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Perspective

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A unified account of why optimism declines in childhood

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Abstract

Optimism is linked to a range of positive social and cognitive outcomes across development. Yet decades of work in psychological science has revealed that optimism declines throughout early childhood. Despite this well-documented decline, there is no agreed-upon theory that accounts for developmental changes in optimism. In this Perspective, we synthesize cognitive, computational, social and neural evidence and discuss three candidate mechanisms that might underlie declines in optimism with age: learning from experience, changing theories of success and wishful thinking, and shifts in valenced learning biases. We argue that declining optimism across childhood is best characterized by an account that integrates these theories. Specifically, we suggest that environmental factors impact the pace at which children's theories and valenced learning biases change with age, and consequently the rate at which their optimism declines. This account suggests that optimism should be conceptualized as an adaptive bias that signals the nature of one's environment and leads to specific recommendations for future lines of enquiry.

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Introduction

In coming-of-age narratives such as *To Kill a Mockingbird*, *The Catcher in the Rye*, *The Bridge to Terabithia*, *The Secret Garden* and *Lord of the Flies*, children's initial unbridled optimism declines as children age and confront the realities of the world. However, declines in optimism in childhood are not merely the fodder of children's books, fairy tales and movies; rather, decades of empirical research suggests that children's optimism (the difference between their explicit expectations of some positive event occurring relative to the ground truth rate of the event occurring) systematically decreases between the ages of 3 and 9 years. Specifically, young children overestimate their performance to a greater degree than older children in tasks that assess memory (for example, estimating the number of items they will remember[1–3]), motor performance (for example, forecasting how far they can jump or throw a ball[4–7]), visual search (for example, predicting how many hidden objects they can find[8]) and probabilistic reasoning tasks (for example, guessing the probability of a desirable randomly determined outcome[9,10]) (Fig. 1). Young children are also optimistic about their own knowledge, personality and trait development, which often have plausible (but not empirically measured) ground truth in the near and far future. For example, 5–7 year olds think that they will acquire more knowledge in the future than do 8–10 year olds[11]. However, despite this well-documented decline in optimism in early childhood, there is no agreed-upon theory that accounts for this developmental change.

Understanding why optimism declines with age is important for both theory and practice. From a theoretical perspective, understanding what causes declines in optimism could shed light on whether changes in optimism constitute a cohesive, conceptual change in children's theory of the self or the world. Given that optimism is studied in a range of other psychological subfields, uncovering the causes of developmental declines in optimism could also have theoretical and practical implications for social psychology, cognitive psychology, neuroscience, health psychology, clinical psychology and comparative psychology. Finally, given the evidence that optimism has both positive and negative consequences for mental health, well-being, achievement and motivation[12–15], understanding the causes of developmental declines in optimism could inform whether (and when) interventions are appropriate.

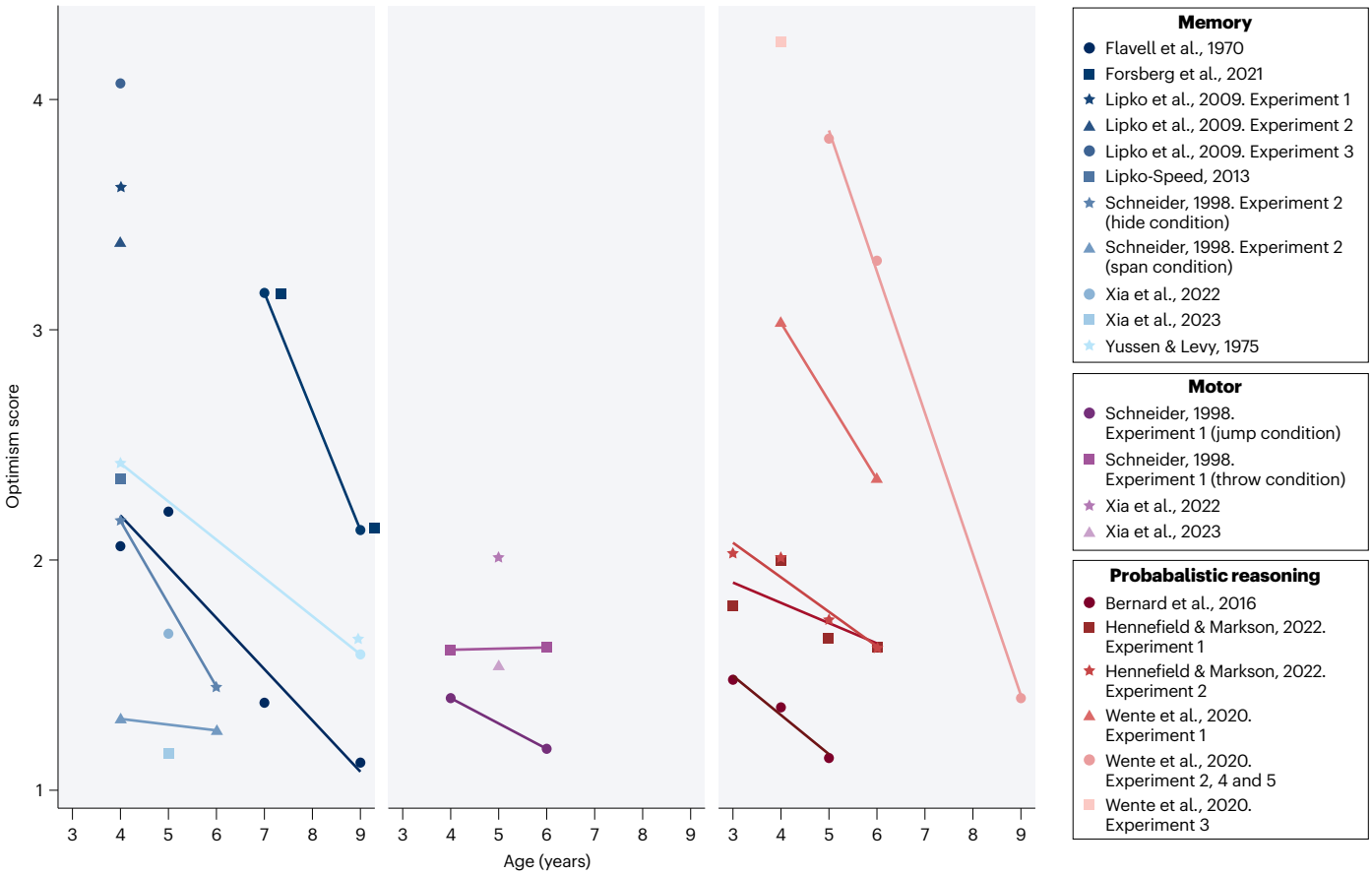

Fig. 1 | Empirical evidence for children's optimism bias. Data from cross-sectional studies for which predicted and actual performance on memory (blue), motor (purple) and probabilistic reasoning (red) tasks are available by age. In all studies, children predicted performance for themselves. Scores were calculated from data available in the publications and represent children's average predictions by age divided by their actual average performance or ground truth. Articles without this information were excluded. For memory performance, if children on average predicted that they would remember 6 items but only remembered 4 items, this would yield an optimism score of 1.5. For motor tasks, if children on average predicted that they would jump 120 cm but actually jumped 100 cm, this would yield an optimism score of 1.2. For probabilistic reasoning tasks, if the base rate of an outcome is 20% and 85% of children predicted this outcome, this would yield an optimism score of 4.25. A score of 1 indicates perfect accuracy. Connected lines indicate studies in which multiple ages were sampled. Data taken from refs. 1,2,7,9,10,53,54,114,129,130.

Box 1 | Definitions of optimism

A shared assumption across fields is that optimism refers to positive expectations about the future. However, there is variability in this definition along two dimensions: the specificity of expectations (whether individuals believe they will live a good life versus the likelihood of passing a test or winning the lottery) and the temporal window of these expectations (expectations about the degree of success in a future career versus predictions of how far one thinks they will jump immediately before jumping). Although these dimensions, in principle, are dissociable, research tends to either assess specific expectations for near-term events (state optimism, task optimism or optimistic biases) or more general or global expectations about long-term events (trait optimism).

Field-specific definitions and measures

In social and personality psychology, some scholars construe optimism as a dispositional trait[131] that consists of generalized positive expectancies about the future without reference to base rates or the average individual. Typically, dispositional optimism is assessed via questionnaires such as the Life Orientation Test[131]. By contrast, other researchers focus on unrealistic optimism, defined as expectations for particular life outcomes that exceed actual performance (for example, predicted performance on an examination versus actual performance) or assess their risk for a particular negative outcome (for example, having a heart attack) as lower than that of a similar peer[132]. In these cases, optimism is typically measured by assessing differences between participants' predictions for specific positive or negative events and base rates.

Developmental researchers have primarily studied optimism in three ways: children's predictions about their memory, motor or visual search performance compared with their actual performance (state optimism)[1,7,8]; children's predictions about desirable probabilistic outcomes compared with ground truth[9,10]; or the degree to which children predict the acquisition of positive (versus neutral or negative) characteristics, abilities or traits with age[11,133].

Cognitive psychology and neuroscience research has focused predominantly on the causes of optimism and optimistic bias. These researchers typically investigate how attention and memory-related biases in the encoding of positive and negative information vary across age and individuals[58], and how these relate to trait optimism[60].

In the animal behaviour literature, state or task optimism is typically assessed via non-verbal judgement bias tasks. In these tasks, cues are differentially paired with reward and punishment. In some cases, these cues are arbitrarily paired, requiring training for animals to learn the pairing, and in other cases these cues are inherently biologically valenced[134]. The critical test of optimism biases is how animals respond to an ambiguous stimulus that is halfway between the positive stimulus and the negative stimulus. The degree to which animals anticipate a reward in response to the ambiguous stimuli represents the degree of their optimism bias.

Relationships between types of optimism

There is evidence that state and trait optimism relate to one another but are not synonymous. For example, adults who predicted a higher likelihood of positive (for example, winning an award) versus negative (for example, ending a relationship) events were higher in trait optimism[135]. Correlations between state and trait optimism have also been found in children. For example, children who predicted positive outcomes for upcoming events had higher levels of trait optimism than children who predicted less positive outcomes[57], and children who more frequently predicted desirable events had lower scores of dispositional pessimism as measured via a parental report questionnaire[9]. However, some studies show that state and trait-based optimism are differentially related to outcome measures. For example, in a sample of law students, situational optimism about law school was more strongly associated with cellular immunity than dispositional optimism[136].

Another question is whether optimistic beliefs in one domain are related to optimistic beliefs in another domain. Although some studies measured children's optimism in multiple domains, most do not directly compare estimates across domains (that is, they do not correlate optimistic expectations across different tasks). However, a meta-analysis of 246 effect sizes from 43 published papers on children's performance predictions (versus actual performance) found that optimistic expectations did not differ by domain[137] (motor, memory and other cognitive task). It is possible that state-based optimistic beliefs become more domain-specific with age as children learn about domains (for example, what constitutes mathematics versus sports versus arts) and biases associated with these domains (for example, gender biases about science, technology, engineering and mathematics (STEM)[98,138,139]).

In this Perspective, we review and integrate cognitive, computational, social and neural evidence to explain why optimism declines between the ages of 3 and 9 years. First we discuss three non-mutually exclusive candidate causes for the age-related decline in optimism that stem from different literatures and time periods and have yet to be connected: learning from experience, theory development and valenced learning biases. Next, we propose a unifying account that integrates the merits of each of the three reviewed theories. We conclude by suggesting future research directions to support a more complete developmental science of optimism.

Subfields in psychology measure optimism in distinct ways (Box 1). Moreover, optimism is distinct from other positive anticipatory states and from metacognition (Box 2). Here, we define optimism as positive predictions or expectations about the future self. In line with most developmental research, we mainly focus on state-based optimism about near-term performance. However, we also touch on research on trait-based optimism (more general or global expectations about long-term events).

Learning from experience

One theory for why optimism declines with age is that changes in children's experiences over time spur rational adjustments in their predictions of their future success. According to this perspective, children's initial optimism and its subsequent decline might stem from two sources of experience that change with age: first-person experience and social feedback (Fig. 2a). This theory stems from a large body of work showing that young children make rational and sophisticated inferences from data[16–19].

Box 2 | Relationships between optimism and other concepts

Other positive anticipatory states

Optimism is sometimes grouped with other positive anticipatory states (such as desires, wishes and wants), and in particular hope[140]. However, one study that set out to empirically establish whether optimism was a unique construct by asking adults to define optimism, hope and other positive anticipatory states found that optimism was described as a cognitive process (that is, a specific belief or expectation about a future outcome) whereas other positive anticipatory states were described as emotions[141]. Moreover, participants reported optimism for general outcomes (for example, that it would be a good week) and for outcomes over which they had some degree of personal control, whereas they reported hope for specific outcomes (for example, getting over an illness) and for outcomes over which personal control was low. These findings indicate that although optimism overlaps with other positive anticipatory states, it also has unique characteristics.

Metacognition

Optimism shares some features with metacognition (the awareness and control of one's own cognitive processes[142]). In particular, some experiments on metacognitive judgements require participants to make predictions about their cognitive performance (for example, after studying animal pictures, individuals are asked how many animals they think they will remember[143]). This approach is similar to studies assessing state optimism in which participants are asked about their expectations for upcoming task performance.

However, there are also important distinctions between optimism and metacognition. First, the target of metacognition is one's cognitive processes and abilities, whereas optimism also applies to the likelihood of general positive events occurring that vary somewhat in personal control (for example, physical appearance). Second, metacognition is also about the control and regulation of learning and cognitive processes, whereas optimism is not. Third, metacognitive judgements include prospective predictions about performance as well as judgements about ongoing task performance or about how one performed after a task[144]. By contrast, optimism assessed in a task-based manner refers strictly to expectations about future performance. Finally, the focus of metacognitive judgements is on accuracy with little regard for valence, whereas optimism reflects the degree to which expectations are positively biased (compared with ground truth or population averages).

Possibility beliefs

Optimism is sometimes associated with possibility beliefs, which creates confusion considering that they have opposite developmental time courses. Although optimism declines with age, possibility beliefs actually increase with age (at least in some cases). For example, preschool-age children think that people cannot act against desires[23,50] (for example, choosing not to eat a desirable ice cream) and that unlikely events (such as eating onion-flavoured ice cream) are impossible[145,146]. Only around age 6–7 years do children start to understand that individuals can act against their desires and choose, for example, not to eat an ice cream that fell on the floor[50]. Thus, contrary to optimism declining with age, research on possibility beliefs suggests that optimism about possibilities might increase with age[147] through first-hand experience and social input[23,148–150].

However, possibility beliefs are actually distinct from optimistic beliefs. Possibility belief studies usually index children's beliefs about what one can or cannot do, whereas optimism studies typically ask how well children think they can do something. In other words, optimism is not about whether some discrete task is possible but, rather, to what degree children think they can achieve a goal. It is therefore conceivable that these sets of beliefs are qualitatively distinct. Future research is necessary to more fully flesh out how possibility beliefs relate to optimistic beliefs. For example, one could ask children whether they think it is possible to jump certain distances and also ask them to predict how far they think they will jump to see whether beliefs about possibilities track with optimistic predictions.

Learning from first-person experience

Children's initially high optimism might reflect the fact that novices are typically poorly calibrated in their performance expectations, and develop more realistic expectations with experience[20]. Young children are, by definition, universal novices. As children grow, they gain more task-specific experience that might help them gauge their future performance on similar tasks. For example, children new to walking typically attempt to walk down ramps that would be dangerous for them if an experimenter was not ready to catch them. By contrast, children with more experience walking have a better grasp of what they are capable of and opt to crawl or slide down ramps that are too steep[21,22]. In older children, experience also impacts beliefs about possibilities: children aged 4–8 years with better self-control are more likely to believe that exerting self-control in challenging situations (for example, choosing not to eat something yummy) is possible[23]. In other words, having experience successfully exerting self-control might reinforce the idea that resisting temptations is possible. Furthermore, children aged 4–6 years are less optimistic about their future performance on more familiar tasks[7]. Taken together, this evidence suggests that first-person experience helps children calibrate future performance estimates.

Young children likely also receive first-person evidence about their abilities that differs from that of older children. For example, in 1 month a 4 year old might learn how to identify letters and numbers which suddenly gives all the symbols in the world structured meaning. These skills will catapult the child into a new phase of learning, interaction and independence. By contrast, in 1 month a 10 year old might learn to add fractions and deepen their knowledge of the Revolutionary War. Although these are great learning milestones, the knowledge gained in 1 month at age 10 years might feel more incremental than the knowledge gained in 1 month at age 4 years. Given that children are sensitive to their rate of learning[24], the rapid change and acquisition of fundamental skills at younger ages might spur children to rationally think that they are capable of quick growth.

Learning from social feedback

The changing input that children receive from their social environments as they age might also spur declines in optimism[25]. Young children's early social contexts (such as home, childcare and preschool) are largely child-centric and focus on growth and learning[26–28]. For instance, many early childcare settings promote open-ended activities that allow children to explore and learn independently, and children are given encouraging feedback for their effort and attention. A teacher might praise a 3 year old's barely legible scribble by saying 'Wow, that looks like the letter E! Nice work!'.

However, the dynamics change as children transition into formal schooling. At the start of primary school, the frequency of explicitly evaluative feedback (for example, grades, direct evaluative feedback or class rank) dramatically increases and the focus shifts towards more explicit learning goals. In response to the same scribble, a teacher might now respond with 'Hmm, I think you are trying to write the letter "E", but the top part isn't quite right'. Children also receive more formal instruction, challenging assignments and more opportunities for social comparison with their peers. This shift in the children's social environment — from one that values free play and effort to one that prioritizes achievement outcomes — might focus children's attention on past failures and/or change their estimates of future success.

Indeed, laboratory-based studies have shown that optimistic young children display helplessness, lower self-competence ratings

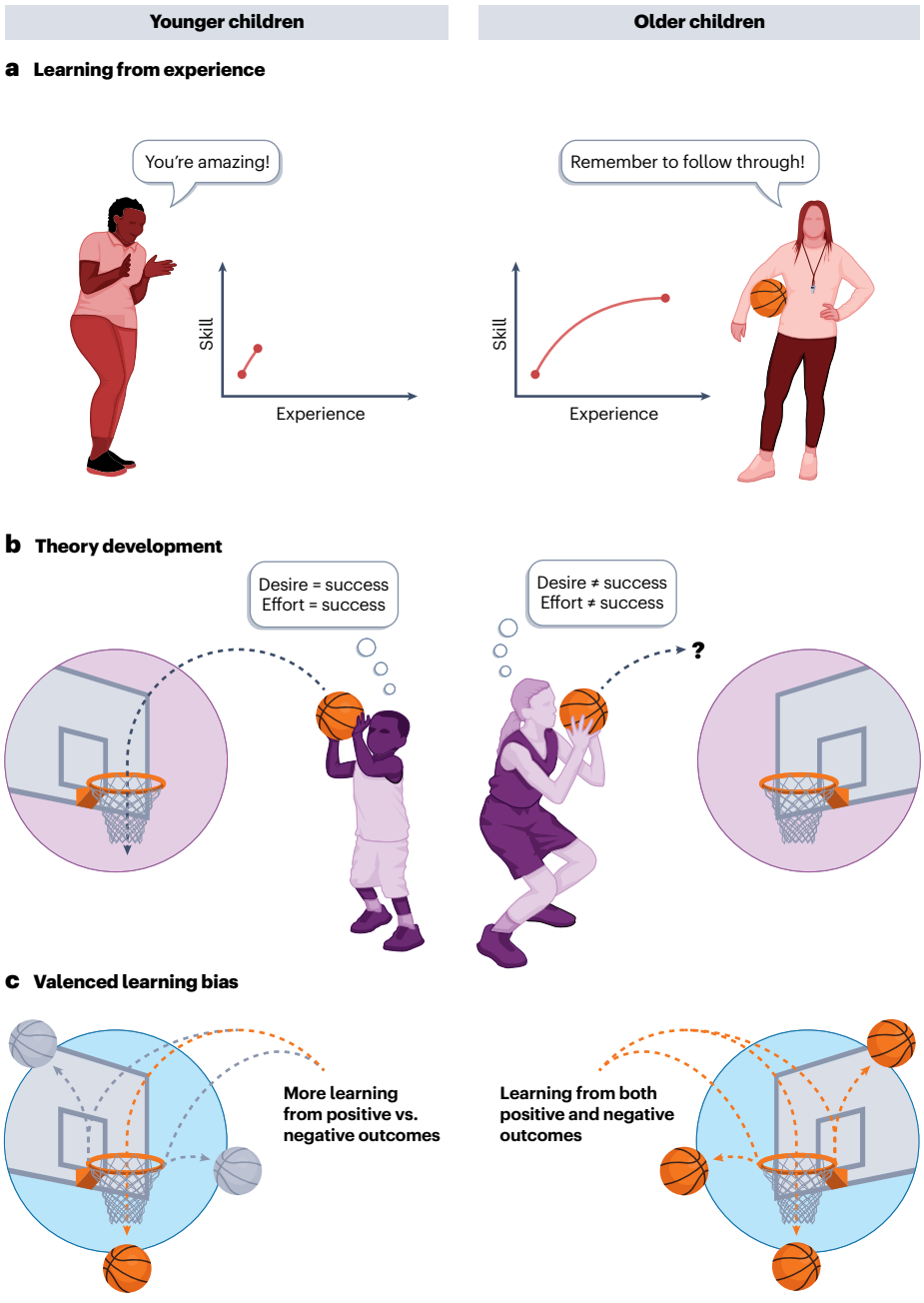

Fig. 2 | Three candidate mechanisms for why optimism declines with age. a, Learning from experience. Young children's rapid skill acquisition at the beginning of learning might spur optimism about their future progress. With age, children also acquire more experience with particular tasks or activities, leading to more accurate performance expectations. For example, a child might become less optimistic about her basketball skills with age through first-person experience of missing many free throws during practice. As children become more independent and capable, social input changes from positive and encouraging (for example, a caregiver telling a child they are an amazing basketball player) to more realistic and evaluative. Thus, a child might recalibrate their expectations about their basketball skills owing to changes in social feedback. **b**, Theory development. Children's theories develop over time, enabling children to recognize that effort and success are independent of one another and to more readily distinguish between desires and expectations. For example, a child's optimism about their basketball ability might decline with age because they realize that their desire to make a shot is independent from their expectation of making a shot (wishful thinking) or that trying hard is not the key causal variable necessary for success (theories of success). **c**, Valenced learning bias. Children's learning changes over time from privileging learning from positive over negative outcomes to increased learning from negative outcomes. For example, an older child may be less optimistic about their free throws than a younger child because the older child is better able to learn and update their beliefs from missing prior baskets.

and poorer performance if given explicit cues that success depends on ability compared with effort[29–31]. Furthermore, kindergarteners in classrooms with more evaluative feedback have more realistic expectations of their class rank[28]. Over time, these evaluative messages might compound to spur the documented declines in self-competency ratings from elementary school to high school[32,33].

Research with adults might provide a clue as to why entry into more formally evaluative contexts influences children's optimism. Although optimism declines with age, adults are still, on average, optimistic about future outcomes[34,35]. However, adults' optimism diminishes as self-relevant feedback becomes more proximal in time, a phenomenon known as 'sobering up'[36,37]. For example, one study measured college students' predictions about their grade on an examination starting 1 month before the examination up until when they were about to receive the graded examination back[38]. Optimism about examination grades systematically declined as the return of the examination grew closer: Although most students were optimistic about their examination grade 1 month before the examination, predictions became pessimistic in the moments before the examination was returned. The shift to ongoing formal evaluations when children move to formal schooling might lead to an adjustment in optimistic expectations for many of the same reasons that adults' optimism decreases as a function of evaluation proximity: to be prepared for negative outcomes should they arise[39].

Shortcomings

Although the learning from experience account can explain how children might reasonably learn to be less optimistic from external factors, it does not provide any proximate-level mechanism for how this change might occur. In other words, this account does not specify what happens in a child's mind when they repeatedly fail to achieve their intended result, when they hear more evaluative feedback or when they compare themselves with their peers.

Moreover, some hypotheses regarding the role of experience in children's optimism bias remain untested. For example, it is not yet known whether the pace at which children acquire fundamental skills relates to their beliefs about whether they are capable of quick growth or improvement, or whether large-scale shifts in evaluative environments (such as the entry into formal schooling) are associated with and lead to declines in optimism.

Theory development

Two accounts posit that changes in children's theories are responsible for age-related declines in optimism: theories of success and wishful thinking. Although these accounts differ in their specifics, both suggest that qualitative changes in children's beliefs about the self drive declines in optimism with age (Fig. 2b). In other words, children's optimism stems from immature theories about the nature of the self and/or the world.

Theories of success

According to the theory of success account, young children are optimistic, in part, because they attribute poor performance to lack of effort — not ability — and think that effort is limitless. For example, a seminal study found that children aged 12 years and older understood that if two children perform well on a test but one child worked harder than another, the child who applied less effort is more competent[40]. By contrast, children younger than 12 years old conflated effort with ability and said that the child who applied more effort was more competent (see refs. 41–45 for similar evidence). These results suggest that children's understanding of effort and ability goes through a series of conceptual changes: effort and ability are initially entirely conflated (ages 5–6 years), then effort is assumed to be the sole source of competence (ages 7–9 years) and then the capability to distinguish between effort and ability develops (ages 10–11 years), which ultimately leads to the ability to recognize the reciprocal relationship between effort and ability (ages 12 years and older)[40].

Moreover, evidence suggests that young children (ages 5–11 years) predominantly view effort as unbounded (for example, that one can apply effort for as long and as much as one likes)[46]. Other work has found that children aged 8–10 years mostly attribute failure to external causes such as bad luck, which suggests that children might be reluctant to even believe that they have low ability or put in low effort[47–49]. Consistent with this claim, children aged 5–6 years displayed helplessness after failure when given cues that success depends on ability not effort[29], and children aged 5–11 years became less willing to persist after failing a task[43]. These findings suggest that young children's immature conceptual framework about the causes of success might promote faulty optimism: if the key to success is effort, and effort is limitless, one could reasonably believe that they can succeed if they simply try harder.

Wishful thinking

Wishful thinking refers to an inability to distinguish wishes from expectations about the self and the world. Children become better able to differentiate their wishes from their expectations with age. For example, children aged 4–6 years made equally optimistic predictions about how far they 'wished' to jump and how far they 'expected' to jump[7] and 4-year-old children say that they cannot act against their desires (for example, choosing not to eat a yummy cookie)[23,50]. Young children (ages 3–6 years) also overestimate their expected performance compared with that of a peer, who they presumably want to succeed less than themselves[9,51,52] (but see ref. 53 for results suggesting that this effect differs by culture). Critically, children provided similarly optimistic performance predictions for themselves and the peer when they were incentivized to want their peer to succeed (for example, they got a reward if their peer succeeded)[52].

Young children also display wishful thinking in probabilistic reasoning tasks where they have no control over the outcome[9,10,54]. For example, 5 year olds were more likely than 7 year olds to guess that an experimenter would draw a rare prize-winning blue egg out of a sample of mostly yellow eggs[10]. Notably, this effect was not driven by worse probabilistic reasoning in younger children — all children said that an experimenter would most likely pull a yellow egg out of a container with mostly yellow eggs when the blue egg came with no additional prize[10]. Thus, young children seem to specifically think that events are more likely to occur when they are desirable, but with age they come to differentiate between what they wish would happen and what will likely happen. According to this perspective, the ability to distinguish wishes from expectations drives declines in optimism.

Shortcomings

Although theory development accounts make compelling arguments, the focus on theory revision as the driver of development stems from developmental psychology research in the 1970s through 1990s; newer evidence suggests that young children might be considerably more sophisticated in both their reasoning about the role that effort and ability play in success and failure and their ability to distinguish

wishes from expectations (see ref. 25 for a review). For example, in tasks with lower cognitive demands than in the seminal older studies, children aged 4–5 years demonstrated an adult-like understanding of the inverse relationship between competence and effort with regard to success on third-person paradigms[55,56]. These findings call into question whether children would be more accurate on first-person paradigms when demands are similarly lowered. Similarly, even though children produce inflated estimates of the frequency of desirable events, their estimates scale with probability: children aged 5–6 years were more likely to say that they would receive a special toy if their chances of obtaining the toy were 66% rather than 33%[9]. Moreover, 5-year-old children think that a very rare, desirable event (for example, receiving a surprise present today) is less likely than more common, desirable events occurring (for example, receiving a present they like at their birthday party)[57]. In other words, young children are quite good at differentiating wishes from expectations when asked about the likelihood of extremely rare, positive events occurring.

Thus, findings from the past 20 years suggest that the age at which children possess the capacity to distinguish effort from ability and wishes from expectations (by 4 or 5 years old) does not align with the linear developmental decline in optimism (from 3 to 9 years old), which challenges the claim that conceptual changes in theories of success and wishful thinking underlie declines in optimism. It is possible that more gradual changes in children's theories of success and wishful thinking between the ages of 3 and 9 years contribute to children's declining optimism during this timeframe. However, it is unlikely that a fundamental conceptual shift in children's theories of success and/or wishful thinking between the ages of 3 and 9 years are the sole, causal source of declines in children's optimism.

Valenced learning bias

The third theory for why optimism declines with age concerns maturational changes in valenced learning biases (Fig. 2c). This theory stems from computational and neural work on learning across development.

Computational and neural evidence

In a key study, 8–17 year olds were tasked with learning the relationship between their effort (rapid button presses) and rewards (coins) couched in a child-friendly cover story about fuelling a spaceship to get from planet to planet[58]. Before each trial, children predicted how many rewards they could obtain. Because the relationship between effort and reward changed over time, children had to learn through trial and error. In line with prior work, younger children were more optimistic than older children and predicted that they would receive more rewards across trials. Fitting the data to a computational model revealed that children increasingly learned from negative prediction errors with age, whereas learning from positive prediction errors was stable across age. Critically, this developmental change in learning from negative prediction errors mediated the relationship between age and optimism. In other words, higher optimism was associated with learning less from worse-than-expected outcomes, and children learned more from negative outcomes — and, in turn, become more realistic — with age.

Neural data also support the hypothesis that a valenced learning bias underlies optimism. Similar to children, more optimistic adults also learn less from negative outcomes[59–61]. Neuroimaging work showed that the right inferior frontal gyrus was less active in response to worse-than-expected outcomes for adults with high versus low trait optimism[62]. Furthermore, experimentally enhancing dopaminergic function via administration of dihydroxy-L-phenylalanine increased adults' optimistic expectations for real-world events compared with receiving a placebo by impairing their ability to update beliefs in response to negative information about the future[63]. Given that there are extensive dopaminergic projections between midbrain dopamine nuclei and frontal cortical areas[64], one possibility is that individuals with less top-down or bottom-up control of dopamine release are more optimistic.

Interestingly, children have immature dopaminergic–prefrontal circuitry, which might make them particularly prone to optimism. Work in rodents shows that dopamine axons from the striatum continue to innervate the prefrontal cortex throughout adolescence[65], and work in humans shows that asymmetries in the early developing ventral striatum and the later developing prefrontal cortex underlie heightened sensitivity to rewards in adolescence[66–68]. Protracted development of the prefrontal cortex across childhood through adolescence underlies age-related improvements in valence-guided behaviour including memory encoding[69], cognitive control[70] and emotion regulation[71]. Relatively less work has explored the development of dopaminergic neurocircuitry in early childhood (ages 3–7 years), probably because this age range is difficult to scan. However, one study found that ventral tegmental area connectivity linearly increased with medial prefrontal cortex between the ages of 4 and 9 years in individuals from high-socioeconomic status (SES) backgrounds[72] (connectivity was not associated with age in children from low-SES backgrounds). Thus, the protracted development of prefrontal connectivity and control of the dopamine-rich reward subcortical areas might underlie developmental declines in children's optimism.

The slow development of the prefrontal cortex also supports children's gradual improvements in executive functioning with age[73,74]. Changes in executive function with age might enable children to inhibit positively valenced learning biases in contexts in which weighting negative information over positive information leads to greater task success. Consistent with this idea, adults made considerably more optimistic predictions when they were asked to produce their predictions immediately versus when they were asked to reflect on their predictions for 15 s, perhaps because they had less time to enact top-down control[75], and valenced learning biases are less contextually variable in children than in adolescents and adults[76].

Shortcomings

This valenced learning bias theory has not been tested in children younger than 8 years old, making it difficult to connect this theory with the research on declines in optimism between the ages of 3 and 7 years. There is some suggestive evidence that young children have a valenced learning bias: An event-related potential study with 4–5 year olds found greater electrical activity following positive compared with negative feedback on a gambling task[77]. However, a limiting factor in this research on valenced learning biases is that valenced learning biases are usually detected through fitting computational models to tasks with many trials and it is challenging to get young children to attend to tasks for long periods of time. Furthermore, the valenced learning bias theory does not explain why children make more optimistic predictions on the first trial of novel tasks, before they can form valenced learning biases. Additionally, focusing on age-related shifts in cognitive change and their underlying neural bases might give the impression that these changes are predominantly maturational (that is, genetically programmed to change with age). Although a maturational account might be true to some extent given that optimistic

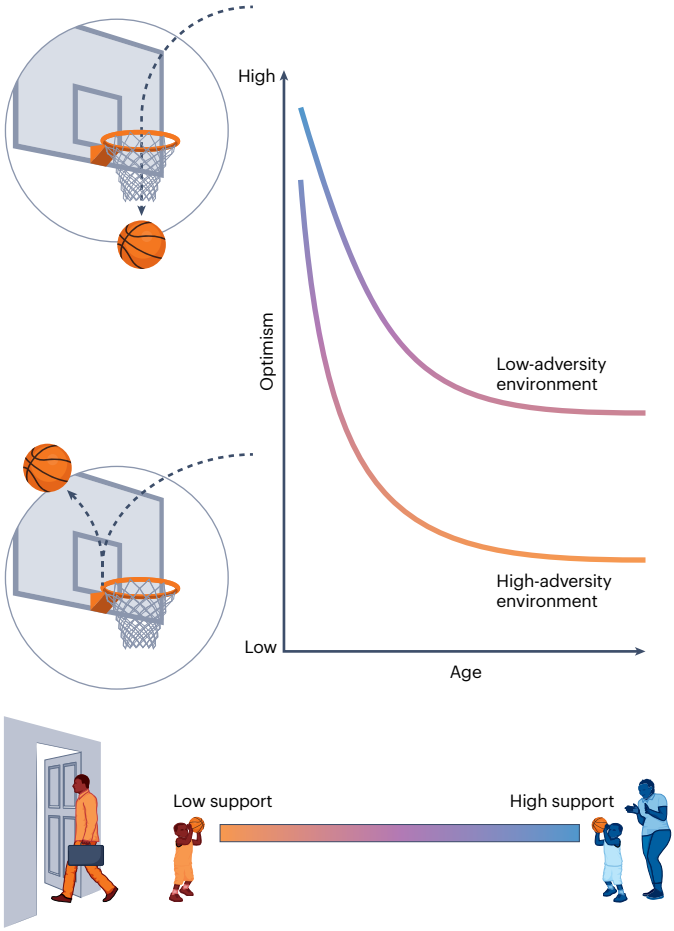

Fig. 3 | Effects of environment on developmental trajectories of declines in optimism with age. The proposal that the pace of children's declining optimism with age is driven by the nature of the children's environment. Across species, immaturity is often associated with high levels of caregiving and support. In low-adversity environments, young children have access to attentive, caring and admiring adults (high support). These nurturing and supportive environments might cause young children to believe that effort and their desires lead to success and permit less learning from negative feedback, leading to high initial levels of optimism. Children's theories and learning biases might change as they grow up in low-adversity environments and transition to contexts where more independence is required (lower support), leading to less optimistic beliefs. However, for children who grow up in high-adversity environments, less support might be offered from the beginning (for example, because parents are working many jobs and are therefore less available), which might accelerate children's theory development and shifts in learning biases and spur faster declines in optimism.

adults learn more from negative information than young children[58], it is also likely that these changes are additionally driven by children's experience and social input.

A unified account

The above review suggests that children's experiences, theories and valenced learning biases change with age, but none of these factors alone provide an integrated, mechanistic account for children's declining optimism across development. We propose that features of each of these theories might work in synchrony to explain this developmental decline. Specifically, drawing from life history theory[78–80], we suggest that environmental factors (such as the degree of adversity and support) influence the pace at which children's theories about themselves and the world as well as their learning biases change with age, and, in turn, the rate at which their optimism declines (Fig. 3). In other words, children's theories and valenced learning biases undergo developmental changes that are partially due to biological maturation and partially due to the environment, as described below. Of course, this account does not preclude the possibility that other cognitive and mechanistic factors besides learning biases and theoretical changes might also influence children's optimism (Box 3).

Environmental impacts on valenced learning biases

Valenced learning biases in children and adults are sensitive to the environment[76,81,82]. For example, adults learned less from negative outcomes when they were generated by a hidden cause versus by their own behaviour[83], and 8–25 year olds adaptively changed their valenced learning biases (for example, weighting positive outcomes more heavily than negative outcomes or vice versa) depending on which strategy was more advantageous in the given context[76]. Together, this work suggests that learning biases vary within the individual by context, and are therefore influenced by the environment.

Across species, immaturity is associated with caregiving and social support[84]. Thus, children might generally be in environments where a positively valenced learning bias is advantageous. If a young child is climbing on a jungle gym with parents nearby to provide help if needed, it might not be bad to downweight the harm from falling and upweight the gains from trying something new (see ref. 15 for evidence that optimism is associated with constructive risk-taking in 4–8 year olds). However, increased independence is expected as children get older, which means there are more risks associated with overly optimistic expectations. For example, if a parent is not standing at the ready nearby, optimism might result in a child swinging beyond their skill level on the jungle gym and falling. In this context, weighting evidence from negative feedback and tempering expectations to align with reality decreases risk. Thus, a changing environment from one of dependence to independence might spur children to learn more from negative prediction errors.

At the same time, children who live in environments that require them to be independent at younger ages (for example, children who help care for siblings because their parents work several jobs) might show faster declines in optimism. This prediction is in line with evidence showing that early life adversity accelerates biological ageing[85–88] and theoretical work suggesting that early adversity might accelerate a shift from exploration to exploitation[80] as preparation for early reproduction and independence. Indeed, correlational studies found that children aged 3–6 years from lower-SES households were more dispositionally pessimistic than their higher-SES peers at age 20 years, even after controlling for current SES[89,90] (but see ref. 9 which found that children aged 3–6 years from lower-SES backgrounds were more optimistic than their higher-SES peers on certain probabilistic reasoning tasks). Moreover, adolescents from lower-SES households showed lower striatal reward sensitivity compared with peers from higher-SES households[91]. In sum, it might be more adaptive for young children in contexts without strong safety nets to learn from negative feedback early in life to promote independence.

Together, this work suggests that both universal changes in experience with development (for example, receiving less care with age)

that might support biological maturation, as well as more individually variable aspects of experience (especially early life adversity), likely shape the trajectory and decline of valenced learning biases with age and, in turn, optimism (Fig. 3).

Environmental impacts on children's theories

Children's changing environments might also explain the degree to which they attribute success to effort. Most learning curves follow an exponential decay or S-shape function[35,92–95]: People start out making rapid progress until they ultimately hit a plateau. Effort might therefore shape progress more for novices who are at the beginning of their learning curves than for experts who might be at a plateau. The experiential feeling of effort might also be less salient to experts, who might find tasks on which they have expertise (for example, driving or typing) second nature[96,97]. Thus, younger children might experience their effort as both more salient and beneficial than older children, which might lead them to optimistically think that they can achieve whatever they want when they try.

Similarly, shifts in children's tendency and ability to separate their wishes from their expectations might be experientially driven. In many cases, the wishes of very young children are their reality: an infant who effortfully reaches for an out-of-reach toy might be provided with that toy by an attentive caregiver; an energetic 4 year old who manages to get a single finger on the next monkey bar might be supported by their parent who makes his or her hand follow suit, leading to a successful swing. Furthermore, in many western cultures, children are often encouraged to shoot for the stars: a 4 year old who declares that their professional plans include a weekly job fighting fires and a weekend job performing on Broadway is unlikely to be provided with practical advice on the challenges of trying to simultaneously pursue these two highly specialized careers, thereby reinforcing high levels of optimism (although this input likely differs based on culture).

At the same time, not all children are in environments that support wishful thinking. For example, being part of a stereotyped group or coming from a less-resourced background might limit a child's beliefs

Box 3 | Other perspectives on optimism in childhood

Optimism as a social signal

Children care what other people think about their abilities[151–155]. For example, children aged 3–4 years selectively show off their capabilities to adults who incorrectly think they are less competent[152]. Thus, younger children might predict inflated performance to show what they think they are capable of to those around them. According to this hypothesis, lower performance predictions with age do not reflect lower optimism but, instead, an understanding that exaggerated prediction errors are demoralizing[156] and embarrassing.

However, children aged 4–6 years show optimistic expectations of their future performance on self-administered iPad games played in their home where there is no experimenter watching them[24]. Moreover, cultural norms around modesty and boasting are not related to optimism in children aged 4 and 5 years[53,115,118,119,157] (although this could be because these norms have not yet been internalized; see ref. 158). This evidence suggests that reputational concerns likely do not drive young children's optimism, but does not rule out the possibility that young children use their predictions of future performance as a social signal of their competencies. Future work is necessary to more fully test this hypothesis. For example, a study could compare children's performance predictions on a task when someone is watching versus when they are alone.

Another possibility is that young children use optimistic expectations to communicate their aspirations to adults so that the adult can support them or help them achieve their goals. According to this account, reduced optimism with age reflects a realization that adults might be less helpful or responsible for ensuring children meet their goals as children mature.

Both the reputational concern and social support accounts predict that optimism should be greater in the presence of another agent. Although not mutually exclusive, these accounts can be distinguished by testing whether optimistic expectations differ depending on who is watching. If optimism is about reputational concerns, then children should be more optimistic when someone they care to impress (versus care less to impress) is watching. If optimism is about seeking support, children should be more optimistic around more competent and/or supportive agents.

Changes in metacognition

Metacognition encompasses the ability to monitor and regulate cognitive processes. Children display metacognitive abilities from a young age. For example, 20-month-old children selectively ask their caregiver for help on challenging versus easier memory trials[159] and children aged 4–5 years report being more confident in their correct versus incorrect responses on a memory task[160]. Despite this early sophistication, aspects of metacognition improve across development. For example, a longitudinal study found that although 4-year-old children were more certain about their correct versus incorrect responses on a memory task, the degree and precision of their certainty increased between the ages of 4 and 6 years[161]. It is therefore possible that incremental changes in metacognition help calibrate children's expectations of future performance.

However, the broad construct of metacognition is unlikely to fully underlie optimistic beliefs for a few reasons. First, metacognitive monitoring does not contribute to children's optimism: children aged 4–6 years accurately monitor their past performance[2,7], and children aged 4–8 years are persistent in overestimating their future performance even when accurate performance feedback is provided (requiring no monitoring)[2,3,53,58]. Moreover, children aged 4–5 years understand that their past performance can predict their future performance[129]. Second, although younger children update their predictions less than older children based on prior poor performance[58], the development of metacognitive regulation should translate to both positive and negative inaccuracies in performance predictions. Thus, although aspects of metacognition might relate to optimism across development, it is likely not a main source of age-related declines in optimism.

about what they are capable of and their access to learning opportunities. Indeed, in one study, 6-year-old girls already believed that they were less smart than boys, and consequently avoided activities for children who are "really, really smart"[98]. Children in less-resourced neighbourhoods often do not have access to high-quality educational materials and once they enter preschool are given fewer opportunities to engage in class discussions[99–101]. These experiences might compound to discourage young children from trying new tasks, and consequently reduce their opportunities to experience rapid improvement at the beginning of learning. In short, children from stigmatized and/or less-resourced backgrounds might not be afforded the opportunities that would spur beliefs that effort is limitless and the key causal variable for success, and consequently show lower levels of optimism than their peers from non-stigmatized and/or more-resourced backgrounds (Fig. 3).

Children's goals and wishes are also not always enacted by caring adults. Declines in optimism with age might accelerate beyond what is typical in cases where children's wishes or goals are not attended to or where children are granted low autonomy to achieve them. Consistent with this idea, children aged 8–12 years whose parents were lower in autonomy granting (that is, parents who did not recognize or support the child's goals or wishes) had lower levels of optimism[102]. In other words, variability in experience might provide children with differential evidence about whether their wishes and expectations should align, which in turn might influence the slope of optimism's decline.

In addition, evidence suggests that parental aspirations or expectations of their children's success are linked to children's own expectations of positive performance[103]. For example, parental expectations regarding children's mathematics achievement predict children's future mathematics success over and above prior performance[104]. Similarly, teachers' expectations across a range of domains have impacts on children's self-evaluations, self-expectations and academic outcomes, even after controlling for baseline levels of achievement[105]. Critically, parental and teacher expectations vary as a function of SES: middle-income parents have higher expectations for academic achievement than lower-income parents[106] and teachers have higher expectations for higher-income students[107]. Furthermore, teachers' expectations based on SES mediate the relationship between children's SES and subsequent achievement in mathematics and language, controlling for prior achievement[108]. This work suggests that supporting children's aspirations, as well as the expectations that parents, caregivers and teachers hold, might contribute to children's optimism; the extent to which these expectations are lower for particular children or groups of children might contribute to steeper declines in optimism.

Thus, to the extent that children are in environments where they have access to learning opportunities and are around adults who obey their wishes and think they are capable of anything, children might hold on to theories of wishful thinking and success that promote optimism. Importantly, we think it is unlikely that binary leaps in theory development underlie age-related declines in optimism. Rather, we propose

Box 4 | Implications for intervention

Optimism is linked to a range of positive outcomes in 6–18 year olds, such as good self-esteem[162–164], higher academic achievement[165,166], fewer internalizing and externalizing problems[163], fewer child-reported depressive symptoms and parent-reported behaviour problems, higher life satisfaction[167] and better general mental health[162]. Thus, although it is normative for optimism to decline with age, interventions might be warranted if a child's optimism prematurely and/or quickly declines.

Importantly, our conceptualization of optimism suggests that a steep decline in optimism might reflect adaptation to a suboptimal environment, rather than an internal, maturational process. In these contexts, lower optimism might help children cope with their day-to-day life because having more realistic expectations about their abilities might be necessary in the absence of strong social or environmental support. At the same time, early declines in optimism might cause children to prematurely disengage from appropriate challenges or form harmful beliefs about their agency, which could hurt their academic achievement and mental health[167,168]. Future work is necessary to figure out if, when, how and for whom optimism interventions might be most effective, and to determine what constitutes a rapid decline.

Given that most cognitive training interventions show limited effect sizes and transfer[169], the best way to change children's baseline optimism might be to ensure that they are consistently in environments that warrant it[76]. Thus, optimism in children could be used as a thermometer to test the soil in which children are growing up to see whether any adjustments are needed for the soil, not necessarily the seed[170]. As such, interventions should be pursued to the extent that they can provide children with safe and enriched environments. Such environments might spur optimism, and could have broad, cascading positive effects on children's outcomes[85,171,172]. Critically, the goal should be to ensure that children are in environments that enable them to rationally be optimistic, but not unable to calibrate their optimism based on future contexts.

Intervening in the environment might be most universally necessary during the transition to formal schooling, which coincides with decreases in optimism. Decades of work have shown that extrinsic rewards and evaluative contexts (which both increase at the start of formal schooling) reduce intrinsic motivation and self-competence beliefs[28,173]. Consequently, parents and educators need to rethink the ways in which students are evaluated, in terms of both external rewards and incentive structures (for example, grades and standardized tests) and how expectations and values are communicated in daily pedagogical interactions (for example, how teachers praise and provide instruction) to create contexts that merit healthy levels of optimism during this important time[174]. Children might also need better support for the emotional tolls that come alongside learning[175]. Going back to the seed and soil analogy, children's optimistic seeds can only grow to the extent that they are in supportive soil. Indeed, rigorous work has shown that growth mindset interventions (which arguably increase optimism) only work to the extent that school environments reflect these belief systems[176,177]. More broadly, considering interventions that intervene on the environment is consistent with calls in other subfields of cognitive development to consider how the social context shapes cognitive processes, and to develop interventions that capitalize on the contextual malleability of cognitive processes[178].

that more gradual, quantitative shifts in children's theory development likely contribute to optimism and that the rate of children's shifting theories is driven by their environment.

Conclusions

We proposed that children's optimism might decline from early to middle childhood owing to children's growing expertise with particular tasks and ongoing social feedback, which instigate changes in children's valenced learning bias, theories of success and wishful thinking. Because children's learning biases and beliefs are formed in response to their environment, the rate of decline in optimism for a given child might be influenced by the nature of their environment, with more adverse environments spurring faster declines.

Our account suggests that optimism is an adaptive bias that signals the nature of the environment children are immersed in rather than as solely an inherent, individual characteristic. This conceptualization of optimism is connected to the animal welfare literature, in which optimism is considered an index of the animals' environmental context rather than an individual difference[109–113], and has implications for interventions (Box 4). Critically, this definition of optimism requires focusing on state (versus trait) optimism tied to measurable ground truth (absolute optimism) or compared with the average (comparative optimism), which can enable researchers to measure the precise degree of optimism both within and across individuals.

Our unified account exists solely as a theory and important questions remain unanswered. For example, there are no longitudinal data on children's optimism so individual differences in the rate of optimism's decline, as well as how this rate differs based on children's experiences, remain unknown. Future longitudinal research could test the prediction that children in more adverse environments will show a steeper decline in optimism with age than children in less adverse environments, and whether neural changes in dopaminergic circuitry track with behavioural changes in optimism and valenced learning biases with age. Future research could also test the prediction that attending an academic-focused kindergarten decreases optimism owing to broadscale changes in social feedback by comparing optimism in children who attend kindergarten with age-matched peers who stay in preschool or children attending an academic-focused kindergarten with more evaluative feedback with children attending a play-based kindergarten.

More generally, some key gaps remain in the developmental optimism literature. First, with the exception of studies on motor development that tangentially index optimism[21], the youngest children in optimism studies are around 3 years old. It is therefore unknown whether declines in optimism begin from birth or whether optimism is relatively stable between birth and 3 years of age and starts to decline thereafter.

One limiting factor for testing optimism in children younger than 3 years old is that most optimism measures are explicit (for example, making physical or verbal predictions) and require basic verbal skills. However, the study of optimism in non-human animals demonstrates that optimism can be indexed on tasks with minimal verbal or cognitive demands. For example, in one study[109] European starlings were trained to press a green lever to receive a reward when they heard a 2-s tone and a red lever to receive a less desirable reward when they heard a 10-s tone. The birds were then presented with a 5-s tone. Birds in enriched (versus impoverished) environments were more likely to go to the green lever when presented with the 5-s tone, suggesting an optimistic bias. Future work could adapt similar ambiguous stimulus–cue decision-making paradigms for human infants to gain insight into the earliest developmental origins of the optimism bias.

Second, research on children's optimism has primarily been conducted in western contexts. Although we would expect declines in optimism across cultures due to biological maturation and normative human experiences, differences in cultural norms might influence the rate of decline. Indeed, work on concepts related to optimism (such as wishful thinking and beliefs about possibilities) suggests that culture might influence children's expectations of future performance. For example, as children get older they increasingly think it is possible to act against their desires (in other words, they increasingly believe in free will). However, the rate of this age-related change in beliefs differed between the United States, China, Singapore and Peru[23], and among these countries children's self-control abilities were only related to their beliefs about acting against desires in the United States; these results suggest that culture might moderate how children interpret their experiences[23].

However, the two studies that directly examined cultural differences in children's optimism found that optimism did not differ between children aged 4–5 years old in China and the Netherlands[53,114]. One possibility is these cultures do not vary on the dimensions most crucial for the development of optimism. For example, although China and the Netherlands differ in their modesty norms[115–119], they are both industrialized cultures that place a strong emphasis on educational attainment and have relatively high parental involvement[120,121]. Optimism might decline at younger ages in cultures where children have less direct instruction and, instead, learn through observation and participation in daily tasks because errors might be more costly[122–124]. For example, children aged 5–6 years in rural Peru (Quechua indigenous community in the Andean highlands) use machetes to help on their family farm[125]. In this context, a child thinking they are overly capable could lead to the loss of a finger. By contrast, children aged 5–6 years in western cultures (such as the United States and Canada) are rarely given knives even with parental supervision. Thus, more research is needed across cultures with more varied parental and pedagogical practices to see how these features relate to the development of optimism.

Finally, although prior work has explored optimism in other species (such as honeybees[126], European starlings[109], rats[127], pigs[113] and macaques[128]), it is unknown whether optimism declines with age in non-human animals. Understanding whether age-related declines in optimism are shared across species would help clarify the mechanism underlying humans' age-related declines in optimism. Specifically, if declines in optimism are a universal or biologically programmed part of development, some degree of age-related declines in optimism might be expected across species. If declines in optimism are shaped by the degree of available social support, then species with shorter weaning periods might be expected to have a faster decline in optimism than species with longer weaning periods. Also, if declines in optimism are largely shaped by specific human-created features of the social environment (such as schooling), then the same age-related declines might not be expected in non-human primates. Thus, cross-species investigation of optimism provides an opportunity to test our account.

In sum, although the decline of optimism across human development is ubiquitous, the rate of this decline might reflect the nature of the children's environments. More research on this phenomenon will lead to a better understanding of how the human mind develops and how best to help children reach their full potential.

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