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ARTICLE

The role of play objects and object play in human cognitive evolution and innovation

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Abstract
In this contribution, we address a major puzzle in the evolution of human material culture: If maturing individuals just learn their parental generation's material culture, then what is the origin of key innovations as documented in the archeological record? We approach this question by coupling a life-history model of the costs and benefits of experimentation with a niche-construction perspective. Niche-construction theory suggests that the behavior of organisms and their modification of the world around them have important evolutionary ramifications by altering developmental settings and selection pressures. Part of *Homo sapiens*' niche is the active provisioning of children with play objects — sometimes functional miniatures of adult tools — and the encouragement of object play, such as playful knapping with stones. Our model suggests that salient material culture innovation may occur or be primed in a late childhood or adolescence sweet spot when cognitive and physical abilities are sufficiently mature but before the full onset of the concerns and costs associated with reproduction. We evaluate the model against a series of archeological cases and make suggestions for future research.

KEYWORDS
play objects, object play, niche construction, innovation, creativity

1 | INTRODUCTION: CULTURAL EVOLUTION AT PLAY

While by no means uniquely human, the reliance of *Homo sapiens* on material culture as a key adaptive feature is more pronounced than it is in any other extant or extinct hominin. It is widely acknowledged that high-fidelity cultural transmission is key to the long-term maintenance of these material culture traditions, although the precise modes of learning and teaching employed by ancient hominins remain debated.[1,2] Modes of high-fidelity transmission are prized because they reduce the costs of learning the many routines and the vast reserve of knowledge of which human culture is composed. Such transmission is the backbone of the creation and long-term persistence of the material culture traditions identified in, especially, the

Stone Age archeological record. Yet if individuals growing up within a particular society learn just their parents' generations' material culture, then what is the origin of major innovations, as also documented in the archeological record?

Recently, different modes of social learning have been proposed as generators of innovations. One of these modes, intentional teaching, has received much attention as an evolved feature of uniquely human social learning that strengthens fidelity in cultural transmission while keeping costs low when learning complex, cognitively opaque skills such as the making of multi-component tools, weaving, or similarly intricate techno-behaviors.[2–6] Cross-cultural research underlines that it is in economically and culturally highly valued domains that teaching is particularly emphasized.[7] Further, observational and experimental field studies in cultural psychology have shown that different modes of teaching may lead to significantly different degrees of innovation among older children and young adults. Such studies have also demonstrated that those differing degrees of creative flexibility are transferred to other domains of activity beyond that originally taught.[8] Hence, when intentional teaching is thought of as interplay between the transfer of skills, abstract concepts, rules and strategies, it not only imparts knowledge, but also facilitates creative problem solving and provides the scaffolding for reorganizing and "playing" with ideas until they produce unexpected or novel outcomes and innovations.[9] Scaffolding may not be entirely absent in other primates,[10] but when coupled with particular social learning strategies, intentional teaching in particular is seen to lead to cumulative cultural evolution in humans.[11]

However, in a recent cross-cultural review of human children as tool users and makers, David Lancy[12] summarizes numerous observations indicating that, in fact, children in traditional societies learn vicariously and in a largely unsupervised manner (Box 1). He lists many examples of children learning to use simple tools and perform simple activities through autonomous exploratory play. This observation is fully consistent with much research in child development. However, Lancy's claim is at odds with research in Western[13] and non-Western (indeed, Kalahari) children[14] showing how strongly they also imitate and overimitate adult actions. Recent experimental work contrasting the ability of individuals at different ages, from toddler to adult, to engage with novel solutions in the physical domain also strongly supports the claim that as individuals mature they actually become less flexible.[15] Indeed, Lancy also specifically remarks that complex tools such as the bow and arrow are often manufactured by specialists, even in contemporary foraging societies. How, then, do individuals mature from independent exploratory learners to experts able to produce and innovate within or even across particular material culture domains? And why do not all individuals become equally adept at using and/or making certain complex technologies?

We argue that, together, life history and niche-construction theory can shed light on this conundrum. In quantitative models of cultural evolution, innovations are seen to simply emerge by chance akin to mutations.[24–27] True inventions, as well as transfers of concepts from one cultural or technological domain (e.g., ceramics, flint-knapping) into another remain effectively blackboxed.[23] Yet, unlike mutations, inventiveness, or the ability to be creative with the materials at hand, and innovation, the emergence of novel cultural variants,[28] are not evenly distributed over human evolutionary history. Indeed, the bulk of prehistory and many parts of history can be described as quite static and conservative, especially with regard to complex multi-component technologies. Such innovations first began to characterize human material culture behavior with the emergence of *Homo sapiens* in sub-Saharan Africa about 300,000 years ago. Especially since about 100,000 years ago, we see a flourishing of material culture diversity in the African Middle Stone Age.[29] Yet, with the global establishment of modern humans, some periods and places still appear to be more strongly associated with innovations than others. Moreover, innovations often come in clusters.

We argue that widespread innovation is not seen earlier and innovations in complex technologies are not more frequent in later prehistory because of the costs and risks associated with tinkering. Salient innovations within domains of complex technology are difficult because they are examples of ill-structured tasks in which the problem does not directly provide a solution.[30] The efficacy of novel manipulations cannot be predicted with confidence.[31] Beyond that, trial-and-error exploration and self-initiated learning is costly because of the time it takes, the cognitive resources it consumes, and the inherent risk of failure.[32] It is here that play, including but not limited to play with miniature replicas of complex tools, becomes important. In contrast to accepted wisdom, which sees play as purposeless, the phylogenetic depth of play behavior suggests that it is both functional and adaptive, especially in contexts of social learning.[33] Human play often strongly reflects adult behaviors.[34,35] Fantasy play allows children, to some degree, to think through the consequences and potential benefits of particular social and technological action schemata before enacting them.[36] These schemata become germane for material culture evolution when such play is paired with objects.

Given the pervasiveness of play, it is more than likely that prehistoric children also played with objects, whether they were unmodified, made by themselves, repurposed adult materials, or provided to them by their peers, older children, or adults. In principle, any object may have been used as a play object at some point.[37] Our focus here is, among other things, on complex technologies having functions that emerge only in the interplay between their different components, which, in isolation, do not hold salient functional cues. Sometimes adult-made miniatures of such technologies constitute a particular kind of play objects, which Lancy calls "qualifier toys."[12] We argue here that these objects offer a particularly strong innovation primer by allowing children to explore the complex, emergent mechanical and material affordances of associated adult technologies. Although probably present, such objects of play are difficult to trace in the archeological record but, to initiate discussion, we point to several possible examples.

In the following, we couple developmental psychological perspectives on play as a functional activity[38,39] with niche-construction theory[40] to suggest that the provisioning of children with miniatures has important selective implications via its subtle impact on innovation propensities throughout individuals' life courses. Building on the suggestion of immediate and delayed benefits of play,[38] as well as our earlier treatment of the role that childhood and adolescence play in Middle Pleistocene human evolution,[36] we develop a cost-benefit model that takes into account not only the perspective of both the user and the maker of such play objects, but places object play and

Box 1. Learning to bow hunt

Bow-and-arrow technology is a key innovation in the human career and a cornerstone technology of most hunter-gatherers around the globe. Although fully functional bow-and-arrow sets can be made relatively simply, most are complex constructs of different raw materials, most of which have undergone some form of transformation from their natural state.[16–18] One of the best examples of the provisioning of complex tools to hunter-gatherer children by adults has been recorded ethnohistorically for the Kalahari bow hunters of southern Africa, who provide children of about three years of age with scaled-down bow-and-arrow sets (Figure 1). Larger, more powerful versions are provided as the children grow older.[19–21] Parents, grandparents, other adults in the group and/or older children will occasionally teach even very young children how to shoot arrows, offering demonstration and explanation. However, most skill is gained through play-hunting in the safe environments of the camp. Small children will target practice on still objects or large insects such as dung beetles and grasshoppers. As they grow older, they start to "hunt" lizards, mice, and small birds, studying their behavior and gaining experience in stalking larger prey.[20] In this way, hunting skills are honed without children being exposed to the dangers of real-life scenarios, keeping them safe until they are able to contribute effectively.[9] Boys of about twelve years old will start to accompany hunting parties and, between the ages of 15 and 22, work hard at hunting. With his first successful hunt of a large antelope, a boy assumes adult hunter status and becomes a potential partner for pair bonding, even though a hunter's career only reaches its peak when he is between 30 and 45 years of age.[19]

In an evolutionary context, technology-assisted hunting is the hunter-gatherer subsistence activity that requires the longest period of teaching and learning. Reaching the necessary levels in skill and technology production requires time, energy, and strong commitment. This extended learning phase, during which productivity is low, is compensated for by higher productivity during the adult phase and an intergenerational flow of high-quality food from old to young.[22]

Figure 1 A Kalahari San hunter demonstrating arrow-shooting technique to an adolescent boy. Note the miniature bow. Getty Images, with permission

innovation in a life-history context. We then turn to selected prehistoric societies to exemplify the type of evidence that can be used to assess our model. Finally, we outline avenues of further research that could shed light on how children's material culture interactions relate to innovation in adult life.

2 | OBJECT INNOVATION IN A LIFE-HISTORY PERSPECTIVE

Human growth patterns and life-history trajectories differ from those of other primates. In particular, *Homo sapiens* has a prolonged middle childhood and postreproductive life span. These allow a stacking of prereproductive, actively reproducing, and postreproducing community members into a three-generation structure.[41,42] Human ontogeny can be further divided into a series of stages, each marked by specific physical and cognitive developments and events, although physical and cognitive maturation do not follow in lockstep.[43] Ethnographic data clearly show that play activities are aligned with gendered adult activities. In much the same way that physical play serves a social and practical function,[44] object play serves to acquaint children with the technologies of adult life in the relatively safe environment of the home base.[34,35]

From a life-history perspective, it is the freedom from reproductive and associated support concerns that facilitates relatively unconstrained trial-and-error exploration and learning. In terms of time and energy, however, such learning is costly. Relative to children, reproductively active adults are preoccupied with activities leading toward the attainment of specified goals and thus spend most of their time in relatively constrained behavioral trajectories. This does not mean that adults do not engage in innovative behavior or object innovation. It does mean, however, that in societies that provide no incentive to innovate *per se*, and in which few or no adults are exempt from primary subsistence activities, innovation, which takes time, energy, and resources, conflicts with food-getting and reproductive concerns. All else being equal, the costs of innovation correlate with the complexity of the technology in question, given that the construction of such objects usually takes a long time and often is particularly costly with regard to raw materials. In addition, when objects consist of many parts, it may not be obvious which component or parameter to change in order to achieve improved performance.

Cross-culturally, children find ways of incorporating play into other activities so that the division between their play and labor is blurred.[45,46] Importantly, developmental psychology broadly recognizes that sufficient amounts of "unstructured time" are crucial for children's development of creative skills and commitment to problem solving.[47] Because play is in proximate terms, driven by its positive affect, all forms of play honor novelty in using, manipulating, and recombining existing structures.[48] Yet small children are less likely to exhibit physical prowess in handling or manipulating many adult artifacts and technologies. Also, they partly lack the cognitive prerequisites that enable older individuals to engage in more focused and sustained degrees of innovative problem solving.

For effective experimentation and innovation to take place, both physical and general cognitive abilities need to advance with age, while the onset of reproduction then sharply modifies the cost-benefit calculation of experimentation. At the same time, many children go through a "conventional phase" during which divergent thinking is trumped by a focus on mastering and reproducing the behavioral conventions that prevail in the social and material environment. In present-day children, this period often peaks around the age of nine years. This, in turn, is followed by a significantly higher focus on and capability for divergence in late childhood and adolescence.[47,49,50] It is not entirely clear, however, whether this extends to all domains of life or is restricted to, for instance, social interactions.[15]

What role does material culture play here? Hints at which physiological processes underwrite such priming toward innovativeness come from studies investigating primate neurological structures in individuals provided with objects. Such experiments show how the interaction with material culture actually changes specific neuronal configurations in the brain.[51] Complementary evidence from developmental psychology indicates that higher diversity in the material objects that human children play with also promotes higher rates of divergent problem solving in subsequent tasks.[52] Furthermore, children's active manipulation and exploration of such concrete, physical exemplars has been shown to assist in narrowing related problems requiring innovative solutions.[30] This coheres well with the observation that innovativeness in many cases relies on various associative mechanisms,[53,54] with the consequence that the overall diversity in the internal (semantic) and external (physical) resources from which associations can be drawn may influence the prevalence of creative solutions.[23] Hence, the increased general preference for novelty in objects, including play objects, in late childhood and early adolescence[55] make these the life-history sweet spot for effective innovation through playful yet able trial-and-error exploration. In late childhood or adolescence, growing physical and cognitive abilities converge with ontogenetically heightened understandings for some forms of reasoning. These abilities are also coupled with a propensity toward novelty, predicting youngsters to be particularly likely to see genuinely novel ways of combining, for instance, technological elements rather than follow established conventions (Figure 2).

3 | RECOGNIZING PLAY OBJECTS AND OBJECT PLAY IN THE ARCHEOLOGICAL RECORD

Recognizing play objects in the archeological record is challenging. The difficulty of ascertaining the role(s) of a given object, however is a much broader epistemological challenge in archeology and is not limited to the identification of actual "toys." Careful contextual analysis can take us at least a good part of the way. Much of children's object-centered activity leaves no traces. Often, children's play objects consist of repurposed adult material culture or objects that are only minimally or not at all modified.[37]

In rare instances, however, play objects that are immediately appreciable as "qualifier toys" stand out clearly: Greenlandic prehistory is characterized by a succession of colonization episodes, including the Paleoeskimo (Saqqaq, Independence I/II, Dorset) and subsequent Neoeskimo (Thule) cultures, beginning around 4,500 BP. Although long-lived, the Paleoeskimo occupation eventually ended around 2,000 BP

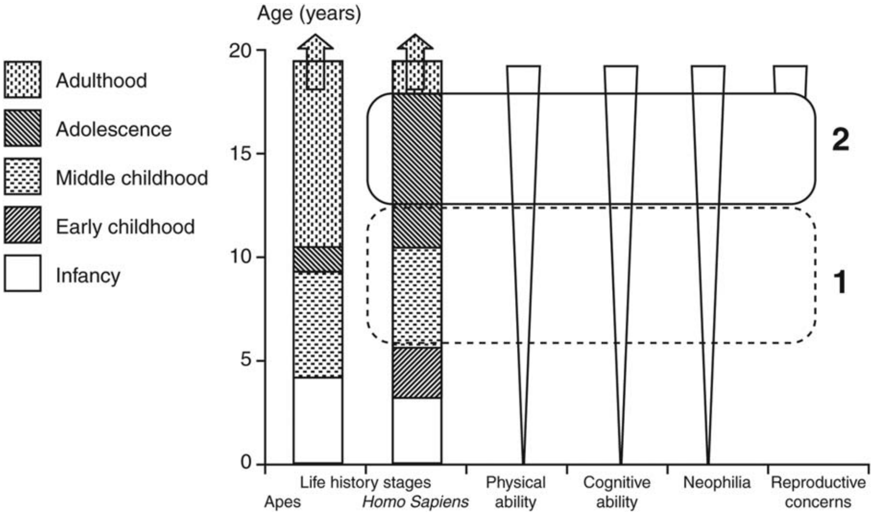

FIGURE 2 A schematic life-history model tracing the costs and benefits of experimentation or innovation in relation to physical and cognitive growth trajectories for apes and humans. Middle childhood (1) serves as a priming period, while (2) adolescence forms the sweet spot for "true" innovations

in western Greenland, leaving only its High Arctic part thinly settled until sometime after AD 1000. Following a lengthy hiatus, a new cultural complex, the Thule, migrated into western Greenland from about AD 1200. All of these arctic economies included highly sophisticated weaponry, instruments, facilities, sledges, and different kinds of watercraft.[56] With broadly similar economies, there are few major differences in the complexity of the Paleo- and Neoeskimo traditions.[57] However, and most pertinent here, there is a dual contrast between the early Saqqaq and later Dorset, but especially Thule cultures. First, Saqqaq material culture is remarkably uniform in Greenland, while Thule material culture is highly dynamic in the development of many different harpoon forms, boat designs, and clothing styles. Second, obvious play objects are absent in Paleoeskimo contexts, whereas the children's material culture from Neoeskimo sites is astoundingly rich,[58] an observation that articulates well with ethnographic reports of children's worlds and objects in these societies (Figure 3).[59,60]

With exceptionally well-preserved sites known from both periods, this difference in the occurrence of play objects in Paleo- and Neoeskimo assemblages cannot be reduced to taphonomy.[58] Thule miniatures include small-scale weapons and dolls.[61,62] Thule children can

FIGURE 3 Inuit practicing bow shooting near the magnetic North Pole. Photographed during the Fifth Thule Expedition, 1921-1924. Inuit bows were exceedingly complex composite tools. Note the boy among the men. Danish Arctic Institute, with permission

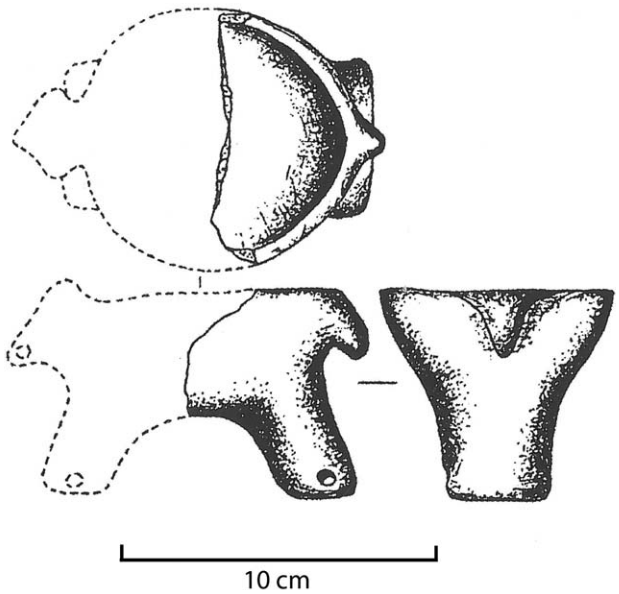

FIGURE 4 Presumably wheeled clay figurine from the Late Tripolye context at Karolina, Ukraine. After Gusev[104]

quite readily be identified through the careful mapping of miniature tent rings complete with different-colored pebble meat and fat pieces.[63] In addition, miniature animal figurines are also common. These served as play pieces and drew attention to the behavioral characteristics of the animals.

All these aspects of material culture are usually discussed exclusively in terms of socialization,[64] but we argue that they may also relate to the striking innovativeness of Thule society. There is a correlation between the kinds of miniatures that are found — weapons, kayaks, sledges, clothed dolls — and the technological domains in which Thule communities were particularly innovative. Despite the very similar environments and economies experienced by Paleoeskimo and Thule groups, growing up in these cultures would have facilitated different degrees of innovation potential because of a greater degree of familiarity with the affordances of specific technologies among Neoeskimo children and adolescents.

The Thule scenario from the relatively recent past serves as a comparatively obvious example of object play by children replicating adult techno-behaviors. Going further back in time, possible examples are somewhat more speculative. One such case may be the invention of the wheel. This technology emerged by early to mid-sixth millennium BP, or possibly slightly earlier. The earliest data points for fully fledged wheeled vehicles, in the form of vehicle parts, wheel tracks, or iconography, are few and remarkably scattered across western Eurasia. The earliest such evidence from the Northern Caucasus, Mesopotamia, Central Europe, and Northern Europe all date to around the middle of the sixth millennium BP.

While this tentative pattern may partly reflect the actual rapidity with which this technology spread across Eurasia, it has also complicated attempts to identify its origins.[65,66] However, a less conspicuous occurrence of the wheel and axle combination appears to predate the emergence of cattle-drawn carts and wagons by at least a couple of centuries. In Tripolye culture contexts of the northwestern Pontic region (mainly present-day Ukraine) dating to the first half of the sixth millennium BP, a range of small zoomorphic ceramic vessels are found, which seem to have been equipped with holes for axles (Figure 4). These apparent "miniature animal containers on wheels," which are broadly accepted as probable precursors of and prerequisites for larger-scale wheeled vehicles,[67,68] may be interpreted as ritual paraphernalia, particularly artful drinking vessels or, indeed, as children's play objects. Here we propose that these items are likely to have been handled and played with by children, whether designed specifically as play objects or with some other intent.

Although themselves not very precisely dated, it is clear that these probably wheeled figurines from Tripolye contexts predate the earliest known full-scale wooden wheels and date to centuries that were, in general, characterized by high degrees of cultural and socioeconomic innovation. In the period from 6100-5600 BP, Tripolye societies of the northwestern Pontic region developed proto-urban, so-called mega-sites, which covered up to several hundred hectares and, at least periodically, gathered populations numbering tens of thousands.[69] These city-like communities were accompanied by significant technological developments. These included a previously unparalleled focus on in-house weaving, as shown by abundant finds of loom weight clusters in houses; novel techniques for large-scale pottery production using three-channeled pottery kilns; and the introduction of cattle-drawn sledges for the transportation of materials and goods.[70,71]

Here we draw specific attention to the latter technology, because the coexistence of an animal-drawn, nonwheeled vehicle and wheeled miniature items very likely presented the priming for the development of wheeled vehicles. Developing full-scale wheels would be an expensive and time-consuming process. The quite evidently adult-made miniatures would have presented opportunities to explore the mechanical affordances of this technology without bearing the costs of full-scale trial and error. At the same time, playing with wheeled objects may have primed youngsters to think more carefully and associatively about this technology.

It is interesting to note that wheeled zoomorphic miniatures have also been used in societies that did not at any point develop full-scale vehicles, notably several mainly second-millennium BP cultures of pre-Colombian Mesoamerica, including the Maya. In these contexts, however, there were no suitable draught animals and, by implication, no preexisting animal-draught technologies with which to combine the wheel-and-axle principle. These examples also highlight that there is no automatism in the linkage between miniatures and full-scale innovative technologies.

A similar case for associative transfer in technology can be made for the European Upper Paleolithic. We are only just beginning to model the lives of children in the Upper Paleolithic[72,73] through their footprints, handprints, and finger flutings recorded in French and northern Spanish caves.[74,75] It is clear, nevertheless, that there are few,[105] if any, recognizable "toys" in the archeological record of this period. An example of a possible object intended for play in the Upper Paleolithic is a bone thaumatrope from Laugerie-Basse, a Magdalenian (18,000-11,000 BP) site in southwest France (Box 2). Thaumatropes are circular disks with an image on either face and a cord threaded

Box 2. Fantasy play and play objects in the Upper Paleolithic

The thaumatrope from Laugerie-Basse is 31 mm in diameter and has a doe engraved on each face (Figure 5). On one face, its legs are extended; on the other, they are folded under her. This has prompted the suggestion that she has fallen to the ground, dying.[80] A more plausible interpretation is that she is exhibiting the springing gait of does, keeping their backs horizontal and pulling their legs up underneath the body. Indeed, the level of the doe's spine remains constant on the both faces of the disc, while its legs move up and down.[81] If the doe was falling to the ground, its hooves would remain on the ground while its body dropped down to ground level. Furthermore, a wounded doe would likely have its ears back, whereas on the disc the doe's ears remain pricked forward, which is characteristic of deer when they are running or feeling energetic. Springing is a dynamic and distinctive deer behavior and thus ideally suited for this type of visual play.[81]

Figure 5 A bone rondelle or "Paleolithic thaumatrope" from Laugerie-Basse. Both faces depict a doe or chamois; Its movement is in split-action. Diameter: 31mm. Drawing: H. Cecil

There are other rondelles that have a narrative quality and may have functioned as children's play objects. For example, a rondelle recovered from the Magdalenian site of Mas d'Azil in southwest France depicts a man confronting a bear (Figure 6). On one face, the man is standing with his left leg raised, his penis erect, and a large stick over his right shoulder. Because the rondelle is broken, only the forelimb of the bear, with its claws extended, can be seen. On the other face, the man is shown lying face down on the ground, apparently having succumbed to the bear attack.[82] Because the visual illusion of motion is absent, it is not technically a thaumatrope, but its narrative quality is suggestive.

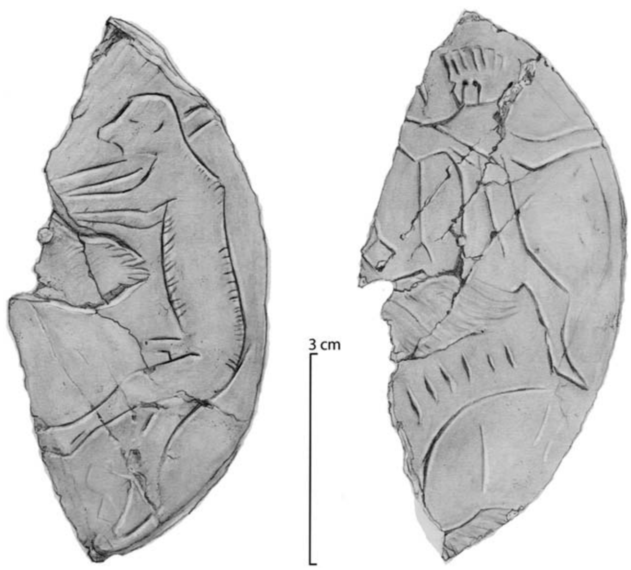

Figure 6 A partial bone rondelle from Mas d'Azil depicting a confrontation between a man and a bear. Maximum diameter: 78 mm. Drawing: J. Gustavsen (redrawn after[82])

Box 3. Play-copying the production of a Neolithic axe-head

Högberg[92] excavated a south Scandinavian Neolithic (4000-1700 BC) knapping site where a square-sectioned flint axe-head was produced. Based on the distribution pattern and technological analysis of flakes, together with other flint implements, he concluded that, alongside a master working on an axe-head, a child playfully knapped an implement resembling an axe-head. The axe production (Figure 7, left) is the technology of the master at the knapping area, highly specialized and uniform, based on selected raw material. The nonsystematic technology (Figure 7, right) is the result of a child's play-copying. It is based on low-quality raw material and has resulted in what looks like a square-sectioned axe-head but could never be used as one.

From this example, Högberg[92] concluded that play-copying can be traced by means of variables such as technological systematicity versus *ad hoc* technology, the use of high-quality (selected) raw material versus low-quality (nonselected) raw material, and typological forms (formal tools) versus nontypological forms (informal tools). In addition, the distribution of debris resulting from play-copying contrasts with that generated by a master. A master's debris is recognized as concentrated within an associated work space, whereas debris associated with play-copying normally is scattered in a less structured manner around the work space. Also, the products of a master's work are typically removed from the knapping site to be used elsewhere. In contrast, products resulting from play-copying are left at the knapping site and not used for other purposes than play.

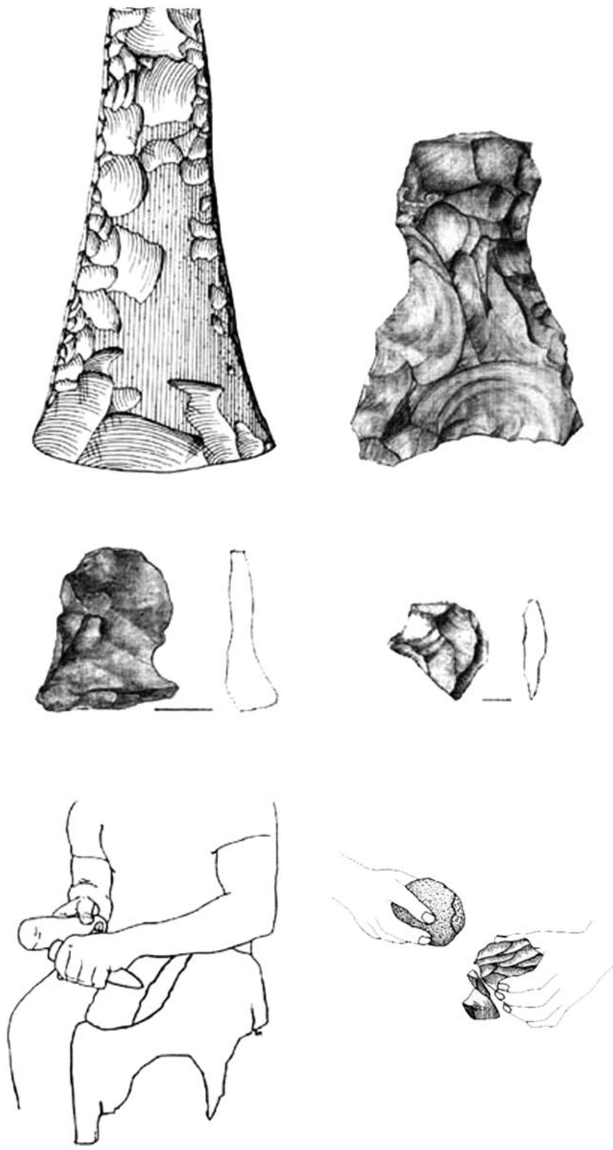

Figure 7 Left: a Neolithic axe-head, a flake from production of such an implement, and a schematic illustration of the technique used for its production. Right: a copy or qualifier axe-head, a flake from its production, and a schematic illustration of the technique used for play-copying

through a perforation in the center. When the cord is manipulated, the disk flips back and forth, revealing the image on each face in rapid succession. Because of retinal persistence, there is a blending of the images, causing the viewer to perceive a single image in motion. Modern-day equivalents are children's "flip books," which are short, thick books in which an entire story enfolds as one rapidly flips through the pages.

Paleolithic thaumatropes are part of a larger category of portable art objects known as rondelles. Rondelles are circular disks often cut from bone (usually a scapula because of its thin, flat surface) or from stones such as slate, or from mammoth ivory. They are often engraved with animals, humans, or abstract designs. Many rondelles have perforations in the center, while some spectacular examples have perforations all around the circumference.[76] While some may have functioned as spindle whorls[77,78] as part of a sophisticated textile industry dating back to $\geq$ 30,000 BP,[79] at least some rondelles may have functioned as thaumatropes. Indeed, these two technologies may be related in the sense that thaumatropes may have been playful qualifier spindle whorls.

Another potential category of Upper Paleolithic play objects is small animal figurines, known from a range of chronological contexts and made from a variety of raw materials.[83] Although such objects are usually interpreted as ritual paraphernalia, our model lends plausibility and evolutionary significance to seeing at least some of them as play objects. It has been suggested that cave art, for instance, played an important educational role in their associated forager communities.[84] Upper Paleolithic mobiliary art, much as in the Thule case, may be another example of how play objects were supplied to children in order for them to learn and explore vital aspects of ecologically and hence adaptively relevant knowledge about animal behavior. The strengthening of associative links between "qualifier toys" such as thaumatropes and adult technologies such as weaving may also have served to familiarize youngsters with extant technologies, but also to prime them for possible later innovations.

Can we find evidence of object play in the deeper evolutionary past and similarly relate such evidence to novel behaviors or innovations in formal technological expressions? In attempting to identify the role of children and their "qualifier toys" over evolutionary time scales, the analysis of the lithic record, ubiquitous also before the European Upper Paleolithic, comes into play.[85] Although not all novice knappers are necessarily children, provisioning children with the opportunity to gain knapping skills during play would diminish the time invested in older apprentices who already have the necessary motor and cognitive skills to be competent in tool manufacture and use.

Lithic production waste can be used to distinguish the work of novices from those of proficient users.[86–89] The fact that younger children do not have fully developed upper limbs, limited hand-eye coordination and lack the strength to manipulate large, heavy rocks leads to characteristic knapping products.[90,91] Hence, careful triangulation between indicators of skill level and physical ability can make such assessments more robust. Once such characteristic debris is identified, its spatial signature can provide further insights. Cross-culturally, groups of children often play in discrete areas within or along the periphery of adult work spaces; this can be demonstrated also in Neolithic[92] and Paleolithic[93] contexts (Box 3). Use-wear analysis could also be employed here: Children are said to follow a "hammer curriculum" involving a great deal of bashing,[12] which may leave discernible breakage patterns on candidate miniatures.

An interesting period of innovation before the Upper Paleolithic is the Middle Stone Age (MSA) of southern and eastern Africa, dated to between about 300,000 and 40,000 BP. This period is associated with the biological and behavioral emergence of modern humans. Miniature cores and tool forms are known from a variety of MSA contexts and, indeed, Early Stone Age and Lower Paleolithic ones.[94,95] However, without further investigation these cannot be seen as evidence of object play. Such miniaturization can probably be more parsimoniously related to raw material constraints. However, returning to our hypothesis that innovative phases might be related to children playing and replicating the techno-behaviors of older members of their societies, it might be useful to look at the MSA of southern Africa. Here, the period between about 80-60,000 BP is well known for major technological innovations, including invention of the bow and arrow by at least 64,000 BP and the production of thin, foliate bifacial points, some of which were pressure flaked, from about 80,000 BP.[29,96,97]

Although we cannot claim direct material-culture evidence of play objects at the time, we suggest that archeological and experimental observations might allow us to capture object play.[9] Earlier, we have argued that because some innovations are costly, object play that imitates adult techno-behaviors is ratcheted along a child's physical and cognitive development, and that replicating adult scenarios without risk has important selective implications.

Recognizing play-copying associated with knapping could help trace children's activities relating to technology in the deep past. For play-copying to be identified, the adult's work must possess a certain level of developed technological skill that the child does not have and therefore does not demonstrate. Based on detailed analysis of Neolithic assemblages, Högberg lists variables such as the use of different raw materials, levels of technological achievement, and levels of productivity as essential for the interpretation of archeological assemblages involving children's activities.[92] Typically, the result of children's play-copying is a set of objects that mimics formal tools found in the assemblage, but lack all significant technological attributes related to formal tools. It is this emulation of shape without imitation of the correct technology used by the master that allows us to distinguish between child knapping and apprentice knapping, in which attempts are made to follow the prescribed technological procedures (Box 3).

Play-copying in stone-knapping is a way communities can organize knowledge transfer between generations. Högberg and Larsson[98] hypothesize that some implements from Hollow Rock Shelter in the Western Cape of South Africa might be the work of children play-copying.[98] These include six small bifacial pieces that are similar to bifacial artifacts identified in experimental and archeological studies as being typical of novice bifacial knapping.[99,100] They are part of an assemblage with evidence of extensive production of fine, expertly made Still Bay points (Figure 8). These pieces were worked with the proper technical approach to point making; i.e., on-edge knapping with the aim to remove thin surface-covering flakes extending over more than half of the face of a piece. However, a proper point production

FIGURE 8 Right: Still Bay points from Hollow Rock Shelter. Left: the six bifacial implements discussed as copy or qualifier products [Color figure can be viewed at wileyonlinelibrary.com]

strategy as recently documented for Still Bay points was not applied.[101] Thus, the copied knapping could never result in formal Still Bay points. The six implements further show several hinge fractures, step-fracture plateaus, and crushed platforms, indicating that they were knapped with an underdeveloped knapping strategy.

This evidence from Hollow Rock Shelter could imply that adults facilitated play-copying for children. Such a strategy would have had much adaptive value. By the time the young ones developed the necessary physical and cognitive aptitudes to master formal knapping they would already, through object play, have gained all the experience needed to contribute meaningfully to a group's socio-economy. Thus, the community would have avoided costly time or energy investment in apprenticing operative hunter-gatherers.[14]

Högberg and Lombard's[101] study of knowledge-transfer systems during the Still Bay (80,000-70,000 BP) in South Africa demonstrates some interregional conventions, but also intraregional variability in the production of Still Bay points. These localized strategies probably reflect flexibility in the organization of knowledge-transfer systems at work during the later stages of the Middle Stone Age in South Africa between about 80,000 and 70,000 BP, indicating that what children may have learned through play-copying varied from group to group.

4 | PLAY OBJECTS AND INNOVATION IN EVOLUTIONARY PERSPECTIVE

Tomasello has noted that "[t]he major part of the ratchet in the cumulative cultural evolution of human societies takes place during childhood. That is, each new generation of children develops in the 'ontogenetic niche' characteristic of its culture. . .. mastering the artifacts and social practices that exist at that time".[102] Developmental psychological studies strongly suggest that humans are evolved to learn conservatively and to be receptive to teaching cues. These evolved propensities for imitation and natural pedagogy facilitate rapid acquisition of the vast amounts of technological and behavioral know-how that makes up each culture.

This conservatism, however, also works against innovation. Technologies are costly[103] and innovation is risky[32] as well as difficult.[30] Given the energetic and time constraints of reproduction and provisioning, life-history theory, here extended to include material culture, predicts that adults in traditional, small-scale societies rarely have the incentive to engage in experimentation and trial-and-error learning when it comes to especially complex technology. Instead, we argue, childhood and adolescence almost certainly are periods of such experimentation.

Children play and are relatively free to experiment until the onset of reproduction. As cognitive and physical abilities mature through ontogeny, innovations are more likely to become salient. Using scale models of adult technologies, such as miniature bow-and-arrow sets, dolls, and so forth, objects of play (thaumatropes, wheeled figurines) and play-copying (knapping activities) allow youngsters to explore the material and causal affordances of the objects, especially those of increasing cognitive opacity. Conversely, making play objects and/or facilitating object play allows experimentation with the mechanical and material properties of substances, components, and wholes. The physical resources, including play objects, that adults use to furnish their youngsters' ontogenetic niche have, we propose, a significant structuring effect on the likelihood that children, adolescents and the adults they become will innovate. While intentional teaching and pedagogical interventions create and maintain long-term traditions,[6] playing with things acts as a primer for innovation within the attendant formal technological domains.

Over evolutionary time, even very small margins in the frequencies of experimentation and the propensities to innovate, not only in late childhood and adolescence, but also later in life, may have important implications with regard to material culture change and adaptation. Indeed, these may be part of the major contrasts in innovation rates between the Early and Middle Stone Ages in Africa and the European Lower/Middle Paleolithic and the Upper Paleolithic. They may also shed new light on some of the striking post-Paleolithic bouts of innovation.

One major question to resolve is whether the initial emergence of object play evolutionarily coincided with other major changes in hominin genetics, growth patterns, and inferred changes in cognitive and linguistic capacities. The current sparsity of archeological evidence of play objects and object play is, as noted before,[85] at least in part due to the lack of a coherent framework for identifying and analyzing these objects and the activities they implicate. Size remains one of the important characteristics of play objects, although as children grow up and require larger "qualifier toys" a smooth transition between adult and preadult objects can be expected. Furthermore, miniaturization can and did occur for a variety of other reasons, making small artifact size alone by no means a sufficient condition for archeologically identifying play objects. Careful contextual and technological analyses, as well as, perhaps, use-wear studies aimed at identifying use and breakage patterns characteristic of object play must be used.

We have here taken first steps toward sketching out a framework that highlights potential examples and analytical thinking about likely play objects and object play through time. Once such "qualifier toys" are identified, we can seek linkages to the emergence and modification of the related formal technologies and explore cross-cultural datasets. In addition, further experimental and observational research in developmental psychology aimed at the object-handling and innovation behavior of preadults at different ages may be able to resolve some of the conflicting results with regard to cognitive flexibility versus rigidity as children grow up. Critically, such studies should be followed with investigations into how innovation behavior changes in individuals and across population samples as they make the transition into adulthood. Finding evidence of children in the Stone Age and tracking how their object play changed over time goes, we argue, well beyond the trivial demonstration that they existed and that they played. More strongly focused archeological attention to play objects, children's play and innovation from an evolutionary perspective, if combined with parallel advances in the evolutionary, cognitive, and behavioral sciences, could be a key component in understanding major factors in human culture change.

GLOSSARY

Life-history theory - an analytical framework that addresses how selection has shaped patterns in a given organism's growth, as well as its reproductive and postreproductive development, behavior, and life span.

Social learning - the acquisition of skills and knowledge by copying others. Social learning strategies include imitation, emulation, and teacher-led learning.

Niche-construction theory - niche construction, or triple-inheritance theory, builds on earlier gene-culture coevolutions models by including a third ecological dimension of inheritance. According to niche-construction theory (NCT), both physical and informational resources that leave lasting and selectively relevant modifications on a given organism's environment constitute a separate category of inheritance. Hence, organisms are not only passive receivers of selective pressures from an external environment, but also active manipulators of these environments with consequences that last across multiple generations.

Immediate and delayed benefits of play - the immediate benefits of physical play, which have been extensively studied, are affective and relate to reduced aggression; the delayed benefits relate to the practicing of important skills and the strengthening of social bonds. This form of play has much in common with grooming.

Cost-benefit model - a systematic approach to estimating the strengths and weaknesses of alternatives. Cost-benefit thinking is closely related to Optimality Theory or Optimal Foraging Theory in that all behaviors are allocated costs in time, energy, and resources, which are weighed against the benefits measured in the same currency.

Ontogeny - in biology, ontogeny captures the development of an organism from the time of fertilization to its mature form and on to the organism's senescence and eventual death.

Taphonomy - the processes, such as burial, decay, and perturbation by biotic and abiotic factors, that influence artifacts and ecofacts from the time they were deposited until they are recovered.

Thaumatrope - a play object consisting of a disk with a picture on each side; the disk is attached to two pieces of string. Twirling the strings rapidly, the two pictures appear to blend into one because of the so-called persistence of vision effect. This creates an effective optimal illusion of a moving picture.

Mobiliary art - also called portable art, the term includes smaller objects of Palaeolithic artistic production that could be carried from place to place. The term is used in contrast to cave art.

Still Bay points - originally defined as a thin ($\leq$10 mm), invasively retouched, bifacial, foliate or lanceolate point with a semicircular or wide-angled pointed butt and lenticular cross section. Recent studies show that cross section varies more than was originally recognized.

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