Journal of Anthropological Archaeology 37 (2015) 100–111

Contents lists available at ScienceDirect

Journal of Anthropological Archaeology

journal homepage: www.elsevier.com/locate/jaa

When are two tools better than one? Mortars, millingslabs, and the California acorn economy

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ARTICLE INFO

Article history:
Received 4 July 2014
Revision received 2 December 2014
Available online 3 January 2015

Keywords:
Human behavioral ecology
Cultural evolution
Technology
Acorn intensification
California
Flaked stone
Ground stone

ABSTRACT

The question investigated by this study is: how much behavioral specialization is necessary before tool specialization is worthwhile? The toolkits of hunter–gatherers vary considerably over space and through time from simple and multifunctional, to complex and specialized. The decision to use one tool over another can be modeled as a fairly straightforward consideration of costs and benefits, but the problem becomes more complex when individual tools are employed in multiple tasks. We introduce a formal model that helps explain when and why multi-use, or flexible tools, might outperform specific-use, or specialized tools, or *vice versa*. This model is used to help understand the adoption of mortars when acorns became a staple food in prehistoric California. The model suggests specialized tools win out when tasks they are designed for are performed often enough, or occur with enough certainty, to make their added cost worthwhile.

1. Introduction

More than merely serving as durable indicators of different patterned behaviors, tools are an integral part of human adaptive dynamics, both reflecting and constraining what people do. If different adaptive behaviors are made up of tasks requiring certain tools, then understanding which tools are optimal in various contexts requires addressing which behaviors are prevalent, which tools are present, and how changes in one can affect the other.

Several interrelated trends toward behavioral specialization have been documented in the Late Holocene archaeological record of California, including increased gender division of foraging labor (Jackson, 1991; Jones, 1996; McGuire and Hildebrandt, 1994), more complex settlement systems (Bamforth, 1986; Hildebrandt and Mikkelsen, 1993; Jones and Ferneau, 2002; Lebow et al., 2007), and intensified subsistence practices (Basgall, 1987; Broughton, 1994, 1997; Codding et al., 2012; Gould, 1964; Jones et al., 2008; Wohlgemuth, 1996, 2004). Paralleling these trends are increases in technological specialization and in the number of tool types employed. Populations living between about 10,000 BP to 5000 BP relied on an exceedingly simple toolkit made up of about six tool types including millingslabs, handstones, cobble/core tools, flake tools, and hafted bifaces that seem to have served a wide variety of functions (Jones et al., 2002). Starting at about 5000 years ago, new tools with more specialized uses were introduced, but rather than replacing the old tools, much of the original toolkit remained in place. Throughout the Holocene, this same process continued, so that viewed as a whole, the dominant trend is an increase in the number of tool categories making up the technological repertoire, paired with a decrease in the functional latitude of each tool.

One of the most obvious signs of subsistence intensification in the Late Holocene archaeological record of California is the advent of the acorn economy. Available evidence suggests that sometime after 5000 years ago, the acorn assumed its place as a staple foodstuff in California (Basgall, 1987; Tushingham and Bettinger, 2013; Wohlgemuth, 1996, 2004). Stone mortars and pestles first appear in the archaeological record in large numbers after this time (Basgall, 1987; Glassow, 1996; Jones et al., 2007; White et al., 2002; Wohlgemuth, 1996), suggesting these implements were integral to acorn processing. However, millingslabs were never completely replaced by mortars, but instead used alongside them, presumably to process foods such as small seeds for which mortars were ill-suited. This suggests that rather than one tool form replacing another outright, there was a complex interplay between behavioral change and technological solutions (see Fig. 1).

To help understand the possible mechanisms behind the California transition to mortars, as well as broader trends in technological evolution, we introduce a formal model that takes into account

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http://dx.doi.org/10.1016/j.jaa.2014.12.002
0278-4165/

tool manufacture, use, and discard within the context of task performance. We focus on the trade-offs inherent in using generalized tools (useful for many tasks) as opposed to specialized tools (designed for specific tasks). Accordingly, the question guiding this study is: how much behavioral specialization is necessary before tool specialization is worthwhile? Or, put more simply: when are two tools better than one?

1.1. Technological change and tool choice

Archaeologists and anthropologists have long studied how and why people use the tools they do, and how they change through time (Bettinger and Eerkens, 1999; Fitzhugh, 2001; Greaves, 1997; Hughes, 1998; Isaac, 1972; Mason, 1895; O'Brien et al., 2001; Oswalt, 1973, 1976; Pitt-Rivers, 1906 [1875]). Many archaeologists have also focused their attention on the organization of technology, or how tools are designed manufactured, used, and discarded according to various constraints posed by the landscape and subsistence strategy (Binford, 1979, 1980; Nelson, 1991; Odell, 2001a; Torrence, 1983, 1989). The vast majority of these studies concern flaked stone (Andrefsky, 1994; Bamforth, 1991; Kelly, 1988; Parry and Kelly, 1987), but ground stone tools have also been profitably investigated (Adams, 1993, 1999; Nelson and Lippmeier, 1993).

Many of these studies have employed an optimization approach to explaining tool design and use (Beck et al., 2002; Bettinger et al., 2006; Bousman, 1993, 2005; Brantingham and Kuhn, 2001; Elston, 1992; Jeske, 1992; Kuhn, 1994; Ugan et al., 2003; Wright, 1994), often explicitly employing the framework of human behavioral ecology (Bird and O'Connell, 2006; Kennett and Winterhalder, 2006; Smith and Winterhalder, 1992). Such an approach makes sense for investigating how and why technology changes because decisions about tools often involve fitness-related behavioral trade-offs that can be modeled, provided the relevant variables can be quantified. Optimization models are generally concerned with individual decision making, but the types of tools used by a culture may affect the fit of such models because the behavioral options of individuals were likely limited to varying degrees by different types of technologies. As technological traditions evolved, the tools available to an individual at any point in time would constrain his or her behavior into culturally agreed-upon task-tool combinations.

While it is true that people can make new tools if necessary and that new technologies are always available through borrowing or invention, in reality, there are limits to both short-term retooling and long-term changes to technological traditions. Over the short term, procurement and manufacturing of tools is often embedded within, and dependent on, the coordinated activities of others (Binford, 1979). Over the long term, making changes to existing technologies, and developing or adopting new technologies is as much a social problem as it is an engineering problem (Bettinger, 1999; Fitzhugh, 2001; Richerson and Boyd, 2001; Rosenberg, 1994). In other words, interdependencies between technological tradition, work organization, and individual behavior may restrict both short-term and long-term behavioral options (see Steward, 1938, 1955). Therefore, even subtle changes to tools glimpsed in the archaeological record may reflect significant behavioral changes.

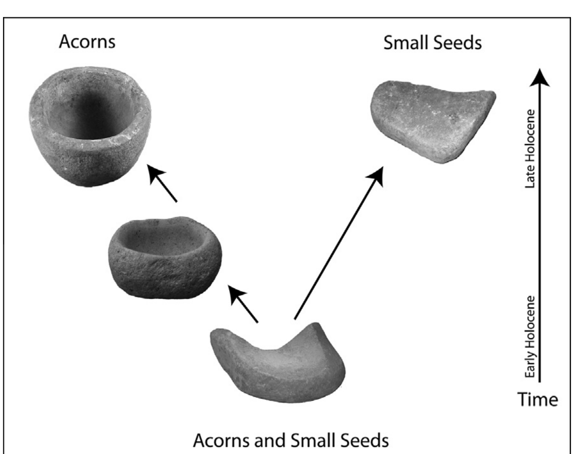

Fig. 1. Idealized changes in California ground stone tools throughout the Holocene.

Researchers investigating technological organization have long suggested people make multifunctional tools when flexibility is important and specialized tools when efficiency is important (Bleed, 1986; Nelson, 1991; Shott, 1986). Because forager mobility imposes constraints on tool design by limiting the weight and number of tools that can be carried (Kuhn, 1994), stone tool users must make trade-offs between tool flexibility (how many tasks a single tool can accomplish) and tool efficiency (how well a tool performs any particular task) (Bleed, 1986; Nelson, 1991; Shott, 1986; Torrence, 1983). Tools designed for specific tasks are more efficient, but may not perform optimally beyond the narrow range of activities dictated by their design. Tools designed to accomplish a variety of tasks reduce the number of tools needed but may not perform each task as efficiently as specialized tools.

Accordingly, a central assumption guiding this investigation is that multifunctional tools permit more flexible task performance but reduce exploitative efficiency. More specialized tools, on the other hand, increase efficiency at the level of the individual task, but limit flexibility in terms of task switching (because specific tasks require specific tools that may not always be on hand). In other words, the cost of employing multifunctional tools is reduced efficiency, while the cost of employing specialized tools is reduced flexibility.

The model we present builds on previous organization of technology models (Bamforth, 1986; Bamforth and Bleed, 1997; Binford, 1979; Bleed, 1986; Nelson, 1991; Shott, 1986; Torrence, 1983), but especially on Ammerman and Feldman's (1974) modeling of hypothetical archaeological assemblages based on how tools and their use-lives relate to work performed. Their model takes the form of a matrix made up of a set of activities or tasks, a set of tools used in performing those tasks, and the "mapping relations," or which tools are used for which tasks (herein termed *tool–task relations*). While this model is a useful illustration of how tool-use behavior may influence the archaeological record, we feel its application is limited by not including some measure of tool efficiency to be optimized. As Ugan et al. (2003) and Bettinger et al. (2006) have shown, the decision to use one tool over another can be modeled as a fairly straightforward consideration of costs and benefits. A situation not specifically addressed by these models, however, is under what situations multi-use, or flexible, tools might outperform specific-use, or specialized, tools or *vice versa*. This is the aim of the model presented here. First, the model is introduced and its behavior explored using a hypothetical dataset. This is followed by an application of the model incorporating ethnographic, experimental, and archaeological data to help explain technological changes surrounding the California acorn economy.

2. Modeling tool choice

2.1. Two-task system

The model is an optimality model in the form of a Markov chain incorporating probabilities of tasks performed and payoffs of