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COMMENTS ON 'TECHNOLOGICAL CHOICES IN CERAMIC PRODUCTION', *ARCHAEOMETRY,* 42(1), 1–76, 2000

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The collection of papers on *Technological choices in ceramic production* in *Archaeometry* **42**(1) marks an interesting and significant point in the continuing development of the relationship between archaeology and the study of ancient technology as a branch of materials science. It is perhaps less the specific content or approach of the papers theselves than the fact that they have appeared in *Archaeometry* at this particular time which marks them as being of significance. This is not to dismiss either the themes or the content, as all four papers contain a great deal that is of interest and value—too much, indeed, to deal with in this brief review. Instead, I shall pick out a number of points for specific comment.

The three ethnographic case studies form part of a long tradition of employing data from contemporary societies to inform archaeological studies, but with these papers, and the paper by Sillar (2000) in particular, we seem to be arriving at a situation in which the wider context moves from the background to the forefront of concern. Such studies should serve to lay to rest notions of pottery as representing a 'subsystem' of the social world and to situate it as a vital part of the wider social formation. Indeed, the point is applicable to studies of technology generally. Similarly, it is encouraging to see history and historical context highlighted in the papers by Livingstone Smith (2000) and Pool (2000), even if space has unfortunately precluded more substantial considerations of this aspect.

It is to be hoped that both of these papers, with their stress on the complexity of the relationship between aspects of local and regional identities (language and social status) will be widely read by those who persist in employing ethnic labels to characterize prehistoric communities (notably in relation to the European Iron Age) in a manner that is over-simplified at best and misleading at worst. Such an approach does nothing to clarify the prehistoric situation and much to confuse it.

The introductory paper (Sillar and Tite 2000), quite apart from providing a useful overview of the general approach and an up-to-date bibliography, focuses on a number of issues of interest. Their brief mention of artefact typologies should draw the reader's attention to the potential value of these constructs beyond their intended purpose of providing structures for the ordering

of data. Although one of the oldest and most traditional of archaeological tools, it is clear that they encapsulate data which can be interpreted in ways that were not originally intended. Recognition of the phenomenological character of typological categorization (Cumberpatch 1997) allows us to draw out features (e.g., colour, design and decoration) which have, or may have, relationships with other aspects of society, beyond simple homologous relationships with other classes of material culture. Clearly, typological traits must be fully assessed and reassessed in order that later assumptions are not uncritically included in broader analyses but, this having been noted, the potential of such studies should not be overlooked.

The one point where I do have some concern is with the notion of embeddedness discussed by Sillar and Tite (2000) and by Sillar (2000). The term 'embedded' is, as I have discussed elsewhere (unpublished), essentially a metaphorical one. As such, it implies a split between the wider social context and that which is embedded within it. I would prefer to see pottery production (or any other aspect of technology) as a structure in the sense in which the term is used by Giddens (1984). The production and use of pottery is not simply integrated into the wider social context, as the term 'embedded' implies, but actually contributes to the production and reproduction of society and social structures through the transmission of structures of day-to-day practice (Bourdieu 1990), a point brought out by Livingstone Smith (2000), although with reference to a slightly different point. This may appear to be a pedantic point, but it is one which does have implications for the way in which we conceptualize the place of practice in the production of standardized material culture and its relationship to the reproduction of social structures and practices.

Sillar and Tite (2000) summarize the character of material science approaches in archaeology most usefully, and draw attention to the problems and tensions within this tradition. The problems inherent in many material science approaches to pottery are brought out effectively, without lapsing into the kind of oppositional language that has so often marred the debate over the place of science in archaeology. It is to be hoped that the implicit challenge here will be taken up by those working within the material science tradition and that future studies will be informed by the 'cultural turn' defined and outlined here.

Conversely, the general approach, as well as the specific content of the articles, should encourage us to enquire as to the kind of a challenge offered by such integrated studies to archaeology, whether traditional or post-processual. I would suggest that the papers emphasize the need for archaeologists to move beyond those approaches to ceramics that emphasize categorization and chronology. There is a widespread, and perhaps general, need to develop the writing of 'archaeoethnographical' accounts of past societies. Sillar and Tite (2000) refer to work on Romano-British pottery industries, but opportunities also exist within other areas, where the fruits of many years' detailed work await innovative approaches. Adrian Chadwick has recently proposed the writing of an ethnography of medieval townscapes (unpublished) and this is an approach which is long overdue in medieval pottery studies. Abundant data exists, largely unsynthesized, and the volume grows annually. The challenge is to produce accounts that transcend chrono-typology to integrate classification and description with the results of excavations of workshops, the study of the movement of pottery, and the presentation of the results of petrological and chemical analyses into broader archaeological and historical studies of medieval society. Such an approach could usefully take on the character of an ethnographic enquiry. This might also answer some of the (at present rather vague and ill-defined) calls for the writing of 'narrative' accounts which might serve both to enrich archaeology and to inform related disciplines, notably social and economic history. Such 'ethnographical' narratives might

address the problems of both the long-term stability in medieval pottery technology and regional traditions of practice, as well as the rapid changes that define the end of the medieval tradition and the inception of the post-medieval. In such a context, it would be of particular importance to define and delineate the relationships between the production of pottery and other social structures in ways similar to those discussed by Sillar.

Finally, and less encouragingly, the implication of the papers is for a change in the structure and practice of archaeology in the UK. Sillar and Tite (2000) refer to large-scale, long-term, research excavations as the ideal context in which studies of technology and society can be taken forward. It is not by chance that the two examples of integrated projects cited are both in the Middle East. The present sociopolitical climate in the UK does not favour such initiatives (Cumberpatch and Blinkhorn, in press), thanks largely to the dominance of commercial interests in dictating the scope and scale of archaeology. Until effective control of archaeological research in the UK is taken from commercial property developers and mining companies and returned to archaeologists (through the deployment of a development tax, for example), it seems unlikely that any of the positive initiatives envisaged in these papers will be taken up, other than within universities. In effect, this means that many of the most highly qualified excavators and many experienced artefact analysts will be unable to participate in the more innovative and theoretically advanced projects, to the ultimate detriment of archaeology as a whole.

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The collection of papers on *Technological choices in ceramic production* in *Archaeometry* **42**(1) drew attention to the fact that archaeological and ethnographic evidence suggests that the 'technological choices' made in the production of traditional clay-based ceramics may be influenced as much by wider social, economic and cultural considerations as by material or functional factors. While accepting this view, the aim of the present contribution is to highlight the complementary view that technology also influences society and culture. It is thus suggested that attempts to place studies of technologies in a wider social context should consider not only the influences of culture on technological preferences but also the influences of technology on cultural preferences. Technological, economic, environmental and social considerations form a system in which these and other factors mutually interact. The sum of those interactions influences the creation, use and deposition of artefacts by ancient man and the resulting material remains recovered by archaeologists.

While acknowledging the role of material science in assessing 'the extent to which physical and chemical performance characteristics have influenced past technological choices', Sillar and

Tite (2000) emphasize the need to encourage archaeological scientists 'to give greater consideration to the social and ideological factors that influence technological choice'.

Ethnographic studies by Livingstone Smith (2000) in northern Cameroon show that, in this case at least, 'environmental and techno-functional constraints cannot explain technical variations, while cultural factors appear dominant', while Pool (2000), studying ceramic firing technology in Mexico, concludes that 'performance characteristics . . . by themselves are insufficient to explain any specific historical instance of technological choice'.

It is fair to say that there are several instances in which the above authors acknowledge that the influence of culture on technology is not an isolated influence. Sillar (2000) notes that technological choices have further repercussions that affect other technologies and that technological choices are embedded in and 'related to wider social and economic practices'. The proposition of the present communication is that the interaction between these factors goes rather further than Sillar and others suggest, in that technological choices not only influence other technological choices, but technology also influences society as a whole. Thus Sillar's 'functional and symbolic aspects of technological choices' may be interlinked with, and may interact with, functional and symbolic aspects of society.

That technology influences society and effects social change may perhaps be most obviously be seen in our own lives, where rapid transport and communication and electronic home entertainments have profoundly changed the way in which many people live their lives. The effects of technology on society may also be seen, however, in the more limited context of ceramic technology. The advent of ceramic vessels would have permitted new cooking methods, such as frying and stewing. Ceramics provided the furnaces and crucibles for smelting and melting metals. They also provided a medium for artistic expression, beautiful painted Greek vases and Chinese glazed porcelain being high points of the potter's art. In the 18th century, porcelain became as sought after as gold, and competition to discover the secret of its manufacture a matter of international importance (Gleeson 1998). On a more mundane level, the production of bricks and tiles permitted stone-like buildings where stone was scarce. Plaster has been used for floor and wall coverings since the Neolithic period, while hydraulic cement had a considerable influence on Roman architecture (Siddall 2000). Demand for the production of ceramics on an industrial scale affected the lives of the workers in the factories and those who had to gather the raw materials and fuel, while imperfect burning of fuel affected the environment all around (Griffiths 2000).

Considering technology in general, its influence on society is seen in many cases. The desire to possess or control access to technology or raw materials has often fuelled wars and ruled the lives of millions, while technology itself has provided the instruments of war. Technology has also, however, provided the tools of agriculture and brought comfort to many in the richer parts of the world.

At lower levels of technology, the influence of social factors on technology may be dominant. When technology becomes more advanced, the influence of technology on society may be more clearly seen. Whatever the final judgement, it will surely benefit our interpretation of the archaeological past to have both aspects of the interaction in mind.

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The overriding thesis among the papers on *Technological choices in ceramic production* published in *Archaeometry* **42**(1) is that potters are faced with choices throughout the fabrication process. These involve, in the main, selections of clays and tempers or aplastics, techniques of raw material preparation, forming methods and equipment, varieties of surface treatment, modes of decoration, as well as drying and firing procedures. The choices and selections are delimited by environmental parameters, technological options, subsistence and economic factors, sociocultural contexts, political forms, religious and belief systems, and individual and group psychological or behavioural variables as well.

The relationships among these factors have been the subject of much discussion in the anthropological and archaeological literature, and have led to the publication of voluminous numbers of books and journal articles on archaeological ceramics and ceramic ethnoarchaeology. A basic paradigm for the study of archaeological ceramics was stated initially by Matson (1965) in the concept of ceramic ecology, which appeared in his *Ceramics and man*. The method and theory of ceramic ecology has been expanded and enhanced (Arnold 1985, 1993; Kolb 1976, 1989a), and in revised form extended into the ethnographic literature through ceramic ethnoarchaeology (Kramer 1985, 1997; Longacre 1991). The concept was a focus for European symposia held in Amsterdam (van der Leeuw and Pritchard 1984) and in Stockholm (Lindahl and Stilborg 1995) and has been featured in American publications (Olin and Franklin 1982; Rice 1984; Kolb 1988, 1989; Kolb and Lackey 1988). It has also been the organizational framework for 14 annual symposia held at the annual meetings of the American Anthropological Association. However, expositions of a holistic approach in ceramic ecology—from raw material selection and mental template of the object to be fashioned through its final disposition, discard or reuse—have not been realized, and there are few analyses of a 'birth to death' assessment of fired clay objects (Kolb 1989a).

During the past three decades, I perceive three distinct, discernable but overlapping phases of archaeological ceramic research: (1) an initial phase concerned predominantly with the documentation of variables of pottery manufacture, provenance, and physicochemical characterization; (2) a phase derived partially from economic anthropology, with an emphasis on the distribution and consumption of the finished products; and (3) a trend towards behavioural analyses and psychological meanings of potters and their products. With few exceptions, the literature on archaeological pottery is particularistic rather than holistic, in that published reports provide in-depth assessments of production, but with a lack of consideration of consumption and distribution, and are rarely concerned with group or individual behaviours and sociocultural meanings (Kolb 1989b). I shall comment on these phases and relate them to the WAC4 papers.

Major compendia on archaeological ceramics consider raw material selections and preparations, methods of fabrication and surface treatments, and drying and firing procedures (Shepard 1965; Rice 1987; Rye 1991; Sinopoli 1992; Orton *et al*. 1993; Gibson and Wood 1995), but

provide minimal to no discussion of pottery distribution, consumption and the ultimate dispositions of the artefacts. Recent encyclopaedic treatments of material culture have chapters devoted to ceramic production rather than consumption—ancient Mesopotamia (Moorey 1994) and Egypt (Nicholson and Shaw 2000). Modes of pottery production have been elaborated in a number of publications on the Mesoamerican and Andean regions (P. Arnold 1991; Costin 1991; Bey and Pool 1992; D. Arnold 1993; Shimada 1999). Rye and Evans's (1976) study of archaeological and ethnographic pottery from Pakistan and Schiffer and Skibo's (1987) examination of technological change stand out. Physicochemical characterization studies were summarized by Rice (1987, 1996b), while Neff's (1992) edited volume documents the applications of some of these analyses. Materials science approaches also play a significant role in this phase, and include 'cautionary' research tales (Bronitsky 1986; Kolb 1997). Pottery function is also a trait of this phase (Skibo 1992; Rice 1996a), as is specialization and standardization (Rice 1987, 1996b; Costin 1991).

Ceramic distribution has been of concern to many archaeologists, but received inadequate treatment until Bey and Pool's introductory remarks and conclusions (Bey and Pool 1992) on the papers from their compelling book, which includes a wealth of significant materials from many cultural, ecological and regional contexts. Pool (1997, 275) emphasizes that 'production and consumption are interacting components of economic systems and should be studied as such' and observes that these components 'involve a tangled web of interactions among producers and consumers' (1997, 286). Regard for distribution and consumption behaviours attracted researchers who have diachronic perspectives often oriented to communities of producers and consumers. Scholars such as D. Arnold (1985, 1993), working in Yucatan, Mexico, and Ayacucho, Peru, assembled detailed diachronic ethnographic data over several generations of pottery producers. Other notable longitudinal studies are Longacre's (1992; see also Longacre and Skibo 1994) meticulous ethnoarchaeological documentation of Philippine Kalinga potters and consumers, Kramer's (1997) seminal analysis of ceramic producing villages in Rajasthan, India, and Deal's (1998) in-depth study of Tzetal Maya of Chiapas, Mexico, pottery production, consumption and ultimate object disposition. This second phase includes a dramatic increase in physicochemical research into vessel contents and residue analysis, and experimental studies (Rice 1996a,b).

Exemplars of the third phase include Michael Schiffer (1996; see also Schiffer and Miller 1999; Schiffer 2000) and important topical papers on behaviour by Wobst and Conkey in Chilton's edited volume (1999). Several papers in Cumberpatch and Blinkhorn's (1997) monograph also address these issues. Lemonnier (1993), beginning with an 'anthropology of technology', has expressed concern about the arbitrariness of technologies and their sociocultural representations and exposed researchers to the analysis of technological choices in a manner similar to that of van der Leeuw (1993), who makes distinctions between techniques, technologies and traditions. Some of this research interest developed from the study of ceramic styles (Rice 1996a) and attempts to discern the sociocultural meanings and messages in decoration. Schiffer's use of linguistic paradigms and communication theory is compelling and deserves further analysis and testing.

The initial WAC4 paper by Sillar and Tite relates archaeological, ethnoarchaeological and materials science parameters to the technological choice of ceramic production. Their assessment of five areas of technological choice, the *chaîne opératoire*, and impinging direct and indirect factors, focuses on the salient questions of who chooses and why such choices need to be made. The documentation of technological choices in their larger context is essential in understanding how ecological (environmental), technological, economic, social and ideological

practices influence the production (and distribution and consumption) of pottery. This exposition 'fits' well into the third phase because of the concern with human behaviour and the need to move beyond descriptions of production and into behaviours, learning, transmission of knowledge and cultural meanings.

The second contribution by Livingstone Smith is a superb documentation and explication of ethnoarchaeological data from the Faro area, Cameroon. Ethnographic interviews with 234 artisans from 52 villages are reminiscent of the longitudinal and spatial parameters of Longacre and his colleagues (Longacre 1992; Longacre and Skibo 1994) rather than D. Arnold's focus on particular communities through time. Technofunctional and environmental factors, the identity of the producers, contexts of production, learning networks, distribution networks and settlement patterns are among the major variables considered. However, none of these taken alone are sufficient to explain technological variation among the Faro area potters. Livingstone Smith concludes that variations in clay preparation techniques result from the long interaction between peoples in the area, with ruptures in social interaction networks establishing social boundaries (see Stark 1998). With this contribution we have an emphasis on ceramic production, but with pertinent enquiries about group behaviour and information transmission which are features of the third phase.

Sillar's paper on dung emphasizes the interdependence of Andean potters, and the choices that potters from 11 communities make in acquiring fuels as a component of the firing procedure and of the holistic production process. The selection of dung over other fuel resources, the firing process (vessel positioning and fuel use), alternative uses of dung, its sociocultural significance and alternative fuels are reviewed. He concludes that embedded technologies must be considered in the selection of fuels, the location of the firing area and the placement of vessels for firing. Such technological choices, he states, 'emerge from wider cultural practices which account for the variability of materials, tools, energy sources, and technical knowledge'. This is a highly significant paper, because few ethnoarchaeologists have devoted any effort to the study of fuel types, sources and selection. A notable exception is Sheehy's (1988, 1992) meticulous archaeological and ethnoarchaeological research at Teotihuacan in the Basin of Mexico, and the work of P. Arnold (1991) and Pool (1997) on the Mexican Gulf Coast. Sillar demonstrates an aspect of the third phase of recent research.

The final paper by Pool augments his earlier publication (1997) interpreting updraft kiln firing in the Prehispanic Gulf Coast. Pool asks and answers the salient questions: why a particular firing technology was selected and why updraft kiln and open firings coexisted. Sheehy (1992) documented only open firing at Teotihuacan, Mexico. Pool assesses contemporary and prehistoric evidence for firing in the Tuxtla region, ethnographically examining four communities from the highland Valley of Oaxaca and four from coastal Sierra de los Tuxtlas. Behavioural and social factors impinge upon the technological selections (Schiffer and Skibo 1987). Pool also examines situational factors, including ecological (environmental), raw materials, behaviours and sociocultural parameters, and devises a 'threshold of performance matrix' to assess kiln versus open-air firings in archaeological and modern contexts in terms of the conservation of space, labour and materials; the cost of construction, and thermal performance characteristics (control of firing atmosphere, efficiency of raw material consumption and particularly fuel efficiency). This approach, again exemplifying the third phase of ceramic studies, has particular value and should be replicated in other culture areas to determine its efficacy.

These four papers represent aspects of the assessment of human behaviours, choices, selection process and sociocultural contexts, exemplifying the trend towards understanding the

sociocultural environment associated with producers and consumers. They include the effects of the psychological subsystem of values, behaviours and ranges of behaviours associated with pottery production and consumption, as well as ideas, ideals, levels of technologies, individual and group skills, and training and learning, among other parameters. These are components of the Ceramic Complex within what is called Holistic Ceramic Ecology (Kolb 1989a). In sum, one may consider these compelling WAC4 contributions as expansions of the method and theory of ceramic ecology and elucidations of the concept, as Matson stated, of 'placing the people (producers and consumers) back in the pottery'.

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Schiffer (1996) has argued that dialogue between proponents of different theoretical perspectives in archaeology can help counteract the tendency for the discipline's practitioners to divide themselves 'into antagonistic camps, seemingly incapable of engaging each other in discussions of substantive issues' (1996, 643). In this comment on papers published in *Technological choice in ceramic production* [*Archaeometry* **42**(1)], I try to promote the kind of constructive dialogue that Schiffer recommends. This collection of papers explores the potential of a 'technological choice perspective' in archaeological and ethnoarchaeological studies of ceramic production. From my own theoretical perspective, that of evolutionary archaeology, technological choice addresses only proximate causes. Nonetheless, I recognize that technological decision-making is a crucial component of the evolutionary process that generates the archaeological record.

The papers in *Archaeometry* **42**(1) offer many valuable and incontrovertible observations about the determinants of ceramic technological choices. Livingstone Smith (2000) demonstrates the diversity of social and environmental factors that determine potters' use of resources in Cameroon. Sillar (2000) explores the embeddedness of Andean pyrotechnology and demonstrates how the wider cultural and ecological context leads to frequent use of animal dung as fuel for pottery firing. Pool (2000) argues that performance advantages of different firing technologies are context-specific, illustrating his argument with the example of polymorphic pyrotechnology (kiln versus open firing) in modern and prehistoric Veracruz, Mexico. The general conclusion emerging from the papers is that technological choices are influenced both by properties and performance characteristics of the materials and by 'a large range of social, economic, and ideological factors that shape the cultural perception of what options are available' (Sillar and Tite 2000, 4).

The technological choice perspective identifies proximate causes. Proximate causes of technological choice in ceramic technology include such things as potters' social status, their attitudes about their craft, intended uses of vessels, the natural environmental conditions in which they find themselves, and other aspects of the 'situational context' (Sillar and Tite 2000, 5). Suppose, however, that instead of asking about the proximate causes of technological choices, we instead ask how the choices that are characteristic of a particular technology came to be configured in the way that we observe. Or suppose that we ask why technologies differ through time and across space. These are questions about the origin of technological design. Like the design of organisms, technological design comes about over time, as the result of the mechanical action of historical processes.[1] Thus, while one can appreciate that the technological choice perspective fosters many insights about proximate determinants of technologies, one can also wish that archaeology had a theoretical framework that encouraged questions about historical processes and how they create technological design and diversity.

The hope that archaeology might develop a viable scientific theory of historical process has given rise in the United States during the past 20 years to an approach referred to as 'evolutionary archaeology'. Sillar and Tite (2000, 15) may be alluding to this when they

[1] I am deliberately ignoring non-mechanistic historical explanations, which rely on intervention by God or some other unobservable force.

mention the use of 'principles of evolutionary biology to account for social phenomena', although they do not provide specific citations. The basic idea of evolutionary archaeology, first articulated by Dunnell (see, e.g., 1980), is that the content and configuration of the archaeological record are determined by mechanisms of variation generation, transmission and selective retention. These are the same mechanisms that produce what Darwin called 'descent with modification' in the living world, although they are acting upon a different substrate in the cultural case (information in human brains, rather than DNA). A number of articles have explored how ceramic change and diversity might be explained by this explicitly Darwinian approach (see, e.g., Feathers 1990; Dunnell and Feathers 1991; Neff 1992, 1993; O'Brien *et al*. 1994).

To extend the Darwinian model to artefacts, culture must be conceived as an inheritance system. Such a conception seems almost inescapable, considering how dependent humans are on social learning to acquire the cultural information that determines behavioural aspects of their phenotypes (Boyd and Richerson 1985). The literature on traditional ceramic technology, for instance, is filled with accounts of how technological practices are passed on through social learning (Neff 1992). In the collection of papers considered here, Livingstone Smith's (2000) study demonstrates that people in Cameroon who live near one another inherit a common set of paste preparation practices. As a result, traditions of ceramic paste preparation techniques can be detected within local areas, while lightly populated areas constitute barriers to the cultural transmission of these techniques. 'Descent with modification' will take place as paste preparation preferences shift within the local traditions.

Recognizing heritable continuity in the archaeological record, in the absence of behavioural data on social networks and spatial propinquity of potters, is trickier and poses a crucial methodological challenge in evolutionary archaeology (Neff 1992, 1993; O'Brien and Lyman 2000a). Lyman and O'Brien (1997; see also Lyman, O'Brien and Dunnell 1998; O'Brien and Lyman 1999, 2000a,b) suggest that the work of earlier generations of culture historians has provided many of the tools that are necessary to accomplish this goal, although absent the explicit theoretical perspective of evolutionary archaeology. Once heritable continuity is recognized, one can go on to ask how selection drove the changes in artefact design that can be observed over time within a given lineage.

This brings us to a significant theoretical disagreement that has arisen recently in evolutionary archaeology. Recall first that artefact evolution takes place as technological design information encoded in human brains changes over time. What causes culturally transmitted information to persist differentially, so that artefact designs evolve? O'Brien and Lyman (2000a,b; see also Lyman and O'Brien 1998) appear to insist that differential reproduction of human bodies is necessary for selection to take place. However, both evolutionary theory and intuition suggest that a selection-driven process that filters information transmitted horizontally (to contemporaries) as well as vertically (between generations) would overwhelm a process that is tied to human reproductive cycles (Neff 2000a,b). The argument that the design information encoded in human brains is shaped mainly by selective processes that are independent of biological reproductive differentials clearly does not imply that artefactual components of human phenotypes have no effect on biological success, but O'Brien and Lyman (2000b) appear to have missed this point. We can admit the latter (Who would argue that artefacts like birth control pills have no effect on reproduction?), while still arguing that the differential survival of cultural information depends overwhelmingly on effects other than differential reproduction of human bodies.

If biological reproductive differentials are only a very minor cause of differential persistence

of design information encoded in human brains (and thus are only involved marginally in artefact evolution), then evolutionary archaeology presently lacks a complete understanding of what 'selection' means in the case of artefacts and other cultural traits. We can say that design information persists differentially because technological variants succeed or fail at different rates, but we lack a good theory of *why* technological design variants succeed or fail. I have suggested elsewhere (Neff 2000a) that proponents of other evolutionary approaches, such as evolutionary ecology (see, e.g., Boone and Smith 1998, Broughton and O'Connell 1998) or dual inheritance theory (Boyd and Richerson 1985), may be able to help us to resolve this epistemological difficulty. Proponents of the 'technological choice perspective' on ceramics may have something to contribute as well.

We may view the proximate causes of technological choice as biases that favour different technological variants in different ecological and historical contexts. As technological variants succeed or fail, the corresponding ceramic technological design information encoded in human brains is replicated differentially. Over the long haul, this process of differential persistence of design information—selection—gives rise to evolutionary change in ceramics. There is more to ceramic evolution than selection, of course: chance plays a part, as do large-scale historical processes that have little to do with the selective advantages of particular ceramic designs (Neff 1992); but selection is the directional force.

As exemplified in the recent *Archaeometry* special section, the 'technological choice perspective' provides an ethnoarchaeological window on the decision-making contexts within which differential persistence of ceramic technological design information arises. Biases on fuel choice by potters, for example, arise partly from other cultural practices, such as animal husbandry, as Sillar (2000) demonstrates. Physical properties of raw materials affect the success of technological variants, but what succeeds in one context is not necessarily what succeeds in another context, and, as Pool (2000) points out, a given variant can be successful for different reasons in different contexts. The decision-making context is the selective context.

But technological choices, even construed as selective biases, are only part of the story in ceramic evolution. Whether a design variant increases or decreases in frequency depends on biases on human decisions that exceed some longevity threshold. Dung became a preferred fuel in the Andes (Sillar 2000) because biases favouring dung affected the decision-making of potters for a sufficient period of time in the past. It persists today because, to some extent, the same biases still obtain. An evolutionary account of ceramic change requires unravelling how *repeated* decision-making biases over time create directional selective pressures that shape ceramic traditions. Decisions have to accumulate in order to drive evolutionary change. This is how proximate causes (technological choices) can accrue into evolutionary history. To the extent that Pool (2000) takes such a diachronic perspective on decision-making in his study of kilns in the Tuxtlas, his paper can be conceived as a contribution to evolutionary archaeology.

In sum, proponents of the technological choice perspective and proponents of evolutionary archaeology have clear grounds for dialogue. As a proponent of evolutionary archaeology, I suggest that technological choice advocates need to think about how long-run effects emerge out of technological decisions made in the short run. The long-run evolutionary effects create the patterning in the archaeological record, and it is the archaeological patterning that we must ultimately seek to understand (O'Brien and Lyman 2000a). On the other hand, evolutionary archaeology has backed itself into a corner by defining selection narrowly as the outcome of biological reproductive differentials. Technological choice proponents can help us out of this corner by drawing our attention to decision-making biases that are more plausible sources of selection-driven change in technological design information. One might

be tempted to think that there is a large gulf between Darwin's mechanistic theory of historical change and the everyday decisions made by human actors but, as Pool's paper demonstrates, the bridge between evolution and technological choice in fact may be relatively easy to cross.

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The collection of papers on *Technological choices in ceramic production* published in *Archaeometry* **42**(1) intend to 'discuss how best to integrate the study of functional and cultural

factors affecting technological choices in ceramic production' (Sillar and Tite 2000). The four papers insist on methodological considerations, and three of them present case studies on technological choices affecting clay processing techniques in Cameroon (Livingstone Smith 2000), fuel in the Andes (Sillar 2000) and firing techniques in Mexico (Pool 2000), respectively. If the authors have the same scope, however, they follow different trends; which are, on the one hand, the 'cultural' approach, which considers that technology is mainly a product of social representations (e.g., Lemonnier 1993) and, on the other hand, the 'behavioural' approach, which stresses the importance of 'natural and physical constraints in the process of decision-making' (e.g., Schiffer and Skibo 1997).

But, no matter which trend is followed, the different papers successfully highlight the complexity of technological phenomena. This complexity is studied through analytical procedures and anthropological data that enable the authors to ponder the different factors at play in technological choices. Such an approach should be most welcome, since analytical procedures serve henceforth the purpose they should aim at; that is, an understanding of phenomena which are above all anthropological in nature. From this point of view, the publication of technological studies in *Archaeometry* can be considered as an auspicious signal for the development of archaeometric studies engaged in understanding cultural facts. However, the diversity of the trends, 'cultural' and 'functional', also reveals some weaknesses in the technological approach, which is still in search of a unifying theoretical framework. These weaknesses appear, in particular, when examining the methodologies followed by the different authors for achieving the announced objective.

The scope of the first case study (Livingstone Smith 2000) is to understand the regional patterns of clay preparation in the Faro area of northern Cameroon. The author distinguishes seven different clay processing techniques on the basis of the material selected for temper. Then, in order to understand this technical variation, he proposes to take into account six parameters: techno-functional and environmental factors, the identity of the producers, the production context, distribution networks, learning networks, and the settlement and population density. Each parameter is examined in relationship with the variability of clay processing techniques. He concludes that the distribution of clay processing techniques cannot be explained by techno-functional and/or environmental constraints. On the contrary, it seems that it may be explained in terms of long-term interactions between people living in distinct areas. Each technical zone would correspond to regional groups that express, on the one hand, small-scale diffusion of technical features, transcending ethnic or ethno-linguistic groups, and, on the other hand, geographical boundaries. The scope of the Livingstone Smith paper is to understand the *diversity* of clay preparation techniques. His results bear (a) on the phenomenon of *homogenization* of technical features, at a local scale, through a process of *appropriation* that transcends ethnic or ethno-linguistic groups, and (b) on the phenomenon of *perpetuation of tradition* through geographical boundaries. As a consequence, the parameters taken into account prove, in fact, to be incomplete for understanding, in particular, the phenomenon of *diversity*. I regret, for example, that zone 3 is not discussed in the light of what is known in other areas of West Africa. Zone 3 is characterized by the use of dung, straw, grog, sand, crushed rock and grog/sand. Dung, straw and grog are frequently found associated in West Africa (for example, in Senegal) where one may wonder if, initially, differentiation in temper was not related to the intention of differentiating clay processing techniques in some relationship with the different functions of pots (even though this intention is no longer present in potters' memories). Is there a relationship between the tradition of zone 3 and the traditions of northern areas, such as Senegal? What about the first zone, characterized by sand addition? Is this tradition also found in other parts of Africa,

in Nigeria? What about the 'simple clay' or clay mixing traditions? Do they occur elsewhere? Could they be related initially to a certain quality of kaolinite? In order to understand variability in 'tempering', properties of tempers should also be taken into account. Dried ground clay or another clay cannot be compared to sand and grog; the consequences in terms of clay hydration behaviour are radically different. From this, one may wonder if the tradition found in zone 2 could be related initially to a certain quality of kaolinite (which cannot be assessed only through a granulometric analysis). With regard to the *homogenization* phenomenon, Livingstone Smith gives us a good insight into the underlying mechanisms. However, for a deeper understanding, more detailed investigations should be conducted at the individual level: it would be interesting to know, for each zone, how many potters have borrowed technical features, who these potters are, and who the potters are who did not borrow technical features (for example, in zone 3, who are the 'two cases' that use sand). Understanding the *perpetuation of tradition* also raises numerous questions. Livingstone Smith proposes a convincing explanatory hypothesis that could be tested, in the future, by comparing similar geographical situations but with different contexts of production. In effect, one may wonder if geographical boundaries act as factors of perpetuation of traditions given particular contexts of production (here, the context is defined in the broad sense of the term, including relationships between the different ethnic groups).

The objective of the paper by Sillar (2000) is to demonstrate how ceramic technology is embedded within the wider technical practices and cultural values of the society. For this purpose, Sillar has chosen to study, in the Andes, animal dung as fuel because 'it is one of the major areas where the interdependence of pottery technology with wider social, economic and technical practices is most visible'. He conducts a detailed and fine ethnographic study about the production and use of dung in the Andes, and underlines the interconnections between different *chaînes opératoires*. However, he tackles different subjects at the same time and, at the end, it is difficult to know if he wants to construct a reference base for interpreting ancient ceramic production or if he wants only to demonstrate that production and use of dung is embedded within a wider network of social and technical practices. In the first case, I regret that he did not model his data in a quantitative way, so that it would permit us to ascertain, from ceramic production, the quantity of dung used for firings, the number of animals necessary to produce the dung, the pasture areas for the animals to graze, and so on. In other words, modelling his data would enable Sillar to propose an extremely powerful and useful referential model for reconstructing alternative past techno- and agrosystems. Now, in the second case, two topics are dealt with: the cultural value of the dung and the consequences of the change in fuel for the social and economic relationships between potters. With regard to the first topic, Sillar shows well the cultural dimension of the dung within the Andean culture. Let us just mention an anthropological study about the use of dung as fuel in India, and the way in which this 'technical practice' is highly embedded within the Indian caste system (Mahias 1994). A comparative study would be mostly informative as regards anthropological regularities. The second topic is highly complex and would deserve a detailed sociological study, but the conclusions would exclusively concern the contemporaneous Andean society since, by definition, a techno-system is particular to the group studied. These are the elementary operations that are cross-cultural and, on the basis of which, ancient techno-systems and their evolution can be reconstructed.

The paper by Pool (2000) aims at understanding the coexistence of kilns and open firings in Mexico which is attested, in the Sierra de los Tuxtlas, for 1700 years. For this purpose, he applies the behavioural approach developed by Schiffer and Skibo (1997). He compares the ancient and

modern situations (which both witness the two firing techniques) in terms of situational factors. They encompass 'those behavioural, social and environmental conditions which are external to the specific set of activities in which an artefact is made and used, but which, nonetheless, condition those activities'. Environmental factors appear not to have varied over the past 2000 years. Social and behavioural factors are studied through the types of pot produced and the context of production (organization and intensity of ceramic production). The types of pot differed between ancient and modern times, as did the organization of production. In ancient times, the ceramic production system embraced a wider variety of production modes than the modern Tuxtlas system. Also, the availability of space was much greater than nowadays. The properties of the two firing techniques are then studied in terms of construction costs, thermal performance characteristics, control of the firing atmosphere, efficiency of raw material consumption and conservation of space. Pool concludes that the adoption of kilns during the Classic Matapacan period is due to performance characteristics which permit the production of fine paste wares with even surface colours. For modern times, the use of kilns should be explained in terms of the gain of space in densely populated areas.

According to the historical periods (ancient and modern), kilns correspond to two different technological phenomena: for the ancient period, the kiln is an *innovation*, whereas in the modern period, the kiln is the *perpetuation of a tradition*. With regard to the phenomenon of innovation, Pool characterizes the performance of kilns and vessels, and concludes that kilns have been invented to respond to the performance characteristics of ancient vessels. In his approach, he fails, in fact, to handle the cultural value of the pots, which may be approached through the potters' intentions, which can be expressed by the following question: For whom were the different wares manufactured and, especially, the wares fired in the kilns? According to Pool, the fine wares fired in the kilns were used as serving vessels, including specialized ritual forms, whereas the Coarse Brown ware was mainly found in open firing. As regards the context of production, Pool mentions different modes of production, and proposes that the modes of production varied according to the firing techniques (domestic production for open firing). As a matter of fact, data given in the paper suggest that the *innovation* of kilns in the Sierra de los Tuxtlas is a much more complex phenomenon than is suggested by the behavioural approach. It could be analysed well in terms of a dynamic interaction between an invention (the invention of a technique with new performance characteristics) and a demand for 'specific' fine ware vessels, which probably took place in a particular sociopolitical context, when defined in terms of consumers (status?) and producers (independent versus attached?). With regard to *perpetuation of the tradition*, it should be noted that the performance characteristics of kilns and vessels do not play any role, contrary to the context of production when defined in terms of the 'space' factor. The importance of this factor could be argued well by the use of comparative data from other cultures (for example, in India, where the same potters use updraft kilns when living in urban areas and open firings when living in villages).

As underlined by Sillar and Tite (2000), the same technological fact (such as the innovation of a kiln) may be a response to different factors, because technological facts are not only determined by environmental and/or physical constraints, but also by cultural factors, which may vary from one group to the other. From this point of view, technological facts are complex. This complexity induces complex methodological problems. One issue in technology is also how to disentangle the different cultural factors involved in technological facts, while proposing explanatory hypotheses that highlight their complexity. The great merit of the technological studies presented here is not only to draw attention to the complexity of technological choices, but also to a domain of research that is essential for understanding changes in past techno-economic systems.

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Introduction To be embedded—What does that mean? What was embedded in what, and how does the active relationship between the partners in the embeddedness work? These are the key questions that spring to mind when reading the three papers by Tite and Sillar (2000), Sillar (2000) and Livingstone Smith (2000). It is, I believe, also a key question in the analysis of human society. The relationship between people and material culture is one of the intriguing relationships in human society and (should be) the main objective of archaeological research. It is not just a middle-range theory on the way to the prehistoric social world. In terms of methodology this, furthermore, puts the focus on the relationship between archaeological and ethnoarchaeological studies.

The embedded nature of culture Earlier on (Stilborg 1997), I have made an attempt to come to grips with the big question—Why do we have a material culture in the first place? Since we do not absolutely need it in order to survive (we could all eat raw vegetables and fruits, and restrict ourselves to living on the Equator) or for our social interaction, there must be another common denominator. The suggestions that I have found, in selected literature on ethnoarchaeology, philosophy and cognitive psychology, are that material culture provides us with a controllable structure in which to enact our daily routines in a safe way, without bothering too much about it. It facilitates the relegation of actions and memories to the subconscious and thereby diminishes the effort that we have to put into conscious thought. In short, it makes it possible for our brains to be free to play with thoughts of finding America, since the majority of the actions performed in maintaining the material structure are controlled by a type of embedding that may be called tradition. Again, the opportunistic choice for the sake of limiting effort and confirming and perpetuating the safety of belonging is to do as you were taught, and as you always have done since then. However, the richness of the structure lends itself readily to be consciously manipulated in order to serve practical and social strategies. This relationship between an independent material structure and active strategies (related to the solution of environmentally introduced demands or possibilities, and to the need to flaunt status or to mark out US versus THEM) makes it easier to understand why objects may change meaning, and have many meanings simultaneously. Like chameleons, things change their meaning (or, rather, have their meaning changed) as they are successively embedded in different settings, but they keep their place in the structural hierarchy of pots and other objects made within the material structure of the society. An interesting example is Krause's experiment (1990), in which he showed cardboard silhouettes of pots from different tribes successively to members of the different tribes and asked them to order them. The result was that it was difficult for any tribe to allocate the pots correctly to the correct *other* tribes—they tended to organize the non-local shapes according to their *own* systems.

The article by Livingstone Smith (2000) illustrates very well that the material cultural structure is not a reflection or a product of a particular social pattern. What we see (in these parts of Cameroon) are, first and foremost, traditions of craft established under the influence of the functional requirements of the finished products, as well as of a number of social strategies, and within the pre-existing ecological parameters.

Tilley (1999) points to a way of making the connection between the structure and the strategies using the concept of a metaphor. By analogous reasoning, objects are entered into symbolic relationships of the following type: C is similar in physical characteristics to D and may be seen as a metaphor for D (Tilley 1999, 28). As an example, the body and neck of a vessel is often used as a metaphor for the human body which, in turn, may be seen as a metaphor for a vessel. A good example (besides the ones in Tilley's book) is provided by my $4\frac{1}{2}$ year old daughter. To her, the parent–child connection is very important and interesting. As the main distinguishing feature is the difference in size, she makes metaphorical connections to the material world—stating, for instance, that BIG LETTERS are parents to the small letters—thus making the material world enact her social strategy.

What I have just described seems very much a closed, reactionary society, with a great inertia against change and development. The answer to the teleological need for progress in prehistoric societies again lies in the concept of social strategies. If you use material culture in the performance of your social strategy, you are putting forward a much stronger argument. This is particularly the case if the material paraphernalia that you are using are new to the society and become commonly accepted. However, in order to do this—to become an innovator—it is logical to assume that you must have a status/prestige surplus that may be invested in the daring enterprise of introducing novelties in a conservative society. The complexity of the actions and the interrelations between the people involved in the innovation process have been discussed by Bargatzky (1986). He also points to studies of innovations in modern times, stressing the need for the innovator her- or himself to posses sufficient status/prestige or to be supported by another person, who has status/prestige to invest.

The need for an embedded ethnoarchaeology Both Sillar (2000) and Livingstone Smith (2000)—the latter most explicitly—want to make their ethnological observations applicable to archaeological studies. However, they seem overwhelmed by the richness of their non-material data, and the connections to archaeological methods and theory remain weak. As for the studies of dung, we rarely if ever find the prehistoric firing places. As for the variation in tempering in Cameroon, I would have preferred analyses employing methods that are commonly used on archaeological materials—such as thin sectioning. Furthermore, comparisons both with patterns of other groups of contemporary material culture AND with historical perspectives on the formation of the differences would have contributed greatly in making it a 'true analytical tool for archaeology'. The lack of this vital link in methodology is common in ethnoarchaeology, and makes it more difficult to use and test the rich scenarios on the remnants of past societies.

Embedding the earliest pottery in Scandinavia The concepts discussed above—embedding, material structures, innovators and metaphors—are all pertinent to the study of the introduction of the first pottery to Scandinavia—the Ertebölle pottery. In my studies of the variation in the raw materials, mixing, shaping techniques, ornamentation and use of the earliest pottery, and the subsequent development of the craft and its relation to the variations and developments in the traditional flint technology, I am retracing the embedding of pottery via innovators into the existing material structure. A short description of the Ertebölle pottery may be in order. At the end of the Ertebölle period—around 4500 BC—pottery was introduced to southern Scandinavia, presumably via contacts with the Neolithic societies on the edge of the

loess areas in northern Europe. The most common shapes of the pots—and, in some parts of Scandinavia, the only shapes—were an S-profiled, pointed-based pot and a low, oblong 'boatshaped' dish called a 'lamp' from its probable use. While the former may have been used for both cooking and fermentation, the latter often show traces of having been used as blubber-lamps, possibly in connection with eel fishing (Hulthén 1980). In southeastern Scandinavia, the pots of the initial stage (or, rather, the earliest stage identified so far) are built using a primitive coiling technique (the H-technique) in which each coil is pressed on to the preceding one with the fingertips (Kjellmark 1903; Andersen 1975; Hulthén 1977; Stilborg and Bergenstråhle 2000), while the lamps are modelled. The H-technique produced very thick-walled pots, which were heavy and slow to heat up. Soon, the potters sought to solve this problem—first by slanting the coils, achieving a thinner wall and a better cohesion between the coils, and later on by adding 'pressing and scraping the surfaces' to the *chaîne opératoire*, thereby further thinning the wall and improving the bonding of the coils. In the end, the N-technique of coil-building was established as a standard that was to remain largely unchanged until the introduction of wheel-turning in the late Viking Age. On several sites in the south-western corner of Scania, a large portion of the Ertebölle vessels are decorated with a surface-covering array of small round and pointed oval impressions (Kjellmark 1903; Stilborg and Bergenstråhle 2000). The ornamentation delineates a small group of sites in Scania and points to the diversity of external contacts that led to the neolitization, as well as to the complexity of the process of innovation. At this point in time, the number of vessels was low, the range of shapes (and possibly of uses) was limited, the choice of raw materials was haphazard, the *chaîne opératoire* was under construction and the ornamentation was standardized, to the degree that it might first and foremost have signalled the 'otherness' of pottery in the Ertebölle society. As I see it, the Ertebölle pottery was not yet embedded—not yet a part of the material structure and perhaps not yet amenable for social strategies. Rather, it represented the foreign—the potential new way of life—exaggerating in its shape and stressing with its grain-impression-like ornamentation ideas and impulses from the societies to the south.

In the ensuing period, the shape-repertoire of the Early Neolithic became larger, most likely signalling an expansion in the diversity of functions. A broader range of ornamental elements was used (i.e., impressions of animal bones) and coincided with growing differences in the use of ornamentation between sites, which earlier on shared the same idea of the shape and ornamentation of the Ertebölle pottery. It must be said, though, that these differences were expressed within the limits of a rigid framework of design that was common for the whole of TRB in southern Scandinavia. At the same time, the technology of the craft had reached a mature level, with an integrated relationship between the choice and treatment of raw materials, the building technique and the size and intended properties of the vessel. In short, craft traditions had emerged, although allowing individual solutions to the integration of the different elements in the *chaîne opératoire*. This embedding of the pottery in the society is most clearly illustrated (Koch 1998; Liversage 1980, 129) by the use of pottery in offerings in bogs and as grave goods. The pottery is being used in contexts in which social strategies play a paramount role in a reordering of elements/items extracted from the basic material framework while at the same time evoking the framework through metaphor (Tilley 1999, 28).

Epilogue At the end of the day, what have we achieved with all these words? It is safe to say that the term 'embedded' has proved to be an interesting analytical tool for discussing the interconnections of the parts of the society resulting from our analytical dissection—the operationalizing of the disparate parts, so to speak. But, was the idea of one separate part of society being embedded in another part a reality for the people living in these societies, or did

they consider their social lives as whole indivisible entities? The existence of metaphors in many societies indeed indicates that separate entities, which may be linked together, are perceived (Tilley 1999). Furthermore, the archaeological evidence at least points to a phase of embedding in the introduction of new objects and the attached functions and ideas into a society (Magnusson-Staaf 2000; Stilborg and Bergenstråhle 2001).

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REPLIES

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I would like to thank all those who took the trouble to write a response to our papers. Space is limited, so I will confine my reply to a few of the most fundamental challenges. While my comments are focused on the use of the concept of technological choice in the study of artefacts, these are ultimately questions about what we are trying to learn from archaeology. Materials analysis is at the core of such questions and archaeometrists need to be clear about the purpose of their research.

Explanation Roux points out the inconsistencies in what different investigators choose to describe, analyse and interpret, and she suggests that this is due to the lack of a 'unifying theoretical framework' within technological studies. I think that this lack of a 'unifying framework' is in fact a strength, that has resulted in a much-needed critical debate about technology and artefact studies. The questions that we ask partly depend on whether we wish to study individual artefacts, specific technologies, activity areas, assemblages, sites or landscapes, and whether we are looking at specific periods or long-term processes of cultural change. This may even affect what factors we describe as cause or effect: at a particular moment in time, the shape of a river channel determines the rate of water flow; however, over the longer term, it is the water flow itself that shapes the course of the river and its banks (Bailey 1981). Similarly, the reasons for inventing pottery may be very different to the long-term implications of adopting the technology. In trying to explain the origins of pottery in specific cultures and environments, we

may try to understand the specific form of the first pots, how they were made, what they were used for and their context of use (see, e.g., Barnett and Hoopes 1995); whereas when looking at the long-term implications of pottery production and use, it is more likely that the analyst would emphasize the adaptive benefits of storing, transporting and preparing food and drink, the emergence of craft specialization and the environmental impact of these activities (see, e.g., Arnold 1985). Both of these are very justifiable explanations; it depends on what we wish to study.

Perhaps there is a need for a certain amount of humility to recognize where our preferred ideas and concepts (theoretical orientations) come from and where they do not necessarily provide the best explanation. The concepts of 'technological choice' and the *chaîne opératoire* highlight the creativity of thinking individuals and how this influences cultural change: they are less concerned with considering the long-term adaptation and survival of the human animal.

Evolution If we wish to interpret 10 000 years of gradual change, it is understandable to place greater emphasis on the models developed within evolutionary theory. Neff states that 'the decision-making context is the selective context', but he points out that 'decisions have to accumulate in order to drive evolutionary change. This is how proximate (technological choices) can accrue into evolutionary history.' '[T]echnological choice advocates need to think about how long-run effects emerge out of technological decisions made in the short run. The long-run evolutionary effects create the patterning in the archaeological record.' (Neff this issue). This obviously depends on the particular part of the archaeological record that we are studying. The archaeological record is an elusive mixture that includes *in situ* events (e.g., a flint knapping floor), deliberately placed arrangements (e.g., burials), amalgamated materials (e.g., those recovered from field-walking) and sequential deposits (e.g., successive occupational layers). Whatever artefacts or assemblages we wish to study, we must take into account the archaeological context that our evidence comes from and incorporate this within the models that we use to interpret the data. The archaeological record is like a faltering staccato of disjointed chords, from which analysts can identify the notes played on individual instruments, isolate the most complete musical phrases, or try to piece together the missing material to reconstruct the symphony. What is the role of artefact studies and materials analysis in this process? I believe that the concept of technological choice can encourage analysts to consider both the physical and cultural contexts of a particular artefact and the social and environmental factors that shaped technological change.

It is possible to describe objects in the archaeological record as 'parts of phenotypes in the same way beaver dams and birds nests are parts of phenotypes' (O'Brien and Holland 1992, 23). But, each person uses a wide range of different objects in a wide variety of different ways; I do not think that evolutionary approaches explain this variation and the degree of rapid non-linear change as effectively as concepts developed in the social sciences. Humans are not outside evolutionary processes but, as yet, I do not think that evolutionary models deal with our recent history very well. People cannot know the long-term consequences of their actions but, as Neff suggests, evolutionary theory needs to accommodate the creative choices that people make and the social context in which they live. Many aspects of our material culture and social structures are (re)produced without reliance on genetic continuity: for example, the Catholic Church is perpetuated by people who take a vow of chastity. As Dunnell has commented, archaeological explanations must consider both human evolution and 'cultural transmission'. People can acquire new cultural traits at any point in their lives, and they can pass them on to their parents, friends and foes as well as their offspring.

Those looking for biological models for the role of material culture in human societies may wish to consider the suggestion from Cullen (1995, 1996) that cultural traits replicate themselves

in a similar way to viruses. According to Cullen, these viral phenomena are 'genealogical independent' from their host, such that host and guest reproduce at different times and by different means, but they are 'dependent' on their host for their continued existence, particularly their reproduction. In an article that outlined how his approach could be used to describe pottery production, Cullen (1996) described how potters play an essential role in (re)producing the pottery, but that the pots are also essential in 'feeding' their human hosts when they are exchanged for food, or when they make raw materials into appetising cooked foods. The pots have a semi-independent life but, to be produced and circulated in society, they depend both on the potters in their workshops and the cooks in their kitchens. Although I agree with the way in which Cullen's work stressed the potential of objects, techniques and ideas to act-back on people (a point also made by Griffiths), in the end I feel that this is merely a quirky biological analogy for the social world in which material culture really exists: what matters is how people perceive and act in that world.

Like evolutionary archaeologists, I am concerned with recognizing the mechanisms that cause variation, generation, transmission and selective retention of cultural traits, but I believe that individual perceptions and motivations are a major aspect of this process. If we accept that individual agency in decision-making has a role in explaining short-term changes in artefact design and techniques, then they should also be considered as factors when modelling longer-term processes. I feel that this is best achieved by the concept of 'social reproduction' and highlighting the role that relatively mundane 'subsistence activities' play in creating, maintaining and changing social relations and ideological concepts (Sillar 2000). Every action that a person undertakes is an opportunity from which they may learn; from this knowledge they may choose either to repeat or to modify their behaviour in the future, however people's individual agencies are framed within the cultural structures that surround and inform them (Giddens 1979, 1984). There can be no complete break from the past, precisely because the very knowledge that we utilize to enact change is itself informed by our previous experience and cultural knowledge. We are partly conditioned by the materials, the techniques and the understanding that we inherit, but we are always able to combine these elements in novel ways and so expand both the material and the conceptual horizons of our universe (Sillar 1996). People are born into pre-existing structures, and every activity that they undertake serves further to embed them in such structures.

Ethnoarchaeology Stilborg points out that a fundamental problem with ethnoarchaeological studies is that they rarely provide a historical perspective on the emergence of the modern pattern. McGuire (1995) makes a similar point in his criticism of Schiffer's behavioural archaeology, pointing out that the use of experimental and ethnoarchaeological research has failed to provide a strong framework from which to interpret processes of change. Very few projects have managed to observe 25 years, or more, of change in ceramic production (but see Longacre and Skibo 1994; and Arnold forthcoming). I would agree with Stilborg that ethnographic data should be augmented by a consideration of the historical context (cf., Sillar 2000), but this information is commonly of a very different order to the ethnographic observations. Like geology, we need to use detailed observation of present-day processes alongside historical records in order to build up a better picture of how observable activities accumulate to create the archaeological record. This is basically the application of uniformitarian principles to archaeology, the problem with this being that we know that many technologies and forms of social organization no longer exist, and we are in danger of forcing the present day into our interpretation of the past (Wobst 1978).

Stilborg also questions the relevance of my ethnographic study of dung as a fuel for open firings and suggests that ethnoarchaeology should use techniques used in archaeology in order to promote

comparison. In my view, ethnoarchaeology should not limit itself to what is current practice in archaeology; it should try to stretch the frontiers of archaeological research, and search for material practices and social consequences that have not been recorded by ethnographers or considered by archaeologists. As an example of the effect that this can have, I would point out that it has only been since good ethnographic studies of pottery firing using dung have been published that prehistoric firing places using the same fuel have been recognized in the Andes (e.g., at Tiwanaku: see Rivera Casanovas 1994; Franke 1995). Roux is justified in criticizing my lack of quantitative data: unfortunately, I did not realize the significance of dung until fairly late on in my research, so I did not make detailed recordings of this type. However, in Sillar (2000, Appendix 3) I describe the number of sacks of dung used in a range of different firings, and Winterhalder *et al.* (1974) provide quantitative information on Andean animal dung production, the dung's calorific values, and its effectiveness as a fuel and a fertiliser.

Embedding I feel that Cumberpatch's critique of the term 'embedded' is largely playing with semantics. The use of the word was intended to emphasize how *every* technique is part of a wider context of artefacts, environments, ideologies, economic systems and social structures. I wanted to move beyond a purely functionalist explanation of technologies, to consider the particulars of the local relations that the technology is a part of—this is as relevant for the Paris subway (Latour 1993) and aeroplanes (Lemonnier 1992) as it is for prehistoric lithics or pots. In fact, Cumberpatch mainly has a problem with the idea that an object, a technique or an economic activity could become 'disembedded'. I too would have a problem with this. The production and use of every artefact always involves people, whose actions incorporate the object into their perceptions and value systems and necessarily embed the object into their social setting. Even at the point of excavation, an object becomes enmeshed in a new setting of finds processing, artefact analysis and museum curation. As Stilborg comments, 'Like chameleons, things change their meaning (or rather have their meaning changed) as they are successively embedded in different settings'. Pool's (2000) description of Mexican pottery firing techniques demonstrated that we need one explanation for how a new technique emerges within one context, but the perpetuation of this technique at the end of the 20th century also requires a different explanation as to how it is embedded within the present-day environment and the socio-economic context of the potters.

It is also worth considering how our archaeological work is embedded within the socio-economic relations at the start of the 21st century. Cumberpatch highlights the current problems of contractor-funded excavation, and the lack of time and resources provided for post-excavation analysis. Much of the artefact analysis in the UK is now done by self-employed finds specialists working from a variety of workplaces, including their own homes. This undoubtedly limits the potential for co-operative interdisciplinary research. The separation caused by different specialists analysing pottery, stone, wood, pollen, bones and so on has become integrated into a modern system of putting-out, and a pay system, similar to piecework, that undermines the analysts' role in developing innovative approaches to their own material. There is a need for resources (from contractors, government bodies and research funds) to support excavators, finds specialists and archaeometrists to come together and work in small groups to consider the interrelationships within their data sets and develop more integrated interpretations. Without this, most excavation reports, finds reports and analytical reports will continue to languish (alongside the excavated materials) in archives that are rarely, if ever, consulted (Swain 1998; Merriman and Swain 1999). We would get 'better value' out of the resources that are put into archaeology if a small amount of this money was provided for re-integrating our research. I believe that a consideration of technological choices and embedded technologies provides a relevant analytical approach for doing this.

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Reading the comments collected here, I wondered if archaeology was anything more than a sophisticated Rorschach test. The comparison between archaeological interpretation and the well known psychological test is probably exaggerated, but it is interesting to see how a series of archaeologists, given the same set of data, will see different things according to their respective 'scientific traditions'. Indeed, some of the comments on the WAC4 papers refer to clear-cut

theoretical backgrounds. Kolb provides an outline of the abundant Anglo-American literature devoted to archaeological ceramics since the 1960s. He concludes that the papers presented at the WAC4 conference are aspects of the method and theory of 'ceramic ecology'—I would simply call that archaeology, but if an ecology label is needed, so be it. Neff summarizes another, very specific approach, namely *evolutionary archaeology*. This theoretical perspective is focused on explaining the 'origin of technological design' with models inspired by Darwinian concepts. Here, my response is such that it calls for a specific paper or discussion. Stilborg considers the concept of 'embeddedness' in the light of the Scandinavian Neolithic, while Griffiths, reversing the problem, draws attention to the influence of technology on culture. Each comment constitutes a specific view on the WAC4 papers and, in a certain way, the papers and the associated comments each make an interesting subject of research on stylistic variations.

As Roux alone made specific comments on my contribution, I will first respond to her. Roux's main criticism concerns the methodological weakness of my approach. In her opinion, I try to understand technical diversity, but my '. . . results bear (a) on the phenomenon of *homogenization* of technical features, at a local scale, through a process of *appropriation* that transcends ethnic or ethno-linguistic groups, and (b) on the phenomenon of *perpetuation of tradition* through geographical boundaries. As a consequence, the parameters taken into account prove, in fact, incomplete for understanding, in particular, the phenomenon of *diversity*.' Although I am eager to improve my work, I am not certain that I understand the full meaning of this criticism. As an example of my methodological weakness, she regrets that the use of dung, straw and grog in zone 3 is not considered in the light of what is found in other areas of Africa. She refers to data from Senegal, where these tempering techniques are also frequently found in association, and where 'one may wonder if, initially, differentiation in temper was not related to the intention of differentiating clay processing techniques in some relationship with the different functions of pots (even though this intention is no longer present in potters' memories)'. In addition, Roux suggests that I have not considered the properties and characteristics of the materials in enough detail, and she seems to suggest that the clays were characterized only by means of granulometric analysis. Specifically, she states that '. . . properties of tempers should also be taken into account. Dried ground clay or another clay cannot be compared to sand and grog since the consequences in terms of clay hydration behaviour are radically different. From this, one may wonder if the tradition found in zone 2 could be related initially to a certain quality of kaolinite (which cannot be assessed only through a granulometric analysis).'

I have several objections to these comments. First, it might be that in ancient times potters selected their tempers according to technical and functional constraints, and that their decisions were passed on to unsuspecting descendants. Such an idea would certainly please everyone. However, I would remain cautious about accepting this hypothesis. The function or functions of a pot are today sometimes very difficult to assess, as potters and consumers do not always agree on the subject (Sall 1996; Gelbert 2000)! As far as I know, it is also far from easy to assess pottery functions from archaeological material.

Second, pottery-tempering practices in Senegal appear to be distributed according to a regional pattern of variation. According to a recent PhD thesis (Gelbert 2000), the distribution of pottery tempering techniques in the Senegal River valley fits with social boundaries rather than with functional parameters. Furthermore, there is, to my knowledge, no evidence of Senegalese potters changing their temper according to pottery function (Sall 1996; Ndèye 1998; Gelbert 2000). In fact, such variations are even rarely reported for sub-Saharan pottery in general (Gosselain 1995).

Roux also wonders if there is a relationship between clay preparation traditions in zone 3 and

those of Senegal. Similarly, she notes that sand addition is also used in Nigeria and wonders at the relationship with the Faro. These are interesting questions, but one must keep in mind that *all* the techniques observed in the Faro area are also observed elsewhere (Drost 1967; Gosselain 1995). For example, grog, apparently one of the most popular tempering techniques in Africa, is used by many populations all over the continent. Dung, however, is used as temper among a limited number of populations, distributed mainly in the Sahel, from Senegal to Sudan. Such a distribution is extremely interesting when one considers that a further use of dung is as fuel for pottery firing. Indeed, dung is used as fuel not only from Senegal to Sudan, but also by populations along the 'east side' of the continent, all the way down to South Africa. Studying the emergence and diffusion of these technologies on a continental scale is certainly of great interest, but that was not the aim of my paper.

Considering the exact nature of the raw materials, I have to admit that their characterization could have been more detailed; indeed, it is always possible to undertake more detailed characterization. Initially, the FTIR, thin-section petrography and granulometric analysis were used to provide for a general characterization of the raw materials—one should note that kaolinite was determined not by grain size analysis but by FTIR. Indeed, these analyses showed that, as far as the clays, the mineral inclusions and grain size are concerned, the materials used throughout the Faro are roughly similar. It might be that a detailed study would reveal that there are different kinds of kaolinite but, irrespective of the tests and analyses, the context of use of these materials should be kept in mind. Pottery workshops are not laboratories where experiments—or even pottery production itself—can be conducted in standardized conditions. One must also remember that potters from different villages, or even from the same village, but using the same source, may prepare the clay in different ways.

Finally, Roux highlights some interesting questions concerning the acquisition and perpetuation of technical traditions at the individual level. However, in this particular case, potters very rarely admit to having changed or acquired another clay preparation technique. In fact, none of the potters whom I interviewed personally ever admitted having done so. In zone 3, as in other areas of the Faro, clay preparation techniques are apparently acquired during apprenticeship.

Considering the overall comments from a more general point of view, there seems to be a general agreement on the fact that technologies are best explained in terms of both techno-functional ('properties and performance characteristics') and cultural parameters. I cannot but agree with such a proposition. In fact, one may wonder who would question such a basic assumption. Any newspaper will reveal that most technical choices are made according to many 'cultural' reasons: for example, I do not think that the failure of the conference on global warming in the Hague had anything to do with technical issues. The real problem apparently lies with the need to distinguish the 'technical' from the 'social'. This old, typically occidental, dichotomy between function and culture, mind and body, goes back at least to Graebner and the *Kulturkreise* school, and has been present in most methodological discussions ever since. The debate between Bordes and Binford—*Culture history versus New archaeology*—is a good example. Today, several anthropologists, such as Lemmonier or Sigaut, have shown that it is futile to consider these aspects separately. It is clear that techniques do always fulfil both functional and cultural objectives. We may discuss *ad infinitum* whether Apple computers are truly better than IBM computers, but no one can deny that objects inform us about the people who produced and used them. Paradoxically, archaeology displays a terrible lack of method in this matter. According to their background, archaeologists 'choose' between the techno-functional or the cultural interpretation, but observed technological variations are never truly explained. It seems that, in consulting ceramic engineers, physicists, chemists and geologists to

investigate pottery technology, archaeologists have forgotten to develop an appropriate methodology. Some, like Schiffer and Skibo (1997), have tried to provide archaeologists with a unified theory, while others, like Gosselain (1998, 2000), have examined new ways to understand the social mechanism underlying technological variations in archaeology. A lot of work remains to be done, however, but people working on the subject in the future should keep in mind that our discipline does not necessarily need sophisticated jargon and fancy analytical techniques to be 'scientific': it simply needs a method to relate objects and people.

Finally, I would like to thank all those who have contributed comments. My special thanks go to Valentine Roux for her detailed criticisms, to Chris Pool, whom I previously forgot to thank for his comments on my original paper and, as usual, to my colleague Olivier P. Gosselain.

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C. G. Cumberpatch hits the nail squarely on the head when he identifies the broader significance of the papers assembled in '*Technological choices in ceramic production*' as 'the fact that they have appeared in *Archaeometry* at this particular time'. Thanks are due to Michael Tite and Bill Sillar, not only for organizing the original WAC4 symposium and assembling the four papers published in *Archaeometry*, but for extending the dialogue that they initiated by soliciting these stimulating comments from six representatives of a wide variety of theoretical perspectives. In my reply, I will first take up specific points raised by the individual respondents, then indulge in some additional reflections of my own.

In his review, Kolb does us the considerable service of situating the articles in their historical context. Kolb accurately identifies the roots of my own perspective in a preoccupation with the economic and ecological aspects of ceramic production and distribution. I cannot speak for the other authors, but I am perfectly content to find my article embraced in the overarching paradigm of Matson's (1965) ceramic ecology, as extended by Kolb (1989). Although ceramic ecology is often misconstrued as techno-environmental determinism, Kolb's Holistic Ceramic Ecology effectively situates the use and manufacture of pottery within a much broader social as well as natural environment.

I appreciate Roux's more critical comments, as they afford me an opportunity to clarify some specific points. Roux characterizes kiln use in the Sierra de los Tuxtlas as corresponding to the different technological phenomena of *innovation* and *perpetuation of a tradition* in the Classic and modern periods, respectively. Roux's distinction is a useful one, which I address in an article that I recently published in *Latin American Antiquity* (Pool and Britt 2000). That article which, to be fair, Roux probably did not have access to, makes the point that the reasons for the invention or initial adoption of a technology are not necessarily those that result in its spread and persistence. The distinction between innovation and perpetuation is less germane to the article under consideration, for two reasons. First, it appears that kilns were initially employed in the Sierra de los Tuxtlas in the Terminal Formative period (AD 100–300), which precedes the Classic period (AD 300–900) that I consider here (Pool 2000, 65; Pool and Britt 2000, 153). Second, the Classic period lasted for six centuries, during which kiln use clearly must be treated as a perpetuated tradition.

Roux faults my article for not handling the cultural value of pots (as represented by their intended consumers) or the dynamic interaction between technological innovation and demand for fine-paste vessels in a particular sociopolitical context. These are certainly relevant issues, although they do not operate in the Tuxtlas case in quite the way Roux imagines they might. Again, I refer the interested reader to the *Latin American Antiquity* article, where Britt and I discuss these matters in greater detail than is possible here. In brief, fine-paste oxidized wares appear as a minor component of Late Formative (300 BC – AD 100) assemblages, which are dominated by black wares and differentially fired black-and-tan wares. We have recovered fine-paste sherds from Late Formative domestic contexts, but they appear to be more prevalent in surface collections from villages than from smaller hamlets. This fact, and their greater frequency in a Terminal Formative assemblage from a domestic unit with an unusually large volume of storage pits, suggests to us that the Formative period fine-paste wares may have communicated differentials in socio-economic status, real or aspired to, in face-to-face interactions involving the serving of food. At the end of the Terminal Formative period, fine-paste ceramic production expands rapidly, and by the Classic period fine-paste ceramics, including highly decorated examples, are a common component of domestic assemblages for elites and non-elites alike. Thus, during the Classic period treated in the *Archaeometry* article, status differences are not reflected in the distribution of fine-paste wares, and I consequently did not discuss them. If I have erred in not presenting these details, it is a fault of my exposition, not with the behavioural approach *per se*. It is perfectly possible to consider the performance characteristics of vessels (and, by extension, the firing technologies employed in manufacturing them) *vis-à-vis* their social contexts of use. This, I admit, is only hinted at in my consideration of the relative importance of even surface colour development in fine-paste and utilitarian ceramics.

With regard to the associations of firing technologies with production modes, Roux is correct that open firing of Coarse Brown pottery at Matacapan appears to be associated exclusively with domestic contexts (better interpreted as 'household industries' than 'domestic production', in Peacock's (1982) terminology), but kiln firing also occurs in such contexts, as well as in more intensive production modes (Pool 2000, 69). In fact, the household industry appears to be the most common production mode for Fine Orange pottery (Santley *et al*. 1989, 124; Pool and Santley 1992, 214). In only one case does Fine Orange production appear to have been attached to elite patrons; the other loci of Fine Orange production are scattered throughout the residential zones of Matacapan (Santley *et al*. 1989, 124; Pool 1997, 219–22). Thus Roux's implied suggestion that fine-paste wares may have been made for elite patrons by attached specialists does not characterize the overall production–distribution system at Matacapan.

Griffiths, Cumberpatch and Stilborg, in different ways, address the relationship between technological choice and the wider society—the phenomenon that Sillar and Tite express as the 'embeddedness' of technology choice. Cumberpatch rejects the term 'embedded' (along with the notion of pottery as a 'subsystem' of the social world), as an inadequate metaphor for the dually interactive nature of the relationship. Instead, he argues, 'The production and use of pottery . . . actually contributes to the production and reproduction of society and socal structures . . . ', invoking ideas of structure and practice elaborated by Giddens and Bourdieu. Griffiths likewise highlights the idea that 'technology also influences society and culture', but seems less troubled with the notion of embeddedness. Stilborg embraces the concept of embeddedness, but asks whether the idea of one separate part of society embedded in another part was a reality for the societies we study. His affirmative response draws on evidence from his own research for a phase of embedding in the introduction of pottery during the Ertebölle period in Scandinavia and Tilley's (1999) discussion of metaphor.

For my own part, I see the notion of embeddedness as a very useful one. If a material metaphor is to be sought, perhaps ceramicists need look no further than the ceramic materials of their own research, in which temper, although physically embedded in the paste, nonetheless alters the mechanical and chemical properties of the paste. I do take exception to one incomplete quotation of my article by Griffiths, which gives the mistaken impression that I do not see evaluation of performance characteristics as an effective means of understanding specific historical cases of technological choice. The full sentence reads '[Cross-cultural associations and *absolute*] performance characteristics [of different technologies can provide clues as to why potters might adopt one technology over another, but] by themselves they are insufficient to explain any specific historical instance of technological choice' (emphasis added, elided parts in brackets). My point (which I make in the next sentence) was that *absolute* performance characteristics that are determinable through mechanical, thermal or other tests must be evaluated with respect to the use of pottery in its specific behavioural contexts.

Neff's comments really constitute a reflective essay, which should stand on its own as another of his perceptive contributions to evolutionary archaeology. He makes two principal points, both of which I agree with. The first is that the differential persistence of cultural information (including how to make pots) must depend primarily on effects other than differential biological reproduction. In this respect, he sees research into technological choice as one avenue for exploring sources of selection-driven change. Neff's second point is that to contribute to an understanding of long-term evolutionary change, technological choice advocates 'need to think about how long-run effects emerge out of technological decisions made in the short run'. In the spirit of the constructive dialogue that Neff engages in, I offer the following thoughts.

As a starting point, Neff suggests that the proximate causes of technological choices (that is, the cultural, behavioural and ecological factors that impinge on technological decisions) constitute biases that favour different technological variants in different contexts. In Neff's view, 'As technological variants succeed or fail, the corresponding ceramic technological design information encoded in human brains is replicated differentially' and, in the long term, differential persistence of design information (selection) produces evolutionary change in ceramics. Consequently, an evolutionary account of ceramic change 'requires unravelling how *repeated* decision-making biases over time create directional selective pressures that shape ceramic traditions'.

Arguing from a different theoretical perspective, Sillar and Tite (2000, 10) propose, 'The longer-term development of "technological traditions" emerges out of the interplay between the conservative force of "cultural choices" and the innovative nature of "individual choice".' Sillar

and Tite (2000, 10) further relate this view to Gidden's (1984) theory of structuration, which concerns 'the dynamic relationship between social structures and the active agency of the knowing subject'. Although the gulf between Neff's Darwinian model of change as resulting from the mechanical action of historical processes and Gidden's poststructuralist formulation of agency is a broad one, I would suggest, at the risk of alienating both camps, that there are nevertheless some grounds for dialogue.

Giddens' (1984, 5–6) model of agency posits that humans act in accord with a 'continuing theoretical understanding of the grounds of their activity' (his 'rationalization of action'), as well as 'unacknowledged conditions of action'. In Neff's terms, these understandings and conditions may be viewed as selective biases for or against technological variants. Giddens's (1984, 5) agents also reflexively monitor the flow of their own actions, as well as aspects of the social and physical contexts of their acts. This reflexive monitoring, performed individually, but also communicated among actors, might be construed as one mechanism by which, in Neff's terms, technological information encoded in human brains is differentially reproduced (another would be errors in the transmission of information between actors). Incidentally, one significant implication of this reflexive monitoring for technological choice advocates is that individuals respond to the reactions of others. We should keep in mind that potters are not the only ones who make choices about pots. Consumers also choose among the products of potters, and their choices may influence the technological decisions of the latter (Pool 2000, 68).

Giddens (1984, 8) also emphasizes that the actions of agents have unintended consequences, which 'feed back to the unacknowledged conditions of further acts'. This aspect of Giddens' model, as well as his differentiation between motivation and intent (Giddens 1984, 8–11), addresses an issue of considerable importance to evolutionary archaeology. Evolutionary archaeologists have usually argued that selection is more important than human intent as a mechanism for long-term change precisely because intentional actions have unintended consequences and because humans are poor predictors of future events (see, e.g., Braun 1995; O'Brien and Holland 1995, 156; O'Brien *et al*. 1998, 493). As a result, intentional innovation is usually seen as one mechanism that generates the variation on which selection acts, and that variation, whether the result of intent or chance, is random with respect to selection. Bettinger and Richerson (1996, 226–8), however, call for more attention to intent in evolutionary theory, noting that intent is most problematic in teleological arguments that conflate intent with outcome. Following Giddens, one might well imagine that agents acting in accord with shared biases (unacknowledged conditions of actions and rationalizations of actions), would be predisposed towards certain innovative technological choices. Within a particular historical social and environmental context, these choices would also have similar unintended consequences, which would in turn have similar effects on the biases that affect subsequent actions. In this way, then, the decisions of individual actors participating in a particular social and environmental context might accrue into directional change.

A final point that I should like to make is that, whether construed in terms of evolutionary selection of behavioural phenotypes or the consequences of human agency, technological choices and the precepts or biases that influence them are continuously tested, contested, communicated and reaffirmed or modified in the activities of day-to-day practice. For this reason, although I agree with Neff that the decision-making context is the selective context, I would add that the selective context is most proximately a behavioural context, albeit a behavioural context that is shaped by and helps shape the broader social context of which it is an integral part. Therefore, I would reaffirm, in accord with my paper in the *Technological choices in ceramic production* special section, that an evaluation of performance characteristics

as they relate to specific natural, social and economic contexts provides an effective avenue for understanding cases of technological change and stability.

In conclusion, the comments on the technological choice articles affirm that technological choice is 'good to think'. I submit that this is precisely because technological choice lies at the intersection of material properties and resources, social context and historical change. Although I doubt they will be entirely acceptable to anyone, I hope that my own attempts to reconcile these perspectives will contribute in a small way to the continuation of the dialogue so auspiciously opened by Michael Tite and Bill Sillar.

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