**Not Wasted on the Young:**

**Childhood, Trait Complexes & Human Behavioral Ecology**

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**Abstract**

Hypotheses about the evolution of multi-trait organismal features often encounter trade-offs between the *precision* and *historical relevance* of tests performed in actualistic contexts. That is, highly precise tests aimed at discriminating between competing hypotheses often incur a risk of explanatory misalignment with the historical phenomenon they target. We illustrate this via a discussion of the evolution of childhood. We argue childhood is a *trait complex*, consisting of multiple, diverse components: patterns of growth, feeding strategies, staggered skill acquisition, and social dependence. The potential of their independent evolution bears important consequences for the evolutionary significance of tests probing the adaptive benefits of childhood in contemporary foraging communities. Via ‘isolation-testing’ such investigations aim for precision at the cost of historical relevance in a potentially serious way. We suggest that integrative investigations relying on the timing and context of components’ evolution, emphasizing historical relevance, frame evolutionary hypotheses more reliably than the emphasis on precise tests currently common, thus bearing a higher explanatory potential.

**Keywords**: adaptation, childhood, human behavioral ecology, hypothesis-testing, learning, trait complex

1. **Introduction**

Every organism’s life cycle is articulated by phases of growth: from conception to death, through development and maturation. Humans (as in many other ways) are weird in this regard. Our life histories have a peculiar arrangement of developmental milestones and come with new additions, childhood for instance. Primates already spend a fair amount of time growing, but childhood as a life-history stage is putatively unique to the *Homo* lineage (Bogin 1997, 2020; Bogin and Smith 1996; but see Gunz et al. 2020 for suggestions of childhood’s preludes among *Australopithecus*). Moreover, it is disproportionately prolonged in our particular hominin twig (Leigh and Park 1998): *Homo sapiens’* childhood is an “exaggeration of an already exaggerated feature of the primate order” (Gurven et al. 2006).

In this paper, we want to make a conceptual argument concerning childhood—claiming it is a ‘trait complex’—and use this to draw out a tension between what we’ll call ‘precision’ and ‘historical relevance’ when attempting to use actualistic evidence to test evolutionary hypotheses concerning trait complexes (as seen in some human behavioral ecological work on childhood). So, we’re both making a potentially general claim about the relationship between actualistic tests and trait-complexes, and a more local claim about the nature of childhood.

Raising children is work. Vulnerable, slow-maturing, and hungry-brained young need to be protected, cared for and fed with food appropriate for their immature dentition. Compared to other apes, this protracted period of dependency is associated with an earlier resume of ovulation and shorter interbirth intervals in humans, a combination of “slow” and “fast” life-history traits (Wrangham and Carmody 2010). Thus, our species has more helpless, needy children, and their needs stack up. If childhood is so costly, what evolutionary story could account for it? And how might that story gain empirical traction? Unsurprisingly, scholars across many disciplines have tackled evolutionary questions about childhood, with perspectives ranging from evolutionary, biological and cultural anthropology, to archaeology, psychology, and public health (see Meehan and Crittenden 2016). Here, we are interested in understanding childhood as an evolutionary phenomenon with deep roots in our ancestral history, rather than specific cultural conceptions of childhood that arose much later[[1]](#footnote-2).

Childhood, we’ll argue, should be understood as a *trait complex*. A trait complex consists of multiple, potentially independent (evolutionarily and developmental) components that tend to ‘hang together’ from the perspective of the end of an evolutionary sequence, but may not have evolved as a package. These instead may have evolved mosaically, at different times and bearing different (or no) adaptive value. In virtue of this, there is no simple logic of causal inference regarding childhood: integrative approaches are needed, rather than what we’ll call *isolation-testing.* By “isolation-testing” we mean characterizing a target phenomenon and related explanatory hypotheses so we can (i) derive clear-cut, competing predictions on the role of isolated factors of interest and (ii) test them against observational or experimental data.

Our strategy is to examine approaches to testing aligned with Human Behavioral Ecology (HBE), which traditionally uses contemporary foraging communities to evidence adaptive hypotheses concerning childhood. We’ll begin by briefly reviewing two central hypotheses in the evolution of the human life course and childhood, the Grandmother Hypothesis and Embodied Capital Theory. We then examine how these hypotheses play out in one common methodological strategy: optimization analyses adopted by HBE. We’ll argue that although the isolation strategies adopted by HBE are required for generating tests, this isolation itself means that they cannot be taken to establish either hypothesis.

Far from suggesting that HBE should not play a role in explaining the evolution of ‘trait complexes’, our claim is that the strategy of isolation-testing does not alone test how the childhood complex evolved. The relevance of tests to the deeper evolutionary history of childhood—their explanatory alignment to the historical phenomenon they are intended to target— needs to be probed or carefully constructed, rather than taken as a working assumption. This paper then, has three main goals: (i) characterize childhood as a trait complex, (ii) highlight the trade-offs between precision and historical relevance in HBE isolation-testing targeting childhood’s adaptive profile in actualistic contexts, (iii) advocating for an integrated approach in addressing the evolution of childhood. Childhood’s heterogeneous nature and temporal spread through deep time make it resistant to the strict tests some HBE approaches aim for. These, we’ll argue, have higher explanatory power when integrated into (and calibrated by) richer historical and archaeological contexts.

1. **What is childhood?**

How evolutionary questions are answered turns crucially on how the phenomenon at hand is characterized. Variation in childhood’s characterization across anthropological subdisciplines (cfr. Meehan and Crittenden 2016) betrays not only different disciplinary interests but also the complexity of ‘childhood’ itself. In the following, we’ll argue that childhood as a life-history stage should be understood as a trait complex.

We call ‘trait complexes’ organismal features that (1) consist of different subcomponents which (2) could in principle evolve independently (‘mosaically’), so long as they can be developmentally or functionally decoupled. Trait complexes coalesce and likely become entrenched at some point during evolution, often appearing as a unified package after the fact.

In terms of life-history*,* childhood can be defined as one of the five stages of human growth and development, following infancy and preceding juvenility, adolescence (another *H. sapiens* oddity), and adulthood (Bogin and Smith 1996). Each stage is characterized by changes in growth rate, feeding system, and physical and cognitive abilities. Childhood is usually comprised between the ages of about 36 to 83 months after birth. It consists in slow body growth, accelerated brain growth, and extended dependence on parents and alloparents for provisioning. Bogin defines childhood as “the period following infancy, when the youngster is weaned from nursing [that is, when breastfeeding ceases] but still depends on older people for feeding and protection” (1997). Despite common usage, then, we shouldn’t conflate ‘juveniles’ and ‘children’: the former can feed themselves. During childhood new motor and cognitive skills mature, such as competent bipedal walking and language improvements (in phonology, vocabulary and sentence length). Towards childhood’s end, the so-called ‘5-to-7 year old shift’ takes place. This period marks increasing capability for inhibitory control, maintaining attention on complex problems, self-regulation, planning, reflecting and other visual/perceptual and social abilities (Weisner 1997).

Bogin insists that childhood is an evolutionarily novel life-history stage (Bogin 1997, 2020). Crucially, this means that childhood could not be obtained by simply altering the developmental timing of primate life stages. Not only is childhood nowhere to be found among social mammals (which postpone puberty by inserting a juvenile period of growth and behaviour), but it wouldn’t merely be the result of a heterochronic tweak in the primate way of running the developmental business. This stands in contrast with interpretations of humans as merely delayed apes (focusing on neoteny as the key heterochronic process, see Gould 1977) and/or as growth prolonged apes (‘hypermorphic’, McKinney and McNamara 1991) (cfr. Bogin 1997). Differently put, you do not get childhood by simply slowing down chimpanzee growth, nor by extending it. In childhood, body growth slows unevenly, with muscle development in the legs charging ahead of arms development after weaning (Bogin and Varela-Silva 2010), while brain growth increases. This makes for a difficult evolutionary puzzle: a simple story involving selection for increased brain size (say) favoring slower or longer growth will not alone generate childhood (see Buskell & Currie 2021 on evolutionary uniqueness).

As such, childhood can be defined both as a particular life-history stage and as a trait complex consisting of subcomponents[[2]](#footnote-3) pertaining to different growth patterns, feeding systems, cognitive development and patterns of dependence on conspecifics. This trait complex has converged in the human lineage, forming a cohesive cluster. However, from an evolutionary perspective, it is less obvious that childhood traits have evolved together as opposed to as a mosaic.

It is now acknowledged that patterns of integration and modularity among traits within a phenotypic complex can vary within a single organism during development. At larger timescales, from generation to generation and between species, the complex tapestry of integration and modularity is itself known to evolve, also to better support adaptability as environmental conditions shift (for a review, see Evans et al. 2023). Therefore, although there may well be relevant degrees of integration and co-variation among traits, especially in the most recent stages of the complex’s evolution, there is no reason to think that childhood growth patterns, for instance, evolved at the same time. On the contrary, available evidence suggests this isn’t the case. Prolonged brain growth has been observed in combination with ape-like brains, as in *Australopithecus afarensis*, suggesting that slow brain growth may have not appeared with large endocranial volumes during evolution (Gunz et al. 2020). Further, it is easy to imagine the evolutionary decoupling of the timing of weaning and specific patterns of growth. In human pre-industrial societies weaning takes place at a very early stage of growth and development (at about 2.5 years, before reaching three times birth weight) compared to any of the other great apes (at about 5 to 7.7 years in chimpanzees and orangutans) (Kennedy 2004). And differently from most other primates and mammals, our weaning is decoupled from the first molar eruption, occuring years before the first permanent tooth pops up (Smith et al. 1994). This suggests that even traits pertaining to the feeding system and dental development have explored different configurations across phylogeny (see also Robson and Wood 2008).

Following this, there is no reason to think that all the traits associated with childhood served similar (or any) evolutionary functions throughout their history. Just as they might be *developmentally* decoupled, allowing for their emergence at different ontogenetic times, they might also be, or have been, *functionally* decoupled: evolving for differing purposes (see Avin et al 2021 for discussion of evolutionary decoupling). This can hold even when the trait complex in contemporary human groups can be understood as fulfilling a single adaptive function. As such, treating childhood as a unitary trait or as a cohesive unit of selection—betting on the stability of patterns of integration and functional profiles throughout evolutionary history without independent reason—is risky[[3]](#footnote-4) (for issues related to trait identification, see Meneganzin et al. 2024). There are dangers in looking back—from the perspective of a particular, stabilized trait complex—and imagining that to explain its evolution we need to explain how the whole setup evolved together, especially when considering novel, complex, and putatively unique stages like childhood.

Defining and characterizing childhood, then, is neither a trivial nor neutral task. Also, how childhood (or features thereof) relates to specific organismal traits at the expense of others matters. It is no wonder that, until recently, as Gopnik et al. (2020) remind us, the long human childhood was treated as a mere epiphenomenon of narrow pelvises and big brains instead of a phenomenon with its own evolutionary significance. Childhood was understood as ‘waiting time’. Elsewhere, delayed maturity is explained as an artifact of a longer life span in general (Charnov 1993, Hawkes 1998): here what needs to be explained is the human lifespan itself, not what we call “childhood”.

Finally, when childhood is presented as a unique human quirk, its ‘uniqueness’ critically depends on which biological constraints on childhood are conserved and which differ from a comparative phylogenetic contrast class. This involves comparative analyses between the distinctive human life history trajectory and that of both extant taxa (modern great apes) and extinct lineages (e.g. Robson et al. 2006; Robson and Wood 2008; Bogin 1997, 2020). Further, this also requires indirect evidence – proxies (or, as Robson and Wood 2008 call them, ‘life history-related variables’) that allow inferences of various aspects of the childhood complex in fossil taxa. Therefore, how childhood is framed in deep time depends on the reliability of such proxies as good predictors of the traits of interest. For an evolutionary explanation of why childhood first established, it is crucial to look at *when* relevant characters of human childhood departed from those of closely related lineages, and under which circumstances (Griffiths 1996). Differently put, as the timing of events across the life course matters (ontogenetically), so does timing across hominin deep history (phylogenetically).

The abovementioned conceptual and epistemic challenges matter for any attempt to explain the evolution of childhood and infer its relevant causes. Let’s consider two major theoretical models for the evolution of human life course and see how they frame childhood.

1. **Grandmothers and Embodied Capital**

Multiple hypotheses have been proposed to explain the evolution of childhood and delayed maturation. These span from the avoidance of resource competition during fluctuations in food supply (Janson and Van Shaik’s “risk aversion hypothesis” 1993), to trade-offs between optimal age at reproductive maturation and physical growth (Charnov 1993), to the “control of fire hypothesis” (Wrangham and Carmody 2010), to models based on the complexity of the human foraging niche, focused on learning (Kaplan et al. 2000) or on cooperation and pooled energy budgets (Kramer et al. 2010).

Two hypotheses, in particular, have been interpreted in human behavioral ecology literature as attributing different weight to learning in selection for an extended pre-reproductive period, thus yielding competing predictions. These are the Grandmother Hypothesis (Hawkes et al. 1998, 2003) and the Embodied Capital approach (Kaplan et al. 2000, 2009). Despite having elements in common, such as highlighting intergenerational resource transfer, they have been traditionally contrasted due to differences in the specific predictions involved. These differences, it is claimed, allow researchers to test such predictions against observational or experimental data (e.g. Gurven et al. 2006, Gurven and Kaplan 2006, Bird and Bird 2002, Blurton Jones and Marlowe 2002, Pretelli et al. 2022). Our brief discussion of these hypotheses is illustrative: we’re aware that more theoretical nuances are available in the literature (see Gurven 2024). However, we think that the consolidated theoretical and fieldwork on this specific contrast is helpful to walk us through our main argument. So, let’s see these hypotheses in turn.

The Grandmother Hypothesis (GH) builds on Charnov’s (1993) ‘assembly rules’ for mammalian life history. In a nutshell, there is a compromise between time spent growing and time spent reproducing, and therefore, for a given evolutionary regime, there will be an optimal age to end the juvenile phase and start reproduction. This timing is influenced by adult mortality rates, which determine the duration of the adult lifespan and the odds of reaching reproductive age. This would account for the variation in life history across various animal taxa. Hawkes and colleagues (1995, 1998, 2003) reasoned that this pattern is well exemplified by humans, suggesting it explains the extended adult lifespan – and in particular, female long post-reproductive lifespan – in light of inclusive fitness benefits provided by kin.

Young require provisioning due to the difficulty of acquiring or processing resources. Variation in Hadza foraging illustrates that when non-demanding resources are available (like seasonal fruit), provisioning is less pressing and mothers and children can forage together. But for most of the year, adults must forage for richer and more difficult resources unencumbered by young, so children waiting at the camp must be provisioned, opening opportunities for older members of the band to help and in doing so enhance their inclusive fitness (Hawkes et al. 1995, Blurton Jones and Marlowe 2002). Hawkes and colleagues project this argument into the deep past, suggesting that the more vigorous and active members of kin groups (older females, aunts and “grandmothers”) would have then been favored by selection, this, in turn, anticipated the weaning schedule of the dependent offspring and delaying the age at first reproduction (which ends the juvenile period).

Under the GH, we have childhoods because we live long, and any benefits deriving from a prolonged childhood are not necessary to explain it. Under the GH there is no direct link between life history and increased brain size: Hawkes and colleagues (2002)[[4]](#footnote-5) claim that the separation by some million and a half years of major changes in hominin life history and the major increases in brain size observed in *Homo sapiens* indicate that encephalization requires a distinct explanation. Big brains matter inasmuch we quickly learn foraging skills once we’ve reached adult size (Blurton Jones and Marlowe 2002). By this hypothesis, childhood can be understood as a *spandrel* (Pievani and Serrelli 2011, Meneganzin et al. 2024), that is, originating as the result of selection for some other correlated trait(i.e., the elongated adult lifespan). There may have been downstream fitness benefits to childhood once it was established—childhood could have become an *exaptation*—but we need not appeal to these in explaining its evolutionary emergence.

By the Embodied Capital approach our delayed maturation, longer lifespan and increased encephalization coevolved with the demanding human foraging niche (Kaplan et al. 2000, 2009). In contrast to the GH, it takes selection to have acted on childhood directly, that is, it is an adaptation: intergenerational resource transfer is so important that, when early learning guarantees high production payoffs, natural selection would have acted on extending early life. Indeed, demanding but energy-packed resources are an important part of human diets, and their acquisition requires high levels of coordination, knowledge and strength. The Embodied Capital framework hypothesizes that these skills and knowledge (the “embodied capital”) are acquired during a protracted period of development. Low productivity and its associated costs early in life would be compensated by lifetime productivity: early investment in embodied capital would pay off future productivity and survival. Under this framework it is predicted, for instance, that children’s foraging proficiency should track knowledge and skill acquisition, gradually increasing as the youngsters become more experienced (Bird and Bird 2002, Gurven et al. 2006, Pretelli et al. 2022).

One point is worth emphasizing here. It is not controversial that childhood learning is required to acquire foraging skills. What is controversial is whether learning is a cause or consequence of delayed growth (cfr. Gurven et al. 2006, p. 464). The EC model suggests that our long childhoods evolved in order to accommodate learning complex foraging skills. Children’s gradual acquisition of skills, specializing in relatively easier foraging tasks early on (like fruit, fish or shellfish) and gaining skills in more complex tasks later is also compatible with models emphasizing cooperation and coordination between young and adults, like the “pooled energy model” in which children not only absorb resources but actively contribute to the economy of the foraging community (Kramer et al. 2010).

For our purposes what matters is the use of the GH and of the EC model to obtain contrasting predictions that can be tested against extant foraging people. For instance, the GH is said to predict foraging proficiency as a function of body size alone – it is limited by “growth-based’’ rather than “experience-based” capital – while EC requires both size and delayed learning (Kaplan et al. 2000, Bird and Bird 2002, Bock 2002, Gurven et al. 2006). Testing these predictions putatively provides access to the evolutionary mechanisms that may have promoted the evolution of childhood. Famous examples are provided by the long-term focus on human hunting as a skill-intensive activity (both for extant and past foragers) that allows testing which factors most significantly constrain hunting proficiency (Gurven et al. 2006, Koster et al. 2020; for a broader discussion not limited to hunting, see Pretelli et al. 2022).

Thus, the GH and EC assign different evolutionary functions to learning in the evolution of childhood. In the next section, we examine one strategy for testing these differing claims: what we’ll call ‘isolation-testing’ in Human Behavioral Ecology (HBE).

1. **The Human Behavioral Ecology of Childhood**

Let’s characterize a strategy for testing claims about the causes of childhood’s evolution, typically associated with approaches within HBE. Crucially, this involves characterizing the hypotheses we saw above in ways that emphasize the *precision* of tests, that is, their ability to discriminate between clear-cut, competing scenarios. This, we’ll show, comes at the risk of an explanatory misalignment with the historical phenomenon targeted—the evolution of childhood as a trait complex. Put differently, while tests may be empirically tractable in actualistic contexts, there is a danger of losing sight of the historical relevance of results. While not necessarily a feature of general hypothesis-testing strategies, we suspect this is a common challenge when studying features characterized by trait complexity and deep history. To see this, let’s begin by looking at how the testing process unfolds.

As we saw in the last section, several hypotheses have been developed in light of the odd phenomenon of childhood in our lineage (and other life-history traits). In a nutshell, one set of hypotheses (the Grandmother Hypothesis and its extensions) takes childhood to be a by-product of elongated lifespans, with any potential benefit arising from childhood being unnecessary for explaining its emergence. Grandmothering mitigates the costs of putting off breeding maturity, thus boosting grandmothers’ inclusive fitness. Another set of hypotheses (the Embodied Capital Framework and its extensions) has it that fitness benefits accrue directly from childhood: it is an adaptation to and for the peculiar human foraging niche, not a byproduct of other benefits. Here, time is required to flexibly and plastically learn the varied foraging strategies, and childhood is an ontogenetic adaptation to accommodate learning. How might we test these hypotheses?

The strategies underlying HBE go as follows. First, notice that both hypotheses make claims about the *adaptive* benefits of childhood in the context of its evolution: those appealing to embodied capital, most obviously, claim that the flexible learning of childhood brings adaptive benefits in the relevant foraging niche. By contrast, according to the GH, it is the gain of physical growth that matters. Second, such hypotheses can often be represented abstractly using optimality models. That is, given a set of idealizing assumptions, by the embodied capital model childhood should be an optimal solution to a design problem, that is, how to learn sufficient skill to make do in particular foraging niches (for discussions of optimality models in human behavioral ecology see Nettle et al 2013). Third, these optimality hypotheses can be used to develop tests of the relevant hypotheses by comparing the expectedoptimality – an optimal age ordering of time allocations and foraging proficiency regarding particular foraging skills – with actualempirical data. This is most commonly carried out via examinations of contemporary foraging communities. Insofar as said communities align with expected optimality, it is thought, our credence in the model raising the correct prediction should increase. In the context of the EC hypothesis, if patterns of childhood foraging simply do not track the optimal ordering of strength-dependendent and skill-dependent activities, this is bad news for the hypothesis: “Any other ordering of these age profiles would provide evidence against the EC” (Gurven et al. 2006, p. 456).

A classic study by Gurven et al. (2006) on Tsimane Amerindians of the Bolivian Amazon aims at testing whether hunting production is more limited by physical capital (as predicted by the GH) or by brain-based capital (skills and learning, as predicted by the EC model). Simply put, looking at when the peak of resource production or performance in some of its components is reached provides a window into the adaptive benefits of extended development and childhood. If the age of peak physical strength does not align with that of peak performance—the latter being significantly delayed with respect to the former, for instance—then the acquisition of skill and learning is interpreted as a driving force in the acquisition of a specific ability. Drawing on observational, interview and experimental data, Gurven and colleagues analyzed the age trajectories of hunting ability and physical growth, testing the EC and GH’s differing accounts of what limits adult productivity. The study famously concluded that the more demanding skills required in hunting (from direct encounters to successful kills) require up to twenty years to be mastered after reaching adult body size. This was taken to support the EC-derived prediction on the age ordering of the less and more demanding hunting skills: indirect encounters and strength peak earliest, while direct encounters, kill rates and return rates peak much later, alongside the incremental acquisition of “experience”. Combined with the observation that foraging niche complexity and life history traits are correlated among taxa (Schuppli et al. 2016), these results are interpreted as highlighting the factors that may have triggered the evolution of childhood.

Elsewhere, Gurven and Kaplan (2006) translate the predictions of the GH and the EC theory in terms of optimal time allocation decisions, based on extensions of the EC theory with time allocation theory (Bock 2002, Bock and Johnson 2004). This is based on the idea that, given the impact that time allocation decisions have on fitness, the optimizing force of natural selection would have acted on the underlying psychological and physiological mechanisms, especially regarding activities involved in acquiring food resources (along with other fitness-relevant activities). So, individuals would allocate their time to maximize utility and fitness (Becker 1991). In the context of EC and GH’s differing predictions, if the EC theory is correct, children should engage more heavily in low-strength and low-skills activities, switching to higher-strength and higher-skills activities later on – a prediction that is met by tests among the Machiguenga and Piro of Peru (Gurven and Kaplan 2006).

Similarly, a more comprehensive study on published records of children and adolescent foragers from 28 societies quantified the degree of skill-intensiveness of various resources and assessed children’s pace of increase in proficiency for the more skill-intensive ones. The slower increase of foraging returns for the more difficult resources (USOs and game) compared to the easier ones (fruit and marine resources) are suggested to “support the view that complex resources require a longer investment in learning and thus, in line with ECT, may have promoted the evolution of childhood.” (Pretelli et al. 2022, p.4).

Such approaches, on the face of it, seek to test hypotheses in a familiar way. Lacking the benefits of practicable repeatable experiments, we can derive expected observations from available hypotheses, and we can test these observations against empirical data. In principle, at least, the hypotheses can be presented as mutually exclusive options that empirical observations might bear on. They thus have the benefits of precision and empirical contact.

Before getting to our central point, it is worth noting there are a few well-trodden worries with this strategy which bear relevant implications for the childhood case. Well-trodden because (despite protestations to the contrary), aspects of an adaptationist stance remain central to the HBE approach. Although behavioral ecology has been vocally critical of the kind of nativist adaptationism typical of evolutionary psychological approaches[[5]](#footnote-6) (see Downes 2001 for a discussion) and remains mechanism-agnostic, that is, about whether behavioral adaptations are ‘innate’ or plastic (Nettle et al 2013), the use of optimality models to explain the evolution of a developmental stage like childhood can only be justified via appeal to the optimizing power of natural selection.

Most notably, the causal hypotheses we are interested in are not (supposed to be) about contemporary foraging communities, but about foraging communities during the evolution of childhood—which spans at least 2 million years of human history[[6]](#footnote-7). The evolutionary question we started with was: why did the *Homo* lineage “invent” *bona fide* childhood, putatively starting from erectine lifeways? Whether some behavior is adaptive in a particular environment, and whether a trait is an adaptation, are of course differing questions. Extrapolating conclusions on the latter from tests that frame the former requires extra inferential justification. Such tests, then, imply a kind of uniformity assumption regarding the link between the traits of the childhood complex and their adaptive profile: contemporary foragers are taken to be representative of foraging groups within our lineage, or to be sufficiently similar to groups in the past. It is worth noting that the uniformity assumption seems required *even if* we take a methodological stance (Godfrey-Smith 2001), in which adaptationism is taken as a ‘hypothesis-generation engine’ (Nettle et al. 2013). But there are several major issues here (some of which are covered more generally in Driscoll 2013 and Borgerhoff Mulder 2013).

First, there is little guarantee of uniformity across childhood’s adaptive profile. Although a careful incorporation of archaeological, paleontological and paleoenvironmental data (wherever available) could potentially empirically (and interestingly!) probe uniformity, it is more frequently taken as a working assumption than as a hypothesis in need of targeted tests[[7]](#footnote-8). However, if uniformity fails in the relevant ecological and sociocultural environments, it may well be that childhood learning, for instance, while undoubtedly providing adaptive benefits in contemporary foraging communities, had a different adaptive weight, or at the very least a distinct cost-benefit profile, in the initial appearance of childhood. At base, the common use of ethnographic information to test claims about childhood’s evolution comes with the usual worries about ethnographic analogies (Borgerhoff Mulder 2013, Currie 2016, Wylie 1985).

Second—and connected to the former point—establishing the adaptive benefits or otherwise of childhood in contemporary communities misses the mark. This is because the relevant hypotheses concern the *emergence* and evolutionary journey of the life-history trait complex, not its final destination alone. There is no guarantee that childhood, even if it is adaptive, is not an exaptation. Indeed, it could well be that a grandmother-like adaptive regime set off a ratchet that then incorporated an embodied-capital regime. As such, at bestestablishing the adaptiveness or otherwise of childhood in contemporary foraging communities gives us information about the maintenance of the trait complex over recent evolutionary time, but this in itself doesn’t explain its emergence. Bogin seems to suggest something along these lines when expressing skepticism about learning-based hypotheses: “they don’t account for the initial impetus for the insertion of childhood into human life history. A childhood stage of development is not necessary for the type of learning listed here. The prolonged infancy and juvenile period of the social carnivores and apes can serve that function” (2020, p. 230). For this reason, he speculates that childhood is best seen as a feature of human biocultural reproduction: “some form of genetically-driven cooperative/communal breeding strategy in the earliest species of *Homo* would have been necessary to promote and sustain the evolution of childhood, with its increased requirements for prolonged and more intensive care” (p. 234, see also Bogin et al. 2014). In short, establishing proximate adaptive benefit is only distantly connected to past adaptation.

These two related worries specifically concern the adaptationism underlying this mode of testing—complaints surely familiar to philosophers of biology, at the least. The next two go beyond these, and focus our gaze on our original philosophical contribution: childhood being a trait complex puts further constraints on the value on the isolation testing sometimes associated with HBE.

Third, then, insofar as childhood is a trait complex, even if we are licensed to treat it as a package deal in contemporary foraging communities, there isn’t obvious reason to treat its emergence and downstream evolution in the same terms. In fact, there’s increasing evidence that the biological and behavioral evolution of the hominin lineage is consistent with mosaic patterns (Foley 2016, Parravicini and Pievani 2019) and that modern human life-history itself was assembled in such a fashion through evolutionary time (Bogin and Varea 2020). Given the diversity of traits subsumed under the ‘childhood’ life history stage, it is plausible that there are distinct evolutionary histories to be told about – for instance – the initial reduction of the infancy (nursing) stage and the cognitive and skill acquisition benefits of the childhood stage. Further, the extra childhood time seen in *Homo sapiens* hints at an even more specific story about how the costs of childhood have been mitigated to preserve its benefits in the last stages of the human career.

Fourth, the strategy of generating quantitative, precise and mutually exclusive hypotheses requires omitting and black-boxing other information – potentially sacrificing historical relevance for precision. In HBE, the specific black-boxing in place is tied to assumption that the nature of the proximate mechanisms underlying the emergence of a trait (or a life-history stage, in our case) can be ignored in the project of explaining its function. This black-boxing is often called the ‘phenotypic gambit’ in behavioral ecology (Ready and Price 2021). This strategy potentially biases the investigation against certain kinds of hypotheses – most obviously, mosaic hypotheses. In particular, simplifying the exact aspects that we’re supposed to explain is dangerous. Being agnostic of the mechanisms behind a specific trait does not work if the goal is answering an evolutionary question that requires detail concerning those exact mechanisms. We’ll expand on this fourth point in the next section, where we focus on isolation-testing.

1. **Black-boxing, gambits & isolation-testing**

We’ve raised four worries about the strategy of using extant foraging communities to test hypotheses about childhood’s evolution and fitness benefits. Some will be familiar to those versed in objections to Evolutionary Psychology, but we think the final two are less recognized. Specifically: because childhood is a trait complex, hypotheses of its evolution that are characterized so as to provide precise actualistic tests sacrifice historical relevance—the grip on the timing, order, and context of the appearance of traits— for precision in a potentially misleading way. Such tests can be said to be explanatorily aligned with highlighting childhood’s adaptive benefits in the recent stages of hominin evolutionary career. However, if not operating in tandem with archaeological and paleoanthropological evidence (see section 6), the implication that such tests are historically relevant for earlier stages of childhood’s evolution requires further justification. Throughout millions of years of evolution, hominin life histories faced specific trade-offs dictated by unstable selective regimes and evolving sociocultural profiles. So, let’s start by focusing on the strategy that maximizes precision, what we’ll call *isolation-testing*.

*Isolation-testing* takes a complex phenomenon and focuses on a small number of that phenomenon’s properties (or specific traits within a trait complex) that are taken to differentiate between relevant hypotheses. These isolated properties are put to empirical tests. As we’ve seen, the Grandmother and Embodied Capital approaches are construed as claims about the proximate benefits of learning—these properties are isolated—and these are tested against contemporary foraging communities. It is paradigm isolation-testing. When is this approach justified?

Philosophical work on justifications of ‘black-boxing’, that is, omitting particular information, when trying to understand token events, can be divided into two strategies: *explanatory* (e.g., Weisberg 2007) and *testing* (e.g., Orzack & Sober 1994). The former claims that the information omitted is not explanatorily relevant—they are details of the particular case that obscure the essential dynamics explaining the event. An HBE defender of the GH, for instance, might insist that the fundamental reason childhood evolved is, at best, an exaptation of kin selection for alloparenting and increased lifespan. Information about the adaptive benefits of childhood might matter for other questions, but is irrelevant for the ultimate explanation of its evolution. The latter defence of black-boxing claims that in order to test a hypothesis one must hold fixed particular variables in order to intervene (or at least pseudo-intervene) on the variable of interest. An EC tester, for instance, might point out that the theory involves a specific claim concerning the adaptive benefit of childhood length, which could be tested using proxies such as the number and type of resources procured by foraging individuals at different ages. In order to compare that empirical data to an optimization model, we need to ignore a bunch of other information. We’ll take these justifications in turn.

As Angela Potochnik discusses, explanatory black-boxing often involves explanatory *independence* but epistemic *interdependence* (Potochnik 2010). By this, she means that the admissibility or empirical justification of the black-boxed explanation sometimes turns on information from *within* the black box. For instance, a typical defense of the phenotypic gambit is that regardless of how the phenotype is produced, what matters is its fitness-enhancing role (see Ready and Price 2021 for a more extended discussion). So, for an HBE defender of the EC model, what matters is the fitness-enhancing role of childhood in providing learning benefits, regardless of what mechanisms might underlie the emergence of such learning skills. But that would precisely be the point of providing an evolutionary explanation of childhood. And if we stop learning the most fundamental foraging skills before growth completes, then the explanation is in epistemic trouble. Given that factors regarding the timing, adaptive benefit, and so on, of particular elements of the childhood complex are exactly what are under empirical scrutiny, we might think that although developing such potential explanations is fruitful, committing to them at this stage would be epistemically imprudent.

Another approach to justifying black-boxing refers to testing. Here the purpose of omitting information is to generate precise hypotheses to be empirically tested. The issue here, specifically for the strategy of HBE, concerns *what* hypothesis is exactly being tested. As we’ve seen, the vast majority of studies draw on ethnographic information from contemporary foraging communities. That is, information concerning the adaptive dynamics of the ‘full package’ as it plays out in those communities. What might this have to do with establishing the evolutionary causal story about how that package emerged? It might provide an opportunity for falsification: as we’ve seen with Gurven and colleagues’ example, if childhood foraging in contemporary communities doesn’t align with the age profile ordering predicted by an optimality model, then that spells trouble for the embodied capital hypothesis. It is worth noting that if childhood’s evolution is complex, it is possible for a once-adaptive trait to become non-adaptive after various phases of exaptation. So even a negative result is not a strict falsification in the sense of generating logically inconsistent claims. Thus, negative results provide very weak evidence which is not borne out by most discussions, implying that these studies do more than simply attempt to falsify the hypotheses. Another approach might appeal to a uniformity principle between contemporary and past foragers; that, say, foragers at any time should be expected to follow the (relevantly) same dynamics, and so potential differences can be ignored in testing adaptive models of foraging. There may well be quite general and interesting things to say about foraging, but we don’t think such uniformity assumptions are justified in this instance. Why? Because the evolutionary journey from an ancestral, non-childhood state, to a contemporary childhood state is exactly what we’re trying to test. Assuming uniformity makes little sense.

So, on the face of it, the black-boxing strategy HBE proponents sometimes appeal to at best only test hypotheses about the evolutionary causes of childhood in a minimal, falsifying sense, or requires extremely risky assumptions about uniformity. In this instance, the idealization involved in isolation-testing takes the hypotheses too far from their intended historical relevance and grip. However, we do think that nonetheless such work can provide a crucial line of testing for such hypotheses. We’ll suggest how in the next section.

1. **Packages & Mosaics**

As we’ve seen, in the context of the evolution of childhood HBE as a strategy involves testing optimality hypotheses against (typically) ethnographic data towards establishing—or at least potentially refuting—hypotheses concerning evolution. We’ve argued that assumptions of uniformity about childhood’s adaptive profile, childhood’s long evolutionary history, and its tricky structure as a trait complex, undermine this strategy. It does so by raising the possibility of mosaic evolution: different aspects of the complex could have evolved at different times, for different (or no!) evolutionary purposes, meaning that attempting to refute hypotheses that already treat childhood as a package makes substantive, risky assumptions. Further, the complexity of childhood makes isolation-testing incapable of providing clear-cut empirical tests, *contra* what some scholars working in the field might claim. In saying this, we want to emphasize that we are not discounting the virtues of formulating precise predictions and testing them against empirical data. Rather, our claim highlights the importance of striking a desirable balance in a challenging trade-off—one that avoids sacrificing its evidential relevance on the altar of empirical tractability or simplicity by departing from critical aspects of the historical target. Indeed, we think such testing work can play an important role, and in this section we’ll sketch how.

Standard adaptationist approaches to evolution involve *retro-engineering*: we characterize a trait *as it is now*, and then posit environmental conditions in the past which could explain that trait’s evolution. One issue with this approach is that it underestimates the role of historyinevolutionary explanations. As Thomas Reydon has shown, evolutionary explanations should be understood as *comparative-composite* explanations, that is, they combine processual information about a lineage with comparative information about how evolution normally works to generate a picture of the lineage’s evolvability (Reydon 2021). Without the history properly understood, the evolutionary dynamics do not gain explanatory traction (see also Currie 2021). Especially for non-individualized but unique trait complexes, this will not do. Instead, we might proceed as follows.

First, the past phenomenon needs to be characterized. This doesn’t (alone) involve characterizing the complex in contemporary lineages—in this case, understanding childhood in modern humans—but in attempting to ascertain the order and timing in which the complex assembled, and the configuration of the complex at different time frames. Again, this implies that delineation is requred. That is, establishing which traits are essential to define a minimal childhood complex, and which are additions superimposed throughout evolution. This involves drawing from the available historical evidence to establish which traits of *H.* *sapiens’* childhood configuration were present by the time infancy first shrunk below that of chimpanzees in the *Homo* lineage. What traits pertaining to patterns of brain and body growth are observable at those earlier stages? What about feeding schedules? And what about cognitive and learning traits? It shouldn’t be surprising that the childhood complex looked very different at the time of the erectines and by *Homo sapiens’* appearance: it is likely, for instance, that the reduction of infancy appears much earlier than when the bandwidth of social learning became demanding (Bogin 2020). No doubt that important consistencies and trends can be recognized over a long evolutionary timespan, but differences might illuminate interesting and relevant changes in the evolution of childhood’s character.

In this respect, paleoanthropology should take center stage as the best means to assess the timing and context of the appearance of key biological traits across the childhood complex. In particular, the availability and increasing interest in immature specimens in the fossil record and the growing research field of “Evolutionary Developmental Paleoanthropology” (Zollikofer and Ponce de Leon 2010, Schwartz 2012, Robson and Wood 2008) come with opportunities for novel insight. This implies assessing when the duration of growth would have extended beyond that seen in apes, imposing new cost-benefit tradeoffs. Analyses of subadult *H. erectus* (like the Nariokotome boy, ca. 8 y.o.), for instance, have allowed for more precise estimates of the growth period through dental and postcranial growth patterns, suggesting that the duration of growth was still close to an ape-like mode (Thompson and Nelson 2016). However, early rapid brain growth in *H. erectus* (Zollikofer and Ponce de Leon 2010) is suggested to have required supplementary foods by mothers and alloparents (Thompson and Nelson 2016). This suggests that in *H. erectus* subadult life (which for Bogin 2020 includes a legitimate ‘childhood’ stage) traits pertaining to the feeding system and accelerated brain growth have started to assemble before the emergence of a longer duration of somatic growth.

Second, evolutionary hypotheses must be developed that make sense of the *ordering* and *timing* of trait-complex components. Crucially, such hypotheses involve positing dependencies between environmental conditions, fitness regimes, and also other traits in the dynamically evolving lineage. Assessing the emergence in concert with some traits of the complex might suggest potential adaptive links. For instance, if the initial shrinking of infancy (or an elaboration of it including supplementary nutrition, Thompson and Nelson 2016) appears to correlate with greater reproductive advantage, perhaps evidenced by an expanded geographic range and with evidence of a communal breeding behavior (e.g. Bogin and Varea 2020), this potentially tells a story about fundamental pieces of a human life history starting to assemble with, say, *H. erectus.* Further, if the extra childhood time seen in *Homo sapiens* correlates with an even longer lifespan, increased encephalization, skills and information acquisition in more demanding environments (as the EC theory has it), this hints at a story about how *Homo sapiens* managed to mitigate the extra costs of a prolonged apprenticeship while preserving its benefits (and, crucially, why this was not possible earlier).

Third, the dependencies posited in those evolutionary narratives can be empirically tested by multiple, integrative routes. This can involve for instance testing the abovementioned dependencies posited by the EC theory against the details of the available archeological and paleoanthropological data, and the knowledge we have about hominin past diets and foraging behavior. For instance, attending to the archaeological evidence of *Homo erectus* (especially later *Homo erectus*) increasing complexity in technology, social organization, and foraging behavior (with more energy-dense foods becoming accessible) can provide information about the context that sustained the early emergence of traits related to feeding system and communal breeding behavior (before prolonged growth became visible through skeletal evidence). Perhaps more interestingly, this integrative approach involves checking whether such dependencies are resistant to new incoming evidence and expansions of the fossil and material record.

Note that these activities do not necessarily occur independently nor sequentially. Results from the third activity can not only undermine hypotheses, but also put pressure on our characterization of the phenomenon: learning more about the timing and configuration of the childhood complex and its correlation with other life-history traits across hominin phylogeny impacts what really needs to be explained about *Homo sapiens* childhood.

Where, in all this, does the HBE strategy come in? Most clearly, it involves testing dependency relationships posited between elements of the trait complex and fitness regimes*.* Recent evolutionary time often brings increased empirical tractability. As mentioned, HBE approaches to testing predictions of the EC theory model have an important grip on the constraints and opportunities of childhood in the latest stages of the human career. But this gives us information about the final destination of a long evolutionary journey, and about the specifics of *H. sapiens’* ecological niche. As extinct growth patterns, ancestral weaning time and lost ecological niches are beyond the possibility of direct, experimental tweaking, what becomes particularly relevant is *variability* among extant foragers as a window into past possibilities and fitness regimes. In particular, variability and plasticity in reproductive cooperative settings, learning strategies and ecological risks can be investigated from an evolutionary, chronological perspective: if some features of the childhood complex require the scaffolding of others, the evidential strands provided by other disciplines (archeology, paleoanthropology, paleoenvironmental sciences) can hint at which ones of these were in place in ancestral times, with HBE being able to infer their relative payoffs. Importantly, we do not claim that taking the trait complex approach onboard will be exempt from any form of idealization and black-boxing as minimally implied in any scientific and explanatory endeavor. Rather, we believe that it would mitigate the problematic black-boxing of those exact elements that are under empirical scrutiny, as seen in paradigmatic isolation-testing.

So, what kind of change does this mean for the HBE strategy in general? Insofar as causal and explanatory hypotheses of human childhood are answerable to that trait complex’s evolutionary history, relevant hypotheses should adapt to and fit that dynamic picture. Whereas typically the HBE strategies of isolation are adapted towards being able to test optimality models against contemporary foraging groups, it may be that some of the fit between the model and those contemporary tests needs to be lost in favor of a closer fit to paleoanthropological phenomena. This is precisely what is meant by working out a desirable space within the trade-off of two epistemic desiderata that are difficult to fully maximize simultaneously, especially in contexts involving complex evolutionary trajectories. So, we should expect some changes in how the hypotheses themselves are characterized. It doesn’t follow from this, however, that the evidence sources (the use of optimality models in foraging groups) must change—rather, how we conceive of these as testing causal claims about childhood’s evolution is transformed from a critical test to a complementary role. And indeed the more that HBE approaches can be linked to other kinds of evidence (the archaeological record, for instance) the more useful they may be. It is an open question downstream, we think, how HBE (and other workers) must adapt their methodology to suit understanding such complex phenomena.

Before concluding, it is worth highlighting an objection: the centrality of characterizing the historical phenomenon at hand puts progress at the mercy of a patchy and unforgiving record. As such, our proposal could be seen as too utopistic a standard to strive for. If we shouldn’t expect the archaeological and paleoanthropological records to provide sufficiently well-resolved information, then doesn’t our proposal fail to get off the ground? We think this objection should be resisted for three reasons. First, even if it is the case that the record won’t give us the information we require, this in itself cannot be an argument for saving the isolation-testing approach we’ve been criticizing. Second, as to an extent illustrated above, the paleoanthropological record is continuously becoming richer, and we are in possession of increasingly powerful tools for interpreting that record. No doubt the record is patchy, but it becomes more forgiving every day. Third, even if the record remains intransigent, as we’ve seen, there is already enough evidence to raise doubts about the reliability of the evolutionary framing provided by isolation-testing. Garnering what clues we can about the history of childhood evolution can guide which aspects of the trait complex we should focus our testing on. Any information about the timing of components of childhood can be useful for figuring out which aspects ought to be coupled, which should be decoupled, and in exploring the potential dependencies between the parts. That is, our emphasis on the likelihood of mosaic evolution should not discourage investigations into interdependencies within the complex. But these interdependencies should be the object of discovery, rather than assumed by established approaches. In fact, addressing childhood as a trait complex potentially reformulates questions about the coherence and configuration of traits in *H. sapiens* in ways conducive to novel understandings of what makes our life history strategies particularly interesting. *How* developmental coherence between traits and a putatively high degree of generative entrenchment were realized in our branch opens up more ambitious research avenues that would arguably be missed by typical isolation-testing strategies.

1. **Concluding remarks**

Providing an evolutionary explanation of complex phenomena like childhood is an ambitious endeavor. Despite skepticism regarding some aspects of how HBE evidence is used, we’re not discouraging the project of understanding the evolution of childhood with behavioral ecology and the examination of foraging communities. Rather, an increased appreciation of childhood being a trait complex, thus potentially assembled in a mosaic fashion throughout hominin phylogeny, necessitates complex inferential strategies. The same line of reasoning can apply to other, similar trait complexes with a long evolutionary history. In the context of childhood, we’ve shown, inferences can’t be limited to carefully carved tests against extant foraging groups but require careful integration of distinct evidential strands at all stages. That childhood evolved to allow learning complex foraging skills cannot be assessed via tests against foraging communities alone. Although precision matters, establishing the relevance of tests to the phenomenon’s history does as well.

As Robert Kelly has cautioned: “…ideas about ancient societies and evolutionary change drawn from ethnography must be tested against the most direct record we have of ancient societies and evolutionary change: the archaeological and paleoanthropological record – the stone tools and bones that are all that remain of our ancient ancestors. We can start with the Hadza or the Ju/’hoansi or the Martu to learn about the past, but we cannot stop with them” (2013, 270). The past will remain reluctant in disclosing some of its secrets—the direct record of ancient lifeways is limited and in need of constant, iterative interpretation. But pursuing a closer integration of HBE testing prowess within an evolutionarily informed framework allows more targeted questions to be asked, and potentially more interesting stories to be told about how the evolution of that odd, putatively unique human life history stage: childhood.

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1. Although there might be interesting and complex relationships to unpack regarding these cultural conceptions, it is not our task in this paper. [↑](#footnote-ref-2)
2. What is taken to be an *essential* component of the complex is an interesting, non-trivial question and we suspect diverging options among scholars could be identified (in the above-cited definition by Barry Bogin, particular emphasis is placed on feeding-related traits and social organization). However, we reserve discussing issues of childhood delimitation for future work. [↑](#footnote-ref-3)
3. There can be arguments for treating childhood as a (composite) trait at specific stages of hominin evolutionary history, as long as core components of childhood can be identified. [↑](#footnote-ref-4)
4. Interestingly, the spirit of Hawkes and colleagues’ (2002) paper was to propose a GH about the socioecology of *Homo erectus,* combining Charnov’s mammal life-history model with paleoanthropology. Here paleoanthropological data are deemed as “the only line of evidence we have for the timing, context, and order of appearance of the modern human patterns” (p. 205). [↑](#footnote-ref-5)
5. Another parallel between our discussion of childhood and the criticism of Evolutionary Psychology is the following. In Evolutionary Psychology, assumptions about the modularity of the mind—functionally specialized computational modules—rely on the idea that patterns of trait modularity/dissociability and adaptive profiles have remained uniform throughout evolutionary history. Just as this is risky when applied to the trait complex of human childhood, given that patterns of integration and modularity among traits have likely evolved, it is equally problematic when used to characterize the evolution of the human mind, especially in light of brain’s developmental plasticity (see Buller and Hardcastle 2000). We are grateful to an anonymous reviewer for inviting us to clarify this. [↑](#footnote-ref-6)
6. Taking *H. erectus* as the lowest phylogenetic boundary for the appearance of childhood (Bogin 2020, but see Zollikofer and Ponce de Leon 2010, Gunz et al. 2020). [↑](#footnote-ref-7)
7. See Page (2021) and Dresow (2022) for general discussion of uniformitarian principles in historical inference. [↑](#footnote-ref-8)