Book Review

A Fresh Look at the Cognitive Origins of Man the Tool-Maker

A review of April Nowell and Iain Davidson, *Stone Tools and the Evolution of Human Cognition*. University Press of Colorado: Boulder, CO, 2010, 234 pp., US$70.00, ISBN #978-1-60732-030-2 (hardcover).

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Recently, there has been renewed interest in the psychological components that underlie complex human tool use. Pictures of tools, sounds associated with tools, and tool names all activate areas of the brain that are also recruited for planning and executing action sequences (Johnson-Frey, 2004). Others have shown that semantic or conceptual representations of tool function and various motor processes appear to work together during tool use, suggesting that tool-use behavior emerges out of complex communication between systems (e.g., Creem-Regehr and Proffitt, 2001; Witt and Proffitt, 2008). From a developmental perspective, studies have indicated that very young children can identify features of tools that are functionally relevant (Brown, 1990), and that the emergence and increasing sophistication of tool-use reflects a developing ability to plan future-oriented behavior, to connect hand-to-tool action programs and tool-to-task goal monitoring, and a growing understanding of the intentions of a tool’s inventor and a culture’s conventions for using tools in particular ways (Barrett, Davis, and Needham, 2007; Casler and Kelemen, 2005, 2007; DiYanni and Kelemen, 2008; Gardiner, Greif, and Bjorklund, in press; Sommerville and Woodward, 2005; Siegel and Callanan, 2007). A missing piece of analysis for much of this work is a consideration of how modern tool-use behavior fits into an evolutionary framework.

In “Stone Tools and the Evolution of Human Cognition”, editors April Nowell and Iain Davidson have assembled a fascinating set of chapters devoted to exploring the role of cognition in early stone tool creation and use. In addition to summarizing familiar concepts and controversies for cognitive anthropologists, this volume provides psychologists with a valuable resource for evaluating core issues that are relevant for empirical investigations of tool use in humans and non-human primates.

*Themes and controversies: An exploration of perspectives on mechanism.*

“Stone Tools” explores stone technologies by time period, which in itself provides a structured and clear examination of changes both in flaking methods, and also in
cognitive structures that may have contributed to, and co-evolved with, tool manufacturing abilities in our hominin ancestors. Contributing authors address several ‘big questions’ that provoke controversy and varied interpretations of available evidence. Does flaking reflect a planful, “cognitive”, systematic, and possible culturally shared process of material evaluation and reduction? Or, in contrast, was any particular instance of stone tool manufacture the result of moment-to-moment analysis and reaction to the structure and form of each core? For example, Moore (Chapter 2) provides a very interesting analysis of possible confounds between hierarchical goal-driven knapping and knapping driven by the idiosyncratic material properties of stones themselves. He suggests that evidence of goal direction may actually be the result of a simpler process of flaking chains in which the outcome of each flake determined the knapper’s next move.

A second focal question concerns comparisons between percussive tool activity of chimpanzees and the knapping process used in Oldowan technologies. Is it valid to compare these two behaviors for cognitive equivalencies? De la Torre (Chapter 3) suggests that archeological evidence of early Oldowan knapping contains complex markers of technology that are mostly absent from the percussive behavior of non-human primates, such as selectivity of materials, precise arm and hand movements, form symmetry, flexible knapping that adapted and adjusted for different types of cores, and controlled conchoidal fracturing. Davidson (Chapter 9) also suggests that chimpanzee and hominin tool making diverge on a variety of cognitively relevant variables such as material procurement, methods of production and use, tool relocation and abandonment criteria, and the invention of multi-component tools (e.g., via hafting).

A third theme, focusing on the role of social reasoning and language, weaves through many of the chapters. Did social exchange during tool manufacture provide a vital context for the evolution of proto-communication and language? Conversely, did intentional communication among tool makers confer an adaptive advantage by which early hominins developed increasingly sophisticated tool technologies? For example, Nowell and White (Chapter 4) look at social structure in the middle Pleistocene and its impact on handaxe manufacture. Though a common conception of this period is one of stasis, and therefore a lack of cognitive sophistication in technology, these authors assert that aspects of social organization such as small population size and short length of childhood and adolescence can explain an apparent lack of innovation in this period. More provocatively, several authors suggest that although formalized language was not necessary for learning stone reduction techniques, Theory of Mind, or reasoning about the knowledge states of others, was a requirement for the learning process. Learning various important methodologies for optimal core reduction likely involved an expert teacher drawing attention (possibly via pointing or other ostensive communicative cues) to various material properties of each core and explicating action sequences that maximized a desired outcome and minimized error (e.g., Wynn and Coolidge, Chapter 5; Stout, Chapter 8). Other contributors discuss the possibility of co-evolution of intentional communicative signals and increasingly sophisticated tool production (such as hafting or combinatorial tool production; Wurz, Chapter 7, Stout, Chapter 8, Davidson, Chapter 9). For example, both Wurz and Stout point to evidence that recruitment of specialized neural representations for action and language, which often overlap, are seen in fMRI data during modern
reproduction of Acheulian handaxes (which themselves represent a more complex technology compared with earlier Oldowan tools). These ideas strike a rich chord for cognitive psychologists, especially those interested in developmental processes, who have now started to investigate the role of natural pedagogy and imitation in a variety of tool use and object learning tasks (Carpenter, Call and Tomasello, 2005; Carpenter, Akhtar, and Tomasello, 1998; Csibra and Gergley, 2009; Gardiner, Greif, and Bjorklund, in press).

Finally, Wynn and Coolidge (Chapter 5) consider the possibility that the Levallois reduction process involves cognitive parameters that are implicated in modern models of “expert” skill performance. Specifically, they propose that tool use relies on the activation of deeply interconnected long-term memories of both declarative and procedural information about tools and the motor programs associated with them. Cues from working memory activate a large network of associated concepts and action sequences, or “retrieval structures”, related to performing tool-related tasks. Expert retrieval structures are so elaborated and automatized that they need only a relatively simple cue in working memory to be recalled and implemented. Experts can easily move between alternative procedures, make few errors, can be interrupted mid-sequence and pick up activities easily. Because retrieval structures require relatively low processing power from working memory, experts may devote remaining cognitive resources to innovation. Wynn and Coolidge assert that Levallois core reduction meets the criteria for expertise given evidence of goal-directed, multi-step core preparation and reduction. Additionally, the apparent use of visuospatial cues such as convexity, platform angle, curvature, and percussion strike zones may have acted as cues to trigger relevant retrieval structures. The Levallois knapper also had to hold in mind at least two goals – maximizing a handaxe blade and increasing the possibility of usable flakes. This speaks to the cognitive complexity and the procedural and motor control involved in handaxe production in various sites during this period.

Lessons for cognitive psychologists: Methodology, evidence, and conceptual inference

Though the many concepts, hypotheses, and methods mentioned throughout the chapters may be familiar to anthropologists, for psychologists, this volume provides a helpful overview of the processes by which anthropologists analyze archeological evidence of knapping technologies. Of particular value to the psychologist’s own “toolkit” is the method of inferring the steps of a tool production sequence known as a chaîne opératoire (see also Bar-Yosef and Van Peer, 2009, for challenges involved in interpretations of chaînes opératoires analyses). In the context of stone tool manufacture, this entails assemblies of available archeological evidence of tool production, and hypotheses about the manner and order in which core reduction and various other componential tool construction occurred. Inferences about the steps taken to produce and perfect the action sequences, as well as characteristics of the finished products, are of interest to scientists because they may reflect perceptual, motor, and cognitive capabilities of Paleolithic populations. Comparisons made in this way are certainly controversial, and these concerns are voiced consistently throughout the volume. However, the general principles of chaîne opératoire can be used by psychologists interested in tool-use development to examine the onset of a tool-use sequence from novice attempts through to the achievement of expert-level automatized performance. The approach bears some similarity to microgenetic methods.
used in developmental psychology (e.g., Siegler and Crowley, 1991) in which changes in children’s strategies for performing a task are traced repeatedly and in great detail over time. Contributors to this volume draw on chaînes opératoires for reasoning about the role of complex cognitive processes in knapping procedures. Similarly, psychologists studying tool use may learn far more about the changing profiles of reasoning that individuals use to become skilled tool users, and also discern points at which innovation occurs.

More importantly, the debates that emerge in this volume serve as an important reminder for cognitive psychologists to be mindful of how tool use may be accounted for by direct perception of physical factors residing in the structure of the material composition of the tool. Certainly, to begin to draw conclusions about the evolutionary origins of modern tool-use, it is clear that researchers will need to consider how any single tool-use episode might be guided by the tool user’s lower order organization techniques (Moore, Chapter 2), or by chaining actions in which each particular outcome spurs the next. Patricia Bauer’s work on “enabling relations” as enhancements for memory illustrates this point well. Bauer and colleagues have shown that infants’ memory for sequences of actions can be facilitated if steps in the sequence are causally related to each other, providing a sort of instruction set to scaffold the performance of a logical sequence of actions to solve a problem. No memory benefit emerges when steps in an action sequence seem to be arbitrarily organized (Bauer, 1992; Bauer, Dow, Bittinger, and Wenner, 1998; Bauer and Fivush, 1992; Bauer and Shore, 1987; Bauer and Travis, 1993; Wenner and Bauer, 1999). Could this be a modern analog for the type of causal reasoning that guided early knapping techniques? Are enabling relations a type of cue for the retrieval structures that Wynn and Coolidge outline? If so, how cognitively complex were the memory retrieval mechanisms for “expert” Levallois reduction technology?

Particularly for developmental psychologists, arguments for and against the necessity of language, symbolic reasoning, and facets of social cognition in stone knapping are especially provocative. Various contributors suggest that language was not necessary for transmission of tool use traditions, but some level of social cognition or recognizing a conspecific’s goals would have been. This is particularly the case for tool innovation and standardization of tool form. In this way, an evolutionary perspective may inform interpretations about the mechanisms driving very young children’s non-verbal tool-use performance and early forms of social orientation in complex goal-oriented tool behavior. Research by Jessica Sommerville and Amanda Woodward, Amy Needham, and well-cited works by McCarty and colleagues, show that over the first two years of life, infants begin to understand how to organize goals and plan complex behaviors that resemble adult-like tool use (Barrett, Davis, and Needham, 2007; Sommerville, Hildebrand, and Crane, 2009; Sommerville and Woodward, 2005; Sommerville, Woodward, and Needham, 2005; McCarty, Clifton, and Collard, 1999, 2001). This development need not be rooted in language. However, it is interesting to predict how language may change the landscape of tool-use around two years of age, when children’s tool use appears to become more “representational”, or based on insight rather than immediately perceptible object properties (Lockman, 2000).

Finally, authors in this volume also point to the role of a Theory of Mind in advancing stone technology, and again it is interesting to consider what kinds of
rudimentary forms of reasoning about others’ minds play significant roles in the emergence of skill building prior to the onset of language. Wurz’s chapter on symbolic reasoning in tool production in the Middle Stone Age is reminiscent of current debates on preschool children’s understanding of various aspects of artifact design. Research by Bloom at colleagues supports the idea that young preschoolers understand that an artifact’s inventor has naming and categorization privileges that object users do not have (e.g., Diesendruck, Markson, and Bloom, 2003; Gelman and Bloom, 2000). In contrast, others have shown that understanding the role of the intentions of an artifact’s designer emerges well after the preschool years (e.g., Defeyter and German, 2003). Discriminating designer and user intent may be important for symbolic reasoning in the context of tool production because standardized form may actually reflect a conventional, socially agreed upon blueprint for connecting function with physical structure.

With this fresh look at the cognitive underpinnings of stone tool production and use, Newell and Davidson have provided a valuable resource for anthropologists and psychologists alike. Psychologists interested in the evolutionary origins of skilled behavior will be particularly engaged by the themes and debates presented by the contributing authors, and thoughtful reading will surely encourage cross-talk between fields. In this way, we may begin to link current research findings with evidence from the archaeological record and further explicate the adaptations that factor into the complex reasoning involved in modern tool use.

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Man the tool maker

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