unknown (Medin & Ortony, 1989). The notion of genes, when first encountered, may easily fit into children's naïve essentialist frameworks, coming to "fill in" the placeholder as a plausible, heritable, internal causal mechanism. Consider, for instance, parents or other adults supporting the emergence of an essentialist framework by discussing the origins of both physical and behavioral characteristics (e.g., "He has his father's eyes," or "She has her mother's temperament.") Such statements may very well offer the young listener the opportunity to imagine this causal link as a placeholder for later genetic explanations. Second, exposure to instruction about genes, in either formal or informal settings, may promote the extension of essentialist beliefs to a wider variety of concepts, similar to how other cultural and linguistic factors have been implicated in shaping later-developed essentialist beliefs, particularly regarding social groups. This possibility would be consistent with our result that adults were more likely than children to endorse genes for intelligence and athleticism. On the ratings task, 90% of adults endorsed genes at least once for intelligence (vs. 66% of children), and 86% of adults endorsed genes at least once for athleticism (vs. 71% of children). For these characteristics, adults preferred genetic explanations over choice or environmental explanations, whereas children did not. There was thus a shift from childhood to adulthood in how these important characteristics were explained.

Future studies should include longitudinal designs to better determine how genetic essentialism emerges regarding individual differences like those under investigation in the current study and how such emergence relates to their earlier-developed psychological essentialist intuitions. It will also be important to better track whether certain dimensions of psychological essentialism either are replaced by, or are fueled by, genetic beliefs. Psychological essentialism is a constellation of beliefs about categories (e.g., including naturalness, immutability, historical invariance, discreteness, uniformity, inherence, and others; see Gelman et al., 2007; Haslam, Bastian, Bain, & Kashima, 2006; Rhodes & Mandalaywala, 2017). These beliefs can be thought of as separable but related strands of thought. One possibility is that genetic beliefs may strengthen certain of these strands over others, for instance more directly promoting expectations of naturalness or immutability. More work is needed to establish this interplay.

Despite the broad expectation across the adult sample that intelligence and athleticism are influenced by genetics, we also found individual differences. For example, a substantial minority of adults endorsed only genes as causally involved in these ability-based characteristics (23% and 34% for intelligence and athleticism, respectively), and a substantial minority of adults thought that genetics were implicated to some degree in being nice or not-nice (33%). As well, an examination of genetic attributions across domains revealed some degree of cross-domain consistency in their preferences for genes; correlations were positive between genetic attributions for *smart* and *sport,* as well as *smart* and *nice* (patterns expressed in children's data as well). Thus, it appears that there are stable individual differences that apply across domains in people's tendency to endorse genetic explanations.

An important question that arises is why we obtain this variability in genetic attributions. Future work can address this question and the related question of how best to design interventions in formal educational contexts to discourage the emergence of "genetic fallacies," such as the expectation that attributes with genetic origins cannot be improved but are fixed at birth or that genetics dictate differences in various forms of ability (e.g., Christensen, Jayaratne, Roberts, Kardia, & Petty, 2010; Dar-Nimrod & Heine, 2011; Donovan, 2014, 2016, 2017; Donovan, Semmens, et al., 2019). Such beliefs are notably in keeping with the phenomenon of fixed mindsets, which can lead to maladaptive coping strategies in the face of failure, reduced motivation, and poorer performance (Burnette, O'Boyle, Vanepps, Pollack, & Finkel, 2013; Dweck, 2006; Yeager & Dweck, 2012). Thus, interventions could be important both for correcting misconceptions and for broader motivational and achievement purposes. For example, biology curricula might be designed to diminish incorrect assumptions of genetic fixedness and may then indirectly encourage focus on the importance of effort, as well as increasing perceptions of the importance of supportive environments.

Future work should also examine children's genetic attributions for a wider range of phenomena. Our work was limited to an examination of individual variation in human attributes, namely intelligence, athleticism, and kindness. We selected this starting point in light of the important societal implications of genetic attributions for human characteristics (e.g., Dar-Nimrod & Heine, 2011), and in light of what was already known about adults (e.g., Jayaratne et al., 2009). Yet it has been well established that genetic beliefs can motivate different kinds of inferences depending on the domain, motivating the question of how these consequences may play out in children. For instance, genetic beliefs can promote prejudicial attitudes for certain groups (e.g., race and gender; Donovan, 2014, 2016, 2017; Donovan, Stuhlsatz, et al., 2019; Haslam & Whelan, 2008; Williams & Eberhardt, 2008), and genetic educational interventions can lead to substantial reductions (Donovan, Semmens, et al., 2019). Furthermore, genetic essentialist beliefs may be used to justify systems of inequality and discrimination and thus function as a form of socially motivated cognition (Brescoll, Uhlmann, & Newman, 2013; Morton, Hornsey, & Postmes, 2009; Morton, Postmes, Haslam, & Hornsey, 2009). Yet essentialism does not always predict prejudice; for instance, attributing differences in sexual orientation to genetic differences can decrease prejudice and increase support toward the LGBTQ community (Haslam & Levy, 2006; Roberts, Ho, Rhodes, & Gelman, 2017), and it can also decrease perceptions of blameworthiness in individuals with mental illness (Kvaale, Gottdiener, & Haslam, 2013). Our data provide no direct information on how genetic beliefs about such varied social groups might develop in children, how cultural and social factors may interact with such development, or how these beliefs may promote or decrease social judgments or attitudes. Separate studies would be useful in studying these phenomena.

It would also be valuable to investigate how children view genes as involved in kind-relevant features (e.g., zebras having stripes, dogs barking). Ample evidence indicates that children expect such features to emerge from an intrinsic, essential basis (Gelman, 2003). If it is true that children could readily incorporate the notion of genes into such a naïve psychological essentialist framework, as we speculate above, then such reasoning might be more easily employed at even younger ages than what we studied. Interestingly, a great deal of formal education on genes focuses on their role in biological variation (e.g., by discussions of adaptation and natural selection, exercises with Punnett squares, and lessons on Mendelian discoveries; e.g., NGSS, 2013). In future research, it would be informative to determine if curricula focusing on the involvement of genes in kind-relevant features would facilitate children's learning about genetics or have consequences for how children extend what they have learned about genes in their explanations for the origins of both kind- and individual-level features.

Another focus of the current study was to examine our findings in relation to those of Jayaratne et al. (2009), who similarly examined people's endorsement of genes, environment, and choice for a wider variety of attributes, but exclusively among adults. Our data replicate one of the broad findings observed by Jayaratne et al.: Endorsement of multiple causes was the most common response pattern for most characteristics. We also extend these findings by demonstrating that children, too, frequently endorsed multiple causes. In fact, on the whole, they did so more than adults. We caution, however, that endorsing multiple causes certainly does not necessarily imply that children have fully articulated theories of how such causes may interact.

We also examined whether there were relations between endorsement of different types; recall in particular that Jayaratne and colleagues (2009) observed frequent negative relations between genetic endorsements and choice- and environment-based endorsements. We did not observe such patterns, however; instead, the clearest broad finding appeared to be the positive relations between choice and environment endorsements in the child sample. It is unclear why we did not replicate past findings. One possibility is that this may simply reflect the smaller size or more limited demographics of the current samples; in contrast to Jayaratne and colleagues, who examined a nationally representative sample of adults, we used a more restricted sample through MTurk (see Berinsky, Huber, & Lenz, 2012 and Paolacci & Chandler, 2014 for discussion of sample representativeness limitations). This possibility brings up the importance of continuing to pursue developmental investigations by gathering data from larger and more representative groupings, as was a main strength of Jayaratne et al.'s 2009 study with adults (for a commentary on the lack of diversity in developmental research, see Rowley & Camacho, 2015).

Another possibility is that the difference reflects which characteristics were studied. In Jayaratne and colleagues' prior work, the characteristics that elicited the strongest negative relations between genes and other explanatory models were mathematical ability, sexual orientation, and violence, none of which were studied here. This suggests it is important to consider the content of the property being considered. In any case, the relations observed here suggest that people do not view these various causal factors as reducing to a simple zero-sum relation, as suggested by the nature-versus-nurture and free-will-versus-determinism debates noted at the beginning of the paper. Though these debates may provide conceptual frameworks for lay theories, it appears that people do not always subscribe to one side to the exclusion of the other.

In sum, our study provides a broad examination of how children apply genetic attributions to a variety of human characteristics. Findings demonstrate that children, even in the elementary years, are capable of appealing to genetic causes but are more restrained than adults in the properties to which they extend such explanations. Children, like adults, also accept that characteristics may arise from multiple causes. The sophistication shown in children's reasoning points to the potential for lay theories that move beyond simplistic genetic determinism. At the same time, in adults we saw a stronger preference for genetic explanations. There are many important questions to be answered about how and why genetic attributions grow in strength across age; establishing the answers to these questions provides an important goal for the future.

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(*Appendix follows*)

Appendix

Text of Instructions

Full Text of Genes, Environment, and Choice Instruction

Genes

This is a picture of a man and a woman, and they're going to have a baby [picture of a man and pregnant woman displayed]. When that baby is born, what kind of baby is it going to be? Will it be a human baby, or could it be something else, like a dog or a rabbit baby? . . . That's right, it's going to be a human baby. And that's because of genes. Genes are tiny things in our bodies. All humans have genes, and so do rabbits, and dogs, and all animals. Even plants have genes. Humans have human genes, rabbits have rabbit genes, dogs have dog genes, plants have plant genes, and so on. When a human baby starts out, before the baby is even born, the baby gets human genes from its mother and father. There are a lot of things that genes do. Some genes make your eyes and hair the color they are. Some genes make your skin the color it is. And since we get our genes from our parents, a lot of times we end up looking like members of our families. Look at this picture of a child coloring [picture of child coloring shown]. His name is Sam, and he's coloring with his right hand. Some kids draw with their left hands, and other kids draw with their right hands. And that can also come from genes–genes that this kid got from his parents make him color with his right hand. Now think about the mom and dad who are about to have a baby [picture of couple displayed again]. What are some things that their baby might have that come from genes?

Note: All children answered the two questions contained in this lesson correctly.

Environment

When we talk about environment here, we mean where you live and everything around you. So, the environment includes the people in your family, your friends, all the people at school, what you read in books, or see on TV or the computer. [Picture of Sam is shown again.] Remember Sam? Sam got his name from his parents, and he got the marker at school, and he learned to draw from his teacher and his friends. And all of that comes from the environment, because the environment is where you live and everything around you.

Choice

Sometimes people can just choose to be the way they are. People can make a choice to be one way or the other. See how Sam is coloring with a red marker? [Picture of Sam is shown again.] He made a choice to color with red instead of another color.

Received August 7, 2019
Revision received January 22, 2020
Accepted January 23, 2020 ■