Journal of Experimental Child Psychology 249 (2025) 106108

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

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

Is biology destiny? The coherence of children's beliefs about physical and psychological traits

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A R T I C L E I N F O

Article history:
Received 20 May 2024
Revised 23 September 2024
Available online 8 November 2024

Keywords:
Folk biology
Folk psychology
Biological determinism
Mindset
Essentialism
Genetic understanding

A B S T R A C T

In adults, biological causes are commonly associated with immutability. However, it remains unclear when during their development children coherently connect these ideas in relation to reasoning about physical and mental traits and whether children reason differently by domain. Understanding this is relevant to illuminating children's conceptions about the body versus the mind. Prior work has suggested that a more sophisticated differentiated understanding of psychological traits may begin to emerge around 8 years of age. In Study 1a, therefore, we examined U.S. third graders' reasoning about the inheritance and malleability of physical and mental traits and whether their ideas coherently covary within each domain. In Study 1b, we further investigated the robustness of this differentiated understanding by exploring whether participating in a curriculum that presented simplified information about physical traits affected thinking about mental traits. Results reveal that third graders display robust coherence in their reasoning about trait inheritance and malleability. Children consistently judged physical traits as more inherited and less malleable than mental traits, with children's ideas about inheritability and malleability showing consistent connections within each domain. Moreover, exposure to science teaching about physical traits did not alter children's perception that mental traits are less inherited and more malleable. By 8 years of age, children therefore clearly distinguish body from mind in theoretically coherent ways. Nevertheless, the covariance between beliefs about inheritability and immutability should provoke caution when talking to children about parent–child resemblances in capacities like

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https://doi.org/10.1016/j.jecp.2024.106108

intelligence lest some children infer that their abilities cannot be improved through effort.

Introduction

Is biology destiny? The idea that because a trait is biologically inheritable, it is also immutable—thus largely impermeable to environmental influence or intentional control—is enduring, lying at the core of adults' essentialist ideas about the malleability of an individual's identity and personality over development (Haslam et al., 2004) as well as debates about the limits of free will. Assumptions of this connection are also consequential for everyday reasoning and decision making. When adults attribute a behavior to biological causes, they perceive it as both more unalterable and more inevitable (Nettle et al., 2023). For example, when adults are told that a person's mental illness (e.g., schizophrenia, depression, anxiety) has a genetic source rather than an environmental or psychological source, they become more pessimistic about the individual's ability to improve over time (Bennett et al., 2008; Berent & Platt, 2021; Lam & Salkovskis, 2007). When adults think that intelligence is biologically based, they are more pessimistic about their chances of enhancing their own intelligence; that is, they become more prone to the demotivating downsides of adopting a fixed mindset (Thomas & Sarnecka, 2015).

However, although adults appear to readily associate ideas about the biological causation of human traits with beliefs about developmental immutability—sometimes with deleterious results—to date it is unclear whether these ideas coherently covary in young children's minds and, if they do, whether this association is generalized across a range of both bodily features (e.g., physical form) and mental features (e.g., personality, cognition) in the same way. That is, do children believe that inheriting a square jaw or big earlobes from their parents means having these physical features throughout their entire life? And similarly, do they also believe that inheriting poor math skills or shyness from their parents means retaining these mental features throughout their entire life? Whereas the first association is potentially beneficial for scaffolding some aspects of biological understanding, an indiscriminate conflation of intuitive biology and psychology in elementary school children's thinking about diverse non-physical or mental features is more problematic. This is because beliefs about the fixity of capacities like math ability that are, in fact, improvable by learning (even if they are genetically influenced) may increase risks of learned helplessness and, in turn, more negative academic and mental health outcomes in children (see Claro et al., 2016; Schleider & Weisz, 2016).

In the current two studies, we therefore systematically explored these questions in U.S. elementary school children. However, before laying out the specifics of these investigations, we briefly review what is known from prior research on children's intuitions about biological inheritance versus trait malleability over development. Given that our research specifically addressed children's beliefs about the inheritance and developmental stability of traits within families, we largely limit this literature overview to research on children's within-category intuitions (e.g., parent–child inheritability of earlobe size, shyness), excluding between-category studies on kind-based variables such as race and gender. We thus exclude consideration of a host of cross-category adoption studies from within the psychological essentialism literature that show that kindergarten children do not violate initial category boundaries when predicting the mature physical form of an offspring from one category that has been nurtured by members of another category. That is, by 4 or 5 years of age, children recognize that a baby cow raised by goats will not develop into a goat (see, e.g., Astuti et al., 2004; Gelman & Wellman, 1991; Hirschfeld & Gelman, 1994; see Solomon et al., 1996, for discussion of distinctions between individual- and category-based studies). Studies like these reveal consequential category-based reasoning competences; however, they do not answer questions focused on traits. For instance, they do not address whether children have internally consistent intuitions as to whether the child of friendly parents is likely to inherit the friendliness trait and, relatedly, is likely to mature into a friendly adult rather than a shy adult. These studies also do not answer whether children's judgments about psychological traits like friendliness might mimic the pattern of their intuitions about physical traits like round noses and pointed chins.

Research on trait malleability and trait inheritability

Little research directly probes whether there is a relationship between ideas about trait inheritability and malleability in early childhood. However, a key result—albeit confined to specific mental states (e.g., novel preferences)—is suggestive that a correlation may begin to emerge around 7 or 8 years of age. Gelman et al. (2007) followed up an adult study that found that U.S. college students' judgments of the inheritability and malleability of a diverse category of psychological characteristics (e.g., musical aptitude, shyness, personal preferences) are correlated. They examined younger students and initially found no correlation when considering the same wide-ranging category of psychological traits. However, when they used a different task and focused on a specific subset of psychological traits—novel personal preferences like hating bananas and loving guinea pigs—they observed connections between third graders' judgments about inheritability and malleability. Specifically, when it was stipulated that banana hating was inherited, children tended to infer immutability.

This result is suggestive about the developmental time frame in which a coherent association between these ideas emerges, but due to the very particular kind of state explored in children (i.e., novel preferences), it remains unclear whether this pattern of association generalizes to other mental or physical states or their inter-relations. Nevertheless, independent bodies of work tracing the emergence of adult-like intuitions about the modifiability of physical and mental states in one case (e.g., Kalish, 1997; Lockhart et al., 2002) compared with intuitions about inheritability of those states in the other case (e.g., Astuti et al., 2004; Bloch et al., 2001) certainly give additional reason to believe that domain-sensitive correlations between these ideas might only manifest in middle childhood. This is because these ideas appear to emerge on different developmental timetables; mature ideas about physical and mental trait inheritance seem to develop on a later schedule than those about trait malleability.

Turning first to research on children's intuitions about trait malleability, results suggest that from at least as early as kindergarten, children understand that not all kinds of traits are fixed. For instance, Lockhart et al. (2002) showed that by around 5 years of age, U.S. children already show a differentiated body–mind pattern, judging bodily traits (e.g., food allergies, height) as less malleable than psychological traits (e.g., being messy, being fearful). Further evidence of this mind–body differentiation is provided by children's judgments that physical trait and mental traits do not respond to the same interventions. Kalish (1997) found that by around kindergarten, children recognize that although desires can change emotional reactions (e.g., feeling sad), they are less likely to change physical reactions (e.g., experiencing physical illness). Finally, Inagaki and Hatano (1993) found that Japanese kindergarten-aged children can also demonstrate quite nuanced theoretical ideas about the casual dynamics of the mind versus the body, recognizing that certain physical traits (e.g., eye color) are more fixed than others (e.g., body weight) while also distinguishing that physical mechanisms (e.g., physical practice) are more likely to change modifiable bodily characteristics, whereas psychological mechanisms (e.g., cognitive effort) are more likely to change modifiable mental characteristics (see also Kinlaw & Kurtz-Costes, 2003; Miller & Bartsch, 1997; Solomon et al., 1996).

As noted, in contrast to this relatively early competence in reasoning about trait malleability, an understanding of the genetic inheritance of traits appears to develop later. U.S. preschool- and kindergarten-aged children exhibit little of the nuanced "differentiated" mind–body recognition displayed, across cultures, by adults on within-category adoption tasks (Astuti et al., 2004; Bloch et al., 2001). To demonstrate the mature differentiated pattern, children should recognize that an offspring that is adopted out from birth is more likely to resemble its unknown birth parents in bodily traits like eye color but to resemble its adoptive parents in mental traits like beliefs, skills, and behavioral preferences. Instead, consistent with an apparently more limited recognition of genetic inheritance, young children often exhibit either a learning bias or a birth bias, concluding that an offspring will consistently resemble either its adoptive parents or its biological parents in both physical and mental traits (e.g., Combette et al., 2024; Ergazaki et al., 2014; Solomon et al., 1996). One specific methodological variant of an adoption task—one in which *two* babies are switched at birth (Hirschfeld, 1995)—has suggested some fragile capacity to differentiate trait types, but the results have been inconsistent. For instance, Springer (1996) found that preschoolers showed nuanced competence on the switched-at-birth task, but this same understanding did not generalize to reveal itself on even a simplified version of the standard adoption task. Similarly, Heyman and Gelman (2000) found some recognition of the inheritability of physical over mental traits in kindergartners on a switched-at-birth-task but it was not robust: There were order effects such that the competence was observable only when children were asked about physical traits first, with kindergartners' judgments about mental traits often at chance. Young children therefore do not reliably display mind–body differentiation in their reasoning about inheritance. Furthermore, they also display other misconceptions that reflect conflations of biological and non-biological causation. For example, they will judge that a mother can choose which physical traits her daughter will have (Weissman & Kalish, 1999) or that animal offspring will inherit traits only from a same-sex parent (Menendez et al., 2024) or only if the traits are functionally beneficial without consideration for whether the traits were inborn or acquired (Springer & Keil, 1989).

Taken together, then, the pattern of findings supports a conclusion that in early development Western children do not have clearly biological intuitions about inheritance. Indeed, it is not typically until middle childhood that, across cultures (e.g., United States, Peru, Fiji), children have been found to display more adult-like differentiated inheritance judgments on adoption tasks and related methods (Heyman & Gelman, 2000; Meyer et al., 2020; Moya et al., 2015; Solomon et al., 1996; but see Astuti et al., 2004, and Bloch et al., 2001, for later development in other cultural groups). Furthermore, it remains an open question how any differentiated inheritance beliefs might relate to immutability beliefs in middle childhood or for what kind or range of traits given that prior research has focused almost exclusively on mental traits and found suggestive associations only for novel preferences.

The current research

In this research, we therefore focused on both physical and mental traits to explore whether, by around 8 years of age, children not only show consistent patterns of association but those that differentiate between body and mind. That is, presuming a replication of prior findings that, by the middle of elementary school, U.S. children intuitively believe that babies are more likely to inherit birth parents' physical traits rather than non-physical traits, do they also believe that physical traits are more likely to remain stable throughout life, whereas non-physical traits are more changeable? Answering this question is relevant not only to understanding the coherence and nuanced distinctions underlying elementary school children's theoretical understandings of the bodily and mental domains but also to informing the design of biology teaching—instruction that intensifies in the U.S. middle elementary school grades around 8 years of age and may inadvertently promote potentially harmful enduring misconceptions that mental traits (e.g., cognitive skills) are immutable simply by virtue of teaching about the inheritability of physical traits.

In Study 1a, we therefore first investigated whether 8-year-olds show a differentiated pattern across two dimensions: inherited parent–offspring resemblance and immutability in relation to physical and mental traits. We examined whether U.S. third graders consistently respond that a baby is more likely to resemble its parents in physical than mental traits and more likely to display immutability in physical traits than in mental traits. We also explored whether children's judgments that either physical or mental traits are inheritable coherently predict their judgments that those traits are also not malleable. Finally, we investigated whether children draw distinctions in their judgments about various kinds of mental traits (see also Gelman et al., 2007; Inagaki & Hatano, 1993). Because it is potentially more deleterious for children to view cognitive traits (e.g., math aptitude) as more inheritable and/or fixed than personality traits (e.g., shyness), we were particularly interested in this contrast. Relatedly, we also wanted to see whether children who make third-party judgments that specific cognitive traits are heritable make more global, theoretically consistent psychological judgments, for example, by endorsing the fixed mindset belief that they (and others) cannot change their intelligence. In addition to illuminating elementary school children's basic theoretical intuitions, Study 1a also served as a baseline to Study 1b, in which we explored the impact of elementary school teaching of simplified facts about the inheritability and immutability of bodily traits. Our focus in this second study was on the fragility of any distinctions that Western elementary school children draw between causality in the biological and psychological domains and therefore the ease with which simplified biology teaching about physical traits might disrupt them. To explore these questions, in both studies we used an approach that differed from most prior child research that has generally used scenarios or stipulated information: Instead, we looked for the presence of coherent predictive associations across several independent tasks involving multiple physical and mental traits including intelligence mindset.

Study 1a

Measures and analyses were preregistered on the Open Science Framework before conducting analyses (https://osf.io/sq8av/?view_only=d7f4012f6fce44dca6fe035565fdb98d). Materials and analytic code for this study are available by e-mailing the corresponding author.

Method

Participants

Participants were 399 third-grade students (ages 8 and 9-years) attending one of eight Massachusetts public elementary schools in the northeastern United States. This age range was targeted because in their study of psychological characteristics, Gelman et al. (2007) found that U.S. children show coherence in their beliefs about novel preferences (e.g., banana lover) around this point. It is also around this age that children robustly exhibit a differentiated understanding of biological inheritance (e.g., Solomon et al., 1996). The eight schools were in three different public school districts. The first district drew students from a medium-income urban neighborhood with a median household income of $108,896, 34.4% of adults holding a bachelor's degree, 18.7% of individuals below the poverty line, and 20.4% of students' families relying on food stamps (https://nces.ed.gov/Programs/Edge/ACSDashboard/2510890). The other two school districts drew students from higher-income suburban neighborhoods with similar characteristics. Median household incomes were from $154,300 to $164,607, with approximately 86% of adults possessing a bachelor's degree, a mean of 1.7% of families below the poverty line, and 2.15% of students' families using food stamps. The urban school district had the following racial/ethnic breakdown: White (39.2%), Hispanic (40.9%), Black (9.2%), and Asian (5.7%) students. The first suburban district was: White (57.5%), Asian (20.2%), Hispanic (9.4%), Black (4.7%) and Other (8.2%) students. The second suburban district was almost exclusively White (87.8%) with Hispanic (3.8%), Asian (2.9%), Black (1.9%), and Other (3.6%) students (see https://profiles.doe.mass.edu).

The study was conducted as part of a project exploring third-grade students' biological understanding and learning (see https://www.evolvingmindsproject.org) in the context of U.S. science education standards that target this elementary school grade for more concentrated life science instruction (NGSS Lead States, 2013). In accordance with institutional review board approvals for this research, no personally identifiable student data were collected at schools, including information about individual names, age in months, gender, socioeconomic background, and adoption status. Of the 399 participants, only those who provided responses to a sufficient number of questions were included in analyses (see Appendix A for detailed inclusion/exclusion criteria). Exclusions resulted in a final sample of 376 participants for analyses of children's judgments about inheritance and malleability and 371 participants for related questions about fixed mindset.

Materials

Children in third-grade classrooms completed a pencil-and-paper questionnaire booklet of three measures. These assessed their intuitions about physical and mental trait inheritability, physical and mental trait stability, and more global but personal endorsements of fixed mindset beliefs.

Trait inheritability judgments. Children were asked questions about six traits: two physical traits (square chin and big earlobes), two cognitive traits (intelligence and mathematical aptitude), and two personality traits (shyness and friendliness). We selected these traits because they are easily understandable for children and are less likely to be perceived as either entirely unchangeable (e.g., eye color, freckles) or inevitably changing over time (e.g., hair length, height), thereby allowing for a degree of variability.

For each trait, participants rated their agreement with a statement about the likelihood that the baby would inherit the characteristic from their parents (e.g., "Parents who are shy [have big earlobes] are more likely to have a baby who is shy [has big earlobes]" on a 4-point Likert scale ranging from 1 (*really not true*) to 4 (*really true*).

Trait malleability judgments. Participants were asked to assess whether the same six traits employed in the inheritability questionnaire were malleable enough to change over an individual's development (e.g., "A shy child can become an adult who is not shy"; "A child who is not good at math can become an adult who is good at math"). Participants were asked to rate their agreement on a 4-point Likert scale from 1 (*really not true*) to 4 (*really true*). To avoid response sets, trait malleability judgment questions were interspersed with trait inheritability judgment questions.

Assessment of intelligence mindset. Because we were interested in how abstract judgments about others' cognitive traits might be related to children's broader conceptions of their own and others' cognitive capacities, we also measured students' intelligence mindset using a modified version of Dweck's (1999, 2013) 3-item fixed mindset questionnaire. In Dweck's original phrasing, the questions used somewhat personal language that could target children's beliefs about themselves as well as others. We used this phrasing; however, in our adaptation we replaced Dweck's term "intelligent" with "smart" and took the precaution of providing a clear definition of what "smart" entails. Specifically, we defined "smart kids" as "kids who do well at their schoolwork." By providing this definition, we aimed to establish a common framework for all participants and minimize potential variations in interpretation (Combette & Kelemen, 2023). Children therefore rated their agreement with statements about the modifiability of intelligence such as "How smart you are is something you can't change very much" and "If you are smart, you will stay smart even if you don't work at all." Participants indicated their responses on the 4-point Likert scale ranging from 1 (*really not true*) to 4 (*really true*), with higher ratings consistent with fixed mindset beliefs and lower ratings consistent with growth mindset beliefs.

Results

Do third graders show a differentiated pattern in their trait inheritability judgments?

Results from a linear regression revealed the existence of a differentiated pattern for physical versus mental traits in children's judgments of the resemblance between birth parents and their offspring. Physical traits were perceived as more inheritable than either kind of mental trait (personality traits: β = 0.39, p < 2e-16; cognitive traits: β = 0.65, p < 2e-16). Within mental traits, a significant difference was also observed, with children regarding personality traits as more inheritable than cognitive traits (β = 0.27, p = 3.1e-10). One-sample t tests against chance (chance = 2.5 Likert scale midpoint), revealed that all judgments of inheritability were below chance (personality traits: M = 2.04, t = − 15.31, p = 2.4e-41, d = − 0.80; cognitive traits: M = 1.77, t = − 24.60, p = 1.02e-79, d = − 1.28; physical traits: M = 2.43, t = − 2.14, p = .03, d = − 0.12). See Fig. 1A.

Do third graders show a differentiated pattern in their trait malleability judgments?

Patterns in children's malleability judgments were similar to patterns in their resemblance judgments. Results from a linear regression revealed that children perceived physical traits as less malleable than both mental traits (personality traits: β = − 0.74, p < 2e-16; cognitive traits: β = − 0.87, p < 2e-16). Within mental traits, personality traits were seen as less malleable than cognitive traits (β = − 0.13, p = 1.64e-03). Only responses for personality traits (M = 3.22, t = 27.26, p < 2e-16, d = 1.42) and cognitive traits (M = 3.35, t = 28.35, p < 2e-16, d = 1.48) were significantly

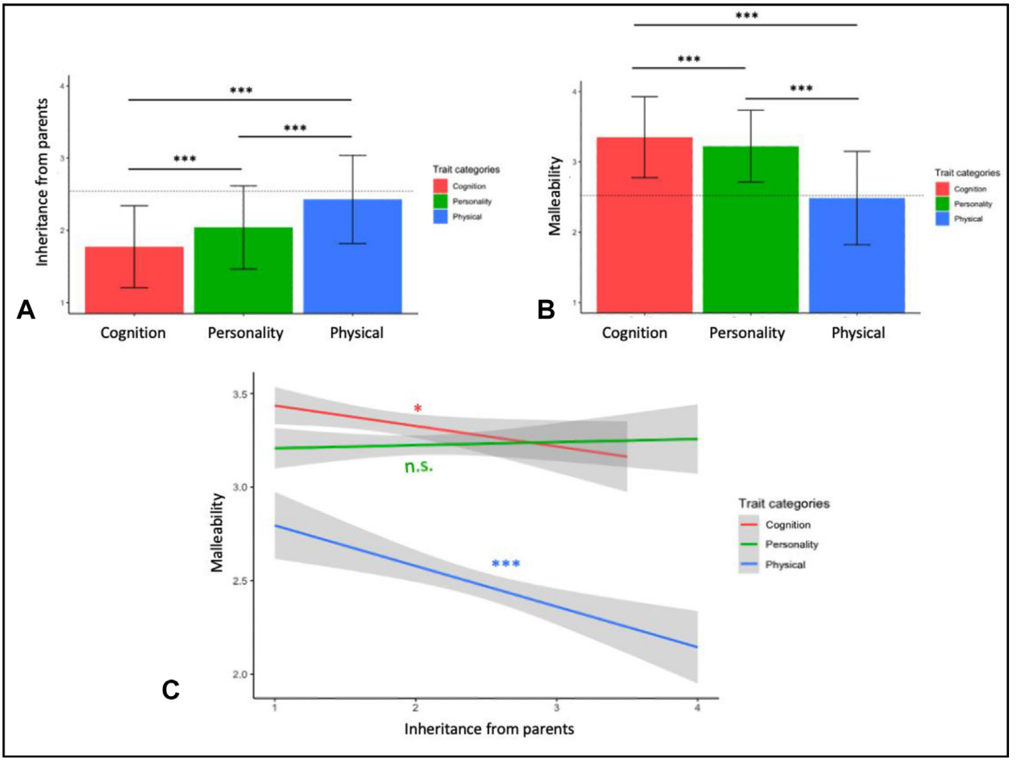

Fig. 1. (A,B) Third graders judged physical traits as more inherited from parents (A) and less malleable (B) than mental traits. Colored bars represent mean responses for each trait category, and error bars represent standard deviations. (C) The more third graders thought physical and cognitive traits were inherited from parents, the less they thought these traits could change. Colored traits represent the regression of inheritability judgments on malleability responses, and the gray areas around the lines represent the 95% confidence Intervals. n.s., nonsignificant; $^{*}p < .05$; $^{***}p < .001$. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.).

above chance, demonstrating that participants were clear that these traits could change. By contrast, responses for physical traits did not significantly differ from chance ($M = 2.48$, $t = -0.41$, $p = .68$, $d = -0.02$). See Fig. 1B.

Do judgments of trait inheritability predict judgments of reduced trait malleability?

Results from a linear regression revealed that the more children thought a trait was inherited, the less they thought this trait was likely to change ($\beta = -0.32$, $p <$ 2e-16). This association was true for physical traits ($\beta = -0.35$, $p <$ 2e-16) and cognitive traits ($\beta = -0.11$, $p = .04$), but not for personality traits ($\beta = 0.02$, $p = .72$). See Fig. 1C and correlation tables in Appendix C.

Do judgments about cognitive trait inheritability predict fixed mindset beliefs?

A linear regression revealed that the more children thought that cognitive traits were inheritable, the more they adopted a fixed mindset ($\beta = 0.11$, $p = .03$). This relationship was specific to mental traits, with similar results found for judgments of the inheritance of personality traits ($\beta = 0.11$, $p = .03$) but not for physical traits ($\beta = -0.006$, $p = .90$).

Discussion

Findings from Study 1a show that third graders possess highly differentiated intuitions about the inheritance and malleability of physical and mental traits. Compared with mental traits, children were more inclined to believe that physical traits are likely to be inherited from parents and remain stable over development. Children's intuitions about mental traits were also nuanced. Within the mental trait category, cognitive traits like math ability were seen as less likely to be inherited from parents than personality traits and also more malleable—which is positive news for educators. In general, therefore, these results indicate that by third grade U.S. children have already acquired an understanding that various traits can follow distinct developmental patterns and they subtly distinguish between trait types within the broad category of mental traits. These results indicate that judgment patterns similar to those found in U.S. adolescents are therefore already present by the middle-elementary school years (e.g., Coley et al., 2017; Xu & Coley, 2022).

In addition, this initial study revealed—for the first time to our knowledge—that, across a range of bodily and mental characteristics, elementary school children show a coherent pattern of association between their beliefs that a trait is inherited and beliefs that it will remain stable. This association held true for physical traits and cognitive traits, with inheritability judgments about cognitive traits also predicting fixed mindset beliefs, although interestingly it was not found in personality traits. Although the reason behind the lack of covariance with personality traits requires further exploration, the absence may elucidate why Gelman et al.'s (2007) study did not reveal a significant association between inheritability/innateness and malleability in the authors' broad category of psychological characteristics, which encompassed a diversity of skills and personality traits. This result underscores the importance of distinguishing not only between physical and non-physical traits but also between different mental traits given that children's beliefs about cognitive and personality traits differ.

In light of these results, questions arise, however, about the resilience of third graders' differentiated beliefs. Previous studies give reasons for suspecting that they might not be robust. For example, introducing simplistic information about genetic inheritance has been shown to evoke genetic essentialist beliefs about various traits—that is, the perception that these categories are genetically caused (Meyer et al., 2020; see also Donovan, 2014, 2016, and Donovan et al., 2019, 2021, for studies with adolescents). In addition, work on inheritability judgments has found that prompting second graders to think about resemblances between parents and children in physical traits primes them to view all traits, including psychological traits, as more inherited (Heyman & Gelman, 2000). Such findings therefore underscore a potential need for caution when teaching about physical traits to elementary school students. This issue is particularly relevant in a context where, at least in the United States, science education standards are increasingly placing teaching of more complex biological concepts in earlier grades (e.g., Achieve, 2014). Such moves are in line with suggestions from developmental research that early to middle elementary school might be the most opportune time to introduce students to more comprehensive explanations of certain biological processes (e.g., genetic inheritance, natural selection) to avoid the entrenchment of early emerging scientific misconceptions (e.g., Combette et al., 2024; Kelemen, 2019; see also Donovan & Haeusler, 2015; Samarapungavan et al., 2017). However, if third graders' differentiated beliefs remain fragile, introducing mechanistic teaching about the biological origin and nature of physical traits might inadvertently foster mistaken overgeneralizations to mental traits. For instance, it might motivate children to believe that mental traits are biologically determined and not malleable. This question was explored in Study 1b in the context of a curriculum about evolution by natural selection. To help students grasp and generalize an accurate understanding of species evolution, this curriculum emphasizes the predictable inheritance and immutability of physical traits. However, does teaching simplified facts about physical trait inheritance and immutability risk inadvertent harm even if it is in the service of promoting broader mechanistic understanding? In other words, does it lead children to make inaccurate generalizations from physical to mental traits, disrupting nascent and potentially fragile intuitions that cognitive and personality traits are relatively malleable?

Study 1b

Method

Participants

Study 1a third-grade participants took part in Study 1b. Their data was tracked over time via anonymized student identity codes.

Materials

The same questionnaire used in Study 1a was employed to assess participants' beliefs after their participation in the curriculum. This data collection occurred approximately 3 months after Study 1a.

Intervention. Children participated in either a shorter version (7 lessons) or a longer version (12 lessons) of a novel investigative curriculum—Evolving Minds—that seeks to teach third graders the basic principles of evolution by natural selection (Kelemen et al., 2023; Puttick et al., 2024). In each case, lessons were 45 min long and led by their regular elementary classroom teachers who had participated in workshops that familiarized them with the lesson plans and common misconceptions about evolution. On average, teachers conducted two sessions per week, leading to a life science curriculum that spanned 1 to 2 months.

To convey the counterintuitive explanatory material and scaffold generalization, lessons incorporated a diverse range of activities focused on non-human animals and plants, including storybook readings, hands-on activities, group discussions, and student notebooks. For example, in initial lessons, students participated in investigative activities (e.g., observations, graphing) in which they considered environmental changes and the evidence of intra-species trait variability in real-world biological populations. Subsequently, they engaged in prediction, explanation, and refutation activities in relation to storybook narratives and graphic depictions of how animal and plant populations evolve as a result of environmental selection pressures. Through these activities, students built a model of the key steps of evolution by natural selection with emphasis on the differential reproductive success over time of population members who happened to have inheritable environmentally beneficial traits. The central difference between the shorter and longer versions of the curriculum—one that is not highly relevant to the current study—is that in the longer version students also applied this model to considerations of fossils and between-species changes (speciation). For more details about the curriculum, see https://www.evolvingmindsproject.org.

The primary aim of these lessons was to scaffold children's recognition that species are not static entities and their understanding that evolutionary change does not occur because individuals modify within their own lifespans but rather is due to a population variation-based mechanism that unfolds over generations. Put simply, species do not change because all the individual members flexibly develop beneficial inheritable traits when they need them (e.g., giraffes developing long necks to reach more leaves) (Kelemen, 2012) or because they only ever inherit functionally beneficial traits (Springer & Keil, 1989). Instead, species change because individuals who happen to be born with environmentally advantageous physical traits are more likely to survive and reproduce. To comprehend this counterintuitive concept—one prone to robust misconceptions from early in development (e.g., Kelemen, 2012, 2019; Springer & Keil, 1989)—children need to understand that babies tend to inherit their parents' physical trait variants irrespective of whether the trait is functionally beneficial or not. Children also need to understand that the trait variant that they inherit will remain stable throughout their entire life even if it is environmentally disadvantageous. For this reason, as part of conveying the broader explanation of evolution by natural selection, Evolving Minds curriculum activities recurrently expose children to certain simplified ideas about physical traits in plants and animals. These are that offspring tend to physically resemble their parents and that the general form of a physical trait that is present from birth (e.g., a long skinny trunk) is not malleable over the course of development. Importantly, teaching these heuristic facts as constituents of the larger evolutionary explanation is not redundant given common early developing misconceptions. Prior research—consistent with Study 1a results where intuitions were at chance levels—indicates that 8-year-old children do not reliably assume that offspring will inherit the hereditary physical traits of their biological parents (see also Brown et al., 2020; Emmons et al, 2018; Ronfard et al., 2021).

Results

In relation to our variables of interest, preliminary analyses indicated no significant differences between children participating in the longer and shorter versions of the curriculum (see Appendix C). For simplicity of presentation, results are therefore collapsed across the two groups.

Does the intervention disrupt differentiated patterns in trait inheritability judgments?

As was found before the intervention, linear regression revealed the existence of a differentiated pattern for physical versus mental traits in children's judgments of the resemblance between birth parents and their offspring. Physical traits were still perceived as more inheritable than either kind of mental trait (personality traits: β = 0.44, p < 2e-16; cognitive traits: β = 0.66, p < 2e-16). Within mental traits, personality traits were again seen as more inheritable than cognitive traits (β = 0.20, p = 7.57e-05). Results from linear mixed models indicated that traits were more likely to be perceived as inheritable after the curriculum (physical traits: β = 0.40, p < 2e-16; personality traits: β = 0.34, p < 2e-16; cognitive traits: β = 0.40, p < 2e-16). Nevertheless, one-sample t tests against chance

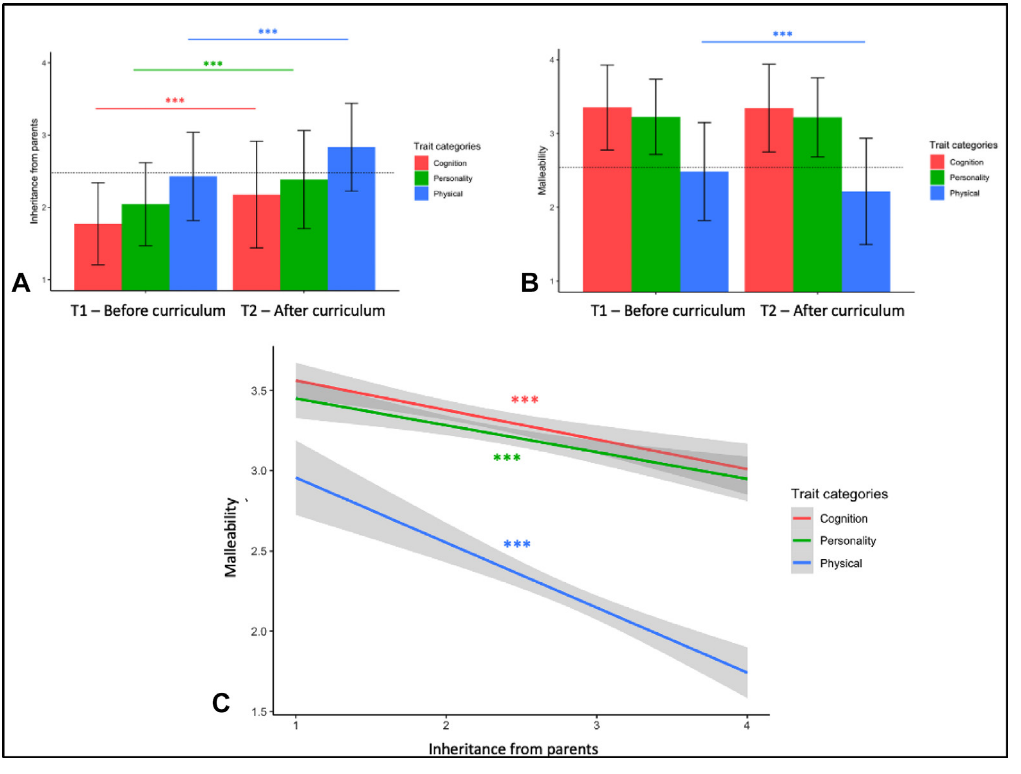

Fig. 2. (A) Participating in the curriculum significantly increased third graders' beliefs that offspring resemble their parents for all kinds of traits but only shifted judgments about physical traits to above chance levels. (B) Participation only affected third graders' judgments about reduced malleability of physical traits. Colored bars represent mean responses for each trait category, and error bars represent standard deviations. (C) After the curriculum, the more third graders thought physical and mental traits were inherited from parents, the less they thought these traits could change. Colored traits represent the regression of innate responses on malleability responses, and the gray areas around the lines represents the 95% confidence intervals. T1, Time 1; T2, Time 2. ***p < .001. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.).

(chance = 2.5) confirmed that even with this overall increase, the effect of the intervention was actually quite targeted; Inheritability judgments about physical traits were the only ones to shift above chance (M = 2.83, t = 10.03, p < 2e-16, d = 0.55), whereas judgments about mental traits remained below chance (personality traits: M = 2.38, t = − 3.29, p = .001, d = − 0.17; cognitive traits: M = 2.18, t = − 8.43, p = 8.10e-16, d = − 0.44). See Fig. 2A.

Does the intervention disrupt differentiated patterns in trait malleability judgments?

As was the case before the curriculum, children showed a differentiated pattern. Linear regression revealed that physical traits were still perceived as less malleable than mental traits (personality traits: β = − 1.00, p < 2e-16; cognitive traits: β = − 1.12, p < 2e-16). Within mental traits, a significant difference was also observed, with personality traits being seen as less malleable than cognitive traits (β = − 0.13, p = .00247). Results from linear mixed models indicated that, relative to before the intervention, physical traits were less likely to be judged as malleable (β = − 0.27, p = 7.04e-10). However, no impact of the curriculum was found on the perceived malleability of personality traits (β = − 0.01, p = .78) and cognitive traits (β = − 0.01, p = .82).

The targeted effect of the curriculum was also confirmed by one-sample t tests against chance (chance = 2.5). Children's judgments about the malleability of mental traits was preserved at above chance levels (personality traits: M = 3.21, t = 25.72, p < 2e-16, d = 1.34; cognitive traits: M = 3.34, t = 27.26, p < 2e-16, d = 1.42), whereas perceptions of physical trait malleability shifted below chance (M = 2.21, t = − 7.26, p = 2.63e-12, d = − 0.40). See Fig. 2B.

Does the intervention disrupt associations between judgments of inheritability and reduced malleability?

As was the case before the curriculum, the more participants thought that babies' physical traits (β = − 0.40, p = 1.42e-10) and cognitive traits (β = − 0.18, p = 9.63e-06) were similar to those of parents, the less they perceived these traits as malleable. Interestingly, after participation in the curriculum, this pattern of coherent association also became true for personality traits (β = − 0.17, p = 4.19e-05). See Fig. 2C and Appendix C for the correlation table.

Does the intervention increase fixed mindset?

Results from linear mixed models showed that participants were less likely to hold a fixed mindset after their participation in the curriculum than before their participation (β = − 0.11, p = 4.48e-04). Results from a linear regression revealed results similar to those of Study 1a; the more children thought that cognitive traits were inheritable, the more they adopted a fixed mindset (β = 0.09, p = .02). This relationship was specific and coherent; fixed mindset was not predicted by the belief that personality traits are inheritable (β = 0.07, p = .08) or that physical traits are inheritable (β = − 0.02, p = .72).

Discussion

Findings from Study 1b underscore the robustness of third graders' nuanced intuitions concerning the inheritance and malleability of physical and mental traits. These ideas appear sufficiently developed to resist children's potential inclinations to over-generalize simplified information about physical traits taught in an early science curriculum to mental traits.

In line with pre-curriculum findings, children maintained the belief that physical traits are more likely to be inherited from parents and remain stable throughout development than mental traits. Within the mental trait category, cognitive attributes such as math ability were also perceived as less likely to be inherited from parents and more malleable than personality traits.

Notably, the curriculum seemed to reinforce beliefs about the inheritability and immutability of physical traits without substantially altering beliefs about mental traits. Students' responses regarding the inheritability of physical traits shifted to above chance, whereas mental traits remained below chance. A parallel pattern emerged in perceptions of malleability, with mental traits remaining above chance levels and physical traits falling below chance levels. This outcome suggests that, in support of cultivating children's construction of foundational explanatory frameworks like evolution by natural selection (Dobzhansky, 1973), early biology teaching can effectively emphasize the hereditary and stable nature of physical traits without collateral damage. Such teaching does not change elementary school children's differentiated intuitions that mental traits are primarily influenced by non-genetic factors and remain subject to developmental malleability.

Study 1b also replicated the Study 1a finding that children's judgments of the inheritability of cognitive abilities predicts their adherence to fixed mindset beliefs. This finding is helpful in confirming that inheritability beliefs are therefore a specific and relevant target to address in interventions when training teachers to interact with students in a way that does not foster a fixed mindset (Combette et al., 2023). The Study 1b results were also interesting and reassuring: On average, children exhibited a lower level of fixed mindset belief after the evolution intervention compared with before it. It remains for future work to understand the mechanisms by which such teaching affects mindset beliefs, for example, whether it is due to some of the specific content of early evolution instruction or children's experience in actively engaging with scientific inquiry and the cognitively demanding task of revising preconceived ideas that involves substantial executive function challenges (Ronfard et al., 2021).

Taken together, these results confirm that U.S. 8-year-olds have a robustly coherent and differentiated theoretical understanding of the body and the mind. Engagement with simplified biological instruction about body parts does not substantially affect their beliefs about mental traits (e.g., math aptitude) that are perceived as significantly under environmental or intentional influence rather than under genetic control and, by association, also malleable.

General discussion

The current studies explored U.S 8- and 9-year-olds' understandings of trait inheritability and developmental malleability and whether they are coherently and robustly related to each other in the manner observed in adults (e.g., Bennett et al., 2008; Berent & Platt, 2021; Lam & Salkovskis, 2007; Nettle et al., 2023). Study 1a revealed that third graders distinguish between physical and mental traits when considering not only parent–offspring resemblances but also trait malleability over the lifespan. Specifically, children demonstrated an understanding that human physical traits are more likely than non-physical traits to resemble those of their birth parents and are less likely to change over development. This finding is noteworthy because it echoes outcomes from adoption tasks (Moya et al., 2015; Solomon et al., 1996) but clarifies that children also demonstrate this understanding on a novel task that directly targets more specific beliefs. This is relevant given previous critiques of adoption task methods that argue that it is not possible to distinguish whether children's answers on such tasks exclusively tap their reasoning about inheritability or inadvertently tap malleability judgments too (e.g., Springer, 1996). By contrast, the targeted and direct approach of Study 1a allowed for discrimination between different aspects of children's reasoning, shedding light on the differentiated intuitive theories of third graders about physical and psychological characteristics.

Study 1a also revealed that by the middle elementary school years, in addition to distinguishing between physical and non-physical traits, children make subtle distinctions between subtypes of mental traits like cognitive traits and personality. This parallels prior findings with adolescents on an adoption task (Coley et al., 2017; Xu & Coley, 2022), albeit with an interesting difference; whereas 8- and 9-year-olds see personality traits as more inheritable and less malleable than cognitive traits, adolescents show the reverse pattern. They tend to view cognitive traits as more genetically caused than younger children, who generally revealed themselves to be empiricists (see also Wang & Feigenson, 2019). Of course, making direct comparisons between findings from quite different methods should be done cautiously. Nevertheless, one possible explanation for this apparent developmental shift in reasoning about cognitive traits derives from older students' classroom experiences. Prolonged exposure to a select cohort of visibly high-performing classmates (e.g., select groups of classroom hand-raisers) may, by adolescence, support inferences that their performance derives from distinctive intrinsic or innate cognitive aptitudes rather than possible external forces (e.g., unequal access to knowledge about educational norms). Consistent with this suggestion, the literature on the inherence bias points to classroom observations as influencing older students' endorsements of fixed mindset beliefs (Goudeau & Cimpian, 2021).

Also relevant to work on fixed mindset is the Study 1a finding that there are not only coherent covariances between judgments of the inheritability and immutability of mental (and physical) traits but also logically consistent, and very specific, associations between children's judgments of the inheritability of cognitive abilities and their tendency to believe that their own and others' intelligence cannot change, in other words, their tendency to hold fixed mindset beliefs. Although similar findings have been documented in adults (Thomas & Sarnecka, 2015), this association had not been revealed in children until now.

In addition to documenting 8- and 9-year-olds' basic intuitions about physical and mental traits in Study 1a, we also tested in Study 1b whether children's theoretical differentiations display robustness when confronted by early science instruction involving somewhat simplified facts about the inheritability and immutability of physical traits. Of interest was whether children's beliefs about mental traits are sufficiently fragile that exposure to these facts—as part of broader teaching about the complex topic of evolution by natural selection—would prompt children to over-generalize and shift toward believing in the immutability of personality and cognitive traits. The question is important because such immutability beliefs have previously been linked with negative mental health and academic outcomes. For instance, students who conceive of their intelligence as fixed tend to achieve lower grades (Blackwell et al., 2007). Similarly, students who conceive of personality as fixed appear at heightened risk of experiencing poorer health, heightened stress, and lower academic performance (Yeager et al., 2014). Study 1b results revealed, however, that students' differentiated understanding is robust and remains intact despite exposure to simplified biological information. Although participation in the early evolution curriculum heightened children's sense that offspring will inherit their parents' traits, on average children still tended to view mental traits as more environmentally or intentionally caused. Furthermore, children's sense that mental traits like shyness and math aptitude are malleable over development remained unchanged. Instead, consistent with the pre-curriculum findings in Study 1a, physical traits were seen as more inheritable and less malleable than mental traits. Finally, the coherent predictive covariance between the belief that if a baby inherits a trait from its birth parents, it will show stability in that trait over development, remained intact.

Finally, one further result is worth noting. In the same way that the early life science instruction did not change children's sense that mental traits are malleable, it also did not promote a fixed mindset. In fact, unexpectedly, it actively did the reverse. At the current time, the reason why the Evolving Minds curriculum promoted an increase in the belief that intelligence is changeable—thus a growth mindset—is unclear, especially given that the topic of mindset was not referenced in these lessons or in any of these classrooms at the time, to our knowledge. Several candidate explanations therefore seem viable. Primary among these is the fact that a key objective of the early evolution curriculum was to reduce essentialist ideas about the fixedness of natural animal and plant categories. It is possible that challenging notions that species have a fixed unchangeable essence scaffolded children's sense that characteristics like intelligence are changeable too. Alternatively, simply engaging with the demanding task of reflecting on and revising children's preconceptions about why contemporary animal and plant species appear as they do may have given children a feeling of self-efficacy. This enhanced sense that they could effortfully modify their beliefs in the context of science learning may have enhanced their recognition that their cognitive abilities are changeable too.

Conclusion

Converging with work on folk dualism that suggests children intuitively distinguish the body versus the mind (e.g., Bering & Bjorklund, 2004; Kelemen et al., 2021), the current findings underscore the presence of a coherent differentiated theoretical understanding of physical and mental traits from at least third grade. Children recognize that inherited biology exerts a differentiated influence on physical and non-physical traits. Crucially, this comprehension appears robust, preventing students from over-generalizing simplified biological information to all types of traits and from adopting a fixed mindset that could hinder their academic progress. Although this information offers reassurance to educators advocating for the implementation of early mechanistic life science curricula, findings that inheritability beliefs consistently predict malleability beliefs also provoke a cautionary note. Tendencies to talk flippantly about mental traits as though they are inherited or innate may evoke immutability beliefs and the inference that biology is destiny. This should prompt adults to exercise caution in how they communicate to children about mental abilities.

These findings also raise several new research questions that warrant exploration in future studies. For example, it would be interesting to test whether children's responses to the malleability questionnaire would remain consistent if the change were in the opposite direction (e.g., a child who is friendly/smart becoming an adult who is not) and whether such an undesirable change would still be perceived as more likely than physical changes.

In addition, it still remains unclear why teaching about parent–offspring physical trait resemblance and constancy in Study 1b increased ideas that offspring will share their parents' mental traits but did not increase the belief that they are unchangeable over development. One plausible explanation might be that, for third graders, parent–offspring resemblance encompasses not only genetic transmission but also environmental factors. This would be coherent with previous studies showing that participants, including children, usually accept more than one explanation for the development of physical and mental traits (e.g., Kinlaw & Kurtz-Costes, 2003; Meyer et al., 2020). Further investigation into the exact factors that third graders associate with the development of mental traits—and which ones trigger associations with trait stability—therefore could shed light on their developing theories about psychological trait development. Lastly, one hypothesis is that fixed mindset decreased after the life science curriculum because curriculum engagement decreased biological essentialism and, in turn, psychosocial essentialism. However, it would be worthwhile to examine this directly. Does decreasing essentialism about natural categories affect psychosocial essentialism and, consequently, fixed mindset regarding mental traits? We encourage future studies to address these pivotal questions, not only because of their importance for understanding the consequences of scientific learning but also to illuminate the development of social prejudices in children.

CRediT authorship contribution statement

Léa Tân Combette: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Deborah Kelemen:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Funding acquisition, Conceptualization.

Data availability

Data will be made available on request.

Acknowledgments

Thanks go to the children, teachers, and science coordinators of all participating schools. This research was supported by a National Science Foundation grant (DRL-2009176) to Deb Kelemen.

Appendix A. Inclusion and exclusion criteria

Only participants who completed questions at both Time 1 (T1, before curriculum) and Time 2 (T2, after curriculum) were included in our analyses. This resulted in the exclusion of 11 students from the longer curriculum group and 12 from the shorter curriculum group. Participants who had missing data for a specific trait category were only included in analyses for which they did not have missing data. To mitigate attrition, when only one answer was missing within a trait category, scores were computed using responses from other traits within that category. For example, if a student did not respond to the malleability question for "shy" but had no other missing values for "personality," the student's malleability score for personality was determined based on his or her response to the other trait within that category (i.e., "friendly"). (see Table A1).

Table A1
Participants' exclusion and inclusion.

Resemblance and malleability	INCLUDED Complete data	INCLUDED Only one missing answer in one category	INCLUDED Missing at least one category	EXCLUDED No data at T1 and/or T2	TOTAL
Long curriculum	120	20	20	11	171
Short curriculum	184	5	27	12	228
Mindset	INCLUDED Complete dataset	INCLUDED Missing one mindset answer		EXCLUDED No data at T1 and/or T2	TOTAL
Long curriculum	152	6		17	171
Short curriculum	208	3		17	228

Note. T1, Time 1 (before curriculum); T2, Time 2 (after curriculum).

Appendix B. Short versus long curriculum group comparison

Impact of the curriculum on the perceived inheritance of traits.

As shown by a nonsignificant Time (pre- vs. post-curriculum) × Group (short vs. long curriculum) interaction in our linear mixed models, the impact of the curriculum on the perceived inheritance of traits was similar in both groups. This was true for physical traits ($\beta = -0.14$, $p = .07$), personality traits ($\beta = -0.04$, $p = .61$), and cognitive traits ($\beta = -0.01$, $p = .85$).

Impact of the curriculum on the perceived malleability of traits.

As shown by a nonsignificant Time (pre- vs. post-curriculum) × Group (short vs. long curriculum) interaction in our linear mixed model, the impact of the curriculum on the perceived malleability of traits was similar in both groups. This was true for physical traits ($\beta = -0.15$, $p = .08$), personality traits ($\beta = 0.02$, $p = .76$), and cognitive traits ($\beta = -0.12$, $p = .85$).

Impact of the curriculum on fixed mindset.

As shown by a nonsignificant Time (pre- vs. post-curriculum) × Group (short vs. long curriculum) interaction in our linear mixed model, the impact of the curriculum on mindset was similar for both groups ($\beta = 0.01$, $p = .82$).

Appendix C. Correlation tables for Study 1a and Study 1b

See Tables C1 and C2.

Table C1
Correlations and means (and standard deviations) for inheritance, malleability, and mindset beliefs in Study 1a.

	Inheritance: Physical	Inheritance: Personality	Inheritance: Cognitive	Malleability: Physical	Malleability: Personality	Malleability: Cognitive	Fixed mindset
Inheritance: Physical		.43*	.33*	−.20*	−.01	−.03	.00
Inheritance: Personality			.55*	−.02	.02	−.02	.11*
Inheritance: Cognitive				.01	−.04	−.10	.11*
Malleability: Physical					.20*	.21*	.13*
Malleability: Personality						.56*	−.11*
Malleability: Cognitive							−.20*
Mean (*SD*)	2.43 (0.61)	2.04 (0.57)	1.77 (0.57)	2.48 (0.67)	3.22 (0.51)	3.35 (0.58)	1.90 (0.60)

Note. For correlations, an asterisk (*) means that the correlation was significant ($p < .05$).

Table C2
Correlations and means (and standard deviations) for inheritance and malleability beliefs in Study 1b.

	Inheritance: Physical	Inheritance: Personality	Inheritance: Cognitive	Malleability: Physical	Malleability: Personality	Malleability: Cognitive	Mindset
Inheritance: Physical		.43*	.42*	−.34*	.01	.02	−.02
Inheritance: Personality			.73*	−.12*	−.19*	−.17*	.09
Inheritance: Cognitive				−.09	−.26*	−.20*	.12*
Malleability: Physical					.18*	.10	−.02
Malleability: Personality						.67*	−.23*
Malleability: Cognitive							−.27*
Mean (*SD*)	2.83 (0.61)	2.38 (0.68)	2.18 (0.74)	2.21 (0.72)	3.22 (0.54)	3.34 (0.59)	1.80 (0.59)

Note. For correlations, an asterisk (*) means that the correlation was significant ($p < .05$).

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