its rationale were surely lost many times, just as Tasmanians lost fishing and fire-starting practices. So how did *Homo erectus* keep rediscovering the enigmatic handaxe shape, over and over for nearly 1.5 million years? Was there a constraining primary function, in addition to a Swiss-Army-knife collection of secondary uses?

In Calvin (1993, expanded in 2002), I describe the handaxe's extraordinary suitability for one special-purpose case of projectile predation: attacking herds at waterholes on those occasions when they are tightly packed together and present a large, stampede-prone target. Briefly, in the beginner's version that uses a tree branch rather than a handaxe, the hunters hide near a waterhole. When the herd is within range, the branch is flung into their midst. The lob causes the herd to wheel about and begin to stampede. But some animal trips or becomes entangled by the branch. Because of jostling and injury by others as they flee, the animal fails to get up before hunters arrive to dispatch it.

Chimpanzees often threaten by waving and flinging branches but, if such are not handy, they will toss rocks or even clumps of dirt in the same general direction. One can imagine that tree branches were soon in short supply near waterholes. If our waterhole hominids resorted to second best, lobbing a rock into the herd's midst, it would not trip animals but it might knock one down. Because of the delaying action of the stampeding herd, this too might allow an animal to be caught. Even when you miss, the herd will be more tightly packed together on its next cautious visit to the water's edge.

What rocks would work best? Large rocks, but also rocks whose shape had less air resistance. Most rocks tumble, but flat rocks (say, from a shale outcrop) will sometimes rotate in the style of a discus or frisbee, keeping the thin profile aligned to the direction of travel and thereby minimizing drag. Because approach distance will increase with heavy predation, range would become important.

Hunters might also have noticed that stones with sharp edges were more effective in knocking an animal off its feet, even when not heavy. Withdrawal reflexes from painful stimuli, such as a sharp prick from an overhanging thorn tree, cause a four-legged animal to involuntarily squat. Even if the spinning stone were to hit atop the animal's back and bounce free, it might cause the animal to sit down. It is the sudden pain which is relevant, not any actual penetration of the skin.

Handaxes, whether thrown by amateurs or experts, whether lobbed or thrown more directly, usually turn into vertical-plane spinners. Unlike a frisbee which rolls endlessly after landing, handaxes rotate to bury their point and abruptly halt. If the point is momentarily snagged on a pushed-up roll of skin, it would both augment the pain and transfer all of its momentum to the animal, pushing it sideways. Ordinarily, righting reflexes would catch the animal before it toppled, but a simultaneous sit-down withdrawal reflex can override this customary protection.

So this is a beginner's technique for a commonplace high-payoff situation, not a general-purpose hunting technique (it strongly depends on a herd-sized target and the consequent stampede). This proposed path of discovery would also work well in cases of loss of shaping technique, promoting a return to flattened rocks with an all-around edge and something of a point.

Consider also the "life history" of a handaxe. Some new sharp ones would be lost in the mud. Of the ones retrieved, some would have been trampled. A broken classic handaxe may make an excellent cleaver, now having a grip that no longer bites the hand that holds it. Many lost handaxes would be tumbled by a flood and then later discovered in the river bed, with some edges smoothed enough to hold comfortably. So (notwithstanding Whittaker & McCall 2001), I see the shape-defining use as special-purpose, but with broken and tumbled handaxes having many secondary uses, including the "Swiss Army Knife suite."

Channel-cutting floods even set up rediscovery of the best shape by the clueless of a lost generation. In watercourses where the animals come to drink, some of the easily grabbed stones throw farther than others and have better knock-down properties. By the time that this *objet trouvé* supply is exhausted, toolmakers know what the most effective shape is, from having recycled some lost handaxes.

Clearly an ability to imagine that a series of blades in a prepared core was present 50,000 years ago – and equally clearly, little cognitive ability was needed 2.5 million years ago for Glynn Isaac's shatter-and-search method for producing the sharp split cobbles. The latter suffice for getting through the skin and amputating limbs at a joint before the competition arrives; they also allow the limb to be swung club-like against tree trunks to produce spiral fractures and extract marrow. Indeed, shatter-and-search and the handaxe together largely solve the major savanna problems of scavenging and waterhole hunting.

So what cognitive ability was needed by early *Homo erectus* for handaxe design? Not much more than for shatter-and-search. Rather than being seen as an embarrassing exception to 50,000-year modernity, the handaxe can be seen – once the singular controlling use is appreciated – as having a very pragmatic shape, where deviations from the flattened teardrop are more likely to result in dinner running away. The step up to staged toolmaking (first shape a core, then knock off flakes) at 400,000 years ago is far more impressive as evidence of enhanced cognition.

A complete theory of human evolution of intelligence must consider stage changes

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Abstract: We show 13 stages of the development of tool-use and tool making during different eras in the evolution of *Homo sapiens.* We used the NeoPiagetian Model of Hierarchical Complexity rather than Piaget's. We distinguished the use of existing methods imitated or learned from others, from doing such a task on one's own.

An important question that remains unanswered in Wynn's target article is whether the differences seen between earlier tool-making and later tool-making reflect a change in developmental stage attained by hominids during different eras in the evolution of modern *Homo sapiens.* While Wynn's previous work (Wynn 1981) related Mode I tools to the preoperational stage, here he concentrates on the development of specific spatial skills without referring to developmental stage. With more current, NeoPiagetian theories, such as the Model of Hierarchical Complexity (MHC), it should be possible to come up with a valid sequence. This sequence allows the specification of developmental stage both of the earliest tool-related behaviors seen in animals, including apes and early hominids, and of how thoroughly distinct each was from that of modern humans.

To show the developmental sequence most accurately, it is necessary to categorize a much wider set of tool use and tool-making tasks from a variety of species, as well as whatever early hominid behaviors can be inferred from other aspects of the archeological record. Second, the stage-complexity of particular practices becomes clearer if one builds a more complete sequence, adding-in prior stages and later stages. What we have posited (Chernoff & Miller 1995; 1997; Miller 1999; Miller et al. 1999) is that chimpanzees solve social problems that are concrete operational, but not tool-making problems at this stage; instead they are one stage lower, or primary stage tasks. *Homo sapiens* within same-sized groups as chimpanzees solve systematic-stage problems (consolidated formal-operational, Inhelder & Piaget 1958; Kohlberg 1990). The common ancestor of chimpanzees and humans probably did not solve concrete-stage tool-making tasks either. Hominids then had to traverse four stages: concrete, abstract, formal, and consolidated formal.

To have an accurate developmental order of different types of tool use and tool making, a more detailed, complete and accurate model of development than Piaget's is necessary. Such a model is provided by the Model of Hierarchical Complexity (MHC; Commons et al. 1998; Commons & Miller 1998; Commons & Wolfsont 2002). This is a nonmentalistic, NeoPiagetian model of stages of performances based on the fact that *tasks* can be placed in order according to their hierarchical complexity. The orders and stages resemble those suggested by NeoPiagetians (e.g., Case 1978; 1985; Fischer 1980; Pascual-Leone 1970; 1976). All of these added more stages than Piaget's model (14 stages in the MHC), allowing for greater precision in categorizing tasks. MHC has arranged in order problem-solving tasks of various kinds: moral reasoning (Dawson 2000; 2002), reasoning about attachment (Commons 1991; Miller & Lee 1999), social perspective-taking (Commons & Rodriguez 1990; 1993) and evaluative reasoning (Dawson 1998), among others. Such ordered changes can be described by using the MHC in virtually any domain because of this model's universality. MHC posits mathematical definitions of "ideal" actions upon which stages are based (Commons & Richards 2002).

Table 1 shows a brief suggested sequence of "ideal" tool use and manufacture tasks. Note that in understanding the stage demands of a task, it is important to distinguish among using existing methods by imitating or learning (1 level of support, Fischer et al. 1984), doing such a task on one's own (0 levels of support, as used by Piaget), versus discovering new methods of tool manufacturing (-1 level, Arlin 1975; 1984). Each decreasing level of support is harder by one stage.

Table 1 (Commons & Miller). *Stages of ideal actions of tool making*

Stages	Tool-making action
1. Sensory and Motor Actions (actions, perceptions)	Looks at stones, touches, or holds a stone. Each of these actions is done singly and not combined with other actions.
2. Circular sensori-motor actions (organizes 2 actions)	Looks at, reaches, and grabs a stone. Bangs a stone by accident on another stone.
3. Sensory-motor (conceptual activity)	Bangs a stone into another stone or other objects, both singly and in combination. Uses simple concepts such as bashing a nut with a stone. Classifies perceptually.
4. Nominal (words, sequences conceptual actions)	Bashes one stone on the other, such that the second stone strikes the first at a place that is near the immediately previous strike. Creates successive modifications that are nonsystematically different along any dimension. Acts on named concepts as seen by actions.
5. Sentential (sequences nominal actions and words)	Hits one stone with the other in a constant direction of movement (each strike at the stone is done in relation to the previous one). Makes Mode I tools that require just a few bangs.
6. Preoperational (organizes sentential actions)	Does one sequenced set of things after another sequence to the same tool. Focuses on only one dimension or aspect of tool making – bashing edges or just producing flakes.
7. Primary (does single reversible actions)	Uses beginning symmetry or constant spatial amount, as described for early Mode II tools. Follows through on tool making until end of task.
8. Concrete (coordinates reversible actions)	Makes one piece of a tool and then attaches it to another piece (e.g., an arrowhead to a stick). Coordinates two separate reversible actions. Carries and stores tools consistently.
9. Abstract (does norm-based actions; unsystematic uses of variables)	Uses a standard unit of measure to produce symmetrical tools. More precisely, applies constant spatial amount. Follows peer social norms (Wynn 1993b) for uniform tool making. Uses variables including points that vary from dull to sharp; edge sharpness; shapes varying from round to long and narrow; materials effects.
10. Formal (controls and studies effects of variables)	Makes and uses multiple specialized tools for different applications. Instantly decides which to use in which situation (i.e., isolates causal variables).
11. Systematic (forms systems of relationships and multiple causal variables)	Systematically develops tools for different situations (problem finding) for the first time (−1 level of support). Tool making is adapted to materials at hand (causal relation 1), and planned function (causal relation 2), making the best tool for that particular situation. Integrates empirically earlier formal-operational methods of tool making when presented the problem.
12. Metasystematic (compares systems)	Compares two systems each with sets of causal relationships for manufacturing tools. Discovers how formal operational causal relations interact (−1 level of support).