Non-Cognitive Values and Objectivity in Scientific Explanation: Egalitarianism and the Case of the Movius Line

Raoul Gervais

Perspectives on Science, Volume 21, Number 4, Winter 2013, pp. 429-452 (Article)

Published by The MIT Press

Non-Cognitive Values and Objectivity in Scientific Explanation: Egalitarianism and the Case of the Movius Line

Raoul Gervais
Ghent University

Although it is now widely accepted that in science, non-cognitive values play a role, it is still debated whether this has implications for its objectivity. It seems that the task of philosophers here is twofold: to flesh out what kinds of non-cognitive values play what kinds of roles, and to evaluate the implications for objectivity. I attempt to contribute to both tasks by introducing the value of egalitarianism, and showing how this non-cognitive value shapes three alternative explanations of the Movius Line. It is argued that although these explanations are motivated by egalitarianism, they are nevertheless objective.

1. Introduction: non-cognitive values in science

In the debate about values in science, it is a time-honored tradition to distinguish between the normative question of whether non-cognitive values should play a role in science and the descriptive question of whether they in fact do so or not.[1] Among philosophers of science, it is now an accepted

The research for this paper was supported by the Research Fund Flanders (FWO) through project nr. G.0031.09.

1. Likewise, it is customary to distinguish between cognitive values and non-cognitive values, where the former include values having to do with scientific methodology (explanatory power, predictive power, consistency etc.) and the latter include social, ethical and political values (the idea being of course that only the latter are a potential threat to the objectivity of science). In what follows, I shall take this distinction and the terminology for granted, though I feel it is fair to point out two caveats here. First, in choosing the term 'non-cognitive values' to cover the wide range of social, ethical and political values, I do not mean to suggest that meaningful distinctions between those values cannot be made, nor that normative claims in these fields are always non-cognitive. My interest here is in the distinction between those values having to do with scientific methodology, and those that do not. Even then however (and this is the second caveat) it should be noted that this distinction itself is by no means uncontested (see Lacey 2004 for a discussion). Indeed, one

Perspectives on Science 2013, vol. 21, no. 4

doi:10.1162/POSC_a_00111

view that the descriptive question has been settled. That is, it is no longer disputed that non-cognitive values play a role in science. Hence, all that is left to do on the descriptive front is to describe these values and their roles in more detail. In the words of Longino: "We should stop asking whether social values play a role in science and ask which values and whose values play a role and how" (2004, p. 127).

In contrast, the debate about the normative question has seen no similar resolution, as theorists still quarrel about the supposedly harmful influence of non-cognitive values on the objectivity of science. Of special importance in this debate is what has become known as the Value-Free Ideal for Science (henceforth VFI), the roots of which go back to at least the mid-twentieth century.[2] In its most robust form, VFI asserts that values should be kept out of science altogether. Stated like this, VFI is obviously too strong, and it has been criticized as such by generations of philosophers, from Rudolf Carnap over to Heather Douglas. Yet for all this criticism, in an appropriately modified version, VFI continues to influence philosophers of science to this day: many still hold that at least in the crucial context of theory acceptance, non-cognitive values should not play a role, if science is to remain objective.

Thus, concerning the debate about values in science, philosophers of science have two tasks they need to address. First, as Longino remarks, they need to provide insight into what kinds of non-cognitive values play what kinds of roles in science, and second, they need to evaluate the consequences these roles have for the objectivity of the scientific endeavor. In this article, I attempt to make a modest contribution to both tasks, specifically in the domain of explanatory inquiry. I will introduce a non-cognitive value that, to my knowledge, has so far not featured in the literature on values and scientific objectivity, namely egalitarianism, and illustrate how this value is operative in motivating and evaluating the merits of different scientific explanations. Thus, egalitarianism plays a role, not only in the (philosophically innocuous) context of motivating explanations, but also in the more controversial context of accepting and rejecting explanations. To illustrate this, I will consider a case study, namely the explanation of the so-called Movius Line (see section 4 below), and show how egalitarianism motivates and shapes three explanations of this phe-

---

might argue that distinguishing between these different kinds of values itself involves making a value judgment. Nevertheless, the arguments in this article do not depend on the possibility of an exhaustive conceptual distinction between the two, but only on the assumption that in the case of a particular value, we will often have an intuitive sense whether it belongs to one or the other.

2. See Douglas (2009), ch. 3 for an excellent overview of the history of this ideal.

nomenon. Next, I will address the normative side of things, and argue that although the three alternative explanations of the Movius Line are influenced by egalitarianism, pace VFI, they are nevertheless objective in a philosophically interesting sense.

Let me conclude this introduction with an overview. As I have said above, in the course of this article, I will try to evaluate the objectivity of three different explanations, but of course one cannot do so without providing some understanding of the notion of objectivity. In sections 2 and 3 I will do just that. I will not attempt an exhaustive analysis by presenting some set of necessary conditions, but, drawing on the literature, I will present four norms of objectivity for explanations. In section 4, I will introduce the Movius Line as the *explanandum* that is meant to serve as a case study, and present a brief outline of its history. In section 5 I will state the reasons why I think the case is an interesting one for philosophers concerned with values in science, and make plain why a certain type of explanations of this phenomenon is motivated by what I call the non-cognitive value of egalitarianism. Towards the end of the section, I will give an account of what I mean by egalitarianism. In sections 6 to 8 then, I will consider three explanations of the Movius line in turn, evaluating their objectivity in light of the norms set forth in section 3. I will argue that although these alternative explanations are motivated and shaped by egalitarianism, they are nevertheless objective.

2. Objectivity in the philosophical literature

There are two obvious senses in which the concept of objectivity might be applied to explanations. First, there is a sense according to which explanations are objective if they provide accurate descriptions, i.e. single out the true reasons why the *explanandum* occurs. This notion of objectivity applies primarily to the result of an explanation. In contrast, the second sense in which an explanation might be objective applies to the process of explanation: it deals with the question if, while constructing explanations one uses methods and criteria that are reliable. Although these issues are intimately connected, and the norms for objectivity I formulate in the next section cover both senses, care must be taken not to confuse them.

In the debate about values in science, the notion 'objectivity' is usually applied to the context of theory acceptance. Intuitively, this notion captures something like a scientist's detachment in deciding whether or not to accept a particular theory. However, this cannot be understood as 'detached from all non-cognitive considerations' or something similar, because this would either simply restate the position of those denying the influence of non-cognitive values on the scientific process, or beg the question against those who take the opposite view. Rather, I think it worth-

while first to compare several notions of objectivity as they are found in the literature, and then apply them to explanation. In this way, we might be able to formulate some norms for evaluating the objectivity of particular explanations.

As is widely known, Longino argues that scientific knowledge is social knowledge; it is the product of science as conducted by a community of researchers (1990). While the non-cognitive values of individual researchers might have some influence, these do not undermine objectivity outright. Objectivity, for Longino, is a gradual notion and varies with the degree to which the following criteria are met: recognized avenues for criticism, shared standards, community response and tempered equality of intellectual authority. To the extent that these criteria are met, a scientific community can exhibit transformative criticism of a method of inquiry (1990, p. 76). What matters is that according to Longino's account, although subjective preferences may seep into the scientific process, shared institutional and methodological criteria in the scientific community (e.g. the double anonymous peer review system) and the responsiveness of the scientific community to criticism, in short, transformative criticism, ensure that in the long run, the theories that are ultimately accepted are those that possess a significant degree of objectivity.

Hugh Lacey divides the idea that science is value free into three component views: impartiality, neutrality and autonomy (Lacey 1999). Here, the focus will be on neutrality, as it "[. . .] derives from 'objectivity,' representing faithfully the object of inquiry" (1999, p. 5).[3] Neutrality concerns the logical implications and various consequences of accepting theories. In particular, a theory is neutral when: i) it has no value judgments among its logical implications, ii) accepting it has no cognitive consequences concerning the values one holds and iii) it is available to be applied so as to further projects linked with any values. For Lacey, the general idea behind neutrality is that although non-cognitive values can influence the significance of a theory, this significance does not itself determine judgments about theory acceptance in the context of impartiality (2005, p. 25). That is, science "[. . .] does not play moral favorites" (2005, p. 26): although theories may be more significant than others given a certain value-outlook, this difference is not due to the proper scientific process, but rather a result of different (e.g. social or cultural) factors. Although this is a broad cluster of ideas, at the risk of misinterpreting Lacey, in what fol-

3. Thus, it would seem that Lacey endorses a notion of objectivity along the lines of the first sense specified above, as a property of a description rather than a process. However, the precise details of Lacey's position do not matter here; what matters is that he construes neutrality as pertaining to the "[. . .] sound acceptance of scientific theory (Lacey 1999, p. 74)", which in any case is just the sense I am interested in here.

lows I shall take a more narrow approach to neutrality, and treat it as making the following claim as regards to the notion of objectivity: accepting a particular theory does not require one to endorse any particular non-cognitive value in addition to those one set out with in pursuing that theory.

Arguably, Heather Douglas provides the most comprehensive analysis of objectivity in science. She distinguishes seven 'bases' for objectivity (Douglas 2009, pp. 118–129). Not all these bases are relevant here, so I will briefly mention four: convergent objectivity, or the idea that evidence gathered through different methods and in different fields all point to the same result; procedural objectivity, or the idea that the same outcome is always produced, regardless of the identity of the particular researcher; concordant objectivity, or the idea that a group of scientists concur on the particular observation; and interactive objectivity, or the way in which results are discussed among scientists.[4] According to Douglas, in assessing the objectivity of a claim, "[. . .] multiple bases acting at once increase the strength of our endorsement of the claim" (Douglas 2009, p. 129).

It is evident that these different notions all touch upon some intuitive aspects of objectivity (to the exclusion of others) and that there are some overlaps. Moreover, these authors are discussing objectivity as a property of the scientific process in general and the context of theory acceptance in particular, while I am focused on explanatory inquiry. However, I think that they do provide enough grounds for positing some reasonable norms by which to judge the objectivity of explanations, both with respect to explanation as a result, and the process by means of which this result is achieved. The overarching intuition here is particularly well summed up by Douglas:

> What holds all these aspects of objectivity together is the strong sense of trust in what is called objective. To say a researcher, a procedure or a finding is objective is to say that each of these things is trustworthy [. . .]. The trust is not just for oneself; one also thinks others should trust the objective entity too. Thus, when I call something objective, I am endorsing it for myself, and endorsing it for others. (Douglas 2009, pp. 115–116).

Thus, in formulating norms for explanatory objectivity, we should keep in mind that in attributing objectivity to an explanation, we are in fact en-

4. On Douglas' account though, these bases for objectivity do not all apply to the same things; some apply to interactions between an individual and the world, some to interactions between a group and the world, and some to an individual's apparent or reported thought processes (Douglas 2009, p. 117).

dorsing its trustworthiness for ourselves and for others. Although according to Douglas, this objectivity is often attributed to the knowledge claim resulting from an explanation, it can of course also be meaningfully attributed to the process by which we come to that knowledge claim: "I will take the ascription of objectivity as a shorthand way of telling others that a claim is likely to be trustworthy, given the processes that produced it" (Douglas 2009, pp. 116–117). On this account, an explanation is objective if we have done our epistemic best in putting it forward; i.e. if the process by which we have reached the explanation is reliable. In turn, this reliability can be understood according Longino's notion of transformative criticism, or the idea that communities of researchers employ diverse perspectives from which a method of inquiry can be criticized. We arrive then, at a notion of objectivity that is inherently social and context-dependent, in the sense that judgments about the objectivity of explanatory inquiries are made relative to the cognitive and non-cognitive values operative in a specific field or discipline. In any case, I think the different concepts of objectivity sketched above, together with the overarching intuitions provided by Douglas and Longino, provide us with enough grounds to formulate reasonable norms by which to judge the objectivity of explanatory inquiry.

3. Explanatory objectivity

The objectivity of an explanatory inquiry is determined by the degree to which the following four questions can be answered affirmatively:

1. Is the explanatory process open for the scrutiny of the scientific community? That is, have the details of the explanatory process been open to criticism and evaluation by experts? Although the issues here are not as straightforward as they might seem (cf. Lee & Schunn 2011, vol. 26), I shall only require that the explanatory process is detailed in scientific journals. This norm is motivated by Longino's notion of transformative criticism, as it presents one way to ensure that the possibility of such criticism is not blocked.
2. Does the explanatory process exhibit neutrality, in the sense that accepting its resultant explanation does not entail accepting any non-cognitive values beyond those one set out with? This norm is meant to rule out the situation that perceived further non-cognitive (ethical, social or cultural) implications have a (positive or negative) influence on the explanatory process.
3. Does the explanatory process suggest ways in which the resulting explanation might be disconfirmed by the evidence? That is, does the resulting explanation have implications (not necessarily deduc-

tive implications) that could be at odds with the evidence?[5] This norm is meant to capture Douglas' procedural objectivity, in the sense that the test of disconfirmability has a definite outcome, regardless of who performs it, where 'performing the test' means comparing the explanation with the available evidence. Of course, when the result is that an explanation is disconfirmed by the evidence, researchers may differ on the question whether this disconfirmation warrants a rejection of the resulting explanation, or that it simply signals the need for additional research and/or refinement of the explanation, but across the scientific community, there should be agreement that a given piece of evidence is either a confirming or disconfirming instance (concordant objectivity). Again, this norm is motivated by the need to allow for transformative criticism, in that it ensures that the potential for such criticism is not undermined in the process of framing the explanation.

4. Does the explanatory process bring together different strands of evidence drawn from different fields of investigation? Of course, it has long been recognized that diversity of evidence is a positive factor when considering the acceptability of a hypothesis (cf. Hempel 1966). However, it has also been pointed out that not every way of diversifying evidence raises the acceptability: mere repetitions of a confirming experiment do not substantially add to the acceptability of the hypothesis. Instead, if our explanatory inquiry includes different kinds of tests under different conditions, then this lends greater support to the resulting explanation. Fur our purposes, I will phrase this relation between variety of evidence and confirmation of hypotheses in terms of scientific disciplines: the more disparate and interdisciplinary the evidence supporting an explanation,

5. As the present case study is an archaeological/historical one, the phrase 'being at odds with empirical evidence' is chosen to avoid talk of falsification and experimental testing. In archaeology and history, the laboratory conditions required for experimental testing are not available, and consequently, there are important differences in the way historical explanations are tested compared to those furnished by natural scientists. According to Cleland "Experimental scientists focus on a single [. . .] hypothesis, and the main research activity consists in repeatedly bringing about the test conditions specified by the hypothesis [. . .]. Historical scientists, in contrast, usually concentrate on formulating multiple competing hypotheses about particular past events. Their main research efforts are directed at searching for a smoking gun, a trace that sets apart one hypothesis as providing a better causal explanation (for the observed traces) than do the others" (Cleland 2001, p. 989). Although I agree that the historical sciences lack experimental testing, I doubt whether finding a 'smoking gun' constitutes their main research effort, as it is of course also possible to proceed by setting one competing hypothesis apart as being a worse causal explanation given the evidence—it is in this sense that I use the term disconfirmable.

the greater its objectivity. This notion of pooling strands of evidence is meant to capture Douglas' idea of convergent objectivity. Note though, that this does not only involve the evidence coming from different disciplines, but also that they are genuinely different strands of evidence gathered by independent procedures: "The strength of the claims concerning the reliability of the result rests on the independence of the techniques used to approach it" (Douglas 2009, p. 120). This last point is meant to bar cases in which multiple techniques just replicate what is in fact just a single line of evidence. In the context of archaeology, the independence of multiple strands of evidence can be divided into three kinds: causal (the various causal processes producing the evidence), epistemic (the various techniques and bodies of background knowledge used to obtain the evidence), and institutional (the disciplinary divisions that are specific to archaeology), where institutional independence is often interpreted as a proxy for the other two kinds (Wylie 2000, p. 233).[6] As the case study in this paper is an archaeological one, I will follow this convention: the fourth question is answered affirmatively if the different strands of evidence exhibit causal and epistemic independence.

Before moving on, it is important to note that these are cognitive-social norms; they are not necessary conditions for objectivity. Nevertheless, I think that together these norms capture most aspects of what philosophers commonly have in mind when they talk about objectivity of scientific explanations. What matters is that they provide us with the means of evaluating a particular explanatory inquiry. In other words, although I do not

6. Thus, in the context of the present case study this double norm (multiple strands of evidence from multiple disciplinary sources) is especially relevant, since the issue of when converging strands of evidence are compelling rather than spurious is itself a central topic in philosophical archaeology. As Wylie notes in an earlier paper: "[. . .] interesting claims about the past typically draw support from diverse elements of the record whose evidential significance is established by appeal to quite different bodies of background knowledge. A hypothesis about the subsistence activities associated with a given site typically depends on botanical analyses of seeds and plant remains [. . .], on palaeo-ecological reconstructions for the area, on reconstructions of lifetime dietary intake based on isotope analysis of skeletal remains [. . .]." (1995, p. 11). In the use of the phrases 'diverse elements of the record', and 'different bodies of background knowledge', we see the double nature of the fourth norm of objectivity reflected: multiple distinct strands of evidence (e.g. plant- and skeletal remains) are gathered from sources within multiple disciplines (e.g. botany, palaeo-ecology, isotope analysis). This is not to say that this idea has gone uncontested: Wylie herself points out that prejudices and biases may in fact cross disciplinary boundaries (1999, p. 312). With this objection in mind, it is even more important that causal and epistemic independence complement each other.

think of these norms as providing necessary conditions, I do claim that an explanation that ticks multiple boxes will intuitively count as objective. That is, it is not sufficient for the explanatory process to be highly interdisciplinary, or to be neutral in the sense that accepting the resulting explanation does not lead one to endorse any further non-cognitive value, while failing all the other tests. Conversely, obeying three of the four norms, while failing to meet one, will not undermine the general objectivity of the explanation. Thus, in a typical case the norms will act complementary to increase the overall level of objectivity. In what follows, I shall consider several examples of explanations that, although clearly influenced, and indeed motivated, by non-cognitive values, are nevertheless objective in this sense.

4. Introducing the Movius Line

The examples I will consider below are all explanations of a phenomenon that, since its discovery in the 1940s by American archaeologist Hallam L. Movius (1944; 1948), has spawned fierce debate among archaeologists and paleoanthropologists: the so-called Movius line. This line concerns the distribution of two types of lower Palaeolithic or Acheulean tools: the more elaborate, bifacial hand-axe and the more primitive tools known as chopping tools. The Archaeological data available at the time showed that although the primitive chopping tools are commonplace, East and Southeast Asia lacked the Acheulean bifacial implements, in particular the hand-axes that were common in other areas during the time. This led Movius to draw a line running through India, alongside the Middle-East and across central Europe (Figure 1).

Now it is important to note that since Movius, discoveries of hand-axe tools in East and Southeast Asia have been made (as figure 1 makes clear). This has led some to regard the line as obsolete. However, while these findings might undermine the concept of the Movius line in the original sense, i.e. as an absolute dividing line east of which no hand-axes are found whatsoever, they have been few and geographically sparse (Petraglia 2006). Moreover, morphological differences between hand-axes east and west of the line have been identified (Lycett & Gowlett 2008, vol. 40), as well as differences in the techniques used for stone tool-making (notably the paucity of Levalloisian stone knapping techniques east of the line). This means that although the Movius Line sensu strictu, according to which there is a complete absence of hand-axes east of the line, might be obsolete, a toned down version of the idea, or the Movius line sensu lato might still be upheld (the terminology is from Norton et al. 2006, vol. 51). In effect, the Movius Line sensu lato is really comprised of four observed differences between east Asia and the rest of the old world: a

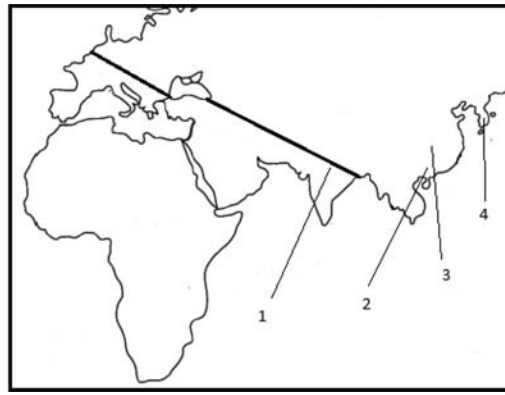

Figure 1 Contemporary depiction of the Movius Line: (1) the Movius Line itself, (2) the Baise basin in China, (3) the Luonan basin in China, (4) the Imjin/Hantan basins in Kora. Northeast of the line, Acheulean hand-axes are rarely found. The few exceptions marked on the map (nrs. 2–4) are not significant enough to challenge the validity of the Movius Line *sensu lato.*

scarcity of Acheulean hand-axe sites in eastern Asia, the relatively lower percentage of hand-axes found at these fewer sites, morphological differences and technological differences.

In spite of the demise of the Movius line *sensu strictu* then, in its *sensu lato* form it remains an important *explanandum* in Palaeolithic archaeology. Indeed, up to this day it continues to figure in academic textbooks (Cartmill & Smith 2009) as well as more general encyclopaedias (Norton & Lycett 2010). The central explanatory question then is why there is such a sharp divide between East and Southeast Asia and the rest of the old world when it comes to bifacial Acheulean implements. Ignoring some of the technical issues mentioned above, the explanatory question boils down to this: Why are Acheulean hand-axes rarely found in East and Southeast Asia, while they are abundant in Africa, Europe, the Middle-East and the rest of Asia around the same time?

Ever since the boundary was originally drawn, numerous explanations have been offered, ranging from the idea that the humans who settled the regions had left Africa before the hand-axe technology was invented (and consequently, that the technology was unable to reach them due to their isolated position) to the lack of suitable materials. Traditionally though, the line was explained in terms of genetic and/or cognitive differences between the two groups of hominins involved, the ones living in east Asia being somehow inferior to those living in the rest of the old world. In

what follows, I shall consider three alternative explanations that explicitly try to avoid this line of reasoning, and are thus clearly shaped by non-cognitive values, before determining whether their objectivity is somehow undermined by their being thus motivated. It is my bet that the Movius line makes an interesting case from the perspective of values and objectivity in scientific explanation, because right from the start, discussion about its explanation has been connected with highly controversial judgments about the cognitive capabilities and cultural achievements of the Palaeolithic humans involved. To illustrate this point, let me conclude this section introducing the Movius line with some oft quoted statements made by the discoverer himself:

> Perhaps the most important single conclusion to be drawn from the implications of the new archaeological material brought to light during the last fifteen years in Southern and Eastern Asia, is that this area cannot be considered in any sense "progressive" from a cultural point of view. Indeed, throughout the early portion of the Old Stone Age the tools consist for the most part of relatively monotonous and unimaginative assemblages of choppers, chopping-tools and hand-adzes . . . In other words, the archaeological, or palaeoethnological, material very definitely indicates that as early as Lower Paleolithic times Southern and Eastern Asia as a whole was a region of cultural retardation (Movius 1948, p. 411).

Of course, the cultural differences of which, according to Movius, the evidence was indicative, constitutes another *explanandum.* To address this *explanandum,* Movius even went so far as to say that the hominins in East Asia belonged to a different evolutionary branch:

> [. . .] one of the most vital reasons why the cultures considered here are different from the classical developments found elsewhere possibly lies in the fact that we are also dealing with men belonging to a different branch of the human stock from that outside the Far East (1948, p. 408).

5. The non-cognitive value behind alternative explanations of the Movius Line: egalitarianism

Although Movius' talk about 'cultural retardation' might strike us unnecessarily harsh, it is tempting to interpret the line in terms of biological or cognitive differences between the respective peoples involved. Indeed, a substantial amount of literature is devoted to the relation between the shape and quality of Stone Age tools, and the mental capabilities or templates of their crafters and users (see for instance Wynn 1991, vol. 1;

Gowlett 1984; Mithen 1994, vol. 4). Moreover, not all judgments concerning cognitive capabilities will lead to different moral appreciations of the subjects involved (consider developmental psychology). However, explaining the Movius line in terms of cognitive differences might provide grounds for viewing Palaeolithic humans living in Southern and Eastern Asia as less intelligent or creative, which in turn might lead to prejudices toward their descendants living in these parts today. This has led to two types of responses from scientists.

The first type of response is to downplay the importance of the line, for example by rejecting its distinction between a hand-axe and chopping culture as simplistic (Yi et al. 1983, vol. 24), by blaming it for introducing a harmful Eurocentric bias in Palaeolithic archaeology (Aigner 1981), or by placing particular emphasis on the few sites where hand-axes were found in Eastern Asia, as might be gathered from an interview with the influential researcher Huang Weiwen, who claims that:

> The question of hand axes relates to the prevailing ideology for understanding the evolutionary framework of Palaeolithic cultures in the Old World. Hallam Movius made the distribution of hand axes the main feature for dividing the West and East. However, this 'Two Culture Theory' [. . .] is misleading and needs to be reevaluated. Movius' ideas influenced the thinking of Paleolithic archaeologists in China, Europe, and the U.S. for the next four decades. This is why Bose Basin sites occupy such an important place in the Paleolithic sequence in China. They clearly illustrate the presence of bifaces in Lower Paleolithic China (Miller-Antonio & Schepartz 2004, pp. 201–202).

As we have already observed however, it is increasingly recognized that, in spite of his negative comments, Movius' basic observation (modified in its *sensu lato* form) has remained correct and supported by the evidence, despite more than six decades of archaeological fieldwork looking for hand-axes in east Asia (Norton et al. 2006, vol. 51; Lycett & Norton 2010, vol. 211). Given this situation, scientists turn to the second type of response: to construct alternative theories that explain the Movius line without referring to cognitive capabilities, mental templates or genetic factors. As such, these explanations are motivated by what one might call the non-cognitive value of egalitarianism.

So what is egalitarianism? Like other values in the context of this debate, it is a motivation to reject explanations that have certain properties, and to construct and accept others that do not have those properties. The question then is what types of properties are at stake here. For egalitarianism to play a role, the explanation must have three properties. First, be-

cause we can only speak of equality between two or more things, the value of egalitarianism can come into play only if the *explanandum* involves some kind of contrast, in other words, if the explanation is to address some kind of difference. Second, the things between which the difference is to be explained should be of a certain type. Of course, an *explanandum* can be about differences between certain states of affairs or events, but for egalitarianism to be a possible factor in deciding among explanations, these two states of affairs or events should be about things that can be the subject of normative value-judgments (e.g., they can be about peoples or societies, but not about rocks or hydrogen atoms). As such, egalitarianism will presumably have a greater impact in the life-sciences, as compared to say chemistry of physics. Finally, the value-judgments that are inherent in, or could be drawn on the basis of, the explanation should be of a moral, political, cognitive or intellectual nature, rather than only touch upon issues concerning scientific methodology (after all, egalitarianism is a non-cognitive value).

Now if the explanation one is considering has these properties (it explains a contrast between two or more things that are appropriate subjects for non-cognitive value-judgments) and explains the contrastive *explanandum* by giving different value-judgments about the subjects involved—then egalitarianism is that value which motivates one to reject that explanation. Conversely, being motivated by egalitarianism, one will typically search for alternative explanations that do not lead to such a different appreciation. Note here, that egalitarianism does not require a researcher to construct a hypothesis that claims that there are no cognitive or cultural differences between the subjects involved, which would itself be a kind of value-judgment and in breach with neutrality as characterized in sections 2 and 3. Rather, the theory should explain the contrast without referring to such factors: it should parsimonious with regards to cognitive, cultural or moral issues.

Before applying this to the case at hand, one last point should be noted. Although egalitarianism leads one to both reject explanations that lead to such different appreciations and seek alternative ones that do not, it is the former that would seem to pose a problem for the objectivity of science, and not the latter. That is, most philosophers would presumably have no problem if non-cognitive values motivate a search for new hypotheses, but rejecting an explanation on the bases of values that have nothing to do with scientific methodology is more problematic.[7]

7. Here it is tempting to invoke the distinction between the context of discovery and the context of justification. The idea would be that as long as the influence of non-cognitive values is safely restricted to the context of discovery, it does not pose a problem

Let us now apply this conceptual framework to the case of the Movius line. As we saw in the previous section, the *explanandum* here is indeed contrastive (Why are Acheulean hand-axes rarely found in East and Southeast Asia, while they are abundant in the rest of the old world around the same time?). The (implicit) subjects here are the early hominins living in the respective regions, and as such, are appropriate candidates for value-judgments—in this case, the value-judgments would be about their cognitive capabilities. Again, as these early hominins are often viewed as the ancestors of the peoples living in these parts today, the urge to pursue egalitarian explanations and reject inegalitarian ones is particularly pressing. Thus, we see how a non-cognitive value can motivate scientists to search in a particular direction for their explanations: in the case at hand, egalitarianism leads researchers to reject explanations of the Movius line that invoke cognitive and/or genetic differences, and to pursue alternative explanations that enable them to explain the contrast without alluding to such differences. In what follows, we shall consider three such egalitarianist explanations, and see whether we can make any judgments about their objectivity.

6. The 'absence of raw materials' explanation

The first explanation we will consider attempts to capture the difference between the chopping culture in east Asia and the hand-axe culture in the rest of the old world by relating it to the difference in raw materials available in these respective areas. It was already noted by Movius himself (1944) that the material available east of the line consists mainly of low-quality quartz and quartzite.[8] It has been argued, therefore, that the lack of suitable material in east Asia prevented its inhabitants from producing the more refined bifacial tools found in the rest of the old world (Toth & Schick 1993). Subsequent studies have drawn on this general explanation to address the paucity of advances stone tools in specific regions in East

---

for objectivity, and is even beneficial in that it generates new explanatory hypotheses, while such influence in the context of justification, for example in the rejection of the cognitive explanation of the Movius line is more controversial. I am hesitant to invoke this distinction however, not only because it has been criticized vehemently in the past decades, but also because I feel that the rejection of the cognitive hypothesis and the search for the alternative explanations are intimately connected: it is the rejection itself that motivates the search, and whether or not this rejection is based on considerations of empirical adequacy or on the basis of a non-cognitive value, as it is in this case, has no a priori bearing on the issue of the objectivity of these alternative explanations.

8. As such, this explanation is as venerable as the explanation in terms of cognitive differences, also proposed by Movius. In fact, Movius believed that both the absence of raw materials and 'cultural retardation' conspired together to create the line.

Asia, such as China (Goa & Norton 2002, vol. 76) and Korea (Norton et al. 2006, vol. 51).

By referring to the availability of raw material as a constraint on stone tool morphology, one can explain the absence of a particular type of stone tool without drawing any conclusions regarding the cognitive development or genetic makeup of the hominins involved.[9] They could have made hand-axes, if only the right material had been available, as the few sites in East Asia where Acheulean hand-axes have been found are taken by some authors to indicate (Hou et al. 2000, vol. 287). In fact, findings like the ones at the Bose basin are taken to imply "[. . .] similar technical, cultural, and cognitive capabilities on both sides of the Movius line" (Hou et al. 2000, p. 1624). Although, as I have stated in the previous section, the judgment that there are no cognitive or cultural differences between the two hominid groups itself involves a kind of value-judgment, Hou et al.'s conclusion need not be followed: the absence of raw materials explanation itself is parsimonious in this regard.

Again, care must be taken not to confuse the sense of explanation as an end product, and the sense of explanation as a process: as a matter of fact, the availability of raw materials on its own is no longer considered to constitute a satisfactory explanation of the Movius line (Lycett & Bae 2010, p. 527), but that does not make the explanation unsuitable for our purposes, as it might well be that the resulting explanatory picture, though incorrect, was arrived at by means of a process that merits the label 'objective'. So how does the raw materials explanation, in the appropriate sense, fare in light of the norms proposed in section 3? Let us consider each of them in turn.

First, as the explanatory process has been detailed in *bona fide* academic journals, the explanatory process has been open to scrutiny from other scientists. Indeed, the fact that there is a growing consensus that the absence of raw materials is no longer a sufficient explanation for the Movius line should make this plain. Second, there is no obvious sense in which accepting the explanation leads one to adopt non-cognitive values other than egalitarianism. Third, there is a way in which the explanation might be disconfirmed by the evidence: suitable material might be found, while no or little hand-axes are found.[10] Alternatively, hand-axes might be found

9. However, this need not be the case: it is possible to embrace this explanation and still claim that the early hominins living in East Asia were cognitively or genetically different from their cousins living west of the line, as do Toth and Schick (1993).

10. Of course, the raw materials explanation might be reconciled with this evidence by inventing ad hoc hypotheses. For example, it has been argued that while there are sites in east Asia that have suitable material for developing hand axes, the early hominins, spreading out from Africa, had to pass through 'technological bottlenecks' (i.e. large areas where

that are made from poorer material, suggesting that lack of quality material is insufficient as explanation. Indeed, highly refined hand-axes made from tabular limestone (a relatively poor material) have been found at certain sites in India (Paddayya 2001). Thus, the third norm seems satisfied: there is the possibility of the explanation being disconfirmed by evidence, yet although scientists might react differently to such a disconfirmation (see note 10), they agree that such evidence acts as an apparent excluder. Finally, when one evaluates the raw materials explanation according to the fourth norm, the outcome seems negative: the only line of evidence referred to in the explanation comes from the presence or absence of raw material combined with the presence or absence of stone tools at archaeological sites, so that even if the techniques used to uncover this evidence are diverse and there is epistemic independence, there is no causal independence to back up a claim to objectivity in the sense specified by the fourth norm.

Nevertheless, the overall result seems positive, in that although the raw materials explanation as it appears in the scientific literature is motivated by the non-cognitive value of egalitarianism, it ticks three of the four boxes. In that sense, the explanatory inquiry leading up to the 'absence of raw materials' explanation can reasonably count as objective.

7. The 'bamboo' explanation

Another explanation that was proposed has the Pleistocene hominids in eastern Asia use bamboo for cutting tools, rather than hand axes (Harrison 1978; Watanabe 1985, vol. 4; Pope & Keates 1994; Westergaard & Suomi 1995). Like the previous explanation, the bamboo-story points to environmental factors, but with the key difference that the technology of cutting was retained, as they switched from stone to bamboo. The line is explained by the fact that it overlaps with the distribution of bamboo in Asia, and since bamboo is perishable, no evidence has been found, while the exceptions (those few areas to the east of the line where bifacial cutting tools were found) can be attributed to minor regional fluctuations in the bamboo distribution (Pope 1989, vol. 10). In this way, one can explain the absence of hand-axes in East Asia without referring to cognitive or genetic factors to account for the technological difference; in fact, so the ex-

---

no suitable material is to be found) to get to these sites. If passing through these bottlenecks took several generations, the technology may simply have been forgotten by the time they reached these sites, and isolation could have ensured that these forgotten technologies were never reintroduced (Schick & Toth 1993, pp. 277–278). Of course, anyone defending this particular ad hoc hypothesis has trouble explaining the occurrence of the established exceptions to the Movius line.

planation goes, there is no difference in technology, only in material. So how does this explanation fare in light of our four norms?

Regarding the first norm, the explanation seems objective. Again, the papers proposing this explanation were published in bona fide academic journals, the different steps that were taken in order to arrive at the explanation are clearly distinguishable and, as such, open to scrutiny and critique. As for the second norm, things also look bright for the bamboo explanation. Although proposed with an eye to avoid conclusions regarding the cognitive or genetic status of early hominids in east Asia, the explanation itself does not lead one to entertain any non-cognitive value beyond this initial egalitarianism.

On the third norm however, the bamboo explanation seems to encounter a problem. Its strength, namely the ability to explain the absence of hand-axes by hypothesizing that the hand-axes were present, but made from perishable material, is also its weakness. How can one prove that a material was widely exploited during a certain time period when there is no material left to discover by means of archaeology? Yet all is not as bleak as it seems. Developments have been made that suggest ways of confirming the explanation. In particular, it has been found that cut marks on materials such as bone made by bamboo instruments have microscopic features that set them apart from cut marks made by stone tools (West & Louys 2007, vol. 34), providing new possibilities of confirming the explanation. Besides, although it might be difficult to confirm the bamboo explanation archaeologically, it is possible to disconfirm it using evidence from other disciplines—which, in any case, is all that the third norm calls for. For example, the bamboo explanation assumes that the climate in eastern Asia was continuously hot and moist throughout the Pleistocene (otherwise, bamboo will not grow), yet recent geological evidence seems to contradict this (Yin & Guo 2006, vol. 51). To give another example, in a recent study, researchers tried to answer an even more fundamental question: whether it is even possible to make complex bamboo tools with simple East Asian stone tools (Bar-Yosef, in press). As it happens, by applying the techniques themselves, the researchers were able to answer the question affirmatively—but of course, if the answer would have turned out negatively, this would have counted against this particular explanation of the Movius line.

Finally, does the bamboo explanation draw together evidence from different disciplines? Certainly: besides considering the basic findings, or discoveries made by paleoanthropologists (the original motivation for the explanation), researchers also had to establish whether there was any bamboo in east Asia at all during the Pleistocene (zoo-archaeology) and whether the climate was suitable and stable enough for bamboo to be

present in sufficient quantities (paleo-climatology). Different causal processes (e.g. climate conditions and patterns of bamboo distribution) producing the evidence are pooled together by different techniques (e.g. microscopic analysis of cut marks and paleo-climatological data analysis) so that the explanatory process exhibits both causal and epistemic independence. In short, the bamboo explanation is objective, in so far as all four questions posed in section 3 can be answered affirmatively.

8. The 'demography' explanation

A relatively recent explanation of the Movius Line is the so-called 'demographic hypothesis'. This explanation points to the effects of the size and density of populations on the cultural transmission of technologies (Henrich 2004, vol. 69; Lycett 2007, vol. 26). In effect, the demographic explanation interprets the Movius line as a demographic threshold: biogeographical, topographical and dispersal factors make it likely that the populations sizes in east Asia during the Pleistocene were much lower than in the rest of the old world (Lycett & Norton 2010, vol. 211). The explanation then draws on the similarities that have been observed between the transmission of genetic information and processes of cultural transmission: both can be modelled and understood as a form of information transmission, broadly construed (Boyd and Richerson 1985; Durham 1992, vol. 21; Shennan 2000, vol. 41). In turn, this has led to the realization that in order to understand patterns of cultural evolution between generations, demographic parameters should be included (Neiman 1995, vol. 60; Shennan 2006). Basically, the smaller the size of the population, the greater the role chance will play in determining what cultural information will be transmitted through the generations. Conversely, population growth will see an increase in the cultural transmission network, and hence, useful technologies will be passed down the generations more successfully. Thus, the relative absence of Acheulean hand axes east of the Movius line is explained by the increase of cultural drift as a result of a sparser population in these areas.

So how does the objectivity of this explanation stand up to scrutiny? As is to be expected, the first and second norms are easily met: the explanatory process is detailed in academic journals so that it is accessible by the scientific community, and accepting the explanation does not require any further commitment, other than to opinions about the effects of population size on cultural drift and about the demographic conditions of east Asia during the Pleistocene, neither of which seems motivated by any non-cognitive values other than the one we set out with.

As for the third norm, the explanatory process does indeed suggest one

powerful way in which the ensuing explanation can be disconfirmed. As it includes considerations about the demographic properties of differently sized populations, population density and cultural transmission theory, one can effectively interpret the explanation as a generalized null model of Early-Middle Pleistocene technological evolution (Lycett & Norton 2010, p. 62). As a null model, the explanation makes a risky prediction: it predicts that the demographic situation of East Asia during the Pleistocene is very different from western Eurasia and Africa. As it is, this prediction seems corroborated by evidence from global patterns of genetic and phenotypic diversity (Prugnolle et al. 2005, vol. 15; Manica et al. 2007, vol. 448). The idea is that as humans migrated out of Africa and became dispersed over larger geographic distances, this led to a reduction in genetic and phenotypic diversity. Although Lycett and Norton stress that "What is now urgently needed are more sophisticated means of assessing Pleistocene demographic parameters in the key regions east and west of the Movius Line" (Lycett & Norton 2010, p. 62), it is clear that the explanation is disconfirmable in principle. Finally, applying the fourth norm to the demography explanation again yields a positive result, as can be easily ascertained by considering the literature quoted above. The explanation pools together evidence ranging from cultural evolution patterns to demographic data (causal independence), by applying techniques from such diverse fields as biogeography, topography and cultural transmission theory (epistemic independence).

The demographics explanation then, ticks all the boxes and is as such an objective explanation of the Movius line, although it is clearly motivated by the non-cognitive value of egalitarianism. To appreciate this last point, note how Lycett and Bae, in discussing the explanation, stress that cognitive and genetic factors are kept out of the picture, which they seemingly treat as an argument in favour of the explanation:

> This model may be considered a null model in the sense that while differences in demographic parameters can be taken as axiomatic for hominins widely dispersed in time and space [. . .], cognitive and/or biomechanical parameters that might otherwise affect the appearance or disappearance of technological patterns need not. Hence, the model is parsimonious in regard to these latter factors and—in contrast to many models of Pleistocene technological change—dislocates any automatic link between technological patterns and putative cognitive or biological parameters (Lycett & Bae 2010, p. 530).

9. Conclusion

In this article, I have tried to make a contribution to two tasks connected with the issue of values in science: first, the descriptive task of providing insight into the kinds of non-cognitive values that play a role in science and what roles these are, and second, the normative task of evaluating the consequences these non-cognitive values have for the objectivity of the scientific process. To this end, I have considered three alternative explanations of the Movius Line as a case study. Let me summarize the results.

Regarding the descriptive task, I have identified one particular non-cognitive value, namely egalitarianism, as one that influences the scientific process. Egalitarianism plays a number of roles: it leads researchers to reject certain hypotheses, and invent and accept others. In their effort to avoid any reference to cognitive or genetic differences between the peoples of East Asia and the rest of the world during the Pleistocene, researchers have invented a number of new explanatory hypotheses. Regarding the normative task, I have provided some cognitive-social norms by which to gage the objectivity of these new explanations. The point is not that the competition between explanations cannot be settled by cognitive values alone—indeed, one could argue that the explanation of the Movius line in terms of cognitive differences faces serious empirical problems, in that we know for a fact that important technological differences between cultures can exist without corresponding cognitive differences between the peoples involved. Nor is it that because the explanatory processes leading up to the three alternative explanations we have discussed are all objective, that any one of them is as plausible as any other: even if we are committed to an explanation that does not refer to any cognitive difference between the hominins on either side of the line, the fact that there are many different candidates does not undermine the objectivity of the explanatory processes that produced them. Some of these explanations might be mutually exclusive, some might be complementary, but if one of these explanations would ultimately be accepted over the others by common consent from the archaeological community, the fact that this explanation had to compete with alternatives that were constructed in an objective fashion, would only add to its credibility. Surely, if an explanation has to compete with serious rivals and still comes out on top, this can only count in its favor.

The point is that as a matter of fact, non-cognitive values like egalitarianism do play a role, and it is part of the normative task to evaluate whether this undermines the objectivity of the scientific process. By applying the norms formulated in section 3 to the alternative explanations of the Movius Line, I have tried to make the case that, VFI notwithstanding, these alternative explanations, although clearly motivated and shaped by

the non-cognitive value of egalitarianism, are nevertheless objective in a real sense.

References

Aigner, J. S. 1981. *Archaeological remains in Pleistocene China.* Bonn: Deutsches Archäologisches Institüt, Kommission für Allgemeine und Vergleichende Archäologie.

Bar-Yosef, O. et al. 2011. (in press). "Were bamboo tools made in prehistoric Southeast Asia? An experimental view from South China." *Quaternary International.* doi: 10.1016/j.quaint.2011.03.026. Retrieved 02-01-2012 from: http://www.sciencedirect.com/science/article/pii/S1040618211001728.

Boyd, R., Richerson, P. 1985. *Culture and the Evolutionary Process.* University of Chicago Press: Chicago.

Cartmill, M. & Smith, F. H. 2009. *The Human Lineage.* Hoboken, NJ: Wiley-Blackwell.

Cleland, C. E. 2001. "Historical science, experimental science, and the scientific method." *Geology* 29: 987–990.

Douglas, H. 2009. *Science, Policy and the Value-Free Ideal.* Pittsburgh: University of Pittsburgh Press.

Durham, W. H. 1992. "Applications of evolutionary culture theory." *Annual Review of Anthropology* 21: 331–355.

Goa, X. & Norton, C. 2002. "A critique of the Chinese 'Middle paleolithic'." *Antiquity* 76: 397–412.

Gowlett, J. A. J. 1984. "Mental abilities of early man: a look at some hard evidence." Pp. 167–192 in R. Foley (ed.) *Hominid Evolution and Community Ecology.* London: Academic Press.

Harisson, T. 1978. "Present status and problems for Paleolithic studies in Borneo and Admacent Islands." Pp. 37–57 in F. Ikawa-Smith (ed.) *Early Paleolithic in South and East Asia.* The Hague: Mouton.

Hempel, C. G. 1966. "Criteria of confirmation and acceptability." Pp. 33–46 in C. Hempel. *Philosophy of Natural Science.* Englewood Cliffs, New York: Prentice-Hall.

Henrich, J. 2004. "Demography and cultural evolution: how adaptive cultural processes can produce maladaptive losses—the Tasmanian case." *American Antiquity* 69: 197–214.

Hou, Y., Potts, R., Yuan, B., Guo, Z., Deino. A., Wang, W., Clark, J., Xie, G., & Huang, W. 2000. "Mid-Pleistocene Acheulean-like stone technology of the Bose Basin, South China." *Science* 287: 1622–6.

Lacey, H. 1999. *Is Science Value Free? Values and Scientific Understanding.* New York: Routledge.

Lacey, H. 2004. "Is there a significant distinction between cognitive and

social values?" Pp. 24–51 in P. Machamer & G. Wolters (eds.) *Science, Values and Objectivity.* Pittsburgh, PA: University of Pittsburgh Press.
Lacey, H. 2005. *Values and Objectivity in Science. The Current Controversy about Transgenic Crops.* Lanham, MD: Lexington Books.
Lee, C. J. & C. D. Schunn 2011. "Social Biases and solutions for procedural objectivity." *Hypatia* 26: 352–373.
Longino, H. 1990. *Science as Social Knowledge: Values and Objectivity in Scientific Inquiry.* Princeton, NJ: Princeton University Press.
Longino, H. 2004. "How values can be good for science." Pp. 127–142 in P. Machamer & G. Wolters (eds.) *Science, Values and Objectivity.* Pittsburgh, Pa: University of Pittsburgh Press.
Lycett, S. J. 2007. "Why is there a lack of mode 3 Levallois technologies in East Asia? A phylogenetic test of the Movius-Schick hypothesis." *Journal of Anthropological Archaeology* 26: 541–575.
Lycett, S. J. & Bae, C. J. 2010. "The Movius Line controversy: the state of the debate." *World Archaeology* 42: 521–544.
Lycett, S. J. & Gowlet, J. A. 2008. "On questions surrounding the Acheulean 'tradition'." *World Archaeology* 40: 295–315.
Lycett, S. J. & Norton, C. J. 2010. "A demographic model for Palaeolithic technological evolution: the case of East Asia." *Quaternary International* 211: 55–65.
Manica, A., Amos, W., Balloux, F. & Hanihara, T. 2007. "The effect of ancient population bottlenecks on human phenotypic variation." *Nature* 448: 346–349.
Miller-Antonio, S. & Schepartz E. A. 2004. "A conversation with Huang Weiwen: Reflections on Asian Paleolithic Research." *Asian Perspectives* 43 (2): 197–204.
Mithen, S. 1994. "Technology and society during the Middle Pleistocene: Hominid group size, social learning and industrial variability." *Cambridge Archaeological Journal* 4: 3–32.
Movius, H. L. 1944. "Early Man and Pleistocene Stratigraphy in Southern and Eastern Asia." Harvard University, *Peabody Museum papers* 19 (3). Cambridge: Peabody Museum.
Movius, H. L. 1948. "The Lower Paleolithic cultures of Southern and Eastern Asia." *Transactions of the American Philosophical Society* 38: 329–426.
Neiman, F. D. 1995. "Stylistic variation in evolutionary perspective: inferences from decorative diversity and interassemblage distance in Illinois Woodland ceramic assemblages." *American Antiquity* 60 (1): 7–36.
Norton, C. J., Bae, K. D., Harris, J. W. K. & Lee, H. Y. 2006. "Middle Pleistocene handaxes from the Korean Peninsula." *Journal of Human Evolution* 51: 527–536.

Norton, C. J. & Lycett, S. J. 2010. *The Movius Line.* Pp. 248–50 in *Yearbook of Science and Technology.* New-York: McGraw-Hill.

Paddayya, K. 2001. "The Acheulan culture project of the Hunsgi and Baichbal Valleys, peninsular India." Pp. 235–58 in L. Barham & K. Robson-Brown (eds.) *Human Roots: Africa and Asia in the Middle Pleistocene.* Bristol: Western Academic and Specialist Press.

Petraglia, M. D. 2006. "The Indian acheulian in global perspective." Pp. 389–414 in N. Goren-Inbar & G. Sharon (Eds.) *Axe Age: Acheulian Tool-Making from Quarry to Discard.* London: Equinox.

Pope, G. G. 1989. "Bamboo and human evolution." *Natural History* 10: 48–57.

Pope, G. G. & Keates, S. 1994. "The evolution of human cognition and cultural capacity: a view from the far east." Pp. 531–568 in R. Corruccini, & R. Ciochon (eds.) *Integrative Paths to the Past: Paleoanthropoligical Advances in Honor of F. Clark Howell.* Prentice Hall.

Prugnolle, F., Mancia, A. and Balloux, F. 2005. "Geography predicts neutral genetic diversity of human populations." *Current Biology* 15: 159–160.

Shennan, S. 2000. "Population, culture history, and the dynamics of culture change." *Current Anthropology* 41: 811–835.

Shennan, S. 2006. "From cultural history to cultural evolution: an archaeological perspective on social information transmission." Pp. 173–189 in J. C. K. Wells, S. Strickland & K. Laland (eds.) *Social Information Transmission and Human Biology.* New York: Taylor & Francis.

Toth, N. & Schick, K. D. 1993. "Early stone industries and inferences regarding language and cognition." Pp. 346–362 in Gibson, K. & Ingold, T. (eds.) *Tools, Language, and Cognition in Human Evolution.* Cambridge University Press.

Yi, S., Clark, G. A., Aigner, J. S., Alimen, H., Davis, R. S., Debenath, A., Pei, G., Hutterer, K. L., Ikawa-Smith, F., Lanpo, J., Kubet, L., Nelson, S. M., Odell, G. H., Sankalia, H. D., Shackley, M., Sohn, P. & Solheim, W. G. 1983. "Observations on the lower Palaeolithic of Northeast Asia." *Current Anthropology* 24: 181–202.

Yin, Q. Z. & Guo, Z. T. 2006. "Mid-Pleistocene vermiculated red soils in southern China as an indication of unusually strengthened east Asian monsoon." *Chinese Science Bulletin* 51: 213–220.

Watanabe, H. 1985. "The chopper-chopping tool complex of eastern Asia: an ethnoarchaeological examination." *Journal of Anthropological Archaeology* 4: 1–18.

West, J. A. and Louys, J. 2007. "Differentiating bamboo from stone tool cut marks in the zooarchaeological record with a discussion on the use of bamboo knives." *Journal of Archaeological Science* 34: 512–518.

Westergaard, G., Suomi, S. 1995. "The manufacture and use of bamboo tools by monkeys: possible implications for the development of material culture among East Asian hominids." *Journal of Archaeological Science* 22: 677–681.

Wylie, A. 1995. "Unification and convergence in archaeological explanation: The agricultural 'wave of advance' and the origins of Indo-European languages." *The Southern Journal of Philosophy* 34 (supplement): 1–30.

Wylie, A. 1999. "Rethinking unity as a "working hypothesis" for philosophy: How archaeologists exploit the disunities of science." *Perspectives on Science* 7: 293–317.

Wylie, A. 2000. "Questions of evidence, legitimacy, and the (dis)unity of science." *American Antiquity* 65: 227–237.

Wynn, T. 1991. "Tools, grammar, and the archaeology of cognition." *Cambridge Archaeological Journal* 1: 191–206.