

Special Issue: Reduction Sequence, *Chaîne Opératoire*, and Other Methods: The Epistemologies of Different Approaches to Lithic Analysis

Levels of Theory and Social Practice in the Reduction Sequence and *Chaîne Opératoire* Methods of Lithic Analysis

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ABSTRACT

There are more areas of overlap as well as distinction between the Reduction Sequence and *Chaîne Opératoire* methods of archaeological analysis than the current debate recognizes. While methodological differences have been acknowledged, high-level theory differs to a greater degree than is currently appreciated, partly due to the social practice of archaeology in different contexts. This paper compares and evaluates examples of reduction sequence and *chaîne opératoire* research to demonstrate how high-level theory goals impact middle-range theory and even low-level theory practices (i.e., how data are constructed and published). The paper then utilizes the distinction between an emic decision hierarchy and an etic production hierarchy to elucidate how the practitioners of both methods can more successfully integrate their approaches. An alternative to both methods is offered to demonstrate how common epistemological problems can be resolved. As an example of this alternative approach, the paper compares blank production behaviors and tool kit morphologies among Levantine Ahmarian, as well as among Levantine Aurignacian assemblages, from Kebara Cave, Israel. This case study demonstrates that the two Ahmarian assemblages are more different, rather than more similar to each other, in comparison to the Levantine Aurignacian assemblages. This suggests that a typological approach to these assemblages conceals significant behavioral data.

This special issue is guest edited by Gilbert B. Tostevin (Department of Anthropology, University of Minnesota). This is article #6 of 7.

INTRODUCTION

The present article attempts to outline the major issues which stimulated the need for this special issue of *PaleoAnthropology* and in so doing offers an example for how to navigate differences in the method and theory of lithic analysis to solve common problems. The paper proceeds in four stages. First, the issue of the nature of the discourse is discussed with the purpose of both identifying areas requiring more exploration and emphasizing the difficulty of intercultural dialogues. Second, the dialogue is broadened beyond the issue of methodological critiques to an examination of how a difference in high-level theories shapes each approach's use of low- and middle-level theory. In the course of this discussion, differences in the institutional context of the social practice of lithic analysis are shown to have ramifications on these differences in levels of theory. Third, the epistemological difficulties faced by both the reduction sequence and *chaîne opératoire* methodologies are discussed as subjects around which analysts from both methodologies should rally. Fourth, a sample analysis is presented to illustrate one methodological attempt at avoiding these common epistemological problems. The Upper Paleolithic sequence of Ahmarian and Levantine Aurignacian assemblages from Kebara Cave, Israel, is used to exemplify this behavioral approach.

THE NATURE OF THE DISCOURSE

An intellectual debate is usually characterized by the alternation of scholarly articles written by two or more individuals positioning and repositioning the debate through time, hopefully coming to a productive consensus or clearer understanding of the multiplicity of views. Such debates can be very productive and enlightening, for example, the style debate between Binford (1965), Sackett (1977, 1982, 1985, 1986a,b, 1990), and Wiessner (1982, 1983, 1984, 1985, 1990) or the evolutionary archaeology debate between Dunnell (1980), Moore (1994), O'Brien (O'Brien and Holland 1995; O'Brien and Lyman 2000), Boone and Smith (1998), Shennan (2000), and Bamforth (2002). In contrast, the reduction sequence vs. *chaîne opératoire* debate has been so one-sided as barely to deserve the label. In the eight years since the publication of Shott's (2003) article in *Lithic Technology*, I know of no direct response from *chaîne opératoire* proponents. This could be understood as an offended silence. Or it could be understood as indifference, a more likely reaction given the decade and a half without a response to Dibble's (1995) very polite critique and reanalysis of Boëda's (1988) interpretation of the collection from Biache Saint-Vaast. This is particularly telling since Dibble's paper in the Levallois Conference volume (Dibble and Bar-Yosef 1995) offers the opportunity to be self-reflective about the epistemology

of different methods of gathering basic observations and measurements (low-level theory) and making inferences on technological process (middle-level theory). In the contrast between a quantitative attribute analysis and the gestalt of a technological reading or *lecture*, there is much to discuss and the fact that the dialogue has not occurred indicates that a new form of engagement is required. Bar-Yosef and Van Peer's (2009) recent critical comparison of the results of a technological sequence analysis based on refitting with a technological sequence analysis based on a *lecture* similarly demonstrates the problem. And it is puzzling why so few *chaîne opératoire* proponents offered open comments to their *Current Anthropology* paper, although many were apparently involved in the peer-review.

Part of the lack of progress in the debate comes from its exclusive focus on methodological issues. Specifically, the methodological critiques have been presented as divorced from the context of the articulation of high-, middle-, and low-level theory in the social practice of lithic analysis in different national contexts. Despite Bleed's (2001) admirable exception, the absence of a discussion of the theoretical differences between the approaches has made the methodological differences appear to be errors of naïveté rather than intentional low- and middle-level techniques consistent with the high-level theory espoused by different cultural perspectives on the goals of lithic analysis. To remedy this situation, the debate needs to recognize that, in addition to the mutual heritage of western European intellectual thought, there are differences in disciplinary orientation as well as institutional baggage that amount to different academic, not to mention popular, cultures among lithic analysts. These differences also make the cross-cultural communication (*sensu* Leone and Preucel 1992) within the debate more fragile.

The means of achieving this recognition of the role of analysts' cultures is through a closer engagement of the literature at all levels of theory and practice. This type of "culture contact" is gradually occurring at multiple levels of academic effort between reduction sequence and *chaîne opératoire* proponents, as examples of different approaches are read in both contexts and students are cross-trained by each group. While individuals trained in both theoretical literatures may not be able to act as culture brokers in Geertz's sense (1960), their ability to contextualize the theoretical differences in relation to the methodological differences may allow useful aspects of both disciplinary inheritances to be reworked in order to move the debate in a new direction. In fact, many examples can be cited that blur the lines between the approaches (Adler et al. 2004; Baumler 1988; Henry 1995; Hovers 1998, 2009; Hovers and Raveh 2000; Tostevin 2003b Tostevin and Škrdlá 2006; Van Peer 1992; Wurz 2002; Wurz et al. 2003). Providing a venue for such studies to be read by proponents of each approach is one of the goals of this special issue.

THE SCOPE OF THE APPROACHES

Before one can address the theoretical perspectives taken by advocates of each method under debate, it is necessary

to compare the scope of the approaches, in terms of types of material culture studied, in order to provide a context for the differences in theory and practice. This is particularly important since the scope of each approach differently situates it in relation to other fields within academia.

Shott (2003) has argued that the American reduction sequence approach and the *chaîne opératoire* approach are fundamentally the same thing. To the extent that Shott summarizes examples of lithic analysts working in both approaches, I agree with him, although I do see both high-level and middle-level theory differences that deserve attention (see below). The different scope of the approaches beyond their application to lithic technology, however, undermines any simple equation between them. The reduction sequence approach is *specific* to the study of stone tool technology, past or present. *Chaîne opératoire*, however, covers *all* material culture behavior, past or present. While initially put in practice by a Paleolithic archaeologist (Leroi-Gourhan 1964), the *chaîne opératoire* approach has since been applied to a broad spectrum of material culture through the work of ethnographers and historians of science as well as archaeologists. The diversity of material culture studies inspired by the *chaîne opératoire* approach includes ethnographic contexts of ceramic production (Dietler and Herbich 1998; Mahias 1993; Stark 1995; van der Leeuw 1993), medieval waterwheels (Cresswell 1993), prehistoric ceramics (Pétrequin 1993; Stark 1998; Stark et al. 1995), ethnographic ground stone celt production (Pétrequin and Pétrequin 1994), prehistoric celt hafting (Pétrequin 1993), ethnographic and prehistoric organic projectile technology (Knecht 1991, 1992; Lemonnier 1989, 1992), Early Upper Paleolithic bead technologies (White 1992), textiles (Cardon 1991), domestic architecture (Lemonnier 1992), harness technology (Haudricourt 1987), industrial aeronautics (Lemonnier 1989, 1992), Renaissance engineering (Gille 1964), irrigation technology (Bédoucha 1993), salt production (Lemonnier 1980), blacksmithing (Brouwer 1990), wine making (Guille-Escuret 1993), and modern cuisine (Schlanger 1990a). A wider survey of the diversity of subjects in the journal, *Techniques et Culture*, would demonstrate an even larger breadth of anthropological subjects covered. Its analytical scope is thus enormously larger than that of reduction sequence. Arguing that *chaîne opératoire* should be called "reduction sequence" because of the earlier work of Holmes (1894, 1897) is thus analogous to arguing that modern physics should be called "optics" because of Newton.¹

Rather than being an antecedent, it is possible to see the reduction sequence approach in American lithic studies as representing one of many sequence study approaches in archaeology, as Bleed (2001: 119; Bleed 2009) has usefully illustrated. Among Americanist sequence study approaches, the analytical subject and scope of the *chaîne opératoire* approach is far more analogous to Schiffer's Behavioral Archaeology program (McGuire and Schiffer 1983; Reid et al. 1975; Schiffer 1976, 1995; Schiffer and Skibo 1987, 1997) than it is to the reduction sequence approach in lithics, to the extent that some roughly equate one with

the other (Bar-Yosef and Van Peer 2009; Clark 2005: 381). While there are notable differences in theory and practice between Schiffer's behavioral chain analysis and the *chaîne opératoire* approach, the similarities are profound and the differences mostly complementary. The study of technical decisions in the sequence of production and use of material culture, contextualized against performance characteristics and social filtering of options, shows the commonality between the approaches, at all levels of theory. We should not be surprised at the convergence of independent innovations in the study of objects in action, as even earlier, although not necessarily ancestral, examples have yet to be acknowledged by archaeologists (although see Bleed 2001: 123). For instance, Frederick W. Taylor's time and motion studies begun in 1881 remain pivotal in the field of engineering (Niebel 1988) and are analogous in many ways to the analytical scope of both the *chaîne opératoire* approach and the Behavioral Archaeology approach.

Shott (2003) is correct that the early theoretical works of Mauss (1935) and Leroi-Gourhan (1943, 1945, 1964) are not without their problems as antecedents to the modern study of lithic technology (see also Bar-Yosef and Van Peer for a discussion of the historical development of *chaîne opératoire* studies within Middle Paleolithic archaeology). Mauss (1935) reads today like a casual stereotyping of how the British walk and the Turks eat, and Leroi-Gourhan's reconstructions of the past are indeed dated. Importantly, however, the direction in which ethnographers and historians of science have taken the body technique and artifact *chaîne opératoire* studies is *nowhere else* as holistic and inclusive of anthropological questions. While studies of *chaîne opératoire* in lithics have not yet demonstrated a diversity of theoretical perspectives (but see below), the potential of *chaîne opératoire* within anthropological research is immense. Conversely, there is only so far one can take lithics alone in understanding the world of human behavior. One does a grave disservice to the potential of the *chaîne opératoire* approach if Middle Paleolithic archaeology alone is the basis of understanding its analytical scope. For this reason, I choose to cite Mauss, Leroi-Gourhan, Lemonnier, Mahias, etc., alongside reduction sequence studies as a way to exemplify the broader anthropological context of technological sequence studies. Shott presents this very differently:

"Anglophone archaeologists have also embraced *chaîne opératoire*, often enthusiastically. But this repetition seems tactical rather than analytical, a way to register intellectual pedigree more than an operational method. There is nothing in their use of *chaîne opératoire* that could not be accomplished as easily and plainly with reduction sequence" (2003: 103).

In one sense Shott is correct that the use of either label should suffice for the presentation of data and interpretations, since replicable observation and characterization of operational sequences (low- and middle-level theory) should be the same between the approaches. But perhaps if lithic analysts *were* more tactical (or perhaps *strategic* is

a more apt term) in how we demonstrate the innumerable connections between our inanimate stone tools and the dynamics of human behavior *beyond* the Stone Age, then we would not have as much trouble justifying our existence within anthropology programs to the numerically dominant sub-discipline, namely social anthropology. In the context of American academia in which anthropology departments are ripping themselves apart along sub-disciplinary boundaries, strategic attempts to position lithic analysis within the larger context of anthropological subjects and questions has an important role. *Chaîne opératoire* and the Behavioral Archaeology program do this far more effectively than reduction sequence. Even with the use of the terms "reduction sequence" vs. "operational sequence," the latter reflects the broader context of technological sequence studies beyond the specific process in lithics. In this sense, there is a benefit to embracing the wider analytical scope of one label rather than the other.

LEVELS OF THEORY

One reason for the absence of a discussion of the theoretical differences between the approaches in the present debate is the fact that the explicit espousal of high-level theory is considerably different in each context (Bleed 2001). Archaeological theory is not conceived of exactly the same way by proponents of the two approaches. This frequently results in explicit statements of theoretical orientation by American reduction sequence proponents and implicit orientations within methodological discussions by *chaîne opératoire* proponents. The request for participants in the present special issue to be explicit about epistemological issues was an effort to remedy this situation. For the present discussion, therefore, I will be explicit about the terminology of different levels of archaeological theory in the hope that it will improve the understanding of the relationship between theoretical goals and analytical practice in both approaches.

Following Thomas (1998: 66–94), archaeological theory can be usefully conceptualized at three levels of operation. Low-level theories include observations obtained in archaeological fieldwork, what are usually termed "data." These include the products of measurement techniques, *lecture* gestalts, statistical representations of counts and attributes, and published artifact illustrations. Middle-level (or middle-range, *sensu* Binford [1977]) theories connect observations to patterns of human behavior through experimental archaeology, ethnoarchaeology, and other types of research designed to recognize causal relationships between the processes of human behavior and their resultant effect on the formation of the archaeological record. High-level theories provide the reasons for asking certain questions of the archaeological record, usually from a specific orientation to explaining reality, be it scientific or not. The *chaîne opératoire* and reduction sequence approaches differ to some degree in their use of theory at all of these levels.

Within middle-level theory, there is much overlap between the approaches, as exemplified by the common task of understanding how human behavior is reflected in

the dynamic processes of lithic technology. As both Bleed (2001) and Shott (2003) note, there are clear similarities in the use of a stage approach to characterize an assemblage as capturing certain portions, as opposed to other portions, of the reduction sequence from raw material acquisition to discard of the exhausted retouched tool (Callahan 1979; Geneste 1985, 1988; Holmes 1894, 1897). Similarly, both approaches use ethnoarchaeology (Bril et al. 2005; Pétrequin and Pétrequin 1994; Shott and Sillitoe 2004; Sillitoe and Hardy 2003; Stout 2002; Weedman 2002) as well as experimental replication (Amick and Mauldin 1989; Bradbury and Carr 1999; Geneste and Plisson 1990; Pelegrin 1995, 2000; Shott et al. 2000) to shape their middle-level theory. Despite this overlap, the differences which *do* result from the practices in each approach are most apparent in low- and middle-level theory, as discussed by Dibble (1995) and Shott (2003). In my view, this is not because they originate at these levels of archaeological practice but because of the pervasiveness of differences in high-level theory, as well as the manner in which theory is discussed by *chaîne opératoire* practitioners. This point requires further clarification.

Chaîne opératoire studies rarely acknowledge a specific high-level theory perspective, apart from *chaîne opératoire* itself, for the origin of the questions they ask of the archaeological record. This is in contrast to the frequency with which reduction sequence studies utilize the organization of technology approach (i.e., middle-level theory developed by Andrefsky 1994; Bamforth 1986; Binford 1979, 1980, 1982; Bleed 1986; Carr 1994; Kelly 1988; Nelson 1991; Shott 1986; Torrence 1989) to pursue questions of high-level theory from evolutionary ecology (Foley 1985; Kelly 1995; Krebs 1978; O'Connell 1995; Shennan 2002; Smith 1983; Smith and Winterhalder 1992; Winterhalder 1986, 1997; for a comprehensive overview, see Krebs and Davies 1997). Despite the fact that *chaîne opératoire* practitioners investigate very similar questions of diachronic behavioral change in raw material economy (Féblot-Augustins 1993, 1997; Geneste 1985, 1988; Tixier 1980) and hunting technology (Geneste and Plisson 1990; Plisson and Geneste 1989), they do not situate the method or results in the context of a high-level theory such as evolutionary ecology. This is the result of two factors. First, they view *chaîne opératoire* itself as a high-level theory that provides both its own questions of the archaeological record and its own analytical methods (Audouze 1999; Pelegrin 1990). Second, *chaîne opératoire* practitioners tend to be more explicit about middle- than high-level theory. As Audouze comments (1999: 168, footnote 1), theories are often expressed in French literature as "concepts" embedded in discussions of methodology and so are often not as distinguishable as, or perhaps even intended to be, theories as in other literature. French prehistorians also tend not to engage theory for the sake of theory itself unless it is central to an issue of data (Sackett 1991). Audouze's argument (1991: 171, footnote 3) for the switch from the dominance of Bordes' method to the *chaîne opératoire* method supports Sackett's conclusion.

THE ORIGINS OF *CHAÎNE OPÉRATOIRE* AS AN ETHNOLOGICAL APPROACH

In applying the distinction in levels of theory to the literature of *chaîne opératoire*, one high-level theory goal stands out as a central theme—the desire to reconstruct the emic-level decisions of prehistoric artisans (for the distinction between emic and etic explanation, see Harris 1976). The epitome of the *chaîne opératoire* approach is the understanding of the cognitive plan of the prehistoric artisan that guided the execution of a technological system (Bleed 2001: 105). This goal of emic interpretation originates in Leroi-Gourhan's development of the concept of *chaîne opératoire* from Mauss' (1935) *techniques du corps*. While Mauss' *technique* consisted of energy utilized through the action of the body, Leroi-Gourhan (1943, 1945, 1964) turned the body into a tool through which energy is applied to the physical world, thereby incorporating both material culture with the body as the tool or means of action as well as bringing the product of the action itself, physical or otherwise, within the domain of study. Only by conceiving of *le geste* or gesture as the articulation and unifying principle between the means and the energy of action was Leroi-Gourhan able to bring material culture under Mauss' conception of *technique* (Schlanger 1990b). As a result, for Leroi-Gourhan, no tool is complete without the gesture used to put the tool into action. This concept of a technical act as both participating in the social world of technical plans as well as the physical world of gestures in action has profound ramifications for the utility of the *chaîne opératoire* concept *beyond* its current use by *chaîne opératoire* lithic scholars. These uses include a model for the study of social archaeology in the Paleolithic, as eloquently proposed by Gamble (1999: 1–97), the situating of technological studies within the social anthropological practice theories of Bourdieu and Giddens (Bourdieu 1977, 1980; Giddens 1979, 1984; see Dietler and Herbich 1998; Hegmon 1998; Stark 1998; Stark et al. 1995), and the application of sequence studies to cultural transmission theory and acculturation modeling (Tostevin 2007, 2012). In contrast to the negative ramifications of the emic goal discussed below, these new uses of Leroi-Gourhan's concept by non-*chaîne opératoire* practitioners represent a positive consequence of the ethnological content of *chaîne opératoire* theory.

Having developed his *chaîne opératoire* concept from the point of view of an ethnological approach to material culture, Leroi-Gourhan put it into practice archaeologically within the context of *palethnologie*, "the ethnographic comprehension of the past" (Masset 1988: 804, translation by Tostevin; see also Leroi-Gourhan 1970, 1983; White 1993: xvi). The timing of the growth of the *palethnologie* school of archaeology is interestingly parallel to the growth of the processual agenda in Americanist archaeology. In particular, *palethnologie's* "ethnographic comprehension" and Binford's (1962) espousal of Willey and Phillips' "archaeology is anthropology or it is nothing" (1958: 2) were somewhat analogous. Leroi-Gourhan advanced the *palethnologie* approach in direct opposition to his view of the exclusive preoccupation of prehistorians with diachronic change (Masset

1988). The processual agenda's focus on culture process as well as the human adaptation within a synchronic, ecological, and systemic context was equally advanced in opposition to a simplistic approach to diachronic culture historical change (Tschauner 1994). Where the two approaches diverged almost immediately was in Leroi-Gourhan's emic-level goal to behavioral reconstruction, which utilized inductive and inferential reasoning appropriate in ethnology compared to the etic and deductive approach of Binford's processual agenda.

What is more significant is the effect of personality on the development of the two approaches. Binford argued that archaeology must develop its own epistemological orientation to middle-level theory through the scientific tradition of literature debates on theory as applied to data in practice (1965, 1977). In contrast, Leroi-Gourhan put an explicit ban on epistemological discussions of his theory (see Audouze 1999: 168–169) so that archaeologists of his school were limited to innovating low-level theory methods of technological reconstruction, such as refitting, *décapage* excavation, and *lectures* (e.g., Boëda et al. 1990; Pigeot 1987; Tixier 1980). The further development of what has come to be the dominant middle- and high-level theory in *chaîne opératoire* practice was thus left in the hands of ethnographers and historians (e.g., Gille 1964; Haudricourt 1987; Lemonnier 1992) who never challenged the emic-level goals on epistemological grounds. Had there been more willingness to challenge the epistemological validity of the emic approach at the beginning of the history of *chaîne opératoire*, despite the personal authority exercised by Leroi-Gourhan as the head of his own intellectual approach, the current reduction sequence vs. *chaîne opératoire* debate would be quite different. This is one example of how the institutional cultures of lithic analysis shape the multinational practice of the discipline.

There are two important ramifications of Leroi-Gourhan's situating *chaîne opératoire* within the context of an ethnological approach to both the ethnographic present and prehistory. One ramification is positive, as noted above. The other has been more negative. Recognizing these consequences of high-level theory goals is vital to making progress in the debate between reduction sequence and *chaîne opératoire* practitioners in lithic analysis.

THE TYRANNY OF THE EMIC GOAL IN CHAÎNE OPÉRATOIRE MIDDLE-LEVEL THEORY

For current ethnographers of the *chaîne opératoire* approach (e.g., Lemonnier 1992, 1993), the social world is seen as directly affecting the choice of technical options at decision points in technological procedures. Through the documentation of such socially-informed choices, the immaterial world can be reconstructed from the material world. As a result, for practitioners such as Lemonnier (1986; 1992: 85–103; 1993), Mahias (1993), and Pétrequin and Pétrequin (1994), a choice between two options in a technological process or *chaîne opératoire* is only of interest to the researcher if it can be demonstrated that the individuals involved in the

technology knew of each potential option. Thus, a choice is only informative of the social realm if the choice is emic, i.e., recognized by the artisan as a choice.

For ethnographic research, this restricted view of the technological process is epistemologically valid, as an artisan can be questioned as to whether or not an alternative option at a given step is known within that group. The perspective, however, is *not* epistemologically valid in the study of prehistory, as there is no one to provide a true emic viewpoint, a critique made frequently by reduction sequence practitioners (Clark and Lindly 1991: 578). Nor is the ethnographic perspective justified in and of itself, as it fails to recognize the validity of the cultural evolutionary (i.e., long term cultural phylogenetic) ramifications of the use of one technological possibility versus another, regardless of whether or not it was a conscious choice. The historical contingency of technological knowledge is thus lost with this emic requirement. Take, for example, the case of two isolated populations "I" and "II," the first of which emically knows only technological solution "A" to an adaptive problem whereas population II only knows technological solution "B." While in isolation, these two technological solutions may exemplify two "equally viable alternative ways of achieving the same end" (Sackett 1986b: 630) handed down between generations through group enculturation, what Sackett called *isochrestic* variation in material culture production methods (Sackett 1990). Yet the descendants of these two populations, inheriting their respective technological methods, would experience a case of cultural evolutionary selection when they come into contact and technological solution B proves its hither to fore unknown adaptive advantage to population II. None of the evolutionary significance of this historical sequence relates to any emic choice among options within either population—they only knew how to perform their technological behaviors a certain way. Emic choices among options in a production sequence had nothing to do with the otherwise important cultural evolutionary result when population II replaced population I because of the new relative advantage offered by technological solution B. Given this situation (one exemplified in many technological fields to judge from arguments in Diamond 2005), the restriction to view only emically-recognized alternatives in the study of the archaeological record both arbitrarily and unnecessarily limits the etic understanding of technological processes and artifact variability in cultural evolution.

Yet archaeological practitioners of *chaîne opératoire* working in the *palethnologie* approach retain the emic requirement in their study of prehistoric technology in many ways (Bar-Yosef and Van Peer 2009: 114). For instance, Pétrequin (1993) uses convoluted scenarios to argue that a technical option was emically known to a given group of Neolithic artisans, despite the absence of its use within that group, because of the group's familiarity with another group which happened to use that technical option. While possible, this type of argument is only necessary if the variation in use of technical options is assumed to be conscious, active style, i.e., the intentional signaling of identity

with that technical option (Wobst 1977). Wiessner (1983), however, has shown in ethnographic contexts that active, emblematic style is often unconscious, unintentional, and only etically recognized—San artisans were not conscious of making arrows whose style was diagnostic (emblematic) of their language group. Nevertheless, they could select out their own arrowheads from a pool of several groups' arrows. More importantly, they reacted with fear and suspicion to the style of an unfamiliar group's arrows, clearly evidencing the past action of emblematic style in boundary maintenance. This example shows how the emic focus at the middle-theory level overlooks meaningful behavior and thus can be counterproductive in the study of cultural evolution.

The emic focus of *chaîne opératoire* high-level theory is responsible for significant differences in low- and middle-level theories in comparison with the reduction sequence approach. For instance, it explains why the emic concept of stages of reduction continues in *chaîne opératoire* studies while the reduction sequence approach is moving toward continuum modeling (Bradbury and Carr 1999, 2001; Ingbar et al. 1989; Shott 1996; and Carr and Bradbury, as well as Shott et al. in this special issue) and thus away from treating reduction stages as anything but poor analytical constructs. It also explains the inferential and emic basis of *chaîne opératoire* experimental knapping; compare, for example, Carr and Bradbury (2001) with Pelegrin (2000, 2003). This emic bias also may be responsible for robbing *chaîne opératoire* replication experiments of the great potential of deductive emic approaches, such as small-scale debitage analysis currently growing in American lithic studies (Baumler and Davis 2000; Hall and Larson 2004).

Understanding the implications of the emic bias is complex but there are significant clues to its effects. Without informants to interview, the emic perspective to technological processes becomes a set of abstractions or gestalts derived by the archaeologist from the specifics of the archaeological record. This is what Bleed (2001: 121) called the "teleological model" of sequence studies and what Bar-Yosef and Van Peer (2009: 105), in their critique of the emic-level goals of *chaîne opératoire*, called "technopsychological" studies after Boëda et al. (1990: 43). Pelegrin best explains the logic behind the use of emic-level abstractions in the characterization of a reduction sequence:

"Such undertakings [flintknapping]—based on raw material which is never standard, and with gestures of percussion which are never perfectly delivered—cannot be reduced to an elementary repetition of gestures, or to the application of immutable sequences (as a machine would do). On the contrary, the realisation of elaborate knapping activities necessitates a critical monitoring of the situation and of the decisions adopted all through the process. If this is the case, then the capacity to mentally evoke the precise desired product is necessary for successful knapping, but it is not sufficient. The knapper has in mind successive goals, that is, a series of intermediary stages and geometric 'cues.' It is in respecting these, and with experience, that the anticipated result may be reached. These intermediary stages form

a chain of intentions organized in a 'conceptual *schema opératoire*'. They are defined through certain geometric parameters, and they may represent the moment when a particular operation or technique changes to another (Pelegrin 1985, 1988a [sic, 1993]). Between these stages, the actual and the real situation is compared with the corresponding concept and diverse action modalities are evoked in order to correct a given state or to progress in the *chaîne opératoire*. Using experience, the knapper chooses the (most) adapted action modality—the one which is both possible and desirable (Pelegrin 1990: 117).

For Pelegrin, therefore, the emic understanding of a prehistoric flintknapping event must be described in the abstract terms of desired end-products, or, alternatively, cues for the pursuit of the reduction for such end-products despite the vagaries of knapping performance. In so doing, *chaîne opératoire* practitioners strive to see beyond the haphazard aspects of reduction to the artisan's intentions. Bleed's (in this special issue) discussion of how concepts from the cognitive sciences can improve the study of archaeological examples of sequenced tasks is an important step in broadening the interdisciplinary understanding of Pelegrin's discussion above, particularly of 'cues.'

The presentation of the abstract *schema opératoire* described by Pelegrin most often takes the form of schematic drawings (*sensu* Inizan et al. 1999: 126–127) as emic principles for the pursuit of desired end-products. In contexts in which numerous, contemporaneous refitting sequences exist, drawings and photographs of the refits of specific core reductions accompany the schematic drawings to support the abstractions (e.g., Valentin et al. 2004). For example, such refits have supported the analysis of differential learning and performance skills in episodes of apprenticeship in Magdalenian campsites (Pigeot 1987, 1990; Ploux & Karlin 1993). Utilizing the refitting sequences, these analyses are fairly comparable in low-level and middle-level theory with quantitative reduction sequence studies (e.g., Whitaker and Kaldahl 2001).

In contexts without extensive refitting sequences, however, the emic focus has led to the construction of abstract cognitive or volumetric rules, such as Boëda's (1993, 1994, 1995) criteria for the production of Levallois and other flaking technologies, but without the evidential support normally associated with other aspects of low-level and middle-level theory in archaeology. Without traditional artifact drawings of debitage and cores (*sensu* Addington 1986 or Inizan et al. 1999: 101–125) accompanied by attribute studies of the dynamic aspects of reduction to substantiate the abstract schematic drawings (e.g., Baumler 1988; Dibble 1987; Henry 1989; Kuhn 1990), there is little evidence independent of the researcher's gestalt for other archaeologists to use to evaluate the validity of the emic interpretations. This critique of Boëda has in fact been made by Van Peer (1992), himself both a *chaîne opératoire* proponent and critic (see also Bar-Yosef and Van Peer 2009). The absence of standard reporting of data produces a scientifically unconvincing argument beyond the appeal to authority. Given the disagreements over how the reduction sequences them-

selves are reconstructed via *lectures* or attribute analyses (i.e., Boëda 1988 vs. Dibble 1995), the appeal to authority fails to be effective. The difference in the willingness to rely on appeals to authority between French and American archaeologists further complicates the issue.

Reduction sequence practitioners are clearly skeptical of such abstractions given their reservations about inferential research as well as the epistemological risk involved in reconstructing prehistoric thought (Dibble 1989). The emic approach has long been debatable in Americanist archaeology for a number of reasons. First, Native Americans are not the evolutionary “other” and so emic reconstructions, usable for the study of cognitive evolution, are not of interest. Second, the Ford (1952, 1954) vs. Spaulding (1953) debate remains an unresolved theoretical problem for the validity of reconstructions of emic types and meanings in prehistoric artifacts. Therefore, the extent to which the reduction sequence vs. *chaîne opératoire* debate will be changed by recent innovations in *chaîne opératoire* methods will depend on how the issues raised by the Ford-Spaulding debate are addressed. I am thinking here specifically of Wurz et al.’s (2003) use of novel multivariate statistics to document desired end-products in a way reminiscent as much of Spaulding as it is of the *chaîne opératoire* approach.

PUTTING THE EMIC APPROACH IN ITS PROPER CONTEXT

Bleed (2001: 120–121) describes the emic approach to characterizing archaeological assemblages through the discovery of a predetermined process as the *teleological model* of sequence studies. He opposes this to the *evolutionary model* which presents technological sequences as reactions to situations encountered in the sequence of production, use, and discard as part of tasks conducted in the environment. This is a useful distinction for many reasons, including the fact that examples of the teleological and evolutionary approaches can be found among scholars on both sides of the *chaîne opératoire* and reduction sequence distinction.

It is also a useful distinction because of Bleed’s arguments for the utility of both approaches to sequence studies, whether targeting lithic technology or not. I agree that there is a place for using an archaeologist’s understanding of the emic view of a technological process to provide etic understanding of culture change. Beyond the principle that free-hand knapping experiments aid archaeologists’ inferences and hypothesis formation (Whittaker 1994), the constraints of technological processes as witnessed from the artisan’s point of view can be informative for understanding where technological variation can occur. Christopher Carr’s “Unified Theory of Artifact Design” (Carr 1995; and other papers in Carr and Neitzel 1995) provides a context for understanding how the emic approach of most *chaîne opératoire* research can be complementary to the etic perspective of the reduction sequence approach. Carr (1995) presents a body of middle-level theory for predicting which utilitarian, technological, and social processes can affect the design of specific physical attributes of an artifact by modeling how the attributes are made in the technologi-

cal process and how visible they are in their social context of production and use. Specifically, he sets up a middle-range theory procedure for evaluating the potential list of processes affecting different attributes according to the attributes’ position in three hierarchies—the decision sequence hierarchy, the production sequence hierarchy, and the visibility hierarchy. The decision sequence hierarchy is the order with which you must decide the attributes of the artifact you want to make, before any manufacture takes place. The teleological abstractions preferred by *chaîne opératoire* practitioners, such as desired end-products or Boëda’s five technological rules for Levallois production, are analogous to a decision hierarchy. The production sequence hierarchy is the order in which you must create the physical attributes of the final product. This is the classic reduction sequence, although without the landscape specificity of the organization of technology approach (Nelson 1991). The third and most important hierarchy for Carr is the visibility hierarchy, the ranking of attributes by how visible they are both physically at different distances and relatively in different social contexts. What social processes can be manifested in an attribute are determined according to Carr’s ethnographic data by the attribute’s contextual visibility. The ramifications of the visibility hierarchy are beyond the present paper, although they are instrumental in uniting various aspects of style theory, the organization of technology, and culture transmission theory as pursued elsewhere (Tostevin 2007, Tostevin 2012). The importance of recognizing the distinction between a production sequence hierarchy and a decision hierarchy is that the former is used as an abstraction to understand the constraints and sources of variation in the latter. In some ways, this is analogous to Pelegrin’s (1990, 1993) very productive distinction between *savoir-faire* (know-how) and *connaissance* (knowledge), or, alternatively, the difference between tactical and strategic knowledge of a given flintknapping method that explains the adaptable and haphazard aspects of reduction. Yet Carr’s distinction forces us to keep the levels of analysis *separate*—a production sequence hierarchy should be the *actual* process executed in the past, demonstrable with quantitative data in the form of attribute analyses or refitted sequences, while the decision hierarchy is an abstract theoretical set of principles which inform our understanding of the constraints seen in the actual data. While abstracted from the pattern in the data, decision hierarchies in Carr’s middle-level theory are not assumed to have any validity as true emic representations or “mental templates” of prehistoric artisans (*sensu* Deetz 1967: 43).

This distinction is already understood by many *chaîne opératoire* practitioners. For example, Karlin and Julien (1994) note, “The reconstruction of certain *chaîne opératoire* allows us to arrange the information in a coherent order and, by various analyses, rediscover the processes involved in techniques of production *and, beyond that*, the conceptual pattern from which they sprang” (1994: 153, emphasis added). Further, Pelegrin’s reasoning (1990: 117) given above articulates why a decision hierarchy is an abstraction. Unlike the practice of many *chaîne opératoire* analysts, however,

the above reasoning *does not require* that the documentation of the existence of the production sequence in the archaeological record be abstract. In my view, this requirement is more a result of the influence of the ethnological origins of *chaîne opératoire* high-level theory than it is a result of sound archaeological epistemology. Following Carr's artifact design theory, therefore, the actual pattern of flintknapping behaviors in an assemblage should be presented from a purely etic perspective, after which the emic-level abstractions of the decision hierarchy can be derived from the data to inform our understanding of the processual constraints. To accomplish this change in the use of abstraction in lithic studies, however, requires abandoning the typological characterizations of sequences and assemblages which are too readily seen as emic entities.

EPISTEMOLOGICAL PROBLEMS WITH SEQUENCE-LEVEL TYPOLOGY: A RALLYING POINT IN THE DEBATE

In viewing the research of both approaches as potentially complementary, the recognition of shared epistemological problems can serve as rallying points for a more positive international discourse on lithic analysis. For instance, both approaches suffer from one significant methodological problem—there is a strong tendency to “type” technological processes. Whether typing methods for producing flakes or typing an assemblage of prehistoric artifacts as belonging to a given industrial complex, giving a typological structure to archaeological data unfortunately results in the presentation of interpretations as data-free labels in the literature rather than comparable descriptions of the assemblages in question that others can use themselves to evaluate the validity of the interpretative conclusion (Clark 1993). As Shott notes (2003: 100):

“Contemporary archaeologists champion culture-specific reduction sequences of *chaîne opératoire*, rejecting Bordes' culture-specific assemblage types just as Bordes rejected an earlier generation's culture-specific tool types. If the latter were invalid index fossils, then Bordes' concept reduced [these] to index communities in a biological sense, Boëda's to index technologies (or ontogenies, to pursue the biological metaphor). French Paleolithic archaeology progressed from essential tools to essential ways to make tools. All have invoked the index concept of essences bounded in time and space that mark traditions, whether they be phylogenies or cultures.”

I cannot agree more with this comment, as I have been at pains to state elsewhere (Tostevin 2003a: 56–57). *Chaîne opératoire* is almost invariably used as typology in an epistemological sense (Adams and Adams 1991) as is Bordes' type-list (Bar-Yosef and Van Peer 2009; Monnier 2009). The *chaîne opératoire* emphasis on emic abstractions partly explains the tendency to continue the index concept despite the change in analytical focus from retouched tools to core technology.

American scholars, however, also typologize the re-

duction sequence concept. Both experimental studies and adaptive explanations in American lithic technology frequently typologize the diversity of technical acts into technological types (Bleed 2001: 121–122). For instance, the investigation of the adaptive difference in the amount of cutting edge per unit volume produced experimentally (e.g., Rasic and Andrefsky 2001), as well as the powerful methods of identifying “reduction types” in an assemblage through statistical formulae (Bradbury and Carr 1999; Carr and Bradbury 2001), all treat “bifacial reduction,” “blade reduction,” and “core reduction” as immutable experimental species. Almost none of these studies, following the early precedents in Amick and Mauldin (1989), define what is meant behaviorally by categories such as “flake technology,” “biface technology,” etc. There are dozens of methods of reducing a core into blades or flakes or bifaces, any of which could produce serious differences in efficacy from an organization of technology view point. Yet how these categories were produced in explicit behavioral detail is rarely reported. What central tendency and dispersion were used for platform thickness in making the experimental assemblage? What was the variability in the exterior platform angle? How was the volume of the core reduced by each flake removal in terms of its width/thickness ratio? What directionality of reduction was used and how did this relate to platform rejuvenation techniques? All of these issues have been connected with potential raw material conservation and tool longevity issues (Dibble 1997; Marks 1988) which would directly affect the questions being asked by these experiments. The deductive approach of such replication experiments loses much of its applicability when the initial conditions of the experiments remain undefined.

While Americanist approaches to experimental flintknapping have failed to recognize the diversity of reduction sequence possibilities within their “types” of reduction, it must be said that they at least use the types in asking meaningful processual (high-level theory) questions about differences between the types. In contrast, until relatively recent papers by Delagnes and Meignen (2002, 2006), Delagnes et al. (2007), and Delagnes and Rendu (2011), *chaîne opératoire* advocates have done little with the diversity of assemblages “typed” to one *schema opératoire* or another. In part, they have been waiting for sufficient data to begin to understand the meaning of the temporal and environmental patterning of these technologies in the past. Rather than immediately testing hypotheses derived from specific high-level theories, they remain cautious. As Beaune notes (2009:120), when “organizing an epistemologically oriented colloquium on the means at our disposal to reconstruct daily life in the Upper Paleolithic (Beaune 2007), the major specialists on lithic technology declined my invitation, some of them arguing that it was still ‘too early’ to tackle the question of daily life.” This patience may in fact be a byproduct of the inferential science of prehistory in parts of Europe, where scholars are much more loathe to be wrong in print than are North Americans who can blame deductive reasoning and the publish-or-perish job market for their published conclusions that later prove incorrect. For France in particular,

the ability of *chaîne opératoire* researchers to progress slowly in applying their data to synthetic explanation as well as to engage in labor intensive data gathering techniques such as refitting can be seen in the job security afforded them by the institutional structure of the CNRS. North American archaeologists, in contrast, face multiple career-ending challenges, i.e., the tenure review process in academia and the corporate nature of CRM research, that encourage both fast publication and labor-saving innovations such as aggregate analysis (Ahler 1989a,b; Hall and Larson 2004; although its efficacy is currently being debated by Andrefsky 2007 and Bradbury and Carr 2009). In this way, the institutional structure of the social practice of archaeology in different national contexts contributes significantly to how lithic analysis is pursued.

And yet, even after two decades of *chaîne opératoire* research, these technologies are still being treated as immutable species. How is one to gauge the degree of similarity or difference (whether in adaptation or shared cultural learning) between an assemblage with a unidirectional recurrent Levallois system, say, and that with a *discoïde* system (Boëda 1993)? Despite the praise afforded them by Audouze (1999), the phylogenetic arguments of Boëda for how one *schema opératoire* can evolve into another are far too abstract to be replicable beyond that of a type.

Both the *chaîne opératoire* and the reduction sequence approaches need to utilize a method for describing each assemblage's technology according to standardized units of analysis that are comparable between assemblages. For instance, to use the analogy of French wine, a type of material culture close to the hearts of many lithic analysts, the current *chaîne opératoire* and reduction sequence systems would type three archaeological assemblages as three different red wines according to a defining label, say Château Pétrus, Château Mouton-Rothschild, and Château Gazin. Using such labels, neither approach can tell you how similar the wines really are to each other. The requirement to report comparable units within each label, however, would lead an analyst using an improved system to note categorical or continuous attribute variables within each wine, such as the grape varieties used in the production of the wine. While *cépage* or "grape varietal" as a variable does not encapsulate all of the variation between wines, it is one of the variables that does satisfy the needs of the new system; each wine varies quantitatively in this variable and the variable is comparable between wines. Thus, Château Gazin is a mixture of 80% Merlot, 15% Cabernet franc, and 5% Cabernet sauvignon; Château Pétrus is recognized as an ensemble of 95% Merlot and 5% Cabernet franc; and, Château Mouton-Rothschild is an ensemble of 85% Cabernet sauvignon, 10% Cabernet franc, and 5% Merlot (Stevenson 1997: 80,116). With these more suitable units of analysis, it is then possible to state *quantitatively* that Château Pétrus is more similar to Château Gazin than to Château Mouton-Rothschild based on these variables. Lithic analysts need something analogous to such units.² Such variables would allow archaeologists to treat assemblages, however defined (McPherron et al. 2005; Tostevin 2009; Tostevin and Škrdla

2006), as the largest unit of analysis and thus avoid reifying analytical categories while endeavoring to study diachronic change in behavioral variability, a task impossible with typological reasoning (Clark 1993; Straus 2003). In brief, we need to shift from a typological (essentialist) approach to one of population thinking, as recently adopted by evolutionarily informed archaeologists.

As noted above, a recent trend in *chaîne opératoire* research by Delagnes and Meignen (2002, 2006), Delagnes et al. (2007), and Delagnes and Rendu (2011) has shown a marked change in the analytical use of assemblages typed into particular *chaînes opératoires*. Instead of treating the identification of the *chaînes opératoires* as the goal, these studies use them as a means to an end. These researchers are now using well-dated assemblages to pinpoint the temporal, environmental, and subsistence contexts of different types of *chaînes opératoires* such as Levallois and laminar flaking systems, the Mousterian of Acheulian Tradition shaping system, the Quina flaking system, and the Discoïdal-denticulate flaking system. This is a wonderful development, particularly with the connection being drawn between faunal exploitation and lithic technology. Delagnes and Rendu (2011) explicitly tie their study of these technological types to the high-level theory of evolutionary ecology through the logic of how the technological system articulates with the subsistence and mobility strategies of the hominin populations. They are in fact using and citing the Organization of Technology approach begun by Binford (1979), Kelly (1988), and Bamforth (1986). This is a remarkable convergence in high-level theory goals; Delagnes and Rendu's Figures 3 and 4 could be added to Binford (1980) without many readers noticing the substitution. Yet despite this very positive reaffirmation that all lithic analysts are truly engaged in the same task of understanding the holistic lifeways of past stone tool users, the emic-approach within this *chaîne opératoire* research may still derail the convergence to some degree. Beyond the thorny issue of eliminating our recognition of technological variability through the qualitative pigeon holing of assemblages into technological types described above, the ecological distinctions for each technology proposed by Delagnes and Rendu (2011), building off of the conclusions of Delagnes and Meignen (2006), are not as quantitatively justified on the order of low-level theory or rigorously articulated with the middle-level expectations of behavioral ecology as you see in parallel examples of other organization of technology studies. For instance, the conclusions in Delagnes and Rendu's Figure 5, showing the placement of the four technological types noted above in relation to the three axes of "tools maintenance," "blank versatility," and "duration of flaking/shaping sequences," are not as quantitatively supported as one would like when employing these conclusions in evolutionary syntheses. The logic of Levallois-laminar assemblages having a very long flaking/shaping sequence but very low blank versatility requires many assumptions. First, there is an emic assumption of which artifacts within the reduction sequence were actually used (an repetition of the "desired end product" problem). As Sandgathe (2004)

has pointed out, the preferential Levallois flake could, for all we truly know, be the “convexity reformation” flake for the purpose of renewing the surface for the removal of the truly desired products, i.e., the small flakes which we otherwise call “preparation flakes.” Stranger things have been shown to be true, thinking of Dibble and McPherron’s “Missing Mousterian” (2006). And what are the ecological consequences of having a long flaking/shaping sequence? Is it time or raw material that is of concern for this variable? If the consequences relate only to the conservation of lithic raw material, the technologies would be better characterized according to a quantitative measure relevant to mobility, such as a mean of the technologies’ flakes’ artifact utility or potential for renewal (*sensu* Kuhn 1994) or cutting edge unit per weight, as suggested by Eren et al. (2008). As is, the reader has little idea how this characterization articulates with behavioral ecology.

Second, what makes Levallois products less versatile? If it is a question of pure morphological variability that equates to versatility, that could be evaluated in numerous quantitative ways. But a blank’s versatility can also be defined as how many tool forms it could take under the application of retouch. In that case, Levallois would be a more versatile technology and should be located at the other end of this axis. According to Brantingham and Kuhn’s model (2001), as well as the overall high width to thickness ratio of Levallois products compared to thick cross-sectioned Quina blanks, Levallois flakes are more readily retouchable and thus have a longer use life and can take many tool forms, compared to a tool created on a Quina blank. There are quantitative ways to apply the lessons of experimental archaeology to evaluate predictions for the ecological attributes of particular technologies, as Eren et al. (2008) has shown. The fact that certain examples of Levallois-laminar assemblages in their case region do not evidence high retouch reduction shows *what those hominins did* with that technology but not *how the constraints of that technology lead to its specific use in all cases*. This distinction is subtle but the latter is the only causal argument for coming to a generalizing conclusion that all instances of Levallois-laminar assemblages would have the predicted mobility pattern. Thus while this new application of *chaîne opératoire* research is very positive and potentially a new goal for insightful and holistic research, it is hoped that more quantitative support for the generalizations about the ecological ramifications of these technologies will be pursued in future research.

ABANDONING THE TYPOLOGICAL APPROACH TO THE CHARACTERIZATION OF TECHNOLOGICAL SEQUENCES AND INDUSTRIAL COMPLEXES

Avoiding the epistemological problems of typology at the experimental sequence and archaeological assemblage level thus requires an evolutionary model of sequence study that “present[s] the behavioral variability encompassed within past technological processes” (Bleed 2001: 122) for comparison between example sequences or assemblages. Such a model of sequence study, however, cannot be tru-

ly represented as situational responses to environmental tasks or constraints, the other half of Bleed’s definition of the evolutionary model. Studies following the situational approach recognize responses at nodes or stages of reduction which may or may not be comparable between different reductions because different situational constraints and tasks may be present in each case. While very useful for the study of reactions within the cultural context of one assemblage, the situational approach tends to produce incomparable results in the same way that the typological end-product concept of the teleological model does. A different concept of node or sequenced behavior is required that utilizes the artisan’s view of constraints in the technological process but documents them in etic observations comparable between assemblages.

I have endeavored to define and demonstrate the use of such sequenced behaviors through my own method (see Tostevin 2000a,b, 2003a,b, 2007, 2012; Tostevin and Škrdla 2006) of studying reduction sequences according to a behavioral approach (*sensu* Schiffer 1976, 1996). In using comparative behavioral units of analysis within each archaeological assemblage, my approach to resolving the typological problems of studying technology is thus different in specifics from both the reduction sequence and *chaîne opératoire* schools and yet has much in common with each. Following the etic and evolutionary model approach, individual flintknapping behaviors among the technical acts represented by an assemblage are measured as central tendencies and dispersions within the assemblage, rather than as anecdotal refits or overly abstract typological constructs of archaeologists, such as “Levallois,” “desired end-products,” and “industrial types.” Following the social archaeology approach of utilizing the social significance of technical acts (Gamble 1999; Tostevin 2007), each assemblage is defined as the association of flintknapping behaviors enacted at that spot on the landscape within the given time range of the assemblage’s palimpsest (see Tostevin and Škrdla 2006 for the development of this argument). In other words, *each assemblage represents one enculturating environment* (*sensu* Boesch and Tomasello 1998; Donald 1991, 1998) created by all of the hominins who have contributed material culture to its palimpsest. This definition is both epistemologically justifiable given Pleistocene site formation processes and analytically appropriate for the study of the evolution of specific technical acts between Paleolithic populations represented by individual assemblages. This is also the structure of the low- and middle-level theory needed to answer questions of technological diffusion, acculturation, and the historical contingency of learned behavior in the Paleolithic (Tostevin 2007, 2012). These questions derive from the high-level theory goals of cultural transmission theory (Boyd and Richerson 1985, 1996, Cavalli-Sforza and Feldman 1981, Durham 1991; Eerkens and Lip 2007; Shennan and Steele 1999) and the archaeological study of Paleolithic societies (Gamble 1999). These are of course the high-level theory questions I am intrigued by and are not necessarily those of interest to all lithic analysts. Nor should they be—lithic analysis should embrace the diversity of archaeologi-

cal and anthropological questions as long as the low- and middle-level theories are replicable internationally.

A characterization of “what artifact makers actually did” (Bleed 2001: 121) needs to capture central tendency and variance in practice for different behaviors within the technological process. The recognition of which behaviors within the process to compare between assemblages also needs to avoid abstractions or “stages” in each assemblage that might not be comparable (see also Shott et al. in this special issue). Therefore, in designing a behavioral approach, I begin with asking, “what do we know *all* flintknappers must do that would be directly visible to archaeologists on artifacts in each assemblage in a comparison?” Asking the question in this way forces one to maintain comparability, utilizes the anthropological significance of the emic viewpoint in the process, and focuses the study on etic and replicable observations. At the largest level, this produces a comparison between two assemblages according to two sets of behaviors³—first, the comparison between each assemblage of the production of flake blanks through the reduction of nodules as cores; and, second, the comparison between each assemblage of the production of the curated retouched tool kit through the selection of blanks from the pool of debitage and subsequent retouch for edge shape and maintenance. The choice of behavioral units within each of these comparisons then proceeds according to what free-hand knapping experiments and controlled experiments have identified as specific choices a flintknapper must make in each task, i.e., blank production and tool kit selection.

For blank production, these choices can be understood as being made in temporal clusters during the process of flintknapping, with some clusters of choices being made on a flake-by-flake basis while others are made once or twice per core reduction. These clusters of knapping choices, represented by artifact measurements and characterizations, have been termed *flintknapping domains* (Tostevin 2000b, 2003a,b) and serve to structure the analysis of learned flintknapping behaviors since these are the physical acts used by an observer to learn a knapping method, with or without spoken language instruction (Ohnuma et al. 1997). The behaviors within the flake-by-flake domains are either *consciously chosen or unconsciously determined* through the knapper’s body performance at the same instant as the blow of the percussor for each flake in the assemblage. These domains include *platform maintenance*, which determines platform thickness, exterior platform angle, and platform surface preparation; and, *the dorsal surface convexity*, which determines the attributes of flake shape chosen by the knapper through the choice of where to strike the core relative to the morphology of the dorsal surface (see Dibble and Rezek 2009; Pelcin 1997; and Rezek et al. 2011 for discussions of these variables in controlled flake fracture studies). In addition to the two flake-by-flake domains, two clusters of decisions are made once or twice during a given core reduction. Unfortunately, controlled flintknapping experiments have only studied the production of individual flakes rather than whole core reductions, with the

result that the choices by reduction are less quantifiable. They are treated therefore as qualitative, discrete variables. Of the stage related choices, two temporal/functional clusters of choices are recognized here—the *core modification domain*, which includes the choice of orientation of the raw material as a core and specific methods of repairing and maintaining convexities, and *direction of core exploitation*, which includes the dominant directions of debitage removal during both the early and late stages of core exploitation. The latter domain is based on the analysis of debitage, not unrepresentative core morphologies at discard as stated in Marks (2003).

The twelve variables within the four flintknapping domains described above (and listed in the left-hand column of Table 2 below) represent the behavior by behavior approach to quantifying the evaluation of the degree of similarity and dissimilarity in blank production between assemblages. The characterization of an assemblage’s tool kit constitutes its own domain of choices enacted during selection of blanks for inclusion into the tool kit, including those pieces traditionally labeled as such despite a lack of retouch, e.g., Levallois products. The variables used to characterize the tool kit choices reflect physical features of the tool shapes which are visible from a distance (Carr 1995) and likely to affect the efficacy of the cutting edge (see Tostevin 2007, 2012; Tostevin and Škrdla 2006).

The definition of each variable’s measurement is provided elsewhere (Tostevin 2000b, 2003b), as is the explicit discussion of the middle-level theory connecting these observations to high-level theory questions of social archaeology (Tostevin 2007). It remains to point out that the simultaneity of the variables within a temporal cluster or analytical domain makes it advisable to scale the weight within each cluster when testing for the similarity and dissimilarity between two assemblages. These tests are conducted on a variable by variable basis, with t-tests and G² likelihood ratio tests (approximating the chi-square distribution) for quantitative variables where appropriate, and with qualitative judgments for nominal variables. Significantly different variables are summed within domains and then divided by the number of variables within each domain in order to account for the simultaneity of the knappers’ choices within each domain. The maximum difference in blank production between two assemblages is thus the number of domains, 4.0, with only 1.0 for the maximum difference between two tool kit morphologies (see Tostevin 2007). This scaling of the significance of each test by the number of tests within the analytical domain also is useful for removing the potential interaction among variables within each domain. Galton’s Problem concerning the interdependence of variables (Thomas 1986, 448) is quite small in this case, however, as the statistical evaluations of the variables’ interactions reveal miniscule levels of correlation (Tostevin 2012).

The above approach is amenable to alteration and augmentation, to fit the contexts of the variability in lithic behaviors in most contexts. The approach, based on the earlier version of Tostevin (2000b), has been recently adjusted

TABLE 1. SAMPLE ASSEMBLAGES FROM THE UPPER PALEOLITHIC SEQUENCE AT KEBARA CAVE, ISRAEL, 1982–1990 EXCAVATIONS.

| Unit | Industrial Complex | Dates | Squares sampled for debitage and tools ¹ |
|------|-----------------------|--|--|
| I | Levantine Aurignacian | 32,300 ± 630 (Pta-4268) ^a 34,510 ± 740 (OxA-3974) ^a | R16 and Q14 plus tools from Q15, Q16, Q17, R14, R15, and R17. |
| II | Levantine Aurignacian | 34,300 ± 1,100 (Gif-TAN-90028) ^a 36,000 ± 1,600 (OxA-1230) ^a | R16, R17, Q14, and Q15 plus tools from Q16, Q17, R14, R15, and R18 |
| III | Early Ahmarian | 35,600 ± 1,600 (OxA-1567) ^a 42,850 ± 550 (RTO 5589) ^b 43,500 ± 2,200 (OxA-3976) ^a | R16, Q15, and Q18 plus tools from Q13, Q14, Q16, Q17, R17, and R18 |
| IV | Early Ahmarian | 37,493 ± 284 (RTO 5681 Combined) ^b 40,400 ± 400 (RTOX 5680-2) ^b 40,500 ± 1200 (RTOX 5799-2) ^b 42,100 ± 2,100 (Pta-4987) ^a 42,500 ± 1,800 (Pta-5002) ^a | R18, R19, R20, R21, Q16, Q17, and Q18 |

All dates are either from Bar-Yosef et al. (1996: Table 3), indicated with the superscript “a,” or from Rebollo et al. (2011: Table 1), indicated with superscript “b.”

and improved by Nigst (2009, 2010) in considering the archaeological sequence at Willendorf II, Austria. Grimm and Koetje (2008) also have applied the approach, based on Tostevin (2007), and adjusted it to the context of the archaeological record of the French Upper Paleolithic open air site of Solvieux (Sackett 1999).

AN EXAMPLE FROM KEBARA CAVE, ISRAEL

Given the above arguments concerning low-, middle-, and high-level theory, the Upper Paleolithic sequence of Ahmarian and Levantine Aurignacian assemblages from Kebara Cave, Israel, provides an ideal scenario to test the strength of the behavioral approach against the traditional industrial labels. The following is not a critique of Bar-Yosef et al.’s (1996) presentation of the assemblages according to the typologically-defined industrial complexes, since such labels constitute the traditional method and standard of archaeological reporting. It is an opportunity, however, to evidence the degree of information lost through the typological categorization, compared to the new information which can be derived from a non-typological approach.

Four assemblages from the Upper Paleolithic sequence at Kebara Cave are compared pair-wise and stratigraphically through time, following the example of pair-wise comparisons in Tostevin and Skrdla (2006) rather than the three-way comparisons in Tostevin (2007). The collections used for the present study were acquired during the exca-

vations of Bar-Yosef, Vandermeersch, Meignen, and Belfer-Cohen between 1982 and 1990 at Kebara Cave (Bar-Yosef et al. 1992; Bar-Yosef et al. 1996; Bar-Yosef and Meignen 2007). Bar-Yosef et al. (1996) describes the four assemblages presented here as follows:

“The lower assemblages (III and IV) would fall under the general category of a blade industry and would fit the description of what Turville-Petre designated as layer E. This type of assemblage was originally called “Early Antelian” by Garrod (1957) and could be attributed now to the Early Ahmarian (Gilead, 1991). The definition of the Ahmarian industry is based upon technological attributes such as the dominance of blades in the debitage, and typologically by the high frequencies of blade tools (i.e. retouched blades and points). It is lacking the typical Aurignacian tools such as carinated and nosed scrapers... The industry of Units IV–III resembles the assemblages of Ksar Akil, layers XIX–XV (Ohnuma, 1988); it distinctly lacks carinated scrapers, and is essentially the same as published by Ziffer (1978) from the Stekelis excavations. While the earlier units lack Aurignacian attributes, retouched bladelets and are richer in blades, the upper units present Aurignacian characteristics...” (Bar-Yosef et al. 1996: 302–303).

Table 1 presents the sampling data, radiometric dates, and industrial affiliations as defined by Bar-Yosef et al. (1996: 302–303). A calibrated radiocarbon study using two

of the newest pretreatment protocols, including new dates for Units IV and III, has been published by Rebollo et al. (2011). All four assemblages are comparable in terms of the respective portions of the reduction sequence, from raw material acquisition to tool discard, captured by the site formation processes in each stratigraphic layer (see Tostevin 2012 for the methods and evidence used for evaluating the comparability of tool kits as well as blank production data for these assemblages).

The analysis of the flintknapping behaviors within each assemblage is presented in Tables 2 and 3, for blank production behaviors and tool kit morphologies, respectively. In each table, the first column from the left lists the behaviors by domain. The second column from the left presents the observations recorded for Unit IV while the third column presents the data for Unit III. The results of the statistical tests between Unit IV and III are provided within each cell in Unit III. Significant differences ($p < 0.05$ for two-tailed t-tests and G^2 likelihood tests; qualitative evaluation for nominal variables) between the central tendencies for each variable in the two assemblages are given in **bold**. The fourth column from the left lists the data for Unit II and the statistical test results from the comparison of Units III and II. The right-hand column in each table presents the data for Unit I and the statistical results for the comparison of Units I and II.

When the results of these low-level theory observations and middle-level theory statistical tests are presented together as a biplot of the difference in blank production vs. the difference in tool kit morphology (Figure 1), an interesting pattern emerges. The blank production comparison between Units IV and III evidence differences in the core modification domain, the platform maintenance domain, and the dorsal surface convexity domain, totaling 2.10 out of a maximum difference of 4.0. The comparison between Units III and II, however, evidences fewer differences, with no difference in core modification but a difference in early debitage exploitation, totaling 1.57 out of 4.0. The comparison between Units II and I is even lower at 0.20 out of 4.0, the result of only one behavioral tendency in the dorsal surface convexity domain proving significantly different, the length/width ratio. When all three comparisons are taken together, the strongest division separates the two Early Ahmarian assemblages, Units IV and III, with less of a division in blank production behaviors between the last Ahmarian assemblage and the first Levantine Aurignacian assemblage. These differences in blank production behaviors are paralleled in the tool kit morphology comparisons, with the two Ahmarian assemblages proving more distinct than similar to each other when compared to the Levantine Aurignacian assemblages.

The wider implications of these results are beyond the context of this paper. What is significant for the above discussion of levels of theory are the analytical distinctions evidenced when one avoids a typological approach to assemblage-level sequence studies. The two chronologically successive Ahmarian assemblages are more different in both blank production and tool kit morphology than

the Ahmarian of Unit III is to the Levantine Aurignacian of Unit II. This stands in stark contrast to the homogeneity between the assemblages traditionally labeled Levantine Aurignacian. This indicates that we are missing significant behavioral data on both functional/adaptive change, as reflected in the tool kit morphology comparison, as well as alterations in the enculturating environment, as reflected in the blank production comparison, within the same site through time.

As such, this approach has clear ramifications for evaluating hypotheses of cultural continuity in lithic traditions in other contexts, such as the hypothesis of continuity between the Levantine Early Ahmarian and the Proto-Aurignacian (or Fumanian) in the western Mediterranean of Italy and France (see Lebrun-Ricalens et al. 2009; Meignen 2006; Mellars 2006; Zilhão 2006). Although this hypothesis has replaced the scenario of an invasive Aurignacian from the Near East or the Balkans (Kozłowski 1992) spreading through the Danube Corridor (see Conard and Bolus 2003 and Teyssandier 2006, 2008 for arguments for an autochthonous Early Aurignacian in Europe), the invasive Ahmarian/Proto-Aurignacian hypothesis rests on no stronger basis than the scenario it replaced. The fact that all of these hypotheses rest on the traditional typological approach to technology and retouched tools that missed significant data within the Kebara sequence should caution us not to assume these scenarios are true until they are successfully tested. At the moment they are almost discussed in the literature as givens. Even beautifully complete reduction sequence refits, such as Davidson and Goring-Morris' (2003) at the Ahmarian site of Nahal Nizzana XIII in the western Negev, will not unfortunately answer this question because of the unevenness of refits in all contexts relevant to the hypothesis. The Ahmarian/Proto-Aurignacian hypothesis begs to be tested with the approach advocated in this paper.

As the results presented above serve to stimulate new ways to test hypotheses about possible culture process changes through time in the area of Kebara Cave and beyond, the behavioral approach provides new data and research potential in a situation in which the traditional typological approach would put an end to the research endeavor, whether using the reduction sequence or *chaîne opératoire* approach.

CONCLUSION

Epistemological problems face both reduction sequence and *chaîne opératoire* practitioners in pursuing sequence studies of prehistoric technology. The debate over the use of each method in lithic analysis is thus an opportunity to address these epistemological issues using new methods rather than an excuse to defend the traditionalist core of each approach. In this context, it is important to recognize both differences between the approaches in analytical scope as well as the use of low-, middle-, and high-level theory. Specifically, *chaîne opératoire* provides the wider and more anthropological context in which to study material culture behavior through time. The reduction sequence approach,

TABLE 2. PAIR-WISE COMPARISON OF BLANK PRODUCTION CHOICES FOR KEBARA CAVE UNITS IV-I.

| Flintknapping Steps by Domain | Kebara Cave Unit IV Ahmarian | → Kebara Cave Unit III Ahmarian | → Kebara Cave Unit II Levantine Aurignacian | → Kebara Cave Unit I Levantine Aurignacian |
|---|---|---|--|---|
| DOMAIN 1: CORE MODIFICATION | | | | |
| Core Orientation | Use of one longitudinal surface | Use of one longitudinal surface | Use of a Longitudinal Surface | Use of a Longitudinal Surface |
| Core Management | Débordants & frontal crest | Frontal crest & core tablets | Frontal crest & core tablets | Frontal crest & core tablets |
| Number of Differences/2 Steps | | 1/2=0.5 | 0/2=0 | 0/2=0 |
| DOMAIN 2: PLATFORM MAINTENANCE | | | | |
| Platform Treatment | Unprepared: 59% Prepared: 41% n=334 | Unprepared: 67% Prepared: 33% n=439 p=.02, Fisher's Exact | Unprepared: 75% Prepared: 25% n=331, p=.02, Fisher's Exact | Unprepared: 76% Prepared: 24% n=354, p=.72, Fisher's Exact |
| External Platform Angle (degrees) | mean: 88.0, s.d.: 14.9, n=289 | mean: 92.0, s.d.: 15.7 n=355, p=.00, t=-3.28, df=642 | mean: 85.7, s.d.: 14.4, n=255, p=.00, t=5.02, df=608 | mean: 84.1, s.d.: 13.7, n=298, p=.19, t=1.31, df=551 |
| Platform Thickness | mean: 4.31, s.d.: 2.56, n=291 | mean: 3.91, s.d.: 2.57 n=357, p=.05, t=1.98, df=646 | mean: 3.85, s.d.: 2.78, n=259, p=.76, t=.31, df=614 | mean: 4.09, s.d.: 2.93, n=302, p=.32, t=-1.00, df=559 |
| Number of Differences/3 Steps | | 3/3=1.0 | 2/3=.67 | 0/3=0 |
| DOMAIN 3: DIRECTION OF CORE EXPLOITATION | | | | |
| Early Debitage Exploitation | Bidirectional & Unidirectional | Bidirectional & Unidirectional | Unidirectional | Unidirectional |
| Late Debitage Exploitation | Unidirectional | Unidirectional | Unidirectional | Unidirectional |
| Number of Differences/2 Steps | | 0/2=0 | 1/2=0.5 | 0/2=0 |

however, provides a better example of epistemological rigor in the use of etic vs. emic observations in prehistoric contexts without ethnographic informants. It is thus possible to see the complementarity of each approach in prac-

tice as well as through the middle-level theory distinction between a decision hierarchy and a production sequence hierarchy. The two approaches should not be uncritically united, however, as epistemological problems common to

TABLE 2. CONTINUED.

| Flintknapping Steps by Domain | Kebara Cave Unit IV Ahmarian | Kebara Cave Unit III Ahmarian | Kebara Cave Unit II Levantine Aurignacian | Kebara Cave Unit I Levantine Aurignacian |
|--|---|---|--|--|
| DOMAIN 4: DORSAL SURFACE CONVEXITY SYSTEM | | | | |
| Length/Width Ratio | mean: 2.17, s.d.: 1.16, n=440 | mean: 2.51, s.d.: 1.24 n=659, p=.00, t=-4.55, df=982.4 | mean: 2.20, s.d.: 1.19, n=442, p=.00, t=4.03, df=1099 | mean: 2.39, s.d.: 1.35, n=522, p=.03, t=-2.13, df=960.4 |
| Lateral Edges | Parallel: 53% Convergent: 22% Expanding: 15% Ovoid: 10% n=432 | Parallel: 58% Convergent: 22% Expanding: 14% Ovoid: 7% n=633, p=.28, G ² =3.86, df=3 | Parallel: 55% Convergent: 21% Expanding: 14% Ovoid: 10% n=415, p=.44, G ² =2.68, df=3 | Parallel: 57% Convergent: 22% Expanding: 13% Ovoid: 8% n=472, p=.81, G ² =.98, df=3 |
| Profile | Straight: 58% Curved: 25% Twisted: 17% n=437 | Straight: 48% Curved: 32% Twisted: 20% n=644, p=.01, G²=10.28, df=2 | Straight: 49% Curved: 32% Twisted: 20% n=429, p=.93, G ² =.14, df=2 | Straight: 53% Curved: 28% Twisted: 19% n=501, p=.46, G ² =1.54, df=2 |
| Cross-Section | Triangular: 45% Trapezoidal: 47% Other: 8% n=434 | Triangular: 42% Trapezoidal: 47% Other: 11% n=642, p=.37, G ² =2.02, df=2 | Triangular: 42% Trapezoidal: 52% Other: 6% n=431, p=.01, G²=9.13, df=2 | Triangular: 42% Trapezoidal: 53% Other: 6% n=493, p=.97, G ² =.07, df=2 |
| Width/Thickness Ratio | mean: 4.35, s.d.: 2.11, n=440 | mean: 3.87, s.d.: 1.79 n=659, p=.00, t=3.89, df=832.2 | mean: 4.00, s.d.: 1.96, n=442, p=.28, t=-1.09, df=1099 | mean: 3.76, s.d.: 2.00, n=522, p=.06, t=1.88, df=962 |
| Number of Changes/5 Steps | | 3/5=0.6 | 2/5=0.4 | 1/5=0.2 |
| Total Difference: Unit IV vs. III | | 2.10 | | |
| Total Difference: Unit III vs. II | | | 1.57 | |
| Total Difference: Unit II vs. I | | | | 0.20 |

both tend to limit our understanding of the past, as shown in the example of a behavioral approach to the Kebara Cave Upper Paleolithic sequence. This paper has thus endeavored to demonstrate what might be done in lithic analysis through the use of archaeologically-appropriate, as op-

posed to ethnographically-appropriate, low- and middle-level methods situated within the larger sphere of high-level questions derived from the entirety of anthropology and beyond.

TABLE 3. PAIR-WISE COMPARISON OF TOOL KIT MORPHOLOGIES FOR KEBARA CAVE UNITS IV–I.

| Tool Kit Morphology Variable | Kebara Cave Unit IV Ahmarian | Kebara Cave Unit III Ahmarian | Kebara Cave Unit II Levantine Aurignacian | Kebara Cave Unit I Levantine Aurignacian |
|--|---|--|--|--|
| Length/Width Ratio | mean: 2.23, s.d.: 1.12 n=52 | mean: 3.09, s.d.: 1.19, n=133, p=.00, t=-4.47, df=183 | mean: 2.60, s.d.: 1.58 n=47, p=.06, t=1.92, df=65.2 | mean: 2.35, s.d.: 1.50 n=101, p=.36, t=.93, df=146 |
| Width/Thickness Ratio | mean: 4.04, s.d.: 1.80 n=52 | mean: 3.49, s.d.: 1.29, n=133, p=.05, t=2.01, df=72.4 | mean: 3.20, s.d.: 1.17 n=47, p=.17, t=1.40, df=178 | mean: 3.34, s.d.: 1.88 n=101, p=.63, t=-.49, df=146 |
| Lateral Edges | Parallel: 57% Convergent: 23% Expanding: 6% Ovoid: 14% n=51 | Parallel: 68% Convergent: 22% Expanding: 5% Ovoid: 5% n=124, (2 low cells) p=.32, G ² =3.48, df=3 | Parallel: 67% Convergent: 12% Expanding: 9% Ovoid: 12% n=33, (2 low cells) p=.32, G ² =3.48, df=3 | Parallel: 59% Convergent: 21% Expanding: 13% Ovoid: 7% n=80, (2 low cells) p=.54, G ² =2.15, df=3 |
| Distal Terminus | Blunt: 50% Pointed: 50% n=32 | Blunt: 24% Pointed: 76% n=88, p=.01, Fisher's Exact | Blunt: 24% Pointed: 76% n=21, p=.99, Fisher's Exact | Blunt: 40% Pointed: 60% n=45, p=.27, Fisher's Exact |
| Profile | Straight: 49% Curved: 24% Twisted: 27% n=51 | Straight: 33% Curved: 39% Twisted: 28% n=129, p=.09, G ² =4.92, df=2 | Straight: 32% Curved: 39% Twisted: 30% n=44, p=.97, G ² =.05, df=2 | Straight: 56% Curved: 27% Twisted: 17% n=93, p=.03, G²=7.21, df=2 |
| Unique Types of Retouch | Normal retouch | Normal retouch | Carinated retouch | Carinated retouch |
| Tool Types | UP tools dominate | UP tools dominate | UP tools dominate | UP tools dominate |
| Number of Differences/7Steps | | 3/7 | 1/7 | 1/7 |
| Total Difference: Unit IV vs. III | | 0.43 | | |
| Total Difference: Unit III vs. II | | | 0.14 | |
| Total Difference: Unit II vs. I | | | | 0.14 |

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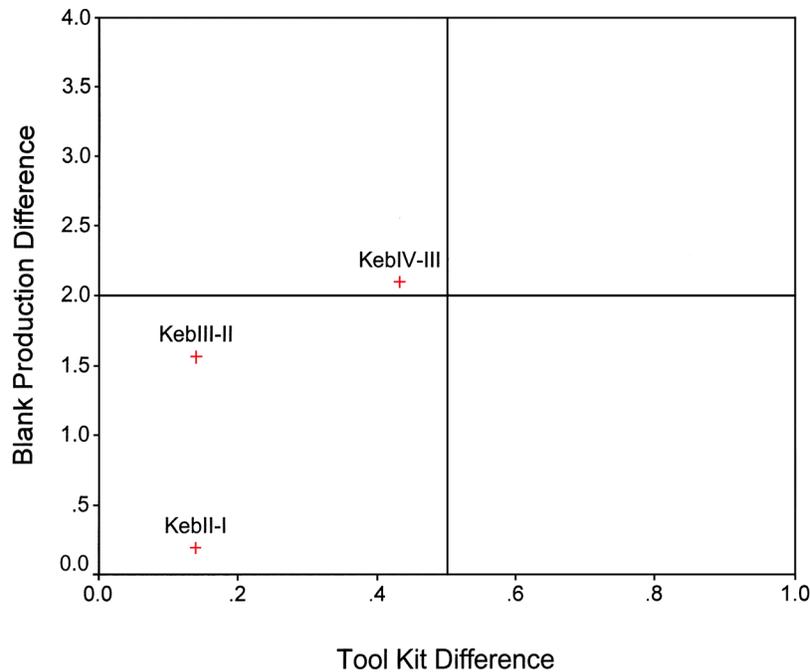


Figure 1. Biplot of differences in blank production and tool kit morphology between stratigraphic pair-wise comparisons of the Upper Paleolithic sequence at Kebara Cave.

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ENDNOTES

- ¹ Despite the aptness of this analogy for the analytical scope and the antecedent argument, the analogy with physics does not hold up for the differences in *theoretical* scope between the *chaîne opératoire* and reduction sequence approaches. The theoretical questions being asked of the wider range of subjects studied by *chaîne opératoire* practitioners are currently quite limited in number compared to the possible list of questions which derive from high-level theory across archaeology and anthropology.
- ² This analogy should *not* be pushed further, i.e., to treat grape varieties as raw materials and then adopt the *domaine contrôlée* system as another reason to focus at the level of industrial variability. This would again lead to the typological problem.
- ³ This example is specific to the material culture contexts of the Old World during the Late Pleistocene. Other contexts may require other comparative structures.
- ⁴ These samples include all artifacts available for study from these units as of the winter of 1997.

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